

Watershed Basics

Stream Systems and Human Influences

This part of the Guidebook is intended to educate people who are just learning about our role in ensuring clean water, but also to provide a refresher for all who are involved in projects or activities related to clean water planning, protection, or restoration.

- Part I: Watersheds and Stream Systems
- Part II: People and Watersheds
- Part III: The Regulatory World
- Part IV: How Is Stream Health Evaluated?

Part I: Watersheds and Stream Systems

I-A Why Clean Water Is Important

Every organism on Earth needs water. Clean water comes from healthy streams, but healthy streams are also an important part of the world around us. To have a steady supply of clean water to drink, we pay for our water treatment plants to withdraw water from local streams, wells, or springs and use chemicals and other processes to make it clean and safe. The dirtier the water, the more it costs to clean it, and the more we have to pay for drinking water. Water can be so dirty that it isn't feasible to make it clean enough for drinking water. The cleanliness of water also impacts agriculture, recreation, industry, wildlife, and other aspects of life.

To understand how our water can be kept clean so there is usable water now and in the future, we must first understand how the water cycle works. We must also understand how water moving through this cycle affects and is connected to the plants and animals that live in and around streams, lakes, and wetlands.

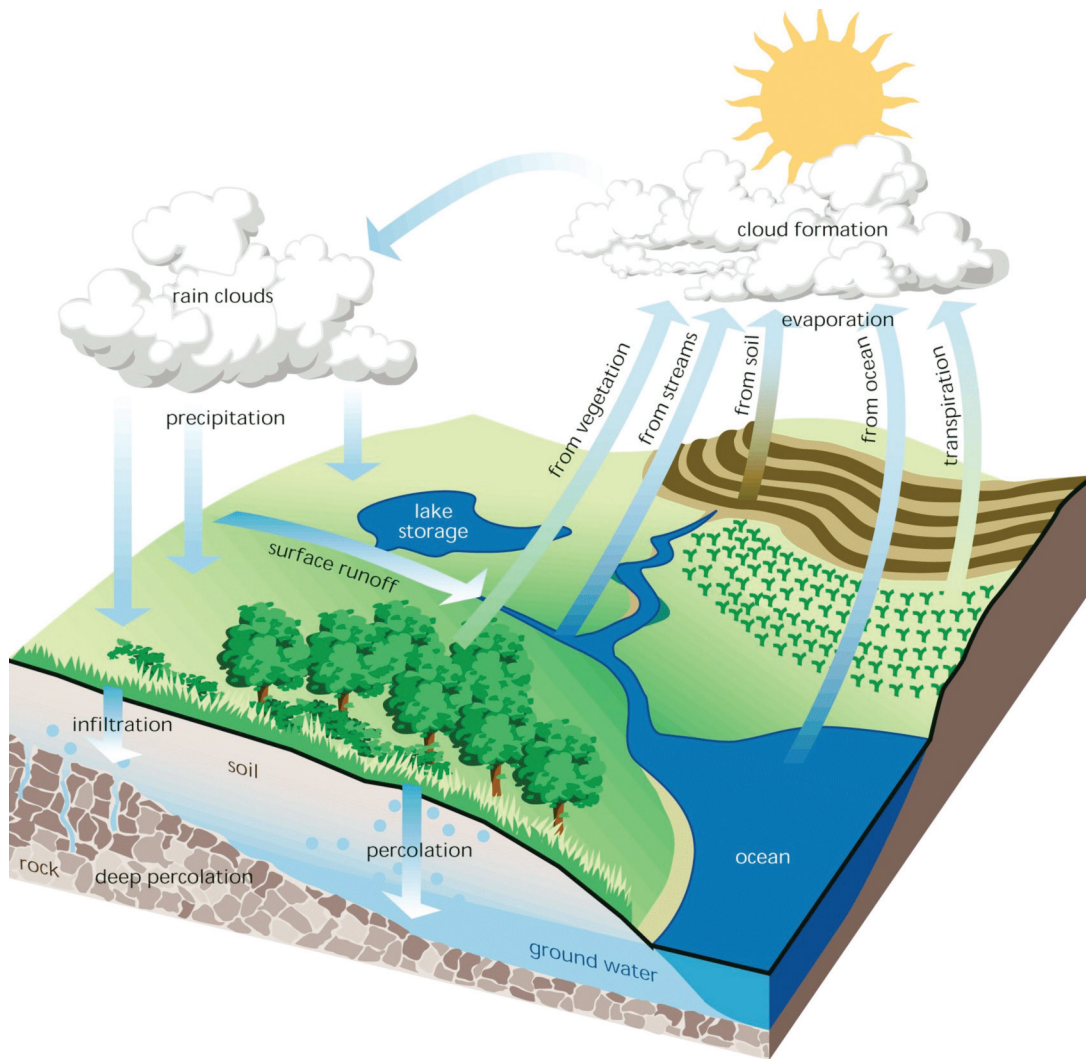
I-B The Water Cycle

The **water cycle**, or **hydrologic cycle**, describes how water exists and moves on, in, and above the Earth. This cycle is continuous and doesn't have a point where it starts or ends. This description begins with the oceans, where most of the water on Earth exists. The sun heats water in the oceans and evaporates some of it into the air. As this water vapor rises, the air cools and causes the vapor to become clouds. As the wind moves the clouds over the land, the clouds become larger with water vapor that has evaporated from the water already on the land and with the water vapor given off by plants, **transpiration**. Changes in temperature cause the water vapor in the clouds to fall out of the sky as **precipitation**. The precipitation can fall as snow, sleet, or rain.

Words in **bold type** face are defined in the Guidebook glossary.

As rain falls or snow melts, it begins to soak into the ground. If there is too much water too quickly, the plants can't soak it up fast enough and the spaces between soil particles are filled. The water that can't soak in begins to move across the top of the land as **runoff**. Any materials on the land, such as dirt, chemicals, oils, fertilizers, etc., whether naturally occurring or put there by humans, are carried along with the

The Water Cycle



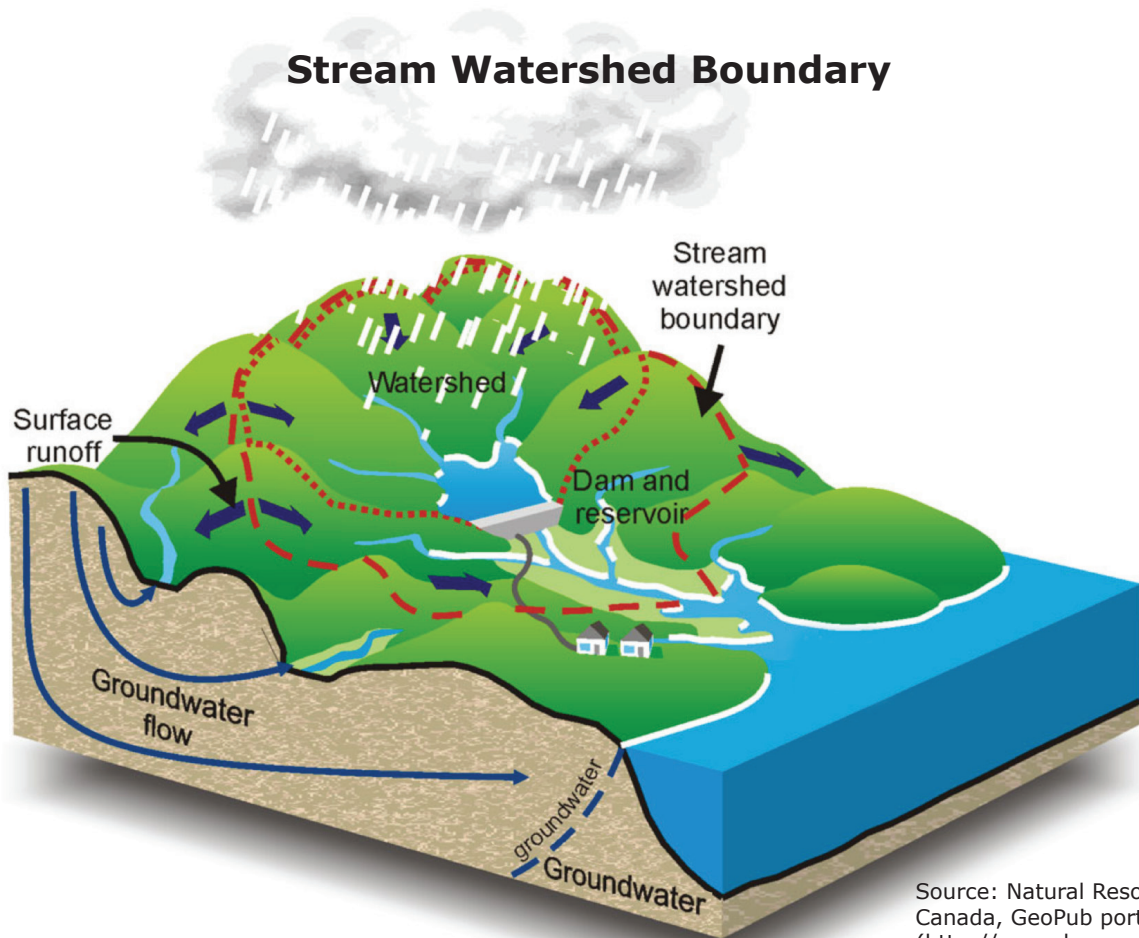
The Hydrologic Cycle from Stream Corridor Restoration: Principles, Processes, and Practices (10/98); Interagency Stream Restoration Working Group

runoff. These materials that are picked up by the runoff and carried into streams and lakes pollute the water and are called **pollutants**. The water that soaks into the ground becomes groundwater which is discussed in section I-F.

The runoff is moved downhill by gravity until it reaches a common low point and forms a stream. This stream can join with another stream and become a bigger stream that continues to be moved by gravity to a common lower point on the land. These bigger streams can join together to form even bigger streams, and so on. A stream that flows into another stream is called a **tributary** of that stream. Eventually all streams flow to the lowest surface points on earth, our oceans, seas, and lakes, where the water cycle continues with evaporation.

I-C What Is a Watershed?

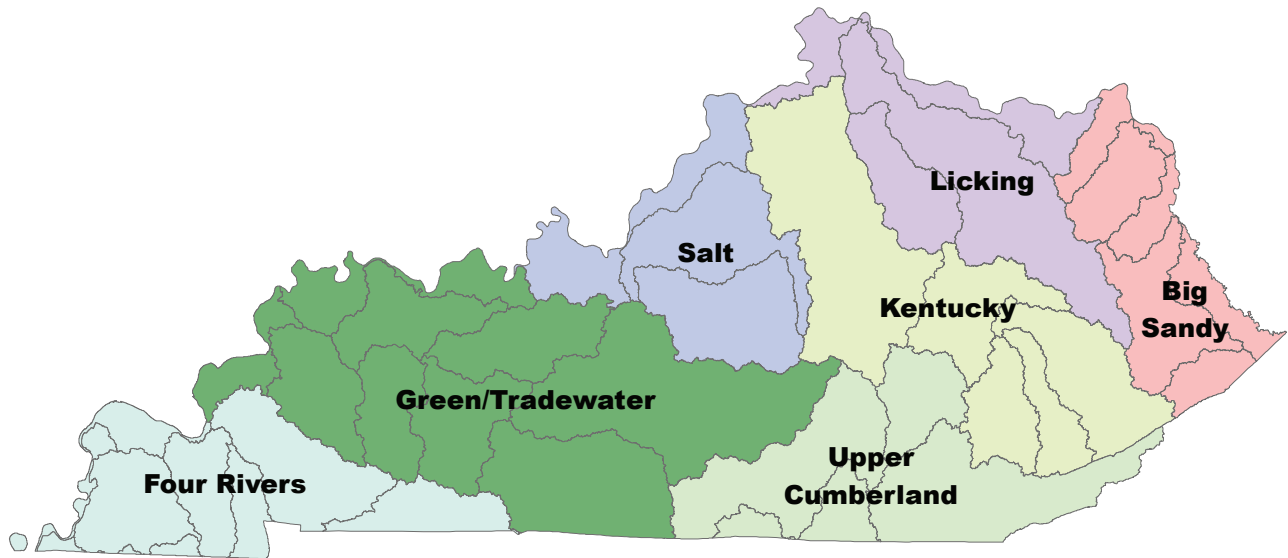
The area of land where the runoff flows to a common stream is called a **watershed**. Each of us lives in a watershed. The boundary of the watershed is the imaginary line drawn around the highest points. This indicates where rainfall or snowmelt ends up: precipitation inside the line flows to one stream and precipitation outside the line flows to another stream. As two streams join together to form a larger stream, the two areas of land that drain to these streams also join together to form a larger watershed. Because smaller watersheds join to form larger watersheds, most people live in more than one watershed. Many watersheds joined together form a very large watershed that is sometimes called a **basin**. There are twelve major river basins in Kentucky.



This Guidebook focuses on watersheds that are smaller than basins. Smaller streams and creeks are sometimes thought of as sub-watersheds. Sub-watersheds are smaller, local drainages such as a creek that may run only a few inches deep. For instance, Eagle Creek is a tributary to the Red River, which in turn is a tributary of the Kentucky River. In this example, Eagle Creek is the sub-watershed, Red River and all its tributaries make up the watershed, and all of these are part of the Kentucky River Basin. A person who lives in the Eagle Creek watershed also lives in the Red River watershed and the Kentucky River Basin.

Streams flow through valleys in the landscape with ridges of higher land separating the valleys. The area of land between ridges that collects precipitation is a **watershed**, or basin.

Major River Basins of Kentucky



There are many combined natural factors that distinguish watersheds. These include geology (rock types), soil type, slope, land surface features, climate, etc. The different combinations of these factors determine the types of plants and animals that grow there. The surroundings of a specific type of plant or animal, where it lives, is called its **habitat**. The plants, animals, and the habitat in which they live are called an **ecosystem**. Large areas where the patterns of ecosystems are similar are called **ecoregions**. The streams found in each ecoregion have similar properties.

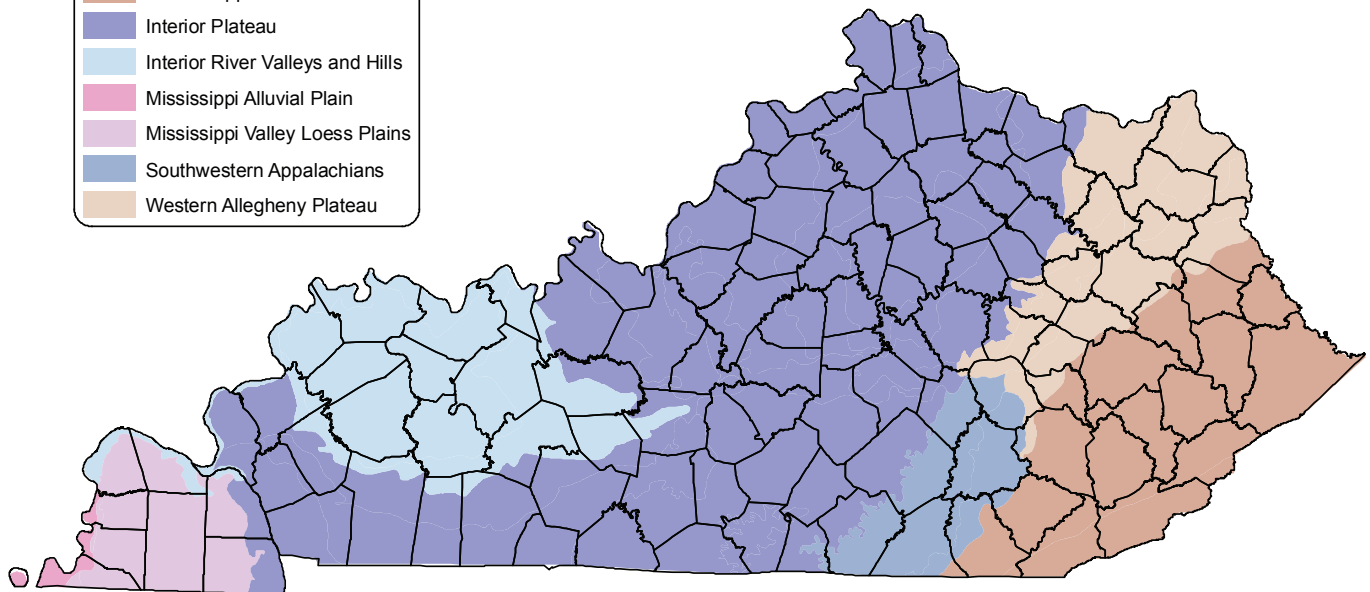
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County Boundaries

Ecoregions

- Central Appalachians
- Interior Plateau
- Interior River Valleys and Hills
- Mississippi Alluvial Plain
- Mississippi Valley Loess Plains
- Southwestern Appalachians
- Western Allegheny Plateau

Ecoregions of Kentucky



I-D Your Watershed Address

When settlers arrived in Kentucky, the Native Americans that lived in, traveled through, and hunted in the state already had names for many of the streams here. The settlers sometimes adopted the Native American names for the streams, but more often renamed them. These stream names weren't always recorded in documents and/or maps. As settlers established communities and towns and then moved on, the stream names were lost or forgotten and new names were given. In addition, the same name was often used for different streams in the same area or across the state. This created a very confusing situation when formal maps of the state were developed. To deal with this situation across the United States, a system was developed by the United States Geological Survey (USGS) that assigned a group of numbers to each permanently flowing stream. These numbers are called the **Hydrologic Unit Code (HUC)**. The HUC (pronounced "huck") is like a zip code for a stream. Just as the US Post Office has added four extra numbers to our five digit zip codes to make them more specific to a single home address, for example 40347-4502, extra numbers added on to the HUC make it more specific to a certain stream. As the HUC number gets larger, the watershed gets smaller. The following is an example of HUCs that have added numbers and become more specific to increasingly smaller watersheds:

Stream	Hydrologic Unit Code (HUC)
Ohio River	05 (2 digit HUC)
Licking and Kentucky Rivers (tributaries of Ohio River)	0510
Licking River	051001
Mainstem Licking River	05100101
Triplett Creek (tributary of Licking River)	05100101130 (11 digit HUC)
Dry Creek (tributary of Triplett Creek)	05100101130120 (14 digit HUC)

Depending on size, as shown above, HUCs are identified using two to fourteen digits. For watershed planning purposes in Kentucky, a HUC that is about 50 square miles in size is recommended. This means the eleven, twelve, and fourteen digit HUCs will be the most commonly used watershed size for planning. Chapter 2 of this Guidebook tells you how to find the HUCs for your watershed.

I-E Erosion

As water is moved by gravity and flows to a lower point, it gains energy. This energy in the flowing water causes it to move particles of soil, rocks, and other material on the surface of the land. The greater the energy in the water, the faster it moves and the larger the particles moved by it. This continuous wearing away and movement of particles over time is called **erosion**. The trees, shrubs, grasses, and flowers that grow in the soil absorb some of the energy in the runoff and slow it down. The vegetation also holds on to the soil with its roots. This lessens the amount of soil carried into streams by erosion. Water running over areas of soil without trees and other vegetation can very quickly erode large amounts of soil and carry it into streams.

Some soils and rocks erode more easily than others. As a stream flows across the land, these different rates of erosion determine the shape of the stream that is carved into the land. The particles eroded from the stream bed and the particles eroded from the land are carried by the stream until curves or other obstacles slow it down and it loses the energy to carry them. As these particles are deposited on the bottom of the stream, the larger particles begin to settle out first, followed by the smaller ones. The accumulating piles of particles of soil and rock in the stream are **sediment** and sometimes form sand bars, or **point bars**, in the stream.



Following storm events, the runoff into a stream increases the flow and energy in the stream. Sediments that have been previously deposited in the stream can be picked up by the flow and re-deposited somewhere else in the stream. These processes of moving and re-depositing sediments are called **sediment transport** and **sediment deposition**.

Streams are constantly changing because the erosion, transport, and deposition are continuous processes. The study of these processes and the way they shape the surface of the earth is called **geomorphology**.

I-F Groundwater

When you look at all the fresh water available for human use on the planet, most of it is in the form of groundwater. Groundwater is stored below the land surface in sediments or rock layers that are called **aquifers**.

Aquifers are replenished, or **recharged**, from some of the rain and snowmelt that soaks into the ground. The process of precipitation soaking into the ground is called **infiltration**. Depending on the land and rock types, this water may move slowly through the soil or it may sink rapidly into sinkholes or sinking streams. Water moving slowly downward through soils and sediments can be cleaned because these act as natural filters for most types of pollution.

The water continues moving downward until it reaches a layer of sediment or rock (the aquifer) that is completely saturated with water. The dividing line where the saturated area begins is the **water table**. The distance from the ground surface to the water

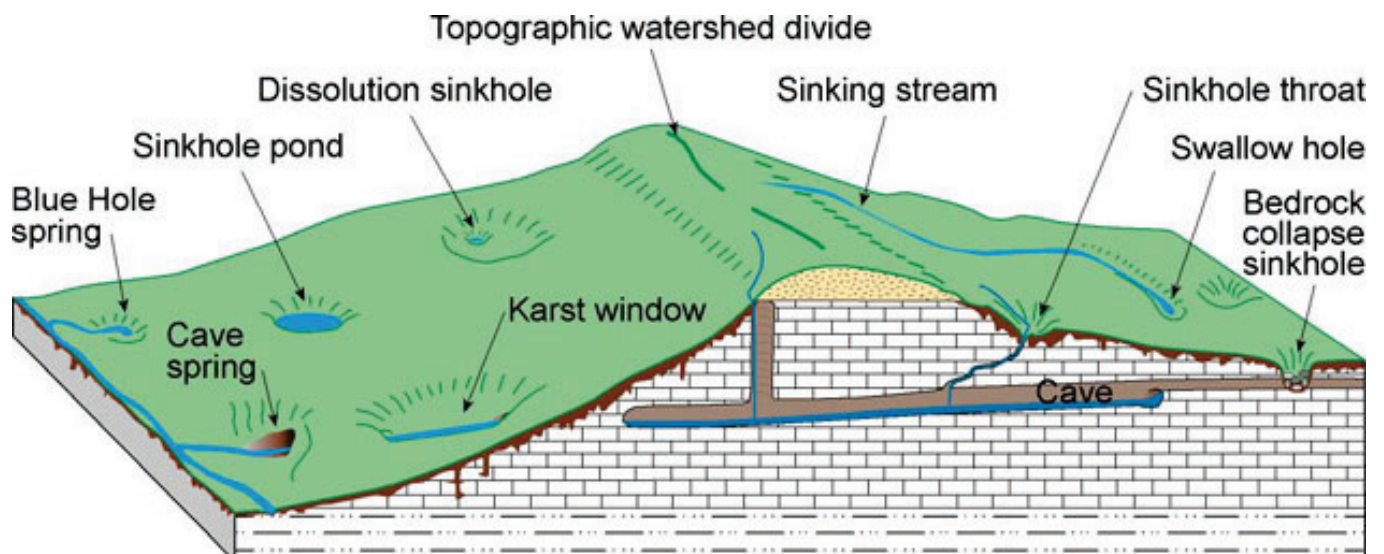
table is called the depth to groundwater, and this distance can range from very shallow to very deep. Once groundwater reaches the water table, it begins flowing more horizontally, generally parallel to the land surface. Groundwater can move through the tiny spaces (pores) between sand and gravel particles or it can move through the breaks in the underground rock. It moves very slowly, perhaps only inches or a few feet per day, through sand and gravel, and is much faster, can be several to tens of feet per day, when moving through broken rock.

Under natural conditions, all of this groundwater follows the slope of the underground sediment or rock, flowing "down hill" toward low points where the saturated layer comes to the land surface and the groundwater seeps out. This seepage discharge point is often in or near a stream. Seeps that have larger amounts of groundwater coming to the surface are called **springs**. Springs and seeps eventually or directly flow into streams. In this way, groundwater also contributes to the water flowing in streams. Streams that receive groundwater usually flow year-round and are called **perennial streams**. Streams that only flow during a rain or snow event are called **intermittent streams**. Some streams seep into the groundwater, instead of the other way around.

As the groundwater moves through the soil, it can become slightly acidic. In areas where the bedrock is mostly made up of limestone, this acidic groundwater will dissolve the limestone. This process of rock being dissolved is called **weathering**. It forms openings and channels in the bedrock called **conduits**. Some of these conduits keep dissolving until they are large enough to become caves.

Groundwater can flow very quickly through these channels and caves underground. During periods with large quantities of rain or snowmelt, the groundwater is recharged by runoff into surface openings. This does not provide for natural filtration of pollutants and the aquifer can be easily contaminated. This recharge also carries some soil from the surface into the aquifer. As more soil is removed depressions on the surface begin to form. These are called **sinkholes**. In some cases the sinkholes form very quickly as a collapse that can cause significant damage to roads and buildings. Aquifers that are formed in limestone geology with sinkhole and cave formations are called **karst** aquifers.

Karst Features



Source: Kentucky Geological Survey

Much of Kentucky has karst aquifers, which results in some unique problems with groundwater pollution. Karst aquifers are present in about half of the state, from northeastern Kentucky through the Bluegrass Region and across south central into western parts of the state. The most famous example is Mammoth Cave in south central Kentucky, which is the longest known cave system in the entire world with approximately 365 miles of mapped cave. Special methods are required to test water for pollution in these areas and pollution prevention management practices must take the karst features into consideration.

Karst aquifers are very different from other groundwater systems. They can be thought of as subsurface river systems. Flow through a karst aquifer is similar to a surface river system. Water moves through bedrock conduits to form small tributaries that come together to form subsurface streams. Depending on the location, these streams may join together to form large subsurface rivers.

Karst aquifers do not always follow surface watershed boundaries. It is not uncommon for karst groundwater to flow beneath ridges and carry water into, or out of, a watershed. Karst groundwater-sheds cannot be determined by looking at features on the land surface. Cave mapping and special studies called dye traces must be conducted to determine the source area for water discharging from a spring.

I-G Wetlands

A **wetland** is a natural area that is covered with water or soggy, but may not be wet all year round. Wetlands are known by several different names. Some of these are marsh, swamp, bog and vernal pond (temporary wetland). They provide a place to live, feed, and reproduce for plants and animals that are adapted to live in a waterlogged environment.

Wetlands are identified by the hydric (water-soaked) soils, hydrologic regime (water flow patterns), and hydrophilic (water-loving) plants found there. Identifying an area as a wetland requires a trained professional that is familiar with the sciences of these characteristics. Wetlands are found on all of the continents throughout the world except Antarctica.

There are two main types of wetlands, coastal tidal and inland freshwater. Since there aren't any oceans or tidal wetlands in Kentucky, they will not be discussed. Kentucky does, however, have a variety of freshwater wetlands. These are found along floodplains of rivers and streams (sometimes called **riparian** wetlands), along the edges of lakes and ponds, or in low areas with poorly draining soil where groundwater comes to the surface or rain and snowmelt collect.

In Kentucky, more than 80% of the original wetlands have been lost due to human activities. Much of this loss has occurred in Western Kentucky where large wetlands are common. However, losses of smaller wetlands add up statewide and significantly contribute to the overall total loss in the state. Today, wetlands compose less than 2.5% of Kentucky's land area, but they still have considerable value for the environment, economic and social factors, and natural beauty.

Once wetlands form, they are constantly changing. Runoff and floodwater from precipitation carry sediment and debris into wetlands. These settle among the roots to the bottom along with dead plant matter and build up over time causing the wetland to become shallower. Often this layer of sediment and decaying material can accumulate until it is thick enough to extend above the surface of the water and begin drying out. Though this surface layer may be dry, the soils below may still be saturated with water and influencing the types of organisms that live there. This area that appears dry may still be identified as a wetland. This situation emphasizes the need for following state, federal and local guidelines for accurate identification.

Wetlands are very unique ecosystems and support a large variety of organisms. As a result of the materials washed into wetlands by runoff and the accumulation of decaying plant matter, there are high levels of **nutrients** available for use by many species of plants and animals. These nutrients, combined with the availability of water, provide an ideal habitat for fish, amphibians, and insects. Also, many birds and mammals rely on wetlands for food, water, breeding grounds, and shelter. In the United States, one-third of the nation's threatened and endangered species live only in wetlands, while half use wetlands during at least part of their lives.

In addition to being unique ecosystems, wetlands also act as filters for pollution and trap harmful pollutants such as excess sediment, human and animal waste, fertilizers, and pesticides and herbicides that would otherwise be washed directly into streams or lakes. Runoff often carries a large amount of these pollutants and when it enters a wetland before draining to a waterbody, the pollution is filtered out. This filtering process is an extremely important function for ensuring clean water in streams and other waterbodies.

Wetlands also provide flood protection. They act as sponges and soak up large amounts of rain and floodwater. One acre of wetlands can store one million gallons of water and release it gradually after rains end. This reduces flooding downstream and allows water to soak into the soil and replenish groundwater. Over half of the wetlands in the United States have been drained or filled causing an increase in flooding in the watersheds where they are lost.

Wetlands prevent erosion, too. As damaging, high energy floodwaters rush into wetlands, the energy is absorbed by the plants and the water is slowed down. As a result, rather than washing away soil, the soil particles that are already in the floodwater are deposited in the wetland. Roots of trees, shrubs, and other plants in the wetland also help to anchor the soil.

More information on wetlands can be found at the US Environmental Protection Agency's website <https://www.epa.gov/wetlands>. The US Fish and Wildlife Service keeps records of the number and condition of the wetlands in the United States. This is called the National Wetlands Inventory. It can be found at the website <https://www.fws.gov/nwi/>.

Part II: People and Watersheds

To understand your watershed system, it's necessary to consider how human activities impact the streams, lakes, and groundwater within the system. The following sections provide general information on how activities such as farming, construction, mining, and pumping of groundwater affect the watershed. Many of the activities have negative impacts and being aware of the potential effects is important when planning watershed protection and improvement.

II-A Land Use

Several factors can influence water as it moves through the watershed. Rivers and streams change with time. Rivers will flood, streams will run dry, and lakes will freeze. These natural events bring changes to the watershed system. However, human activities in the watershed have the biggest influence on rivers, streams, and groundwater. For example, streams channels are often changed (moved or straightened) to increase farming land or to provide water for industrial purposes. Frequently, the results of stream channel changes are reduced stream bank stability and increased erosion. A farmer, who altered a stream channel, may find some of his best soil and pasture washed away. One way to understand how human activity influences the watershed system is to look at land use.

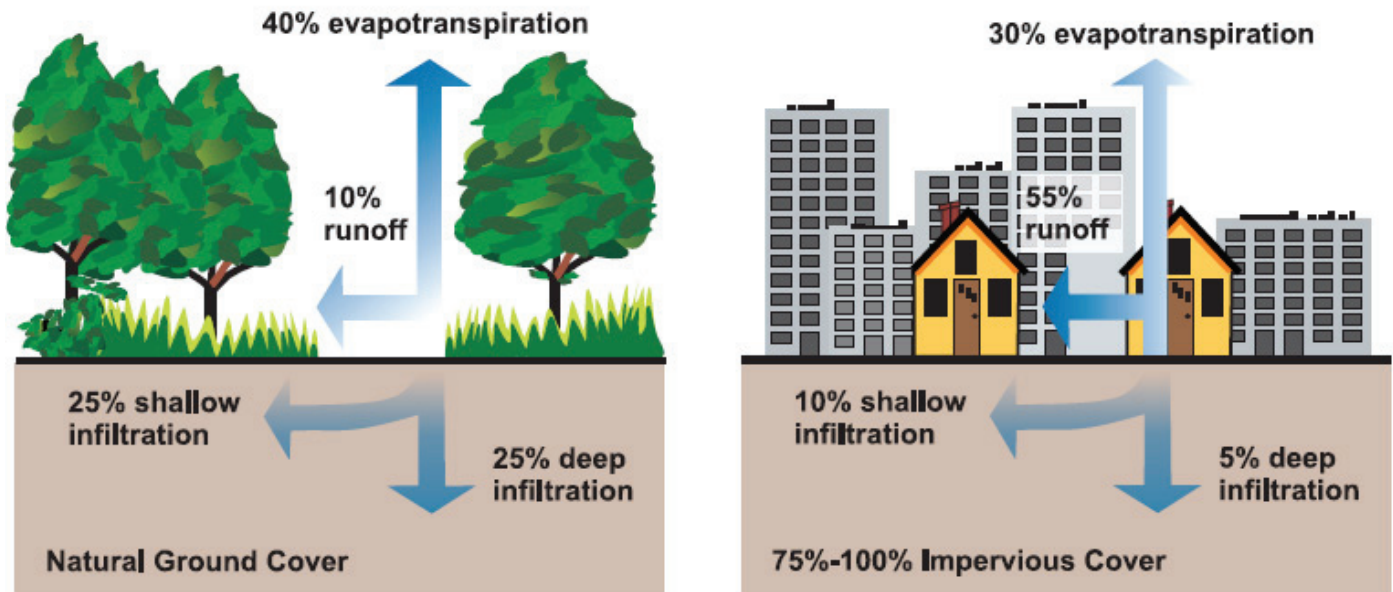
At first glance, it's easy to see alterations to the watershed landscape. Obvious changes include parking lots, neighborhoods, tilled farmland, highways, and dams. Changes can be found anywhere human activity occurs, even on a forest hiking trail. These changes are common features of a modern landscape and may seem normal; however, these changes alter water's natural flow and movement. Even the smallest human activity has the potential to affect the water cycle. For example, a car travelling on a dirt road will loosen soil which will then be carried by runoff, maybe into a stream. The list of activities with the potential to alter the hydrologic cycle is exhaustive and includes such routine acts as washing dishes, watering the yard, and even taking the dog for a walk. A few of the more common landscape alterations are included here for information purposes and to help visualize how land use might impact the flow of groundwater, streams, and rivers.

II-A-1 Land Use in Cities and Towns

Impervious surfaces include parking lots, highways, neighborhood roads, sidewalks, driveways, and more. An impervious surface is any area that has either been paved over or is so hard packed that rainwater cannot soak through to the groundwater below. It's not just the pavement that's a problem; rooftops take up a lot of space. An urban area will have miles and miles of impervious surfaces that prevent infiltration and alter the way rainwater recharges the groundwater below.

Anyone who has driven by a construction site probably noticed the amount of exposed dirt and dust. Without a protective layer of grass or trees to hold the soil in place, erosion quickly becomes a problem. When rain hits the loose dirt, some of the water may sit and soak into the ground. But if the rain fall is moderate or heavy, or the ground is sloped, the water may run across the surface and straight to a nearby pond or stream, carrying soil with it.

Impervious Impacts



In areas with a large amount of impervious surface, there is less rainwater recharge to the groundwater table.
Source: The US Environmental Protection Agency

What about all the water used in households' bathrooms and kitchens and in businesses every day for countless different purposes? Where does the used water go? The water may contain chemicals and **bacteria** that are harmful to the environment and have to be treated. Wastewater treatment facilities clean the water but sometimes can't handle the amount of dirty water produced. When a facility receives too much dirty water, the system will overflow and the polluted water will spill onto the surrounding land or stream.

Some communities in Kentucky have sewers that carry both stormwater and wastewater. These are called **Combined Sewer Systems (CSS)**. Normally, the water in these systems all goes to a treatment facility. When rainfall or snowmelt is heavy, the flow in the CSS can exceed pipe capacity, resulting in untreated water being discharged directly to the stream. These discharges are called **Combined Sewer Overflows (CSO)**.

Other communities in Kentucky have separate sewer pipes for wastewater and storm water. The pipes that carry wastewater in these systems are called sanitary sewer systems. Properly designed, operated, and maintained sanitary sewer systems are meant to collect and transport all of the sewage that flows into them to a wastewater treatment plant. However, occasional unintentional discharges of raw sewage from sanitary sewers occur in almost every system. These types of discharges are called **Sanitary Sewer Overflows (SSOs)**. SSOs have a variety of causes, including but not limited to severe weather, improper system operation and maintenance, and vandalism.

Communities of certain sizes (a population of at least 50,000 and an overall population density of at least 1000 people per square mile) in Kentucky are required to manage their storm water. These communities are called **Municipal Separate**

Storm Sewer System (MS4) communities. Each regulated MS4 is required to develop and implement a stormwater management program to reduce the contamination of stormwater runoff.

II-A-2 Land Use in Rural Areas

Changes to water flow paths are also visible in rural areas, including on agricultural or farm land. Whenever a patch of land is cleared of the vegetation, loose soil is exposed. This exposed soil is easily eroded by wind, ice, and running water. Farm animals are also a concern. Manure, or animal waste, can get washed into a stream or river. Animals may even disrupt streams directly by walking and standing in the stream bed. Many agricultural practices rely on pesticides, herbicides, and fertilizers. In the same way that loose soil is washed into a body of water, the chemicals or fertilizers may also be washed into a stream or soak into the groundwater. This is especially a problem if the products are not applied to the land or crop in the appropriate or prescribed manner.

Rural areas usually don't have as much impervious surface as populated areas, but imperviousness remains a problem. Even if only ten percent of a small area is covered with impervious surface, the stream will demonstrate negative impacts. In addition, looks can be misleading; a pasture that is overgrazed or grazed in winter or wet conditions can become quite impervious and hasten the passage of pollutants to the receiving stream.



Cows stand in a Kentucky stream. Animal waste can be detrimental for a stream system and overload the water with nutrients and bacteria.

Forests act as natural filters for water and help to keep the water runoff clean and free of pollutants. Forests are also natural resources and provide timber for construction and other uses. Logging in the forest creates changes to the system. Roads have to be built to transport harvested trees. Dirt roads impact water runoff in the same way as construction sites. Rainwater hits the road and carries away loose soil and dirt into streams.

Human waste isn't just a problem in a large city. Homes in rural areas may be connected to **package treatment plants, septic systems** or may even use **straight pipes** to discharge waste water. All package treatment plants and septic systems require maintenance and periodic cleaning. It's common for older or neglected septic systems to break down and leak. This waste water ends up in the groundwater or may flow into a stream. It is sometimes the case that homeowners are unaware of their responsibility to maintain and clean out their septic systems.

II-A-3 Land Use for Water and Energy

Mining for energy resources or for valuable minerals or other materials present many of the same issues associated with construction and logging. Then there are problems that are unique to mining. One of the more obvious changes to the watershed is the clearing of vegetation and grasses. Soil is moved and transported. Once again, erosion is an issue. As the water runs across the mined earth, it interacts with the exposed minerals. The minerals are comprised of different elements that may make the water more acidic or heavy with metals. Water with acidic pH levels and high metal concentrations can be harmful to plants and animals. Different forms of mining common in Kentucky include coal mining and quarries, an open pit from which limestone and other earth materials are extracted. Water quality issues associated with quarries are an increase in sediment and a change in pH. Mining can impact both groundwater and surface water bodies.

II-B Dams and Hydromodification

Dams, or impoundments – both large and small – are common in Kentucky's streams. These are hydro-modifications or alterations to the natural flow of water. Even small instream (low-head) dams can interfere with aquatic life. Larger impoundments can collect pollutants and impact water temperature in and below the dam. Dams can have both negative and positive impacts on oxygen content, due to stagnating water or aeration that occurs as water falls over a structure. Dams operated to release large quantities of water all at once contribute to downstream erosion.

Other alterations, hydromodifications, may be present in the form of stream straightening. Found in both urban settings and in rural areas where land owners want to control the stream channel, straightening a stream can lead to erosion problems. Water flows faster and with greater energy in a straight channel. Stream banks are less resistant to erosion. Large sections of stream banks often collapse and send more soil into the water to be carried downstream.

II-C Water Extraction

Since water is such a vital component of life on this planet, it makes sense that humans use a large share of the available fresh water. Water use causes changes to stream flows and groundwater that are not easily recognized. Excess usage is obvious during drought conditions, when pumping can cause a stream to go dry. Reduced stream flow means less water is available for the plants and animals in the stream system.

Part III: The Regulatory World

A few humans living in a large watershed and using the land in the watershed for various purposes usually don't have a large impact on the quality of the stream. However, as more humans move into the watershed and increase the amount of impervious cover and the number of land uses in the watershed, the stream begins to develop problems related to the cumulative impacts. Until the mid-1900's, streams were used to conveniently dispose of any unwanted or unusable item or substance. People didn't understand or didn't think about how watersheds worked and their importance until the accumulation of waste in the streams and lakes began to have impacts on their health and safety.



November 3, 1952 Cuyahoga River fire (photo credit James Thomas, from Cleveland Press Collection, Cleveland State University Library)

III-A The Clean Water Act and Designated Uses

In the late 1960's and early 70's, citizens and government officials in the United States realized there was a crisis with our streams and lakes. The water was so polluted that the Cuyahoga River in Ohio was one of several that actually caught on fire – more than once! In order to address the problems, Congress made laws in 1972 to protect surface water that have come to be known as the **Clean Water Act (CWA)**. The US Environmental Protection Agency (EPA) is responsible for overseeing the requirements of the CWA.

The CWA is made up of many sections that address different issues related to protecting the water. In general, it requires that the waters of the nation be **fishable, swimmable, and drinkable**. Healthy watersheds produce water that is fishable, swimmable, and drinkable. Such watersheds support a wide variety of aquatic life and are a valuable resource.

It also identifies two different types of pollution that threaten the quality of water in our waterways. They are **point source pollution** and **nonpoint source pollution (NPS)**. At the time the Clean Water Act was developed, the major problems in the waterways were being caused by point source pollution, the waste being discharged through pipes into the waterways from industrial processes and sewage treatment plants. As the years of point source regulation passed, water quality began to improve, but there were still water pollution problems across the nation.

In the late 1980's, EPA began to focus on the impacts of NPS, or runoff pollution, that was being carried into the waterways and preventing states from achieving the fishable, swimmable, and drinkable requirements. NPS is addressed in Section 319(h) of the Clean Water Act. The funding that is provided by EPA to fix NPS is often called 319 funding.

To support the fishable, swimmable and drinkable goals, the CWA requires states to set water quality standards to protect and manage their streams, lakes, and rivers to minimize or eliminate point and nonpoint source pollution. In Kentucky, the standards include criteria for various water quality measurements like dissolved oxygen, temperature, pH, and other measurable qualities and are part of our state regulations.

As part of the development of the water quality standards, states must identify uses for each body of water in their state. In Kentucky, the Division of Water has identified

the possible **designated uses** of streams, rivers, and lakes and they are listed here:

- drinking water for humans
- **primary contact recreation (PCR)** for humans - swimming
- **secondary contact recreation (SCR)** for humans - boating, fishing, wading
- Outstanding State Resource Water (OSRW) - have unique features
- aquatic habitat for plants and animals that live in water – can be **warm water aquatic habitat (WAH)** or **cold water aquatic habitat (CAH)**

Words in bold typeface are also defined in the Guidebook Glossary

The Kentucky regulations that set the water quality standards and designate the uses are found in Title 401 of the Kentucky Administrative Regulations Chapter 10 Sections 031 and 026 (401 KAR 10:031 and 10:026). These regulations can be found on the Kentucky Legislative Research Commission website .

III-B Special Uses

Special use waters are streams and lakes that are worthy of additional protection and are identified and listed in state or federal regulations. The **special uses** for streams in Kentucky are:

- **Reference Reach Waters** – These are the most unchanged streams or lakes in each ecoregion. These reference streams are used as the best examples we have of how undisturbed streams in the regions are supposed to look and function. This is useful when we have the opportunity to restore streams that have been damaged, because it gives an ideal, something to aim for. It is important to know that very few, if any, of our streams are in pristine natural condition. The Reference Reach streams are the least changed in each region.
- **Cold Water Aquatic Habitats (CAH)** – These are surface streams that will support native aquatic life or self-sustaining or reproducing trout populations on a year-round basis.
- **Exceptional Waters (EW)** – These are streams or lakes that exceed the quality necessary to support reproduction of fish, shellfish and wildlife, and recreation in and on the water. Waters placed in this category are reference reach waters, Kentucky Wild Rivers, some outstanding state resource waters and waters with “excellent” fish or macroinvertebrate communities.
- **Kentucky Wild Rivers** – These are portions of nine rivers in the state that have exceptional water quality and beauty. The Wild River designation includes all visible land on at least 2000 feet on either side of the stream. Any change in land use within the Wild River boundary requires a permit, and clear cutting and strip mining are not allowed.
- **Outstanding State Resource Waters (OSRW)** – These are streams or lakes that have unique features, including those with federally threatened or endangered species.
- **Outstanding National Resource Waters (ONRW)** – These are streams or lakes that meet the requirements for an outstanding state resource water classification and are of national ecological or recreational significance.

- **Federal Wild Rivers** – These are specifically designated in the Wild and Scenic Rivers Act, which defines them as those rivers, or sections of rivers, that don't have dams, have undeveloped watersheds or shorelines, unpolluted waters, and can only be reached by trail.
- **Federal Scenic Rivers** – These are specifically designated by Congress as rivers, or sections of rivers that meet all of the requirements of a Federal Wild River, except they can be reached by roads in some places.

III-C Required Reporting for Streams

The Clean Water Act, Section **305(b)**, requires states to submit a report to Congress every two years on the quality of the waters in the state that have been assessed. This report combines water quality information from state and federal agencies and tells which streams, rivers, and lakes have been monitored and assessed and are or are not supporting their designated uses. These waters are rated as:

- *good* if they *fully support* their use(s)
- *fair* if they *partially support* their use(s)
- *poor* if they are *not supporting* their use(s)

Another report that is required by the Clean Water Act is described in Section **303(d)**. This report is a subset of the list of the impaired (not supporting or partially supporting designated uses) streams from the Section 305(b) list of assessed streams. These 303(d) listed streams will require a study that identifies the types and amounts of pollutants in the water and how they will be reduced. These studies are called **Total Maximum Daily Loads (TMDLs)** and they determine the amount of pollutants a waterbody can receive and still meet its designated use(s).

These two reports, the 305(b) and the 303(d), have been sent to Congress through the U.S. Environmental Protection Agency (EPA) as two separate reports in the past. As of 2006, EPA has directed all states to submit these two reports combined into one report called the **Integrated Report**. The Integrated Report has **Volume I and Volume II** that correspond to the 305(b) and 303(d) lists respectively. The same types of information are in the report, but it is packaged differently. These reports are available on the Kentucky Division of Water's website .

It is important to know that the Integrated Report only provides information for the streams in the state that have been monitored and assessed. All of the streams in the state have not been monitored and assessed.

Part IV: How Is Stream Health Evaluated?

While land use has the potential to affect the health of the watershed, assessing the impacts requires careful study. The health of a watershed and its water quality is measured using many different tests and assessments. These tests and assessments can generally be grouped as water chemistry and physical properties, habitat, and biological. The goals are to identify the condition of the stream, problems and concerns, and provide a health check for the water body system.

IV-A Water Chemistry and Physical Properties

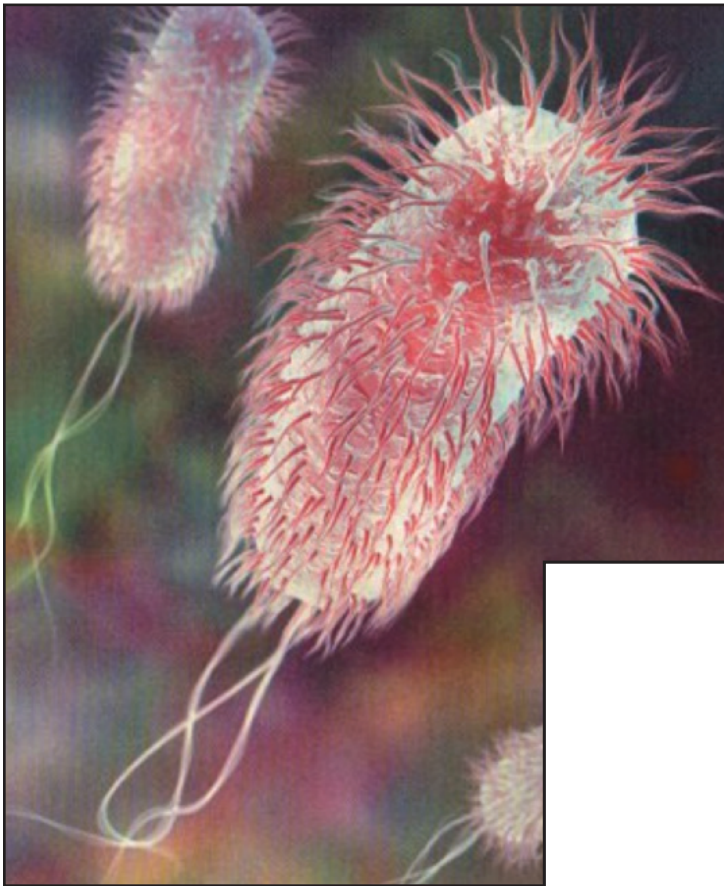
A water sample from a stream or lake can provide a very good snapshot of different water quality properties. Some of these tests are performed on the water in the stream at the time the sampler is there; these are called field tests or field analyses. Other tests are performed on water collected from the stream and sent to a laboratory; these are called lab analyses. Field tests are used to measure temperature, pH, conductivity, dissolved oxygen and suspended solids. Lab analysis is required to measure bacteria, metals, nitrates, phosphates, pesticides and other potential chemical or biological pollutants.

Bacteria:

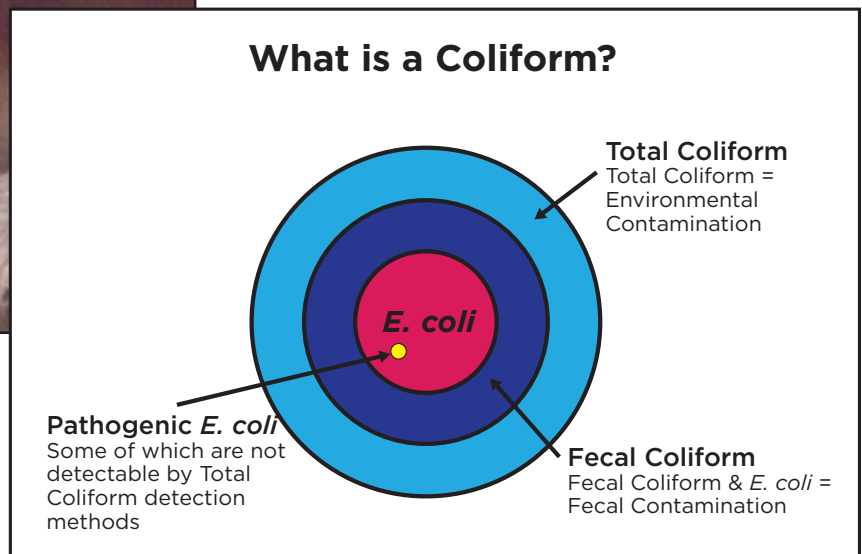
Bacteria are organisms that are microscopic, not able to be seen with the naked eye. They are found everywhere, on our skin, inside our bodies, in soil, in water, on plants, etc. Fortunately, most of these are harmless to humans. Some of them are actually very helpful to humans and are involved in the processes that keep our bodies functioning properly.

There is a group of 16 different bacteria that have similar properties. This group is called **total coliform** bacteria. These are found in soils, plants, and in the intestines

and waste of warm-blooded and cold-blooded animals. Coliform bacteria aid in the digestion of food. Of these 16 total coliform, there are six that are found only in the fecal waste (poop) of humans and other warm-blooded animals. These six are called **fecal coliform**. Of the six fecal coliform, there is one member of the group called *Escherichia coli*, abbreviated as *E. coli*. *E. coli* has several different forms and one of these is a strain that can cause dangerous illness in humans.



Enlarged photo of microscopic *E. coli* bacteria



You can become infected with these bacteria by eating food and drinking water contaminated with them. You can also become infected when your mucus membranes (eyes or inside your mouth and nose), or cuts and open sores, come in contact with the contaminated food or water. Fecal coliform bacteria can enter the water through sewage or other sources of human and animal waste.

Human and animal wastes also contain other organisms that can't be seen with the naked eye and cause disease and illness. These include viruses and parasites. Bacteria, viruses, and parasites that cause disease and illness are called **pathogens**.

Samples of water are usually analyzed in a lab for the presence of fecal coliform and/or *E. coli*. The two main reasons the presence of these bacteria are used to indicate whether water is safe for use are:

1. These bacteria are fairly easy to detect in a lab test.
2. If these bacteria are present, then pathogens are possibly also present.

A controlled amount of the water sample is placed in a container with a source of food that allows the bacteria to reproduce. The container is then placed in an incubator for a specific amount of time to encourage the bacteria to reproduce in large clusters called colonies that can be seen with the naked eye. These colonies can then be counted. The bacteria are reported by the lab in **colony forming units (cfu)**.

Water samples that will be tested for fecal coliform and *E. coli* must be collected from the stream following very specific procedures and taken to a lab for analysis.

Biochemical Oxygen Demand (BOD):

Biochemical Oxygen Demand (BOD) measures the amount of oxygen consumed by microorganisms as they decompose organic matter in a water body. BOD also measures the loss of oxygen due to chemical reactions. Oxygen levels in water can vary widely depending on such factors as temperature. BOD directly affects the amount of dissolved oxygen in rivers and streams. The greater the BOD, the more rapidly oxygen is depleted in the stream. If BOD is high, then organisms that depend on a supply of dissolved oxygen become stressed, suffocate, and die.

BOD, or the rate of oxygen consumption in a stream, is affected by a number of variables: temperature, pH, the presence of certain kinds of microorganisms, and the type of organic and inorganic material in the water. A river with a greater amount of organic material, such as leaves and woody debris, will likely have a higher BOD level than a fast running river with riffles and little decomposing organic material.

Water bodies are more likely to exhibit high BOD levels if they are impacted by large amounts of dead plants and animals, animal manure, effluents from pulp and paper mills, wastewater treatment plants, feedlots, and food-processing plants, failing septic systems, and urban stormwater runoff.

The methods for collecting BOD samples are similar to steps described for collecting dissolved oxygen (DO) samples, with an important difference. At each site a second sample is collected in a BOD bottle and delivered to the lab for DO testing after a 5-day incubation period. BOD₅ is measured in milligrams per liter (mg/L).

Conductivity:

Conductivity is a measure of the water’s ability to conduct an electric current. It is an indicator of the presence of dissolved solids in the water. Pure water has a very low conductivity. Conductivity is affected by temperature; the warmer the water, the higher the conductivity. Discharges of some chemicals to streams can change the conductivity. The discharge from a failing sewage system would raise the conductivity because the sewage contains chlorides, phosphates, and nitrates. Oil that enters the stream from a leaking storage tank would lower the conductivity.

Conductivity in streams and rivers is affected by the geology of the area through which the water flows. Streams that run through granite bedrock will have lower conductivity, and those that flow through limestone and clay soils will have higher conductivity values.

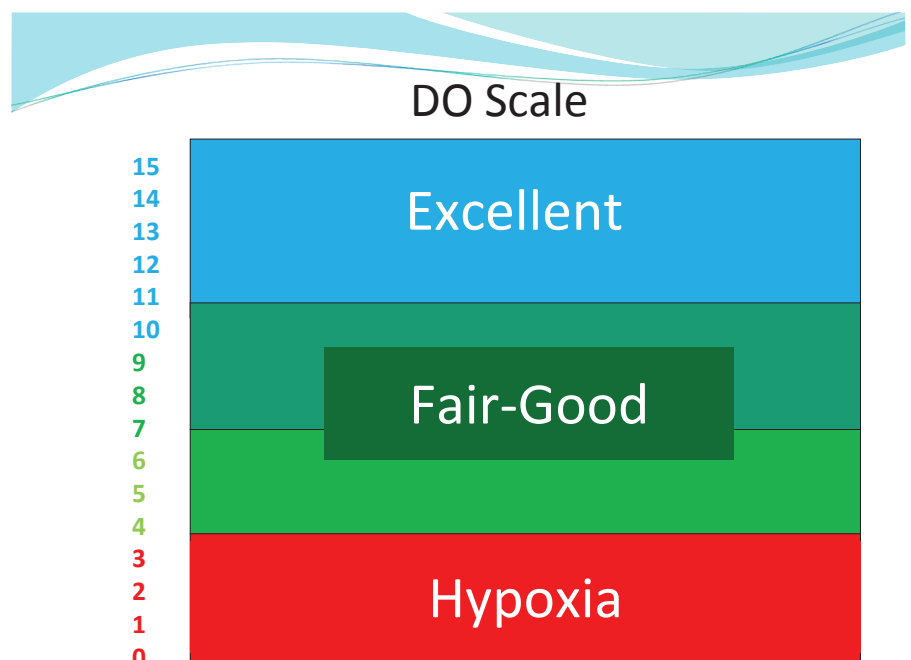
Conductivity is measured in units called micromhos (pronounced mikro – moes) per centimeter or microsiemens (pronounced mikro – seemins) per centimeter. Studies of streams and lakes have shown that streams with measured conductivity levels between 150 and 500 micromhos per centimeter are the best for most fish and other stream animals. Conductivity levels that aren’t in this range could mean that the water isn’t livable for certain stream animals.

Conductivity is usually measured in the stream at the time that other samples are collected.

Dissolved Oxygen (DO):

Most aquatic organisms obtain the oxygen they need to survive from oxygen dissolved in the water. Oxygen enters water from the atmosphere and/or from groundwater. In streams with rapid currents or riffles, more oxygen is usually present compared to stagnant (still) water. Cold water can hold more **dissolved oxygen (DO)** than warm water. In winter and early spring, when the water temperature is low, DO concentrations are higher. During warmer months, the DO concentration falls.

Loss of DO will occur if too many bacteria in the water consume oxygen as organic matter decays. Eutrophication causes the depletion of DO. This is especially a problem in a stagnant body of water such as a lake with a large amount of decomposing material and warm temperatures. In the summer, lakes around the country may report fish kills due to eutrophication. The amount of DO will vary during the day, with temperature changes.



DO is measured in the stream at the time that other samples are collected. It is measured in the unit milligram per liter of water (mg/L). The Kentucky surface water standard for DO is 4 mg/L, which is the acute level, and 5 mg/L, which is the chronic level. The daily average for DO should at a minimum be 5.0 mg/L. The minimum for an instantaneous measurement should be 4.0 mg/L.

Metals:

Metals are present in water as metal ions. They may be naturally occurring and the results of rocks, minerals, soils coming into contact with water. For example, water acts as a weathering agent on a rock. The rock slowly dissolves and releases the metals into the environment. The most common naturally-occurring metals are calcium and magnesium. These are generally the result of the weathering of limestone, a common rock type in Kentucky. Water hardness describes water that contains a relatively high concentration of metals. These can build up and cause “scaling” on pipes and plumbing systems. A high concentration of metals may also be the result of pollution. Metals from rusting cars are shed on parking lots. Runoff from the parking lots goes into storm drains which are then discharged into streams. Waste water from industry often contains metals which end up in streams. Metals from industrial activity are also discharged into the atmosphere. Mining activities also increase the amount of metals released. In waters with a low pH, (acidic) more metals are dissolved and the concentrations in the water can reach levels toxic to organisms and humans.

When deciding to test for metals, look at land use in the watershed. As in the case of pesticides and herbicides, the collection of water samples for metal analysis requires a careful monitoring or collection plan.

Nutrients:

Nutrients are the ingredients in soil, water, and organisms that are essential for life, yet excess nutrients are not healthy for streams. Nutrients in groundwater are also potentially harmful. Excess nitrogen in drinking water is dangerous to humans, especially small children and infants.

The amount of nutrients in the watershed will vary depending on several factors. In the summer, nutrients levels may increase due to fertilization of farmland, lawns and gardens. Not all of the fertilizing nutrients will be used by the land or plants and excess nutrients are washed away during a rainstorm. Decomposition of organic matter also releases nutrients and streams may experience greater nutrient loading during the winter as dead leaves and other organic debris decompose, or decay.

Excess nutrients are usually the result of pollution from land use activities. Nutrient sources include stormwater runoff, waste products from farm animals and domestic pets, failing septic systems, and discharges from industrial and municipal wastewater treatment plants.

A small pond provides a good example of excess nutrients and their impacts. A pond naturally supports a certain amount of plant life and fish life. Nutrients enter the pond and are taken up by the plants. The fish eat the plants, die, and decay. Thus,

the nutrients are recycled. But what if extra nutrients are washed into the pond from the farmland around it? The extra nutrients mean more plants grow, especially if the temperatures are warm. More algae than normal will bloom, die, and decay. Bacteria breakdown the decomposing algae and consume more oxygen. This process causes a depletion of available dissolved oxygen. With less oxygen in the water, fish will suffocate and die. This entire process is called **eutrophication**. In streams, under the right conditions, stream plants called **periphyton** will grow on rocks or logs. Their algae blooms cause unsightly conditions, odors, and poor habitat for the organisms living in the water body.

A much larger example of the impacts of eutrophication is seen in the Gulf of Mexico. Over the past 100 years, nutrients from farmland around the Mississippi River basin have been washed into streams and rivers. The mouth of the Mississippi River is the final destination for these nutrients. While the Gulf of Mexico is a large water body, it is unable to process the excess nutrients. Large dead zones, or areas that periodically cannot support aquatic life (e.g., **hypoxia**), have developed. This is a good illustration of the concept that what happens in your watershed can have far-reaching impacts downstream.

Nitrogen and Phosphorus:

Two primary nutrients are nitrogen (N) and phosphorus (P). These two elements are essential for plant growth and are found in fertilizers applied to farm land and neighborhood gardens. They are also found in water bodies. Nutrients are measured in a water sample submitted to a laboratory.

The amount or concentration of nitrogen and phosphorus are measured and reported in the unit milligram per liter of water (mg/L). Most laboratory methods require samples to be collected and placed in coolers and maintained at a temperature of 4°C. Generally, the lab will need to analyze the samples within 48 hours of collection.

Phosphorus (P) and nitrogen (N) are measured in several forms. Formations of the various phosphorus and nitrogen compounds are governed by factors such as pH, temperature, oxygen concentration, and biological activity. The forms that are of primary concern are the forms that are used by plants and other organisms. It is important to know the amount that is available for growth.

Phosphorus (P) will bond with oxygen (O) to form Phosphate (PO_4). Phosphorus can be measured as the following:

- Total phosphorus (TP)
- Orthophosphate (OP). Orthophosphate represents the fraction of TP that is soluble in water and available to organisms for growth.

Nitrogen will bond with oxygen (O) to form nitrate (NO_3) or nitrite (NO_2). It will also bond with hydrogen to form ammonia (NH_4). Nitrogen can be measured as the following:

- Total Nitrogen (TN). TN refers to the total amount of nitrogen in a sample.
- Total Kjeldahl Nitrogen (TKN). TKN represents the fraction of TN that is unavailable for growth or bound up in organic form; it also includes NH_4 .
- Nitrate-nitrogen (NO_3)
- Nitrite-nitrogen (NO_2)

The US EPA has set a safe-drinking water standard or maximum contaminant level (MCL) for nitrate of 10 milligrams per liter of water. If water contains nitrate at concentrations higher than the MCL, it is considered unsafe for human consumption. Kentucky surface water standards limit the amount of un-ionized ammonia (NH_3) to 0.05 mg/L in surface water systems.

Pesticides and Herbicides:

Pesticides and herbicides are human made chemicals used to control bugs, insects, and weeds that disrupt agricultural production. Pesticides and herbicides in groundwater and streams are a result of modern agricultural practices and are not part of the natural environment. If excess pesticides and herbicides are applied to land or if they are accidentally spilled, the chemicals may be transported to the groundwater by soaking into the soil or by surface runoff to a stream. Since the chemicals are not naturally occurring, they may persist in the environment or degrade slowly. As they degrade, the resulting degradation compounds may also pose threats to the environment. While pesticides are commonly found in water bodies around the country, they may not be a concern in your watershed. Knowing how land is used in the watershed (e.g., for agricultural purposes) will help you decide if pesticide/herbicide water samples should be collected. Also, if you are aware of groundwater or surface water samples that have been tested for pesticides and herbicides, it would be useful to obtain the results. It's additional information that will help you determine all of the water quality problems in the watershed. Pesticides and herbicides are toxic to the plants and animals in streams at small concentrations. Public water supply systems frequently test the water supply to ensure that pesticides and herbicides are not present, since the chemicals are also harmful to humans. Many different collection and laboratory methods are used for pesticides and herbicides and a careful monitoring plan should be created prior to sample collection. The US EPA and the state of Kentucky have strict regulations for the amount of pesticides and herbicides allowable in water.

pH:

The pH of a sample of water is a measure of the concentration of hydrogen ions. The actual term "pH" refers to the way hydrogen ions are calculated. Measuring pH is important because it indicates whether the water is acidic or basic. The scale for measuring pH ranges from 0 to 14. A water sample with a pH of 7 is considered neutral, and is neither acidic nor basic. If the pH is below 7, then the water is acidic. If the pH is above 7, it's basic. Bleach is considered basic with a pH around 12.5. Vinegar is considered acidic with a pH around 3. The largest variety of animals living in water prefers a pH range of 6.5-8.0. pH outside this range reduces the diversity in the stream because it stresses most organisms and can reduce reproduction. Also, solutions that are too acidic or too basic change the solubility (amount that can be dissolved in the water) of materials in the watershed. For example, rocks with heavy metals may leach metals into acidic water because of the increased solubility. In other words, metals are more toxic and mobile in waters with a lower pH.

The pH of a stream will vary, but will depend on such factors as the local geology and the pH of rainfall. As rocks dissolve, hydrogen ions are released into the water. In the last several decades, rainfall has become more acidic as a result of particulates

released into the atmosphere. The acid rain lowers the pH of a receiving water body. Another form of pollution that will change the pH of water is runoff from a mining operation. The runoff may be highly acidic and would likely kill any fish living in the system.

The test for pH is usually performed in the stream at the time that other samples are collected. The Kentucky surface water standard for pH is in the range between 6.0 and 9.0.

Temperature:

The plants and animals that live in a stream are dependent on certain temperature ranges for their optimal health. Variations above or below that range effect the life processes of these organisms. The best temperatures for fish depend on the species: some survive best in colder water, whereas others prefer warmer water. Most of the animals living in Kentucky's streams, lakes, or wetlands are sensitive to temperature and will move in the stream, to the extent possible, to find areas with their optimal temperature. If temperatures are outside this optimal range for a prolonged period of time, organisms are stressed and can die. In addition to having direct impacts on life processes, warmer water cannot hold as much dissolved oxygen. Low oxygen amounts cause many negative impacts to organisms living in the stream.

Temperature will vary depending on the weather and seasonal changes. Daily variation also may occur, especially in the surface layers, which are warmed during the day and cooled at night. Elevated temperatures can occur if the trees and other vegetation which normally provide shade for the stream are removed. Water body temperatures will also increase in impoundments (a body of water confined by a barrier, such as a dam), or may increase if the water receives industrial discharges, urban storm water, or groundwater inflows.

Stream temperature for scientific studies is usually measured in degrees Celsius (°C). For other purposes, temperature can be measured in degrees Fahrenheit (°F). Stream temperature is taken in the stream at the time that other samples are collected. In Kentucky streams designated as Warm water Aquatic Habitat (WAH), temperatures should not exceed 31.7°C (89°F). A stream designated as a Cold water Aquatic Habitat (CAH) must be able to support reproducing trout populations on a year-round basis.

Total Suspended Solids (TSS) and Turbidity:

Total suspended solids (TSS) concentrations and **turbidity** are each used to measure the amount of solid material (e.g., soil, algae) suspended in the water. However, the TSS test measures an actual weight of material per volume of water, while turbidity measures the amount of light scattered from a water sample (more suspended particles cause greater scattering of light). In a water body with a large amount of suspended material or high turbidity, the water will likely appear muddy or cloudy. The water in a stream or lake with little suspended material is clear; it is easy to see objects at greater depths. Less light is able to reach plants at deeper depths in the stream or lake when there is a higher concentration of suspended material in a water body. Suspended materials are also likely to be carrying other pollutants such as metals and bacteria.

The amount of TSS and turbidity is influenced by how much runoff enters the water. Heavy rains and fast-moving water cause erosion and carry soil and other materials into the water. After a heavy rain, a stream near a cleared patch of land may look muddy. Stream banks cleared of vegetation are especially at risks of increased TSS and turbidity. Stormwater drains are also sources of suspended material.

TSS and turbidity are both generally measured in the laboratory. TSS concentrations are measured in milligrams of suspended solids per liter of water – mg/L. Turbidity is reported as nephelometric turbidity units (NTU) or Jackson turbidity units (JTU), depending on the instrument used to perform the measurement. TSS and turbidity values will vary greatly between different water bodies.

IV-B Habitat Assessment

The stream habitat includes all of the places where specific plants or animals can live; such as on rocks, under rocks, in the spaces in between rocks, in piles of leaves, on plants, in mud, in sand, under logs, in piles of twigs, etc. A large variety of habitat in the stream supports a large variety of plants and animals that live there. Some habitat is related to the features of the stream itself, while other habitat is related to the streambanks and adjacent land, or **riparian area**.

Habitat assessment is another way to measure the health of a stream. The purpose is to look at individual features that provide habitat in a particular length of a stream and determine how well they are functioning individually. These are then combined into one overall measurement of how livable the stream is for stream animals. The selected length of the stream that is to be assessed is called a **reach**.

A habitat assessment method that is used to perform this measurement was developed by the EPA. It is called the Rapid Bioassessment Protocols. It can be found in Chapter 5 – Habitat Assessment and Physicochemical Characterization at the following EPA website [https://www.epa.gov/rapid-bioassessment-protocols](#). It uses a scoring sheet that focuses on ten stream features.

Some streams flow through hilly land and have many **riffles** and **runs**. Riffles are places in the stream where the height of the stream drops to a lower point and the bottom is rocky. Because of this drop in height, the bottom of the stream and the rocks located there, are very close to the surface of the stream or sticking out of the surface. This causes the surface of the water to look rough and bubbly instead of smooth. Runs are places in the stream where the water moves quickly out of a riffle. Runs are deeper than riffles, so rocks don't stick out of the water and the surface is smooth. These steep streams that have many riffles and runs are called **high gradient streams**.

Other flat streams are **low gradient streams**. These are streams that flow through flatter land and have few, if any, riffles, many glides and pools, and mostly fine sediment bottoms. **Pools** are the deepest parts of the stream and normally have the slowest flow. **Glides** are the areas where the water is flowing more quickly out of pools in the stream and becoming increasingly shallower.

To be able to accurately assess the habitat in both types of streams, there are two versions of the EPA scoring sheet: one for high gradient streams and another for low gradient streams. Copies of each of the scoring sheets are included in Appendix E.

Scoring High Gradient Streams

When using habitat assessment to determine the health of a reach of a high gradient stream, the following ten questions must be answered and the features rated from zero to twenty on the scoring sheet:

1. What are the types and sizes of natural materials, such as the rocks and sticks, in the stream?

This measures how many potential places are available for the animals in the stream to live. To have a healthy variety of animals living in the stream, there must be a lot of different places for these animals to live. Many of the stream animals are very small, so they don't need large places to live. Some live on the tops of rocks where the flow is fast and the dissolved oxygen levels are high. Others live in piles of decaying leaves where the dissolved oxygen level may not be as high, but a steady supply of food is provided by small particles, released as the leaves rot. Others may burrow in sand, where they are hidden and safe, to wait for a food to float by so they can jump out and ambush it. Still others may constantly swim or float in the water, prepared to swim away from danger or toward food. The possibilities are endless, and each type of living space is used by specific animals.

2. How much of the rocks on the bottom of the stream are covered with sediment?

This is a measurement of the amount of sediment covering the places where animals live and making them unavailable. This results in fewer types of animals living in the stream.

3. What are the depth and flow speed combinations found in the stream?

This measurement determines how many different combinations of depth and flow speed are available to support a variety of animals. The depth and flow speed of the water affects the temperature, amount of oxygen, and amount of food moving past in the water. Different animals require different depths and speeds of water to survive.

4. What are the sizes and numbers of islands or point bars formed by sediment?

This is a measurement of how much sediment is being moved by the stream. If there is a lot of dirt being washed into a stream or worn away from the streambanks and carried by the water, it will settle out at a place in the stream where the water is slowed down by a curve in the stream, a tree that has fallen into the stream, a large rock, a bridge, etc. As more sediment begins to collect, the water is slowed down even further, so more sediment settles there. This will cause an island or point bar to form and appear above the surface of the water. This is a natural process, but too much sediment in the stream will cause too many islands and point bars. These may even get larger and cover the entire width of the stream. They will change frequently and don't provide good places for stream animals to live.

5. How much of the stream bottom is covered by water?

This is a measurement of how reliable the different areas of the stream are for the animals that live in it. Streams that regularly have parts of the bottom exposed, and are without water flowing over them, are not dependable places for stream animals to live.

6. How much of the stream has been straightened?

Determining the amount of stream that has been straightened is a measurement of how much the places for stream animals to live have been affected or destroyed. In the past and even today, it has been a common practice for humans to use tools and equipment, such as bulldozers and backhoes, to channelize the curvy, natural path of a stream into a straight, unnatural trench. This is done for a number of reasons, such as making it easier to mow, getting rid of flood water faster, it's cleaner looking, etc. However, channelization destroys all of the habitat and natural functions of the stream. In addition, as soon as the straightening project is completed, the stream will begin to wear away the banks to try to get back to its natural, curvy shape. This means a large amount of dirt will be eroded into the stream and the sediment will move downstream and damage or destroy the habitat for stream animals.

7. How many riffles are in the stream?

This is a measurement of how much of the stream provides places to live with high dissolved oxygen levels for stream animals. The stirring, bubbling, and churning of the water in a riffle causes a lot of oxygen in the air to dissolve in the water. Stream animals that need high levels of dissolved oxygen often live in or near riffles. There are a lot of riffles in streams that have mountains or hills in their watersheds, so there is usually a lot of dissolved oxygen in these high gradient streams. Streams flowing through flat land don't have these riffles or the high levels of dissolved oxygen, so stream animals that need a lot of dissolved oxygen will not be found in these streams. The habitat assessment for these flat, low gradient streams is based on different factors than those for steep streams.

8. How stable are the banks of the stream?

This is a measurement of how much of the streambanks are eroding and falling into the stream. When large areas of bare dirt, exposed roots, undercut areas, and trees falling into the stream are seen along the streambanks, it is a sign that the banks aren't stable and too much sediment is entering the stream. This sediment covers up and fills in the places where stream animals live. Also, the high levels of mud and sediment in the water make it difficult for fish and other stream animals to absorb the dissolved oxygen they need and make it difficult to find food.

9. How much of the streambanks are covered with native plants?

This is a measurement of what types of materials are being washed or dropped into the stream from the plants (trees, shrubs, grasses, wildflowers, etc.) growing on the streambanks or in the riparian area (the land adjacent to the streambanks), and how much cover is being provided for the stream. These plant materials, such as sticks, logs, and leaves, provide a food source and places to live for the animals living in the stream. When nonnative plants start growing in an area, they often take over, crowd out the native plants, and reduce the variety of sizes and kinds of plants. The animals living in the stream have developed by

depending on the materials from the native plants, and often can't use the materials from the nonnative plants. This causes the native stream animals to die off. Also, when there is a healthy mix of native plants growing along streams, there is a variety of heights of plants that can provide shade for the streams. This helps keep the temperatures in the streams in the range that the stream animals need to survive.

10. How wide is the riparian area?

This is a measurement of how much nonpoint source pollution is being filtered out of the rain and snow melt runoff before it enters the stream. As this runoff moves across the land in the watershed, it picks up any pollution on the land and carries it along. As the runoff flows through areas of land covered with grass, shrubs, trees, etc., it slows down and drops some of the pollution it is carrying. Other pollution is absorbed by the plants or attaches to them. A wider riparian area covered with these plants provides the opportunity for more pollution to be filtered. This means less pollution enters the stream, so there is less effect on the stream animals.

Scoring Low Gradient Streams

When using habitat assessment to determine the health of a reach in a low gradient stream, most of the same ten questions must be answered and scored with the following three differences:

2. What types of materials are covering the bottoms of the pools and is there a variety of types?

This is a measurement of how fine or coarse are the sediments on the pool bottoms. Low gradient streams don't have rocky bottoms, so many of the small spaces for macroinvertebrates to hide in aren't present. If the pool bottoms are covered with gravel and firm sand, as well as mats of roots and underwater vegetation, then there will be more spaces available than if the pool bottoms are covered with soft sand, mud, or clay that pack tightly together without any spaces available for macroinvertebrates.

3. What are the sizes and depths of the pools?

This is a measurement of the variety of combinations of size and depth of the pools. These different combinations will create areas with different water temperatures and levels of dissolved oxygen, as well as different speeds of flow. Different animals require different depths and speeds of water to survive. This variety means more places for different macroinvertebrates and fish to live.

7. How curvy is the stream?

This is a measurement of how stable is the stream system. The increased number of curves, or bends, in a stream will absorb more of the energy in the water and slow down the force of the water during floods. This will decrease the amount of erosion of the banks and stream bottom. In addition, the increased number of curves adds to the length of the stream. This combination of changes in flow speed and additional stream area creates more variety of places for macroinvertebrates and fish to live.

IV-C Biological Assessment

Since the water in a stream is constantly moving downstream, a sample of the water collected from the stream will only give information for that moment in time. There could have been a huge storm the week before that washed a lot of dirt into the water that had already settled out by the time the sample was collected. Or, the next day after the sample was collected a property owner could dump some old containers of pesticides in a ditch that flows to the stream and quickly flows downstream. These pollution

events would not be detected in the sample collected. However, there is a sample that can be collected that shows the effects of any pollution from the watershed that enters the stream over time. This is a sample of the stream animals that are mentioned so frequently in the Habitat Assessment section. The stream plants, **algae** and **diatoms**, can be collected and used to determine pollution effects, too. The plants and animals are sometimes referred to as **flora** and

fauna. Collecting a sample of these flora and fauna and identifying them is called a **biological survey**. Using a biological survey(s) to determine watershed health is called a **biological assessment**. When the stream animals are used in this way, they are called **biological indicators**. Since different organisms can tolerate different conditions and levels of pollution in the water, they can be used to indicate the quality of the water.



Mayfly larva
www.benthos.org
Photo by Rich Merritt



Stonefly larvae
www.benthos.org | Photo by Rich Merritt



Stonefly adult
www.benthos.org | Photo by Howell Daly



Dragonfly larva with zebra mussels attached
www.benthos.org

Many of the animals found living in streams are **benthic macroinvertebrates**. These are animals that live on, in, or around the bottom of streams, don't have backbones, and can be seen with the naked eye. They are often the immature forms, or **larvae**, of insects that live on land as adults.

There are several reasons to use the benthic macroinvertebrates for biological assessments. They make good indicators of watershed health because they:

- live in the water for all or most of their life
- stay in areas suitable for their survival
- are easy to collect
- tolerate different amounts and types of pollution
- are easy to identify in a laboratory
- often live for more than one year
- don't move very far in the stream
- are exposed to all conditions and pollution in the stream

Benthic macroinvertebrates that are used as biological indicators for water quality can be grouped



NABS (www.benthos.org)
Dobsonfly larva feeding on stonefly larva
www.benthos.org
Photo by Larry Serpa

by their sensitivity to pollution. The presence in a stream of many or all of the individuals in the Sensitive Group would indicate good water quality. However, a variety of macroinvertebrates from each group should be found in a healthy stream. If only a few individuals, or none, of the Sensitive Group are present in a stream, and the macroinvertebrates are mostly from the Moderately Tolerant and Pollution Tolerant Groups, this would indicate fair water quality. If most or all of the macroinvertebrates present are from the Pollution Tolerant Group, then poor water quality would be indicated.



Pouch Snail
www.epa.gov
Photo by Wayne Davis

Benthic macroinvertebrates play an important role in a stream system. They provide a food source for larger animals, especially fish. Some of these macroinvertebrates eat algae and bacteria. Others shred and eat leaves and other decaying material that enters the stream. By feeding on and using the nutrients in these materials, the benthic macroinvertebrates make these nutrients available to the larger animals that eat them. Also, when they die and decay, the nutrients in their bodies

Sensitive Group

- Stoneflies
- Water Penny Beetles
- Mayflies
- Caddisflies (except net spinning species)
- Dobsonflies
- Alderflies
- Snipeflies
- Mussels
- Riffle Beetles

Moderately Tolerant Group

- Damselflies
- Dragonflies
- Caddisflies (net spinning species)
- Crayfish
- Amphipods
- Blackflies
- Isopods
- Craneflies

Pollution Tolerant Group

- Midgeflies
- Worms
- Leeches
- Pouch Snails

Source: www.epa.gov



Damselfly larva
www.epa.gov
Photo by Ohio DNR



Freshwater Mussel alive in stream and empty shell (inset)
www.epa.gov
Photo by Jeffrey D. Grabarkiewicz

become food for other benthic macroinvertebrates in the stream.

Native plants and animals live in a balance in a natural stream system with a healthy watershed. When nonnative plants and animals are brought into a stream, they can begin to grow and take over the stream system. These nonnatives move into the habitat of the natives, causing them to begin to disappear from the system. The nonnatives also use up the food sources that the natives have always depended on. This also causes the natives to begin to disappear from the system. When large numbers of nonnative plants or animals are observed in a stream or watershed, this is a sign that the stream isn't healthy. An example of a nonnative animal that has taken over in some streams and lakes in the United States is the zebra mussel. In addition to taking the habitat and food from native animals, the zebra mussels also grow on or cover up the animals and kill or weaken them.

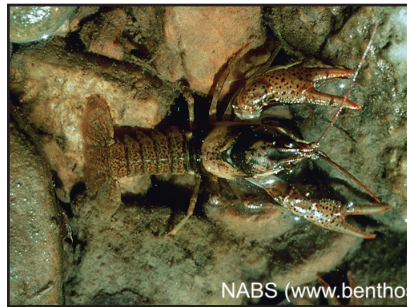


NABS (www.benthos.org)
Damselfly adult
www.benthos.org
Photo by John Wallace



NABS (www.benthos.org)

Midgefly larva
www.benthos.org
Photo by Dave Penrose



NABS (www.benthos.org)

Crayfish
www.benthos.org
Photo by Bob DiStefano



NABS (www.benthos.org)

Case-making Caddisfly larvae
www.benthos.org
Photo by J.C. Hodges, Jr.