# CHAPTER

# 3

# OVERVIEW OF WATERSHED IMPAIRMENTS

# Overview of Watershed Impairments

In this chapter you will learn about the following:

- **potential watershed impairments and their causes**
- **consequences of having impaired waterways**
- **impacts that behaviors and land use have on our waterways**
- **water quality laws and monitoring practices that help us track and improve water bodies**

## WATER QUANTITY & QUALITY

### WATER QUANTITY

Water quantity refers to the volume of water that is available. Water comes from groundwater sources, such as underground aquifers, and from surface water sources such as lakes, streams, and reservoirs (figure 3.1). Different methods are used to determine the amount of available water in these various sources.

The main way to evaluate the quantity of water in streams and rivers is through a **stream flow hydrograph** (figure 3.2).

Data is collected from rivers and streams using flow gauges managed by the US Geological Survey and others. The gauges tell us how much water flows past a certain point over a certain period of time. If a lot of water flows past a gauge, then the quantity of water in the river is large and vice versa.

To determine the quantity of water in lakes, we must know the depth and shape of the lake bottom and how the lake level changes over time. The depth and shape of a lake bottom are determined with **sonar** devices that reveal the variations in lake depth and indicate how the surface area and volume of the lake change with lake depth. Lake gauges, much like the flow gauges used in streams and rivers, are used to determine how the lake level changes over time. The data can then be plotted on a hydrograph.

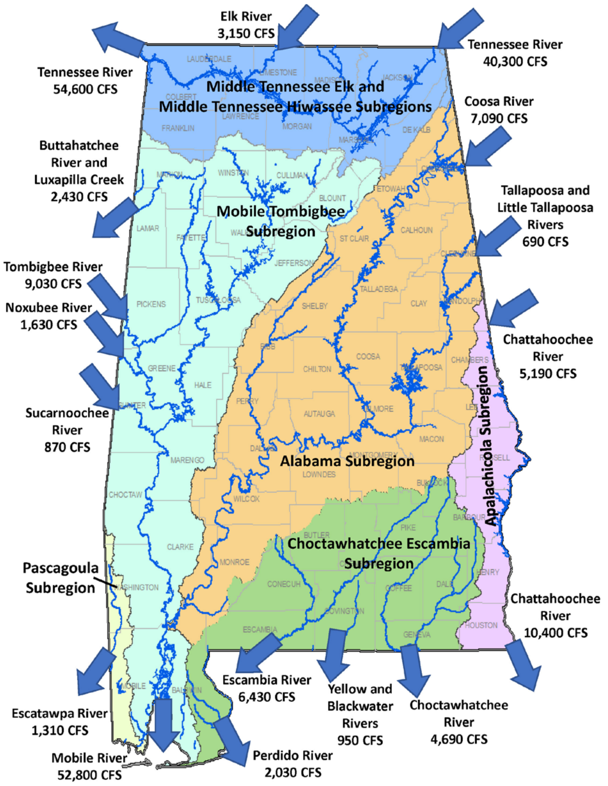


**Figure 3.1.** Average stream flows into and out of Alabama from 1975–2014. (Photo credit: Alabama Department of Economic and Community Affairs, Office of Water Resources)

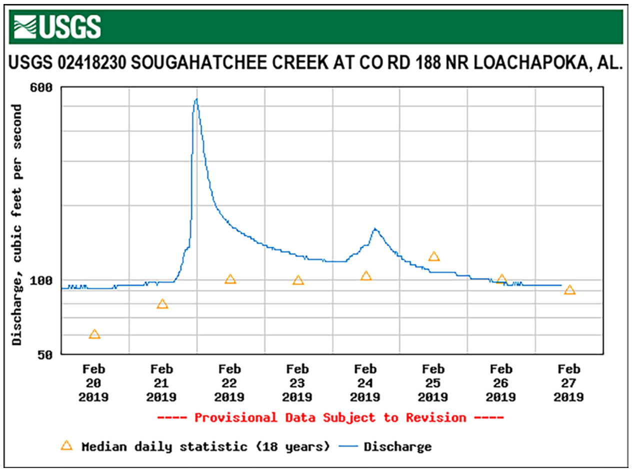


**Figure 3.2.** US Geological Survey stream flow hydrograph. (Photo credit: United States Geological Survey)

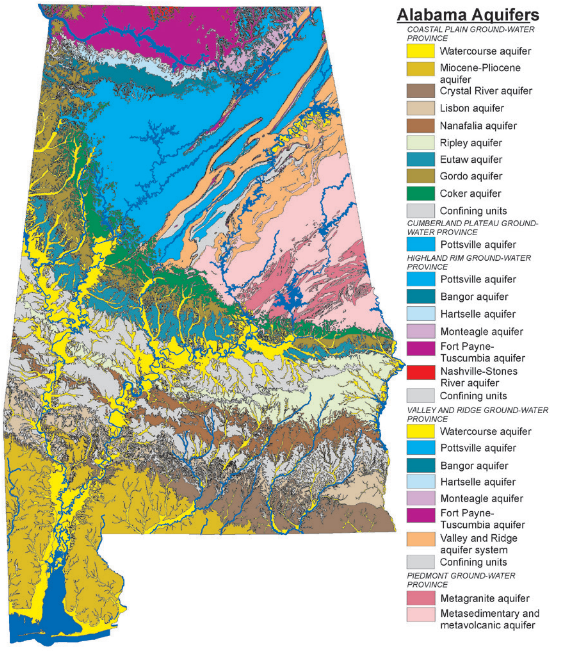


**Figure 3.3.** Principal aquifers in Alabama. (Photo credit: Alabama Department of Economic and Community Affairs, Office of Water Resources)

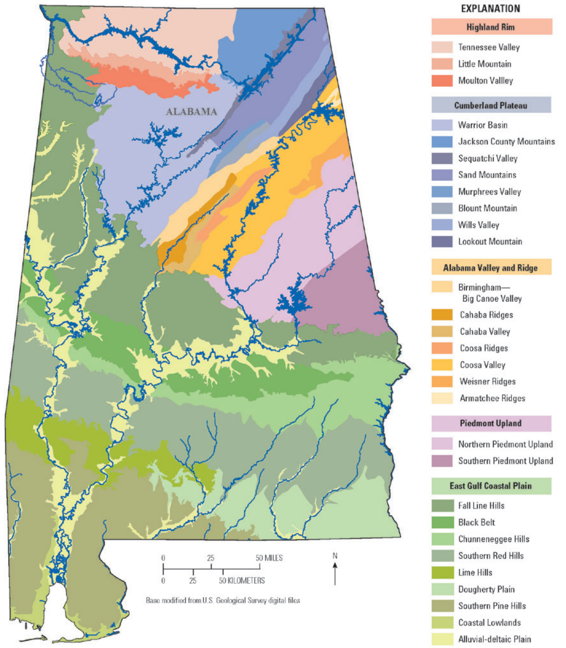


**Figure 3.4.** Physiography in Alabama. (Photo credit: Alabama Department of Economic and Community Affairs, Office of Water Resources)

The amount of water in groundwater sources is hard to quantify, because there is so much variation in underground geologic properties and the depth of the earth's surface. So how much water is actually contained in Alabama's surface and groundwater sources? The Geological Survey of Alabama[7] estimates that the state has around 586.5 trillion gallons of water available, 553 trillion of which are contained in underground aquifers (figure 3.3).[6] Interactions between the various soil layers and aquifers must also be understood, which is very difficult (figure 3.4). Complex flow models, mapping, and other methods often are used to estimate the quantity of water in underground sources.

Two major factors affect the daily, monthly, and yearly differences in water quantity levels both above and below ground: natural variations in climate and changes caused by human activity.

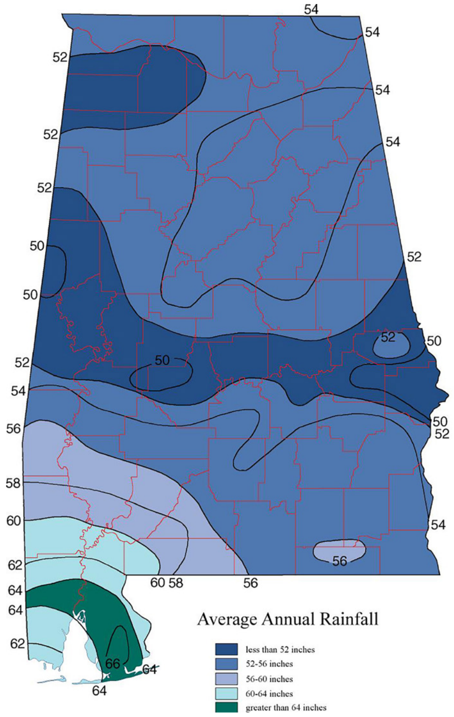
Climate can have a huge impact on the amount of water in surface and underground sources. Events such as droughts, ice storms, and floods can alter the availability of water on a daily, monthly, and yearly basis.

Alabama has a humid, subtropical climate and receives an average annual rainfall of 53 inches (figure 3.5). This precipitation varies from a low of 48 inches in some east-central and west-central areas of the state to a high of 68 inches along the Gulf Coast.[10]

The difference in geographic region as well as preceding weather conditions can make the relationship between rainfall and stream flow more variable. For example, a heavy rainfall after a dry period can cause more water to go to groundwater recharge and less to stream flow. If the ground is already water saturated due to a prior heavy rainfall, then more water runs off the land into streams, ponds, and lakes.

Human activity also affects water quality and quantity. Humans alter the flows of streams and rivers by building dams and diverting water for a variety of uses. In order to conserve and protect the precious resource of fresh water, it is important that we use our water resources in responsible ways.

**Figure 3.5.** Alabama average annual rainfall. (Photo credit: University of Alabama)



## WATER QUALITY

Water quality is a term used to describe the chemical, physical, and biological characteristics of water, usually with respect to its suitability for a particular purpose or designated use. Examples of designated uses of water bodies in Alabama include public water supply, shellfish harvesting, swimming, fish and wildlife, agriculture, and industry.[8]

The chemical, physical, and biological characteristics of water, or *water quality parameters* as they often are called, determine whether the quality of water is good enough for drinking, recreation, irrigation, aquatic life, or other designated uses. By examining these parameters along with their interactions with each other and the surrounding environment, we can assess the overall condition of a body of water.

These parameters also indicate the health of a watershed. Because all watersheds are connected across the landscape, the quality of a body of water is a great indicator not only of how well that watershed is functioning but how well the surrounding watersheds are functioning. Some of the key chemical, physical, and biological parameters used to evaluate water quality are discussed below.

**Table 3.1. Common Water Quality Parameters**

| |
|---|
| **Chemical Parameters of Water** |
| Electrical conductivity |
| pH |
| Dissolved oxygen (DO) |
| Nutrients (nitrogen, phosphorus) |
| **Bacteriological Parameters** |
| Bacteria (fecal coliform, *E. coli)* |
| **Physical Parameters** |
| Temperature |
| Total suspended solids (TSS) |
| Turbidity |
| Stream flow (discharge) |
| **Biological Parameters** |
| Benthic macroinvertebrates |
| Biochemical oxygen demand (BOD) |
| Submerged aquatic vegetation (SAV) |

### Chemical Water Quality Parameters

The chemical characteristics of water are a measure of the substances (such as nutrients, heavy metals, and pesticides) that are dissolved in it or are in particulate (solid) form. Following are descriptions of common chemical parameters.

**Electrical conductivity** is the measure of a solution's ability to conduct an electrical current. It is affected by the amount of total dissolved solids (TDS) in the water. Both organic and inorganic solids make up the total dissolved solids found in water. Common inorganic solids include potassium, sodium, chloride, carbonate, sulfate, calcium, and magnesium. The higher the level of TDS, the higher the electrical conductivity will be. Measuring TDS and electrical conductivity is a way to estimate the salt content of a body of water. This information is useful in determining the suitability of water for irrigation and drinking purposes.

Conductivity is affected by water temperature; the warmer the water, the higher the conductivity. Environmental conditions, such as geology, drought, changing seasons, and heavy rainfall, also can affect the conductivity of water by altering the concentrations of dissolved salts. Groundwater often has higher levels of dissolved solids than surface water because of the contact it has with rock and soil. When streams and rivers are flowing slowly, TDS and conductivity are usually higher because there is less water to dilute the dissolved materials. When flows are very high, TDS levels are typically lower.

| pH | Examples of Solutions |
|---|---|
| 0 | Battery acid, strong hydrofluoric acid |
| 1 | Hydrochloric acid secreted by stomach lining |
| 2 | Lemon juice, gastric acid, vinegar |
| 3 | Grapefruit juice, orange juice, soda |
| 4 | Tomato juice, acid rain |
| 5 | Soft drinking water, black coffee |
| 6 | Urine, saliva |
| 7 | "Pure" water |
| 8 | Sea water |
| 9 | Baking soda |
| 10 | Great Salt Lake, Milk of Magnesia |
| 11 | Ammonia solution |
| 12 | Soapy water |
| 13 | Bleach, oven cleaner |
| 14 | Liquid drain cleaner |

**Figure 3.6.** The pH scale is a measurement of the acids and bases in a solution.

**Figure 3.7.** Low dissolved oxygen levels can cause fish kills.

**Figure 3.8.** Algae growth can result from excess nutrients that can lead to reduced dissolved oxygen and fish kills. (Photo credit: Cam Brothers).

The symbol **pH** stands for *pondus Hydrogenii* (= "weight of hydrogen," the simplest element) and is a measurement of the acids and bases in a solution. It is measured on a scale that ranges from 0 (very acidic) to 14 (very basic) (figure 3.6).

A reading of 7 (neutral) represents the pH of completely pure water. A pH range of 6.0 to 8.5 generally will support freshwater fish and bottom-dwelling aquatic organisms. The pH can have a significant effect on aquatic life.

Natural waters reflect the pH of the surrounding soils. The pH can change throughout the season and within the day. Water that is either too acidic or too basic can kill aquatic plants and animals.

The pH also can affect the solubility and toxicity of other substances found in water. Runoff from urban and industrial areas may have significantly higher or lower pH, and may contain cadmium, chromium, lead, and other elements that, under normal conditions, are insoluble. This means they do not dissolve in water and are not toxic to aquatic organisms. But when the pH of water is too low (the water is too acidic), many of these substances become more soluble and may become toxic to aquatic plants and animals.

**Dissolved oxygen** (**DO**) is the measure of dissolved gaseous oxygen ($O_2$) found in water or other liquids. Gaseous oxygen enters water by diffusing from the surrounding air, by agitation or rapid movement of the water (aeration), or as a by-product of photosynthesis from plants. Oxygen is removed from water through plant respiration and decomposition of organic matter.

Adequate DO is necessary for high-quality water and is a good indicator of a waterbody's ability to support aquatic life. Like water, oxygen is a necessary element for all forms of life, including fish and other aquatic organisms. Fish "breathe" by absorbing DO through their gills. Water with too little DO can put stress on aquatic life and even cause large fish kills (figure 3.7).

Many factors can affect the amount of DO in water:

- volume and velocity of water flowing in the waterbody
- climate and season
- type and number of organisms in the waterbody
- altitude
- amounts of nutrients in the waterbody
- organic wastes
- riparian vegetation
- groundwater inflow
- dissolved or suspended solids

In a water quality context, nutrients refer primarily to nitrogen and phosphorus. Nitrogen (N) is one of the most abundant elements on Earth. About 80 percent of the air we breathe is nitrogen. It is found in the cells of all living things and is a major part of proteins. In the environment, nitrogen is found in many forms, including ammonia ($NH_3$), nitrites ($NO_2$), and nitrates ($NO_3$).

When plants and animals die and decompose, ammonia is produced. Ammonia is converted into $NO_3$ with the help of bacteria and used in plant and animal growth. Nitrogen can eventually be returned to the atmosphere by volatilization.

At optimal levels, nitrate is an important nutrient because it helps plants to grow. An excessive level of nitrate, however, can be quite harmful to water quality. Too much nitrate in water can result in a rapid growth of algae and other plant life (figure 3.8).

The over-enrichment of water with nutrients is called *eutrophication*. An excessive growth of aquatic plant life in response to increased nutrients can make water extremely murky and raise its temperature. When the plants die and start to decompose, bacteria begin to use up all of the oxygen in the water. The oxygen level can become so low (a condition known as *hypoxia*) that many types of fish, insects, and other animals can no longer survive. Common sources of nitrates include commercial fertilizers, wastewater treatment plants, animal wastes, septic systems, and decaying plant residues (e.g., compost).

**Phosphorus** (P) is a nutrient required by all organisms for the basic processes of life. Phosphorus is a natural element found in rocks, soils, and organic material. It clings tightly to soil particles and is used by plants, so its concentration in clean waters is typically very low. However, phosphorus can pollute water very quickly when too much of it enters from sources such as these:

- fertilizers
- animal wastes
- industrial discharge
- sewage
- drinking water treatment

In natural waters, phosphorus is usually in the form of phosphate ($PO_4$). Like nitrogen, phosphorus is a plant nutrient. Excessive amounts can cause the rapid growth of algae and aquatic plants.

When large masses of algae and plants die, the bacteria that decompose them use up the available oxygen, which leads to hypoxia. Extremely low dissolved oxygen concentrations can cause fish kills. In addition, the loss of oxygen in the bottom layers of waters can free phosphates trapped in the sediment, which further increases the phosphorus in the water. A very high level of phosphate in drinking water may cause digestive problems in people and animals, but otherwise is not toxic.

## Bacteriological Water Quality Parameters

**Fecal bacteria** are microscopic organisms found in the feces of humans and other warm-blooded animals. Fecal bacteria by themselves are not usually harmful; in fact, they occur naturally inside of you. They are found in the human digestive tract and aid in the digestion of food.

***E. coli*** is a species of fecal coliform bacteria that is specific to fecal material from humans and other warm-blooded animals. The EPA cites the presence of *E. coli* as the best indicator of health risk from water contact in freshwater recreational waters.[15] A variety of bacteria, parasites, and viruses, known as pathogens, can potentially cause health problems if humans ingest them.

Fecal coliform bacteria, including *E. coli* bacteria, are indicator organisms. When found in water, they indicate the potential presence of pathogenic organisms, such as bacteria, viruses, and parasites that can cause disease and illness.

When bacteria counts are high in a river or lake, there is a greater chance that pathogenic organisms also are present. If you swim in water with a high level of fecal bacteria, you have a greater chance of developing some type of illness, such as typhoid fever, hepatitis, cholera, gastroenteritis, dysentery, or getting an ear infection. The World Health Organization estimates that every year more than 3.4 million people die as a result of water-related diseases, making this the leading cause of disease and death worldwide.[4]

Fecal bacteria can enter a body of water with the effluents from wastewater treatment plants and septic systems (figure 3.9).

Other sources include livestock, pets, and wildlife (figure 3.10). The survivability of fecal bacteria in water depends on the water's temperature and the amounts of nutrients and sediment it contains.

**Figure 3.9.** Sanitary sewer overflows can introduce fecal bacteria into local waterways.

**Figure 3.10.** Waste from livestock, pets, and wildlife can be washed into local waterways.

### Physical Water Quality Parameters

The physical parameters of water are a measure of its natural attributes, including temperature, total suspended solids, turbidity, and stream flow.

**Water temperature** is a critical factor in determining the rates of biological and chemical processes that occur in and around bodies of water. Temperature affects the oxygen content of water (cold water can hold more oxygen), the rate of photosynthesis by aquatic plants, the metabolic rates of aquatic organisms, and the sensitivity of organisms to toxic wastes, parasites, and diseases. Water temperature can be changed by weather, the removal of streambank vegetation that provides cooling shade, the impoundment of water by a barrier, such as a dam, the discharge of industrial cooling water, the runoff of urban stormwater, and the inflow of groundwater.

**Total suspended solids** (**TSS**) include solids that float in water or on its surface and are large enough to be trapped by a filter. (TSS differs from total dissolved solids, or TDS, which was discussed earlier.) TSS can include silt, decaying plant and animal matter, industrial wastes, and sewage. High levels of TSS can make water murky. We can measure the clarity of water and the levels of TSS by measuring the water's turbidity (figure 3.11).

**Figure 3.11.** Silt and clay particles can create a turbid pond. (Photo credit: Alabama Forestry Commission)

The turbidity of water increases as levels of TSS increase. The effects of high turbidity and TSS are numerous:

- Water becomes warmer as suspended particles absorb heat from sunlight, which causes oxygen levels to fall.
- Warm water holds less oxygen than does cool water.
- Photosynthesis decreases because less light penetrates the water, resulting in even further drops in the oxygen level.
- The combination of warmer water, less light, and oxygen depletion makes it impossible for some forms of aquatic life to survive.

Water with a high level of TSS often has higher concentrations of bacteria, nutrients, pesticides, and metals. These pollutants may be attached to particles of sediment that are washed into a body of water after a storm. Once in the water, the pollutants can be released from the sediment or travel farther downstream. Water with a high level of TSS can cause problems for industry, because the solids may clog or scour pipes and machinery. See table 3.1 for physical water quality parameters.

**Stream flow,** or discharge, is the volume of water that moves over a point during a fixed period of time. Stream flow affects the concentrations of dissolved oxygen, natural substances, and pollutants in the water, as well as the temperature and turbidity. Thus, stream flow should be considered when measuring water quality.

Stream flow includes both the volume of water in a waterbody and the velocity of the water moving past a given point. It is often expressed as cubic feet per second (cfs). The flow of a stream is directly related to the amount of water moving through the watershed and into the stream or river channel. The discharge rate of a river or stream varies over time. For example, stream flow during summer may be much lower than in spring or after a heavy rain (figure 3.12).

**Figure 3.12.** Stream flow may be lower in summer.

Figure 3.13. An aquatic dragonfly nymph, found in a stream, will complete its life cycle to become an adult dragonfly (left). Benthic macroinvertebrate lab specimens (right).

## BIOLOGICAL WATER QUALITY PARAMETERS

The biological characteristics of water, also known as *biocriteria*, are a measure of the water's ability to support aquatic plant and animal life. Some of the common biological parameters are discussed below.

**Benthic macroinvertebrates** are bottom-dwelling (benthic) organisms that are large enough to be seen with the naked eye (macro) and lack a backbone (invertebrate) (figure 3.13). Examples are snails, worms, crayfish, and clams. Most benthic macroinvertebrates complete part or all of their life cycles attached to submerged rocks, logs, or vegetation.

These organisms are important biologically, because they play a vital role in the natural flow of energy and nutrients. Many invertebrates also feed on algae and bacteria. Benthic macroinvertebrates are excellent indicators of the health of a waterbody, because many of them have very specific tolerances to pollutants and react to changes in water quality. Consequently, if a stream is inhabited by macroinvertebrates that have a high tolerance to pollution, while the more sensitive species are missing, this indicates a pollution problem may exist.

**Biochemical oxygen demand (BOD)** measures the amount of dissolved oxygen used by microorganisms when they decompose organic matter in water. Sources of organic matter are woody debris, dead plants and animals, animal manure, effluents from industry (such as pulp and paper mills, food-processing plants, wastewater treatment plants, and feedlots), failing septic systems, and urban stormwater runoff. As the amount of organic matter in water increases, the number of microorganisms and the amount of oxygen they use increase. The result of excessive BOD is the same as the result of inadequate dissolved oxygen—aquatic organisms become stressed and can suffocate and die.

**Submerged aquatic vegetation (SAV)** is a type of plant that grows below the surface of the water. These plants may be rooted or floating. SAV supplies food and shelter to fish and invertebrates, adds oxygen to the water, traps sediment, reduces turbidity, and absorbs nutrients such as nitrogen and phosphorus. When water contains a lot of SAV of varied species, the quality of the water is good. When the number and diversity of SAV species start to decline, chances are that something has happened to degrade the water quality.

## POINT & NONPOINT SOURCES OF POLLUTION

Water pollutants are substances or conditions that change the natural state of an aquatic ecosystem, leading to degradation. Alabama utilizes their drinking water from both ground and surface water.

Many of Alabama's water resources are highly susceptible to pollution due to our unique geology and climate. Dissolved pollutants reach groundwater through a process called *leaching* and reach surface water when carried in runoff.

Pollution impacts people, plants, and animals that live near or use our waterways. Great strides have been made toward maintaining and restoring water quality throughout the United States since the formation of the EPA and passage of the Clean Water Act in 1972. This has been accomplished through regulating point source pollution, such as industrial and sewage discharge. However, a more diffuse source of pollution, **nonpoint source pollution (NPS)** threatens the nation and Alabama's ecosystems.

### POINT SOURCE POLLUTION

Point source pollution is pollution that is discharged from a clearly defined, fixed point such as a pipe, ditch, channel, sewer, or tunnel. The EPA defines point source pollution as the following:

"Any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged."[16]

**Figure 3.14.** Water flowing out of a pipe can carry pollutants to nearby waterways.

This term does not include agricultural stormwater discharges and return flows from irrigated agriculture. In Alabama, one major type of point source pollution is the millions of gallons of permitted wastewater discharged by industrial facilities and municipal sewage plants into the surrounding waters every day. Discharged wastewater, whether treated or not, can contain substances that are harmful both to aquatic and human life. Untreated or partially treated wastewater also can lower the amount of dissolved oxygen in streams and rivers, reducing the quality of the water as habitat for aquatic plants and animals.

### NONPOINT SOURCE POLLUTION

Nonpoint source pollution is pollution that *does not* originate from a clearly defined, fixed location. It is caused when rainfall or snowmelt, moving over and through the ground, picks up and carries natural and human-made pollutants, depositing them into lakes, rivers, wetlands, coastal waters, and groundwaters.

NPS pollution originates from everyday activities that occur across the watershed, such as fertilizing a lawn, watering livestock in a stream, and constructing roads. Even pet waste is an issue. As the runoff moves over the land, it picks up and carries away natural and human-made pollutants, finally depositing them in surface water and even in underground sources of drinking water. For this reason, NPS monitoring is extremely difficult, because the contaminants are not easily traceable to an exact source or point of origin.

In urban and suburban areas, much of the land is covered by pavement and buildings, which does not allow rain and snowmelt to soak into the ground where it lands. Instead, most of the water that falls on impervious surfaces runs off to storm drains, which deliver the untreated water to nearby waterways (figure 3.15).

**Figure 3.15.** Water flowing into a storm drain will be delivered to nearby streams.

**Figure 3.16.** Stormwater runoff can carry numerous pollutants including oil.

In some watersheds, as much as 55 percent of rainfall runs off an urban landscape that is covered by parking lots, roads, and buildings; only 15 percent of rainfall soaks into the ground. In comparison, a more natural landscape will infiltrate 45 percent of the rainfall with only 10 percent running off.[5] Stormwater runoff can carry pollutants such as oil, dirt, chemicals, lawn fertilizers, and litter directly to streams and rivers, where they can negatively impact water quality (figure 3.16).

Pollutants can include the following:

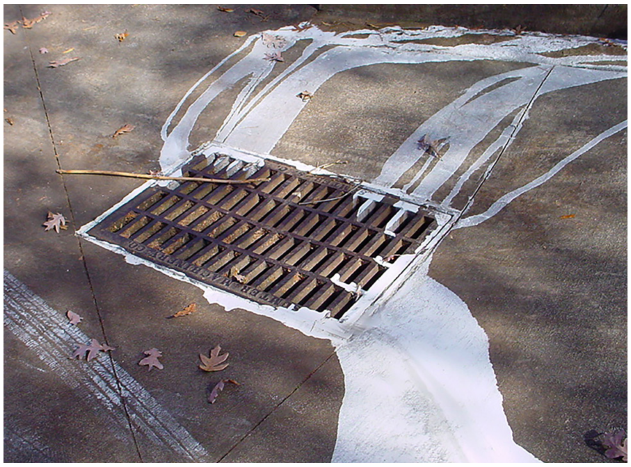
- sediment
- oil, grease, and toxic chemicals
- pesticides and nutrients
- viruses, bacteria, and nutrients
- heavy metals
- thermal pollution

These pollutants can harm fish and wildlife populations, kill native vegetation, foul drinking water supplies, and make recreational areas unsafe and unpleasant. Designing urban development to minimize runoff can help to protect water quality and groundwater resources.[5]

## Did you know?

- The EPA estimates that each American household generates 20 pounds of chemical waste each year, much of which is improperly disposed of and ends up in rivers, lakes, and aquifers.[15] [16]
- In an effort to control this nonpoint source pollution, many communities have set up chemical waste collection programs to encourage the proper disposal of household chemicals. Learn how to properly dispose of chemical waste in your area.

**Figure 3.17.** Paint is washed off into a storm drain, contributing to the pollution of local waterways.



## WHAT IS HAZARDOUS WASTE?

Simply defined, a hazardous waste is a waste with properties that make it dangerous or capable of having a harmful effect on human health or the environment. Hazardous waste is generated from many sources, ranging from industrial manufacturing process wastes to batteries, and may come in many forms, including liquids, solids, gases, and sludge.

In the United States, more than 90 percent of the raw materials extracted from the environment, transported, and processed are eventually discharged as waste or atmospheric emissions.[14] The EPA developed a regulatory definition and process that identifies specific substances known to be hazardous and provides objective criteria for including other materials in the regulated hazardous waste universe.

Both point and nonpoint sources of pollution have, to some degree, affected all of Alabama's water bodies. Nonpoint source pollution, however, is the leading cause of the nation's surface water quality problems. The EPA estimates that more than half of all water pollution in the United States originates from nonpoint sources!

The effects of NPS pollution seldom show up overnight and often go unnoticed for years, making NPS pollution very difficult to control. There are five major categories of NPS pollution: sediments, nutrients, pathogens, hazardous and toxic substances, and pharmaceuticals.

**Table 3.2. Types of Nonpoint Source Pollutants and their Effects**

| Pollutant | Nonpoint Source | Effects |
|---|---|---|
| Bacteria–pathogens | Livestock and pet waste, septic systems, boat discharge | Introduces disease-bearing organisms to surface water and groundwater, resulting in shellfish bed closures, swimming restrictions, and contaminated drinking water |
| Nutrients (phosphates and nitrates) | Fertilizers, livestock and pet waste, septic systems, suburban/urban development, soil erosion | Promotes algae blooms and aquatic weed growth, which can deplete oxygen, increase turbidity, and alter habitat conditions |
| Sediment (soil) | Construction, driveways, ditches, earth removal, dredging, mining, gravel operations, agriculture, road maintenance, forest operations | Increases surface water turbidity, which reduces plant growth and alters food supplies for aquatic organisms; decreases spawning habitat and cover for fish; interferes with navigation; and increases flooding |
| Toxic and hazardous substances | Landfills, junkyards, underground storage tanks, hazardous waste disposal, mining, pesticides/ herbicides, auto maintenance, runoff from highways and parking lots, boats, marinas | Accumulates in sediment, posing risks to bottom-feeding organisms and their predators, and contaminates ground and surface drinking water supplies. Some contaminants may be carcinogenic, mutagenic, and/or teratogenic, and can bioaccumulate in tissues of fish and other organisms, including humans. |
| Pharmaceuticals (personal care products) | Wastewater, stormwater runoff, landfill leaching | Contaminants of emerging concern (CECs), including pharmaceuticals and personal care products (PPCPs), are increasingly being detected at low levels in surface water, and there is concern that these compounds may have an impact on aquatic life. It is important for EPA to evaluate the potential impact of CECs and PPCPs on aquatic life and have an approach for determining protective levels for aquatic organisms. |

(Adapted from Bureau of Land and Water Quality, State of Maine Department of Environmental Protection)

**Figure 3.18.** Pet waste stations like this one in Opelika, Alabama, can help prevent pet waste from being washed into streams.

## Did You Know?

- A single gram of dog feces contains 23 million fecal coliform, a type of bacteria that can be harmful to humans and can indicate the presence of pathogenic bacteria and viruses.[11]

## Nonpoint Source Pollutant 1: Bacteria–Pathogens

Most bacteria are harmless to healthy people, but fecal bacteria may contain pathogens, meaning they can cause disease. Disease-causing bacteria and viruses can enter bodies of water from many sources, including failed septic systems, boat discharges, livestock, waterfowl, and even the family pet. For example, runoff from agricultural areas where manure is either deposited by livestock or collected and spread on fields can be a source of bacteria and viruses, some of which may be pathogenic. Urban areas may also be a source of pathogenic bacteria and viruses, especially where the concentration of dogs and other family pets is high or where sanitation facilities are inadequate. Bacteria carried in stormwater runoff are a major issue because they can pose health and environmental risks and can have economic impacts.

As they decompose organic matter, bacteria compete with other aquatic life for limited dissolved oxygen. As bacteria levels rise, their oxygen consumption increases and the concentration of dissolved oxygen in the water drops. In addition, elevated levels of bacteria indicate that water quality is impaired and the water is probably unsuitable for drinking and other domestic uses. Its suitability for recreation and its ability to sustain aquatic life also may be impaired. Waterborne diseases, such as hepatitis, cholera, and salmonella, can result from elevated bacteria levels and can pose severe risks to human health. Because bacteria can come from many sources, identifying the sources and controlling their levels can be extremely difficult and expensive.

## Nonpoint Source Pollutant 2: Nutrients

Nutrients themselves are not pollutants. They are vital to plants and animals and are necessary to sustain life in general. However, excessive amounts of nutrients (especially nitrogen and phosphorus) cause water quality problems and threaten the surrounding ecosystem. Fertilizers and human/animal waste are the main sources of nutrients.

The two main nutrients of concern are nitrogen and phosphorus. Nitrogen is highly soluble; it dissolves and moves easily into surface water. Leaching of nitrogen through the soil profile and into groundwater is also a concern. Phosphorus is less soluble and mobile than nitrogen but can attach to soil particles and be transported via runoff.

Nitrogen and phosphorus are components of manure and other animal wastes, and of the fertilizers used in urban, suburban, rural, and agricultural areas. When excess nitrogen and phosphorus runoff the land into streams and lakes after a storm, these nutrients stimulate plant growth, but not necessarily the kind of plant growth that is beneficial. An overabundance of aquatic plant life can lead to eutrophication and make water unsuitable for habitat, recreation, fishing, and other important uses.

**Figure 3.19.** Goats are just one form of livestock that can introduce nitrogen and phosphorous into ground and surface water.

In 2014, an estimated 13,295 (1000 nutrient short tons) of nitrogen (N), 4,695 (1000 nutrient short tons) of phosphate ($P_2O_5$), and 5,254 (1000 nutrient short tons) of potash ($K_2O$) were applied as inorganic fertilizer in the United States.[13]

In Alabama alone, an average of 68,225 (1000 kg) of nitrogen and 39,936 (1000 kg) of phosphate was purchased for commercial fertilizer in 2011.[12] If not applied properly and in the correct amounts, these important plant nutrients can become pollutants in our waterways.

Nitrogen and phosphorus also can originate from the atmosphere. Scientists believe that the combustion of fossil fuels, such as oil and coal by power plants, large industries, and automobiles, is a major source of nutrients in the atmosphere.

### Nonpoint Source Pollutant 3: Sediments

Sediment is the loose particles of clay, silt, and sand found in soil that is carried off the land by wind and water erosion. By volume, sediment is the top pollutant in Alabama's rivers and streams. It is caused mainly by erosion resulting from bare land, poor farming practices, construction, development, and streambank erosion. These areas are at especially high risk of increased erosion, because they generally lack sturdy vegetation to help keep soil in place and to block wind and water moving across the surface (figure 3.20). In Alabama, high-intensity rainfall causes most of the soil erosion. Intense rains and the resultant erosion normally occur in spring or summer.

### Did You Know?

- Animal agriculture manure of cattle, swine, goats, poultry (chickens and turkeys), sheep, horses, and others is a source for nitrogen and phosphorus in our groundwater and surface water. Based on the 2007 Census of Agriculture in Alabama, the estimated nitrogen and phosphorus from animal manure was 133,956 (1000 kg of N) and 41,438 (1000 kg of P) (figure 3.19).

Eventually, sediment finds its way to bodies of water and settles to the bottom. While this soil is productive on land, in the water it blocks light needed by aquatic plants, obstructs waterways, and smothers aquatic habitat. Larger, heavier particles, such as gravel and sand, settle out sooner than smaller, lighter particles, such as silt and clay, which may stay in suspension for very long periods, travel long distances, and contribute significantly to surface water turbidity.

Sediment can cloud the water, preventing light from penetrating to the leaves and stems of aquatic vegetation. Although sediment is always present in water bodies, excessive amounts can create harmful conditions for plants and animals living in or near the water. Excessive sediment also can smother benthic macroinvertebrates and clog waterways and ports.

Figure 3.20. Sediment is the top pollutant in Alabama's rivers and streams.

## Nonpoint Source Pollutant 4: Hazardous Substances

Hazardous substances include any material that can be harmful to humans or the environment. Pesticides and toxic chemicals (cleaners, paint, solvents, freon, oils, etc.) are common examples.

**Pesticides** include insecticides, fungicides, herbicides, and other materials designed to eliminate or control pests. They are used extensively by farmers, homeowners, commercial exterminators, golf course managers, parks departments, schools, highway departments, utility companies, and others to control insects, weeds, and other unwanted pests.

The agricultural sector currently accounts for 60 to 70 percent of total pesticide use, and more than 65,000 pesticides are registered in the United States. Many of these have been identified in our nation's lakes and streams. According to the EPA, in 2011 and 2012, an average of 1.1 billion pounds of pesticides were used per year by the United States at an annual cost of about $9 billion.[3]

Pesticides can enter a body of water through surface water runoff, wind and water erosion, leaching, and "spray drift," which occurs when wind blows a pesticide into a body of water as it is being sprayed over an area of land. Once in a body of water, pesticides often decompose into more toxic compounds, increasing the threat to the surrounding environment. Although pesticides are used to control only certain target species, they often unintentionally harm surrounding organisms. Furthermore, because some pesticides decompose rather slowly, they can build up in the food chain and have a cascading effect throughout the system.

**Toxic chemicals**, such as spilled oils and fuels found on city streets, are examples of harmful substances that can runoff the land surface and be washed into surrounding bodies of water. Combustion of fuel from automobiles and factories can introduce hydrocarbons and metals into the atmosphere. These can eventually end up in water through precipitation or runoff (figure 3.21). Industrial facilities without the proper means to control runoff also can contribute toxic chemicals to the environment. Various businesses and even homeowners may use chemicals such as solvents, paints, and cleaning solutions that can harm aquatic environments.

The effects of toxic chemicals usually are greatest near urban areas where there is a lot of business, industry, and increased transportation activity. Toxic chemicals can have detrimental effects on drinking water quality, water used for recreation, aquatic plant and animal life, and the pipes and pumps associated with industrial and other facilities. Cleaning up water contaminated by toxic chemicals can be very difficult and quite expensive.

Figure 3.21. Parking lot runoff can include oil from automobiles.

### Nonpoint Source Pollutant 5: Pharmaceuticals

Pharmaceuticals and personal care products are potential pollutants and have been detected in over 80 percent of the waterways tested in the United States according to the USGS. These compounds are not typically removed by conventional wastewater treatment. The effects of this “cocktail” on aquatic and human life are largely unknown; however, fish sex has been altered when exposed to some of these compounds that may mimic hormones. The products that we pour down our sinks often inadvertently end up in a waterway. Reflecting on the household products we use and how we dispose of them can have significant environmental benefits.

## CONSEQUENCES OF IMPAIRED WATER QUALITY

Water pollution is a serious problem that can have staggering consequences for the economy, biodiversity, and human health. Millions of dollars are spent annually to control point and nonpoint source pollution and to reverse the harmful effects of poor water quality on the environment.

Degraded water quality can seriously limit the biodiversity of aquatic and terrestrial species and their habitats. Harmful conditions, such as hypoxia, eutrophication, and algal blooms, can destroy aquatic life. Increased sediment can clog the gills of aquatic organisms and cloud the water. Populations of benthic macroinvertebrates and other aquatic species that have low tolerances to contaminants can be reduced or eliminated from a system. Native riparian vegetation that shades the water and prevents soil erosion can be replaced by invasive weeds and plants that do not protect the waterbody or its functions. Perhaps the most important consequence of impaired water quality, of both fresh and salt water, is the risk it poses to human health.

The following findings were submitted to Congress from the 2017 EPA National Water Quality Inventory Report, which summarizes the outcomes of four National Aquatic Resource Surveys and the site-specific assessment results reported by the states to the EPA:

**Rivers and streams.** An estimated 46 percent of river and stream miles are in poor biological condition, with phosphorus and nitrogen being the most widespread of the chemical stressors assessed.

**Lakes, ponds, and reservoirs.** Around 21 percent of the nation’s lakes are hypereutrophic (have high levels of nutrients, algae, and plants). Phosphorus and nitrogen are the most widespread stressors in lakes.

**Coastal waters.** An estimated 18 percent of the nation’s coastal and Great Lakes waters are in poor biological condition, and 14 percent are rated poor based on a water quality index. Phosphorus is the leading stressor contributing to the poor water quality index rating.

**Wetlands.** Roughly 32 percent of the nation’s wetland areas are in poor biological condition, with leading stressors including surface hardening (soil compaction) and vegetation removal.

### Did You Know?

- Forty percent of the monitored rivers in the United States are too polluted for fishing, swimming, or aquatic life.
- The Mississippi River—which drains nearly 40 percent of the continental United States, including its central farm lands—carries about 65 million tons of nitrogen pollution into the Gulf of Mexico each year. The resulting hypoxic coastal dead zone in the Gulf each summer is about the size of Massachusetts.
- About 1.2 trillion gallons of untreated sewage, stormwater, and industrial waste are discharged into US waters annually.

## HOW LAND USE AFFECTS WATER QUANTITY & QUALITY

The quality and quantity of our water resources are determined by natural environmental conditions and the activities of humans. In this section, you will learn about the ways human actions can impair or degrade water quality and quantity. In later sections, we will focus on ways people can improve the watershed by implementing various watershed management and protection strategies.

Water quality and quantity are closely linked to the way land is used and the type of land cover. Specific land use categories include agriculture, industry, recreation, residential, and urban. Most land use types have the potential to generate pollutants that can impair water quality and/or reduce water quantity. Land cover refers to the biological or physical features of the land surface. Types of land cover include forests, hay and pasture agricultural fields, crops, wetlands, grasslands, open water, and developed lands (urban and suburban).

When people change the way land is used in a watershed, they usually alter the land cover at the same time. For example, when a new housing development is built, forests and fields are replaced largely by new types of land cover, such as lawns, roofs, and pavement.

Here are some activities that can impact both water quantity and water quality:

- urban and agricultural irrigation
- using excess fertilizers and pesticides
- mining and resource extraction
- construction of roads and buildings
- disposing of municipal and industrial wastes and wastewater

Unless these land use activities are done carefully, the effects can be severe. Such activities can alter the natural hydrology of a system, alter the land cover, create pollution, increase erosion and sedimentation, allow exotic species to invade at the expense of native vegetation, and harm biodiversity.

Adequate supplies of good quality water are vital to the health, social, and economic well-being of all Alabama citizens. Water quality and quantity are at risk in areas of the state because of our growing population and rapidly changing use of the land. We must ensure that our water resources are available for generations to come.

Urbanization has enormous effects on water quality and quantity. The amount of wastewater, industrial contaminants, and solid waste per unit area generated in urban areas is dramatically greater than in rural areas. Urbanization also changes the hydrology of an area because of increases in impermeable surfaces such as houses, parking lots, and roads.

The conversion of permeable soil to impermeable surfaces reduces the amount of infiltration and increases the amount of runoff and sedimentation. Excess sediments and pollutants become concentrated in streams and rivers, altering the quality of the water. When stormwater can't soak into the soil, the amounts of stormwater runoff and peak flows increase. Stream channels degrade by cutting down and widening as banks erode to accommodate the large volumes of water.

To control increased peak flows and runoff, streams and rivers often are channelized. The process involves straightening a section of a stream, building retention walls along the streambanks, and sometimes making the banks and bottoms concrete. This alters stream composition and flow and reduces the stream's ability to regulate and adjust itself.

The decrease in water infiltration caused by urbanization reduces the amount of groundwater recharge—the downward replenishing flow of rainfall through the soil profile to an underground aquifer. The withdrawal of water for growing populations also puts increased demands on local water resources, both above and below ground, and can leave streams, rivers, and wetlands with insufficient water to function properly.

Construction sites usually remove habitat for native plants and animals and expose the soil surface to wind and rain erosion. This increases erosion and sedimentation and makes it possible for invasive species to outcompete native vegetation for resources. The loss of native vegetation further reduces wildlife habitat and valuable shading along shorelines.

We often focus on the effects rather than the causes of pollution. People can cause serious impairment to water quality and quantity when they change the land use or land cover type in a watershed. It is important to utilize Best Management Practices BMPs as we manage the land to ensure that we protect the watershed and water quality. The effects of these changes can indirectly alter the whole ecological system.

## FUTURE WATER USE STATISTICS IN ALABAMA

Alabama's population is expected to rise from 4,655,269 people in 2010 to 5,386,917 in 2040 for an increase of 731,648 people (16 percent).[2] This means increased need for drinking water, development for housing and transportation, and wastewater treatment needs that all impact watersheds.

The subbasins with the highest projected population increases are Wheeler Lake (196,964), Cahaba (102,872), and Lower Tallapoosa (53,073) (figure 3.22). Those subbasins account for 48 percent of the increasing population for the state from 2010 to 2040. The increases in population in these subbasins are associated with the urban areas of Huntsville and Decatur (Wheeler Lake subbasin), Birmingham (Cahaba subbasin), and Montgomery, Prattville, and Millbrook (Lower Tallapoosa subbasin).

The subbasins with the greatest projected population declines from 2010 to 2040 include Middle Tombigbee-Chickasaw (-6,286), Middle Alabama (-4,758), and Lower Tombigbee (-4,417) (figure 3.22).

Total water use in Alabama for 2015 was determined from estimates of water withdrawals in eight categories: public supply, self-supplied residential, irrigation, livestock, aquaculture, self-supplied industrial, mining,

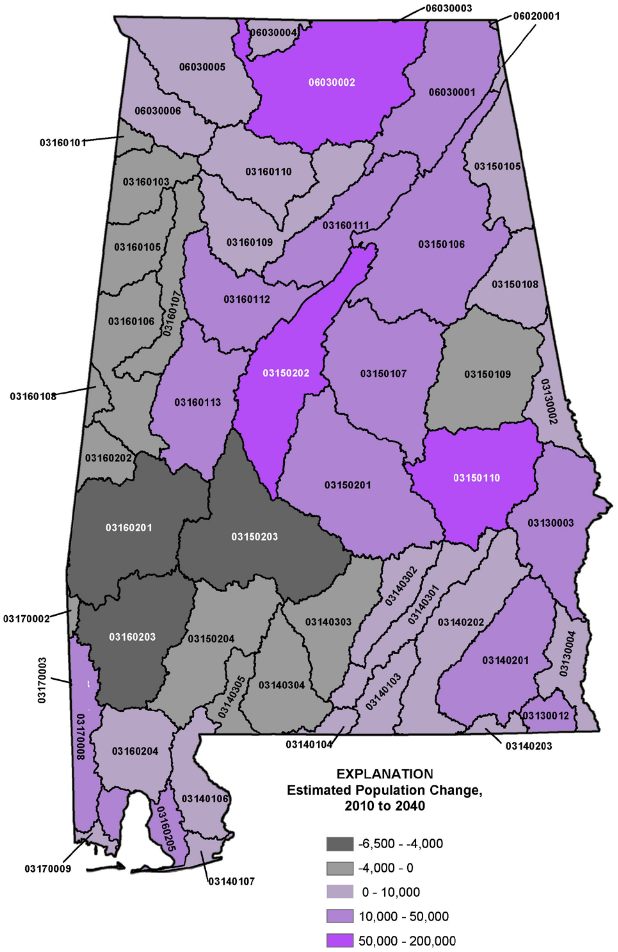


**Figure 3.22.** Estimated population change in Alabama, 2010–2040. (Photo credit: Alabama Department of Economic and Community Affairs, Office of Water Resources)

and thermoelectric power. Total freshwater withdrawals were estimated to be 9,295 million gallons per day (MGD). Estimates of withdrawals by source indicate that total surface water withdrawals were roughly 94 percent of Alabama's total water withdrawals (8,250 MGD), and the remaining 6 percent was from groundwater (501 MGD.)[2] Gross per capita use averaged 2,092 gal/d for the 4,779,736 residents in Alabama. Gross per capita use is the total water withdrawn divided by the total population. The large per capita use may be related to the large thermoelectric-power withdrawals in relation to the population size.

Total water withdrawals for 2040 are estimated to be 10,331 MGD. Estimates of withdrawal by source indicate that total surface water withdrawals for 2040 are approximately 95 percent (9,763 MGD) of the total, and the remaining 5 percent from groundwater 568 MGD (Atkins 2017). Total withdrawals increase from 9,999 MGD in 2010 to 10,331 MGD in 2040, an increase of 332 MGD (3 percent.)[2] Changes in agricultural practices, population growth, industry, mining and more can significantly impact the amount of water a state uses every year.

### Did You Know?

Water-use data are usually expressed in **million of gallons of water used per day** (MGD) and **acre-feet**. You'll understand the data better if you can visualize how much a million gallons is. A good-sized bath holds 50 gallons, so a million gallons would be 20,000 baths. If you built a pool that would hold a million gallons, you would need to build a pool about 267 feet long (almost as long as a football field), 50 feet wide, and 10 feet deep.

- An acre-foot is the amount of water needed to cover 1 acre of land in 1 foot of water.
- One acre-foot equals 325,851 gallons of water. It would take 1 million acre-feet of water to cover Rhode Island in 1 foot of water.

### Some conversions:

- 1 MGD = 1.547 cubic feet per second
- 1 MGD = 694.4 gallons per minute
- 1 MGD = 1.121 thousand acre-feet per year
- 1 million gallons = 3.0689 acre-feet

## WATER QUALITY LAW & POLICY IN ALABAMA

There was no comprehensive water law in the United States until the 1960s, when several federal laws related to water quality were passed (table 3.3). Perhaps the most important legislation of this era was the Clean Water Act (CWA) of 1972, which today is the foundation of surface water quality protection in the United States.

### Clean Water Act of 1972

The CWA was prompted by the serious degradation of many of the nation's streams and rivers, growing concern over disease epidemics caused by waterborne bacteria, and several high-profile oil spills. In 1987, the CWA was amended to address nonpoint source pollution by requiring that states develop nonpoint source management plans.

The CWA was established to restore and maintain the chemical, physical, and biological condition of the nation's waters. Currently, the CWA sets surface water quality standards for major rivers and lakes in the nation and requires that public and private facilities acquire permits for discharging wastewater. The CWA requires the US Army Corps of Engineers to issue Section 404 permits for all dredging and filling projects as a way to protect wetlands. While the CWA protects the quality of surface waters, it does not address water quantity issues or the quality of groundwater resources (except groundwater that is used as a public drinking water supply).

The quality of surface water in Alabama is regulated by the water quality standards established in the CWA. There are three types of water quality standards:

1. surface water quality standards (also referred to as stream standards)
2. effluent standards (for wastewaters)
3. drinking water standards (also cover groundwater used as a public water supply)

**Table 3.3. Federal Laws Related to Water Quality**

| Federal Law | Date | Purpose |
|---|---|---|
| National Environmental Policy Act (NEPA) | 1969 | Required an Environmental Impact Statement (EIS) for federally funded projects |
| Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) | 1972 | Required registration and regulation of pesticides and other agricultural chemicals |
| Endangered Species Act (ESA) | 1980 | Protected animal and plant species that the US Fish and Wildlife Service designates as threatened or endangered |
| Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) | 1990 | Created a $1.6 billion superfund to clean up abandoned hazardous waste sites and required major industries to report annual releases of toxic wastes into the air and water or onto land |
| Coastal Zone Act Reauthorization Amendments | 1990 | Focused efforts on reducing polluted runoff in 29 coastal states |

**The Alabama Water Pollution Control Act (AWPCA)** of 1971 provided the authority to establish and maintain a comprehensive state water quality management program. The act, codified as Title 22, Section 22-22-1 et seq., Code of Alabama 1975, provided the foundation for the Alabama Department of Environmental Management (ADEM) water quality program. The act includes the following as its purpose:

> to conserve the waters of the State and to protect, maintain, and improve the quality thereof for public water supplies, for the propagation of wildlife, fish, and aquatic life, and for domestic, agricultural, industrial, recreational, and other legitimate beneficial uses; to provide for the prevention, abatement, and control of new or existing water pollution; and to cooperate with other agencies of the State, agencies of other States, and the federal government in carrying out these objectives.

## Riparian Doctrine

Each state has its own regulatory system to allocate use of surface waters and groundwater. Water-abundant eastern states make use of the riparian doctrine. The western United States developed the system of prior appropriation. A few states adopted a hybrid riparian and prior appropriation system.

Alabama abides by the doctrine of common-law riparian rights in which a landowner must own a parcel of land adjacent to a stream, river, lake, or pond for the right to use the water, and it prohibits transfer of water off riparian tracts of land (2016 Code of Alabama). A riparian landowner has the right to make "reasonable use" of water that does not interfere with the reasonable use of a downstream riparian landowner. Reasonable uses include drinking water, watering livestock, landscape watering, and irrigation. Because the water right is attached to the riparian land, nonuse does not extinguish the right, and new, reasonable uses may start at any time.[9]

**The Alabama Environmental Management Act (AEMA)** was passed in 1982 and created the Alabama Department of Environmental Management to provide a comprehensive and coordinated program of environmental management. The act gives ADEM the ability to adopt, issue, and enforce rules, regulations, orders, notices of violation, certificates, and permits, and to develop standards and environmental policies for the state. The act also provides ADEM and its authorities to enforce provisions of the AEMA and the AWPCA through civil actions or administrative orders, including orders with penalties.

Alabama's water quality standards (WQS) are found in chapters 335-6-10 and 335-6-11 of the ADEM Administrative Code. ADEM conducts a comprehensive review of WQS at least once every 3 years.

ADEM's water quality monitoring program is managed by its Field Operations Division (FOD) and includes the following programs:

- Coastal Waters Monitoring Program
- Rivers and Reservoirs Monitoring Program
- Rivers and Streams Monitoring Program
- Wetland Monitoring Program
- Fish Tissue Monitoring Program
- Compliance Monitoring Program

## SURFACE WATER QUALITY STANDARDS

ADEM evaluates waterbody data and information using Alabama's Water Quality Assessment and Listing Methodology (adem.alabama.gov/programs/water/303d.cnt) and assigns the waterbody to a specific category based on available data and the waterbody's use support status.

Water quality standards include the following specifics:

- The pH standard for the seven water-use classifications is a minimum of 6.0 and a maximum of 8.5.
- The water temperature standard for the seven water-use classifications is a maximum of 32 degrees C, except for some streams and lakes in the Tennessee, Cahaba, and Warrior watersheds. These watersheds have been designated by the Alabama Department of Conservation and Natural Resources (ADCNR) as supporting certain cool-water fisheries and therefore should not exceed 30 degrees C. No more than a 2.8 degree C rise above the normal (or ambient) stream temperature is permitted.
- Numerous biotic indices based on aquatic macroinvertebrates have been developed for the assessment of river ecosystems, which are well suited to identify the impact of pollutants. Biotic indices should be used in conjunction with, and not as replacements for, conventional indices based on physical and chemical characteristics.

ADEM's assessment process allows for different minimum data requirements and criteria exceedance thresholds for the varying waterbody uses. For example, in waters classified as Outstanding Alabama Water (OAW), Alabama's highest designated use, the assessment methodology requires less data and allows for fewer exceedances of a toxic criterion to be considered for inclusion in Category 5 (§303(d) list.

Data and information that may be considered when assessing state waters could include: water chemistry data, such as chemical-specific concentration data; land use or land cover data; physical data, such as water temperature, conductivity, and habitat evaluations; biological data, such as macroinvertebrate and fish community assessments; and bacteriological data, such as *E. coli* or *Enterococcus* counts. Waters classified as "fish and wildlife" or higher (or "limited warm-water fishery" on a seasonal basis) must provide protection of the aquatic life use. All classifications must provide protection of the human health use.

### Wastewater Effluent Standards

During the late 1970s and early 1980s, a number of communities and regional authorities in Alabama developed area-wide wastewater treatment plans and/or basin plans under §208 and §209 of the federal CWA. Those plans, referred to as 208/209 plans, have served as a guide to providing wastewater collection and treatment in Alabama's more populous areas and statewide watershed planning.

Facility plans were developed in order to receive EPA construction grant funds for the building of wastewater treatment facilities for cities in Alabama. Similar plans for smaller communities have been and continue to be developed using funding provided under §205(j) of the federal CWA. These plans are usually developed by regional planning agencies using funds provided to the state by the EPA. Area-wide wastewater treatment plans are reviewed by the state to ensure consistency with water quality goals and objectives.

## DRINKING WATER STANDARDS

**The Federal Safe Drinking Water Act (SDWA)** of 1974 established standards to ensure the safety of both surface water and groundwater sources used for public drinking water. Under the SDWA, the EPA sets standards for drinking water quality and oversees the states, localities, and water suppliers that implement those standards. The EPA sets drinking water standards based on three criteria:

1. whether the contaminant harms human health
2. whether the contaminant can be detected in drinking water
3. whether the contaminant is known to occur in drinking water

In Alabama, the ADEM is responsible for implementing and regulating the drinking water standards set by the EPA. They make sure that public water systems regularly monitor their water supplies, assess their results, and comply with the standards. Drinking water supplied by public water supply systems is routinely tested for about ninety different contaminants to ensure compliance with state and federal standards (www.epa.gov/safewater/contaminants/index.html).

There are two categories of drinking water standards: primary and secondary.

1. **Primary standards** protect against contaminants, including pathogens, radioactive elements, and toxic chemicals, that are harmful to human health. Primary standards set the maximum amount of each pollutant that can be in the drinking water supplied by a public water system. These limits are known as maximum contaminant levels (MCL).
2. **Secondary standards** protect against contaminants that are not harmful to human health but pose a nuisance because they can cause unacceptable odor, taste, color, corrosion, foaming, or staining. Maximum limits also are set for these contaminants and are known as secondary maximum contaminant levels (SMCL).

How does drinking water get to your home? Water is delivered from a groundwater or surface water source to a treatment plant where it goes through an extensive process to remove volatile substances, particles, and bacteria. Most Alabamians receive their drinking water from municipal water systems.

There are no federal regulations for private water supplies. Water quality testing is the responsibility of the individual owner of the water supply. Private, domestic water supplies should be tested at least once a year. The quality of water in a private well can change over time if the land use changes either in the immediate area or farther away where recharge of the aquifer occurs. Drinking water should be tested at the source (at or near the wellhead) and at the tap (kitchen or common-use area).

Even with strict rules and standards, a water supply system still may become contaminated and violate certain drinking water standards. When a violation occurs, the public water supply system must notify its customers of the violation, what it means to them, and what steps are being taken to correct the situation. The quality of water in private wells is not regulated by the state. Regular testing and monitoring of the water quality in private wells is up to the well owner.

ADEM maintains a list of laboratories certified by the state to analyze drinking water samples. The list can be found at www.adem.state.al.us/programs/water/dwother.cnt.

## WATER QUALITY TESTING, MONITORING & REGULATION

### WATER QUALITY TESTING & MONITORING

How can we ensure that the state's surface waters, wastewater effluents, and drinking water sources are meeting federal and state water quality standards? The answer is through water quality testing and monitoring.

Scientists, regulatory agencies, industries, and municipalities use many different instruments to test the quality of surface water, groundwater, and drinking water. Among these instruments are Secchi disks, probes, nets, sondes, gauges, and meters.

Basic surface water quality assessment packages include tests for *E. coli* and *Enterococcus* spp. bacteria, nitrates, phosphorus, pH, sodium, chloride, fluoride, sulfate, iron, manganese, total dissolved solids, and dissolved oxygen. Other tests may be appropriate if a particular contaminant is suspected. For example, some groundwater sources are tested for arsenic, selenium, and uranium, and both surface water and groundwater sources used for drinking are often tested for harmful pesticides. Regular testing shows whether the water quality is changing, and it helps to detect when some sort of activity is degrading water quality.

Many types of contaminants can be found in fish, but some of the most common are mercury, arsenic, polychlorinated biphenyls (PCBs), volatile organic compounds (VOCs), and dioxins. Of particular concern are pollutants that bioaccumulate in the food chain. By the time a bioaccumulated pollutant reaches the top of

**Figure 3.23.** Alabama Water Watch volunteers monitor water chemistry. (Photo credit: Alabama Water Watch)

the food chain (humans, predators), the concentration of pollutant ingested is much greater than it was for those at the bottom of the food chain. Pollutants can accumulate in living things any time they are ingested. They are stored at a faster rate than they are broken down or excreted.

As Alabama's state environmental regulatory agency, the ADEM submits all surface water quality monitoring data to the EPA's storage and retrieval data warehouse (STORET)—a repository for water quality, biological, and physical data. STORET is used by state environmental agencies, the EPA, and other federal agencies, universities, private citizens, and many others. These organizations submit data to the STORET warehouse to make their data publicly accessible.[10]

Water quality monitoring is a fundamental tool in the management of Alabama's freshwater resources. ADEM uses a watershed management approach to manage water quality (using a rotational 5-year river basin assessment and monitoring strategy) and to protect and restore Alabama's water resources.

Water quality is monitored to accomplish the following:

- identify particular pollutants of concern
- identify whether the quality of the water is appropriate for a particular use
- determine the quality of a particular waterbody
- detect trends in water quality
- determine the effectiveness of watershed restoration and enhancement projects

ADEM implements a basin rotation approach to monitoring waters and establishing total maximum daily loads (TMDLs). In general, the draft TMDL date follows the basin rotation monitoring schedule, because the availability of water quality data is the primary driver in the TMDL development process.

When the quality of water is tested, the biological, chemical, and physical characteristics of water are analyzed. The results determine the overall quality of a body of water related to its suitability for a specific use. Testing for water quality over a period of time (water quality monitoring) helps us to understand the dynamics of a particular body of water and whether the water quality is improving or declining.

ADEM sends a publicly accessible Water Quality Report (305(b) Report every two years to the EPA as part of the national water quality assessment required by the Clean Water Act. This report provides a summary of activities related to surface water quality and an assessment of surface water quality conditions in Alabama.[10]

Citizens also can get involved in monitoring their local waterways through citizen science programs such as Alabama Water Watch (AWW). Although AWW data is not used by EPA in reporting, local water monitors can alert ADEM to potential issues by maintaining a consistent water monitoring regime that shows significant water quality changes.

**Figure 3.24.** Lake Martin is classified as a Treasured Alabama Lake.

## ALABAMA'S WATERBODY DESIGNATED USES

To better monitor and protect the water quality of waterways, we use water quality standards and water classification systems to monitor impaired and improved waterways. Water quality standards were first adopted in 1967 by the Alabama Water Improvement Commission (AWIC), but they have been amended many times since. In 1982, the Alabama Department of Environmental Management (ADEM) was formed by merging AWIC with elements of the Alabama Department of Public Health (ADPH).

Water bodies are given designated uses that describe the best purposes reasonably expected of waters. This system is used to monitor the degree to which the quality of waters is consistent with their designated use or uses. According to the Clean Water Act, water quality should be consistent with "fishable/swimmable" use when possible. In Alabama, waters can be assigned one or more of seven designated uses pursuant to ADEM Administrative Code r. 335-6-11.

The following are designated uses for Alabama's water bodies ranked best to worst quality:

1. Outstanding Alabama Water (OAW); Treasured Alabama Lake (TAL)
2. Public water supply (PWS)
3. Swimming and other whole-body water-contact sports (S)
4. Shellfish harvesting (SH)
5. Fish and wildlife (F&W)
6. Limited warm-water fishery (LWF)
7. Agricultural and industrial water supply (A&I)

## OUTSTANDING ALABAMA WATERS (OAW)

Alabama has two special waterbody designations: Outstanding National Resource Water (ONRW) and Treasured Alabama Lake (TAL) (figure 3.24). These high-quality waters are protected or require a thorough evaluation of discharges from new or expanded point sources of pollutants. They may be assigned to any one of the first five designated uses in the list above.

The best usages of waters assigned to this classification are activities consistent with the natural characteristics of the waters. Beneficial uses encompassed within this classification include aquatic life support and wildlife propagation, fish and shellfish harvesting and consumption, water contact recreation, agricultural irrigation, livestock watering, and industrial cooling and process water supply.

## PUBLIC WATER SUPPLY (PWS)

The best usage of waters assigned to this classification is as a source of water supply for drinking or food-processing purposes after approved treatment. Water bodies assigned the PWS use are considered safe for drinking or food-processing purposes if subjected to treatment approved by the department equal to coagulation, sedimentation, filtration, and disinfection, with additional treatment if necessary to remove naturally present impurities.

Beneficial uses encompassed within this classification include aquatic life support and wildlife propagation; fish and shellfish harvesting and consumption; drinking and food-processing water supply; water contact recreation; agricultural irrigation; livestock watering; and industrial cooling and process water supply.

## SWIMMING & OTHER WHOLE-BODY WATER-CONTACT SPORTS (S)

The best usage of waters assigned to this classification is for swimming and other whole-body water-contact sports. Water bodies assigned the S use, under proper sanitary supervision by the controlling health authorities, will meet accepted standards of water quality for outdoor swimming places and other whole-body water-contact sports.

Beneficial uses encompassed within this classification include aquatic life support and wildlife propagation; fish and shellfish harvesting and consumption; water contact recreation; agricultural irrigation; livestock watering; and industrial cooling and process water supply.

## SHELLFISH HARVESTING (SH)

The best usage of waters assigned to this classification is the propagation and harvesting of shellfish (oysters) for sale or for use as a food product. Waterbodies assigned the SH use will meet the sanitary and bacteriological standards of the Food and Drug Administration (included in the *National Shellfish Sanitation Program Model Ordinance* latest edition, chapter IV), the US Department of Health and Human Services, and the Alabama Department of Public Health. The waters also will be of a quality suitable for the propagation of fish and other aquatic life, including shrimp and crabs.

Beneficial uses encompassed within this classification include aquatic life support and wildlife propagation; fish and shellfish harvesting and consumption; water contact recreation; agricultural irrigation; livestock watering; and industrial cooling and process water supply.

## FISH & WILDLIFE (F&W)

The best usages of waters assigned to this classification are fishing; the propagation of fish, aquatic life, and wildlife; and any other usage except swimming and water-contact sports or as a source of water supply for drinking or food-processing purposes. Water bodies assigned to the F&W classification are suitable for fish, aquatic life, and wildlife propagation. The quality of salt and estuarine waters within this classification will be suitable for the propagation of shrimp and crabs.

These waters may be used for incidental water contact and recreation during May through October, except in the vicinity of wastewater discharges or other conditions beyond the control of the ADPH. Under proper sanitary supervision by the controlling health authorities, these waters will meet accepted standards of water quality for outdoor swimming places and will be considered satisfactory for swimming and other whole-body water-contact sports during the months of May through October.

## LIMITED WARM-WATER FISHERY (LWF)

For the months of December through April, the best usages of waters assigned to this classification are fishing; the propagation of fish, aquatic life, and wildlife; and any other usage except swimming and water-contact sports or as a source of water supply for drinking or food-processing purposes.

From May through November, the quality of waters within this classification will be suitable for agricultural irrigation, livestock watering, industrial cooling and process water supplies, and any other usage except fishing, bathing, recreational activities (including water-contact sports), or as a source of water supply for drinking or food-processing purposes.

## AGRICULTURAL & INDUSTRIAL WATER SUPPLY (A&I)

The best usages of waters assigned to this classification are agricultural irrigation, livestock watering, industrial cooling and process water supplies, and any other usage except fishing, bathing, recreational activities, including water-contact sports, or as a source of water supply for drinking or food-processing purposes. Except for the natural impurities that may be present, the waters will be suitable for agricultural irrigation, livestock watering, industrial cooling waters, and fish survival.

The waters will be usable for industrial process water supplies after application of any special treatment needed under a particular circumstance. This classification includes watercourses in which natural flow is intermittent and nonexistent during droughts and which may, of necessity, receive treated waste from existing municipalities and industries, both now and in the future.

## WATERBODY CATEGORIZATION

We have discussed how waterbody usages can be categorized and used for assessing water quality, but how exactly is water quality assessed?

The water quality assessment process begins with the collection, compilation, and evaluation of water quality data and information used to determine whether or not a waterbody is supporting all of its designated uses. Decisions arising from water quality assessment can carry long-term consequences, so it is important that the data and information used to assess water quality are accurate, sufficient, and of high quality. Limited water quality data, water quality data older than 6 years, or estimated impacts from observed or suspected activities are considered evaluated assessments and are not sufficient to place or remove waters from an impaired category.

### Impaired Waters in Alabama: The CWA §303(d) List & 305(b) Report

Section 305(b) of the Federal Clean Water Act requires states to report on the quality of its surface water at least every 2 years. ADEM keeps a list of waterbodies in Alabama that do not fully support their designated uses based on water quality data and information. These impaired waterbodies are placed on the CWA §303(d) list and submitted to the EPA after the public has had the opportunity to comment. The list includes the presumed causes and sources of water quality impairment for each waterbody, as well as a schedule for the development of total maximum daily loads (TMDLs) for each pollutant causing impairment.

**Figure 3.25.** Children often play in Rocky Brook Creek that runs through Opelika Municipal Park.

Assessment and listing methodology is used to determine the use support status of each waterbody for which water quality data and information are available. Waters are classified into one of five major categories/subcategories:

- **Category 1:** The water attains the water quality standard, and no use is threatened.
- **Category 2:** The water attains some of the designated uses; no use is threatened; and insufficient or no data are available to determine if the remaining uses are attained or threatened.
- **Category 3:** Insufficient data (or no data) is available to determine if any designated use is attained.
- **Category 4:** The standard is not met or is threatened for one or more designated uses, but the development of a TMDL is not required.
    - **Category 4a:** A TMDL has been completed and approved by the EPA.
    - **Category 4b:** Other pollution control requirements are reasonably expected to result in the attainment of the water quality standard in the near future.
    - **Category 4c:** Pollution is not the cause of the water quality standard not being met.
- **Category 5:** The waterbody does not meet applicable water quality standards or is threatened for one or more designated uses by one or more pollutants.
    - **Category 5a:** A TMDL is underway or scheduled or will be scheduled.
    - **Category 5b:** A review of the water quality standards will be conducted before a TMDL is scheduled.
    - **Category 5c:** Additional information will be collected before a TMDL is scheduled.

Category 1 waters are those that fully support all of their designated uses. Category 2 waters may support some of their designated uses, but there is insufficient data to determine if all uses are supported. Category 3 is water for which no applicable water quality data and information are available. Category 4 is water whose designated uses are impaired and are waiting implementation of appropriate corrective actions. Category 5 is water whose designated uses are impaired and for which a total maximum daily load is required.

**Table 3.4. Impaired Waterbodies (2016), per Section 303(d) of the Federal Clean Water Act**

| Waterbody | River Basin | County | Uses | Causes | Sources | Size/ Acres | Year Listed |
|---|---|---|---|---|---|---|---|
| Callaway Creek | Alabama | Elmore | Fish & Wildlife | Nutrients | Agriculture<br>Municipal | 13 | 2010 |
| Three Mile Branch | Alabama | Montgomery | Fish & Wildlife | Pathogens *(E. coli)* | Urban Development | 7.6 | 2006 |
| Mill Creek | Alabama | Autauga<br>Elmore | Fish & Wildlife | Siltation | Urban Development | 8.86 | 2010 |

Before the ADEM submits this information to the EPA each year, it places the draft 303(d) list on public notice for a 30-day public comment period. In Alabama, the public also may participate in the TMDL development and implementation process through watershed organizations (Alabama Department of Environmental Management 2018). Alabama's TMDLs that have been approved by the EPA and the TMDLs that are on public notice may be viewed on ADEM's website. For more information about how to become involved, see ADEM's Guide for Citizen Participation.[4]

Identification of the Category 5 waters is required by Section 303(d) of the Federal Clean Water Act. This group of waterbodies comprises the 303(d) list of impaired waterbodies. The list provides a framework for Alabama to manage its water resources and to make decisions related to restoring and protecting water quality. TMDLs are continually being written for impaired stream segments.

Not all impaired waters of the state are included on the Section 303(d) list. By definition, the list is limited to impaired waters that require development of a TMDL. Streams or segments of streams listed are removed from the 303(d) list once a TMDL is developed for them. This does not mean, however, that the waterbody has been cleaned and is no longer impaired.

### Total Maximum Daily Load (TMDL)

The EPA requires that a TMDL be developed by state regulatory agencies for waterbodies on the 303(d) list. A TMDL is a document that establishes the maximum amount of a particular pollutant (from point and nonpoint sources) that can enter a waterbody without adversely affecting its designated use. It serves as the starting point or planning tool for restoring water quality.

The maximum pollutant load for a particular body of water is established by conducting a detailed water -quality assessment. During this assessment, pollutant loads are allocated among the various point and nonpoint pollutant sources that may be affecting the waterbody. A margin of safety and the effects of seasonal variations are figured into the maximum load calculation. The TMDLs are developed according to a specified schedule and must be approved by the EPA after an opportunity for public comment. Once approved, the waterbody is removed from the CWA §303(d) list.

Table 3.4 is an example of three of the 329 records on the 2016 Alabama §303(d) list as it appears on the ADEM website. There is more information for each waterbody, including size in acres for bays/lakes and length in miles for rivers. The last column in the example is the year when the segment was first listed as an impaired waterbody. For recommendations on how to report problems, see Water Quality Reporting in Appendix C.

**Figure 3.26.** Watershed stakeholders tour the Pepperell Branch watershed.

**3.27.** Alabama lakes provide scenic sunsets throughout the state.

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