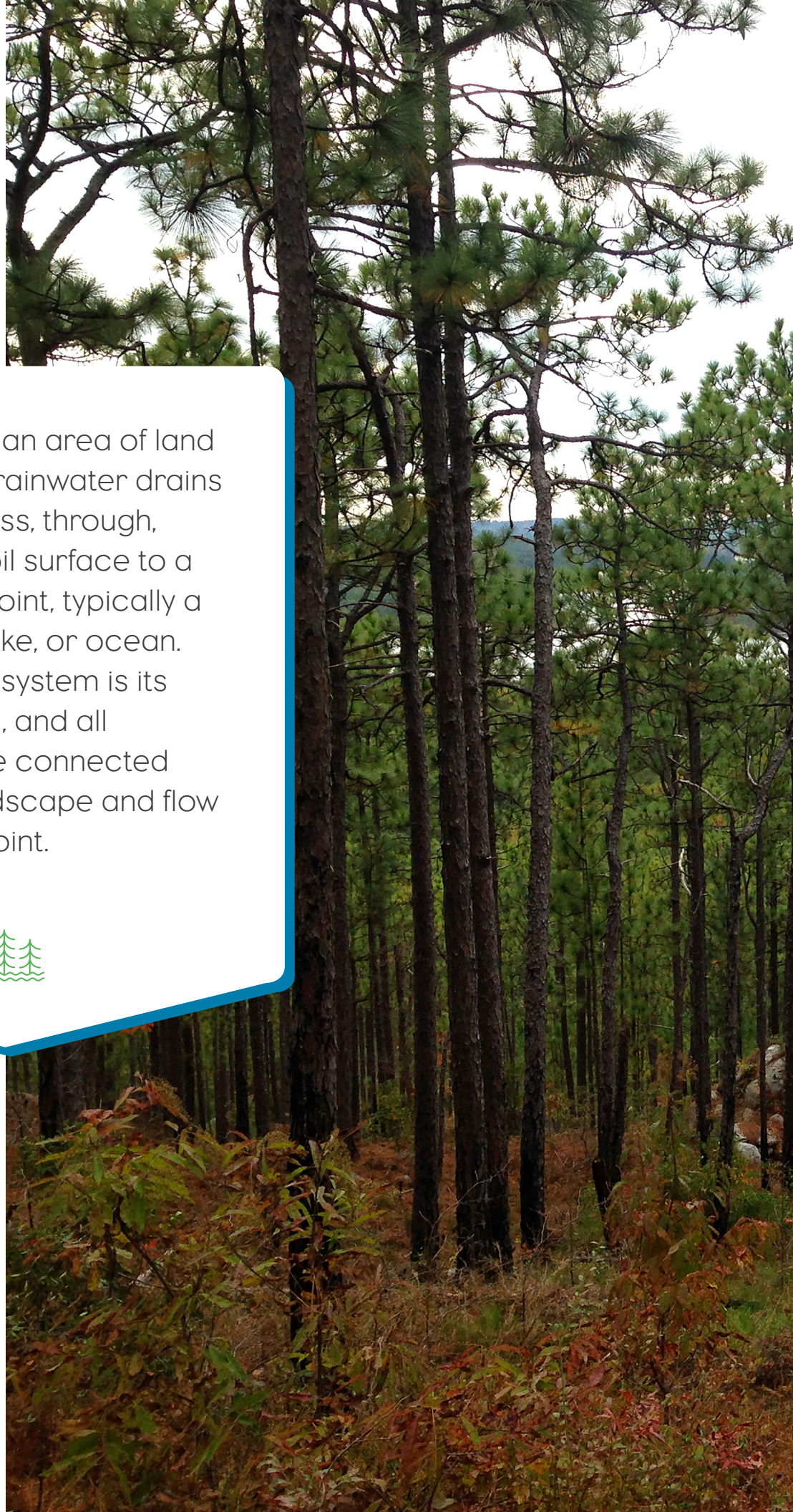


A watershed is an area of land through which rainwater drains by flowing across, through, or under the soil surface to a common low point, typically a stream, river, lake, or ocean. Each drainage system is its own watershed, and all watersheds are connected across the landscape and flow to the lowest point.





CHAPTER

2

**OVERVIEW OF  
WATERSHED  
SYSTEMS**





# Overview of Watershed Systems

In this chapter you will learn about the following:

- **watersheds and how they function**
- **watershed hydrology and the water cycle**
- **natural features found in watersheds**
- **streams and riparian zones**
- **the different ways watersheds are used**
- **watersheds in Alabama**
- **how Alabama uses watersheds**

## WHAT IS A WATERSHED?

A watershed is an area of land through which rainwater drains by flowing across, through, or under the soil surface to a common low point, typically a stream, river, lake, or ocean (figure 2.1). Each drainage system is its own watershed, and all watersheds are connected across the landscape and flow to the lowest point).<sup>3</sup>

We all live and work in a watershed, as all land is part of a watershed. Your everyday actions (work, play, and general living) can impact (positively or negatively) the quality of water that flows from your watershed. As water flows through the system, the impacts are cumulative. This means that everything you do on the land can impact the water that flows to your downstream neighbors. Likewise, everything that landowners above you do impacts the quality and quantity of what flows across your land.

The functions of rivers and streams are to transport water, transport and deposit sediment, transport and replenish nutrients, and provide biological functions (food, shelter, shading, movement, etc.).

The boundary between two watersheds is called a *divide*. Watershed divides are defined by the elevational high points or ridges (the highest point of an area of land, such as the top of a hill or mountain) that surround a given drainage system or network of drainage systems. Any water that falls outside of a watershed divide will enter



**Figure 2.1.** Water flows across land to a common low point. (Photo credit: Texas Watershed Stewards)

another watershed and flow to a different point. All of the land that drains water to a common point is considered to be in the same watershed.

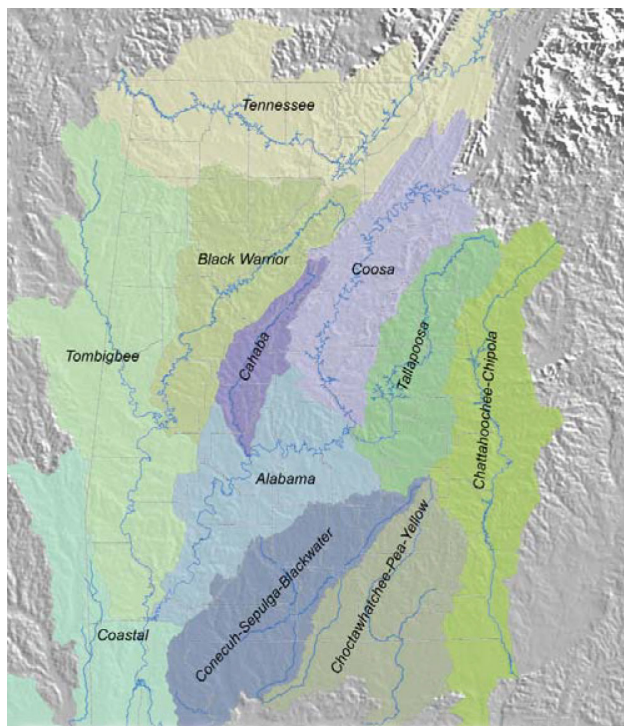
Watersheds come in many different shapes and sizes and have many different features. They can have hills or mountains or can be nearly flat. They may include farmland, rangeland, small towns, and big cities. Watersheds may be as small as the creek that flows near your house or as large as the Mississippi River Basin, which drains 1.2 million square miles. The water bodies within a watershed also can be categorized according to their size and function.

## WATERSHED BOUNDARIES

The term *hydrology* means the “study of water.” Watershed hydrology is the study of water as it interacts with various parts of a watershed, including the land, the sea, and the sky (discussed in section 2.3).

Watersheds can be categorized and defined at various hydrological levels. Hydrologic regions are the largest watershed units, and they may contain several major river basins (figure 2.2). The Alabama, Black Warrior, Cahaba, Coosa, Tallapoosa, and Tombigbee basins are all part of the greater Mobile Basin.<sup>12</sup>

Watersheds are nested systems of smaller watersheds called *subbasins* or *sub-watersheds*, as illustrated in figure 2.3.



**Figure 2.2.** River basins in Alabama. (Photo credit: Donn Rodekohr from Alabama LID Manual)

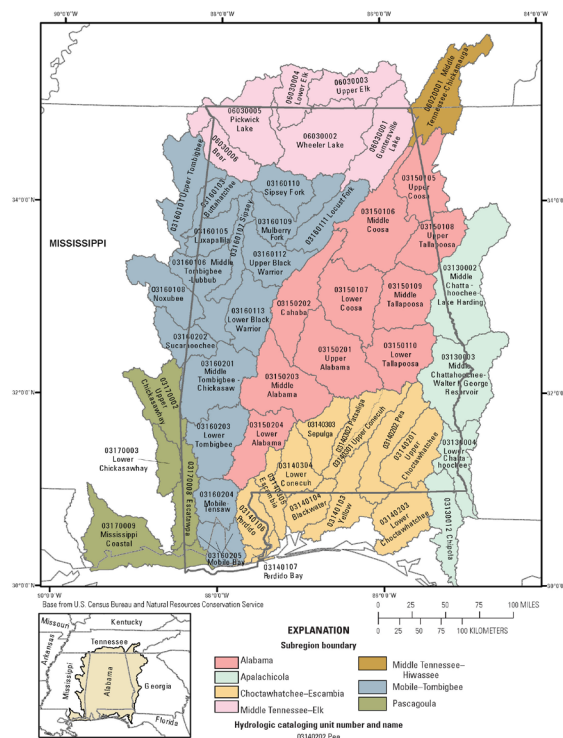
These hydrologic regions are subdivided into progressively smaller units. Each unit of measurement has a hydrologic unit code (HUC) that describes the level of subdivision and the geographic location of the hydrologic unit. Hydrologic units are nested within one another. For example, HUC-6s are nested within HUC-8s, and HUC-4s are nested within HUC-6s. State maps of Alabama use the United States Geological Survey (USGS) 8-digit HUC or cataloging unit (CU) watersheds as the spatial framework for defining its watershed assessment categories and for targeting the watersheds it views as its highest restoration priority.<sup>15</sup>

## PRINCIPLES OF WATERSHED HYDROLOGY

Nearly 75 percent of Earth's surface is covered by water which has been around since Earth was formed several billion years ago. All of the water on Earth is constantly moving and recycling via an endless process known as the *water cycle*, or the *hydrologic cycle* (figure 2.4).

The water cycle is one of the largest physical processes on Earth. It is driven by energy from the sun and by the force of gravity, and it supplies all of the water needed to support life. There is no beginning or end to the water cycle—it is always happening.

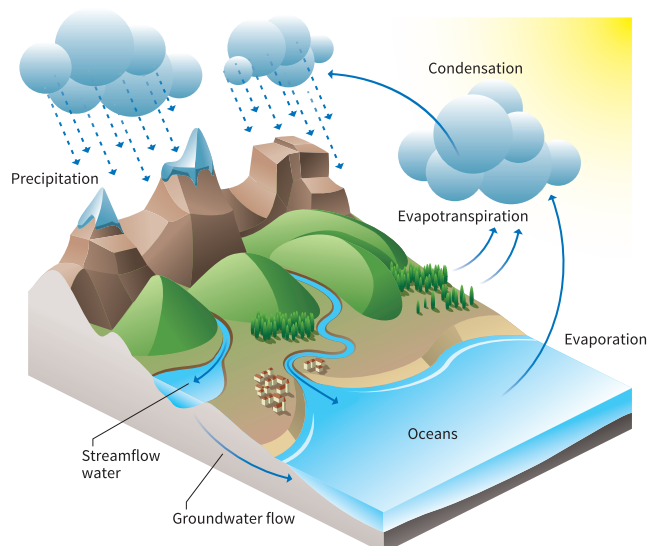
As seen in figure 2.4 the components of the water cycle include evaporation, condensation, precipitation, transpiration, and runoff. **Evaporation** occurs when



**Figure 2.3.** Subregions and subbasins in Alabama. (Photo credit: Office of Water Resources)

the water in lakes, oceans, rivers, and streams (surface water) is heated by the sun and converted to a gas called water vapor. Evaporation also occurs in trees and plants through a process called **transpiration**. In this process, liquid water evaporates from plant leaves and stems and is converted to water vapor. On a broader scale, approximately 80 percent of all evaporation on Earth originates in oceans, with the remaining 20 percent occurring from inland water sources (streams, rivers, lakes, etc.), and vegetation.

**Figure 2.4.** The water cycle is one of the largest physical processes on Earth.





Many factors determine what happens to the rainfall received. These factors impact how much water evaporates, infiltrates, and moves through vegetation, as well as the amount and velocity of overland flow that may erode the soil surface and enter the stream.<sup>9</sup> Some of the factors include the following:

- type, quantity, and density of vegetative cover
- storm intensity and duration
- soil moisture prior to the storm event
- soil water holding capacity
- slope

**Condensation** is the process by which water vapor returns to its original liquid state (figure 2.5). It typically occurs in the atmosphere when warm air rises, cools, and, as a result, loses its capacity to hold water vapor. Excess water vapor then condenses to form clouds. Condensation in the atmosphere also may be visible as fog, mist, dew, or frost depending on the physical conditions of the atmosphere.

**Precipitation** occurs when condensed water in clouds becomes too heavy to remain suspended in the air and falls to the earth as rain, sleet, hail, or snow. Precipitation is a major component of the water cycle and the primary source of fresh water found on the surface of the earth.

Several factors affect the movement of precipitation once it lands in the watershed. It can follow one of five pathways:

- It can be **absorbed** and **intercepted** by plants and utilized in various biological processes.
- It can **filter** through the soil profile and end up as groundwater (water that is stored in underground layers of rock and sand known as aquifers).
- It can **evaporate**, both from the surface of the earth or as it falls from the sky.
- It can be **stored** in ice caps and glaciers, which can store frozen water for thousands of years.
- It can **runoff** into streams and rivers and become surface water that eventually makes its way to the ocean. Runoff occurs when the rate of precipitation exceeds the rate at which the water can be absorbed into the soil. Runoff also occurs when water falls onto an impervious surface, such as a parking lot (figure 2.6) or a sidewalk, where it can't easily be absorbed into the soil.

No matter which pathway precipitation follows, it always continues cycling and recycling through the various steps in the hydrologic cycle. This process occurs continuously in all parts of a watershed and in all parts of the world.



**Figure 2.5.** Condensation forms on a window.



**Figure 2.6.** When rain or snow falls on impervious surfaces, such as parking lots, it often runs off into storm drains and local waterways.

## NATURAL WATERSHED FUNCTIONS

As the water cycle is occurring, a watershed system must be able to balance the influx of water to optimize watershed function. A healthy and connected stream, floodplain, and riparian area provides tremendous ecological services such as the following:

- erosion control
- water quality improvement
- wildlife and aquatic habitat
- recreation
- water storage
- flood protection

A watershed has five primary functions that can be categorized into hydrological and ecological functions.

**Hydrological functions:**

- water capture
- water storage
- water release

**Ecological functions:**

- providing diverse sites for biogeochemical reactions to take place
- providing habitat for plants and animals of various kinds



## HYDROLOGICAL FUNCTION 1: WATER CAPTURE

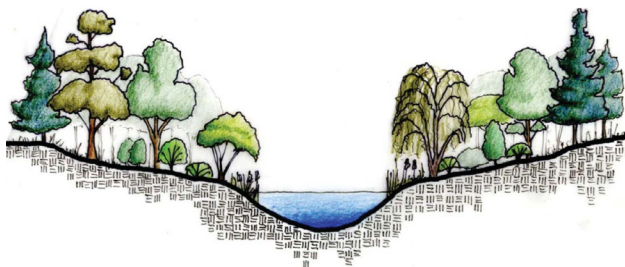
Water capture is the process by which water from the atmosphere is captured or stored in the soil. A healthy watershed is a catchment, capturing the rainfall like a sponge, storing the water to slowly release later. Vegetation is important to slow down and capture the water in the soil. Water can infiltrate the soil surface and percolate throughout the soil profile.

Infiltration is the movement of moisture from the atmosphere into and through the surface of the soil. Percolation is the downward movement of water through the soil profile. Infiltration and percolation rates are affected by several factors, including the soil type (primarily texture and depth), topography, and climate. High infiltration rates occur when there is good vegetation cover and soil organic matter, structure, and depth.

## HYDROLOGICAL FUNCTION 2: WATER STORAGE

Once water is captured in the soil, it is stored in the pores (air spaces) between soil particles. The amount of moisture that a soil can hold depends on the soil's depth, texture, and structure. For example, less water can be stored in sandy soils than in clay soils. This is because sandy soils are made up of large soil particles with large pores in between these particles. Water drains more easily through large pores than through small pores.

The kinds, amounts, and distribution of vegetation on the ground also greatly affect the amount of water stored in a watershed. For example, a piece of land can be dominated by shallow-rooted annual species (rye grass), deep-rooted perennial species (sturdy grasses, trees, and shrubs), or a mixture of these. Different types of plants use water in varying amounts and from varying depths in the soil profile, which affects how much water can be stored in a watershed.



**Figure 2.7.** Schematic section of a streambank with riparian vegetation. (Photo credit: Alabama Low Impact Development Handbook)

## HYDROLOGICAL FUNCTION 3: WATER RELEASE

Water is released from a watershed when it moves through the soil profile to seeps and springs or across the land surface as runoff, ultimately flowing into streams and rivers that flow to oceans. Water is safely released when it moves out of the watershed without causing environmental problems. There are two ways water is released:

1. **subsurface flow**—the flow of water below the land surface that is in excess of the water that can be stored in the soil
2. **overland flow**—the flow of water over the ground surface that occurs when precipitation exceeds the soil's infiltration rate

The kinds and amounts of vegetation in a watershed affect the amounts of water released and the rate at which it flows through a drainage system. Vegetation protects the soil surface from the impact of raindrops, which can damage soil structure and reduce infiltration.

Vegetation protects the soil from erosion across the land and along streambanks, while also slowing the release of water into streams as shown in figure 2.7. During heavy rains, vegetation can help prevent the erosion of streambanks, reduce the amount of sediment in the water, and help maintain the water's quality.

## ECOLOGICAL FUNCTION 1: PROVIDE DIVERSE SITES FOR BIOGEOCHEMICAL REACTIONS

Biogeochemical cycling refers to the biological, physical, and chemical transformations of elements that are found in soil, water, and air. Many of these interactions are quite complex and very important in maintaining proper watershed function.

Nutrient elements, such as nitrogen, sulfur, phosphorus, carbon, and hydrogen, and organic materials containing these nutrients are constantly undergoing biological, physical, and chemical reactions with the surrounding environment. These processes help to maintain the plant and microbial communities found along water bodies in a watershed. Plants and microbes, in turn, fuel additional reactions and biogeochemical cycling. These communities also help to maintain the global atmosphere through a complex cycle in which carbon is trapped in plant biomass, preventing its release into the atmosphere as carbon dioxide, a greenhouse gas.



## ECOLOGICAL FUNCTION 2: PROVIDE HABITAT FOR PLANTS & ANIMALS

Habitat refers to the natural home of a plant or an animal. A healthy habitat contains everything a species needs to survive—food, water, cover, and a place to raise young. Our human habitat might include our home, our place of work, and the grocery store. The habitats of plants and animals, on the other hand, might include a small puddle in a backyard or a massive rainforest on another continent. Because different living things have different needs for food, water, and cover, each kind of plant and animal requires a specific kind of habitat. Healthy and abundant habitat is critical not only to the survival of plants and animals but also to the overall function of a watershed.

Watersheds provide critical habitat for all kinds of aquatic and terrestrial plant and animal species. The types of habitat found in a watershed depend on the environmental factors that exist there. The amount of precipitation a watershed typically receives defines the type of habitat and the types of plants and animals found there, which would be adapted to living in those dry or wet conditions, as seen in figure 2.8.<sup>9</sup>

**Figure 2.8.** Cypress trees and other plants adapt to living in or near water. (Photo credit: Alabama Forestry Commission)

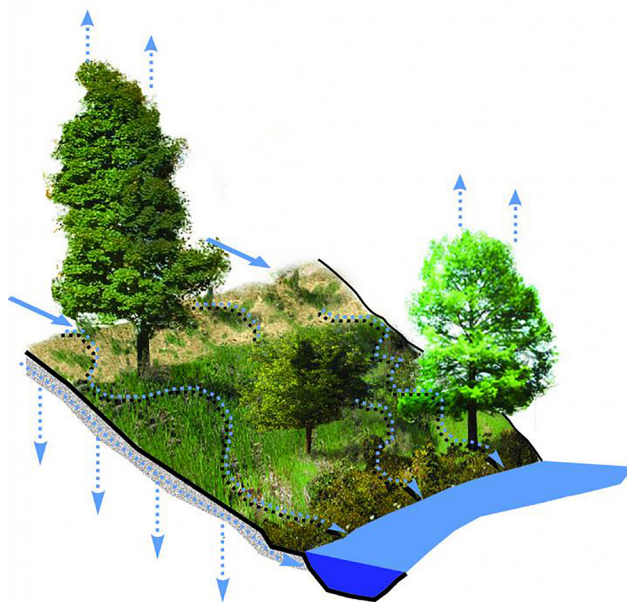


## NATURAL WATERSHED FEATURES

Healthy watersheds contain natural features that help it to carry out its essential functions. These features include **uplands**, **floodplains**, **riparian zones**, and **water bodies**. These features are intimately connected and work together to ensure that a watershed is functioning properly. In general, watersheds and all of their natural features function to capture, store, and release water safely; to filter out sediments, pollutants, and other potentially harmful materials; and to provide diverse sites for biogeochemical reactions and habitat for plants and animals.

An **upland** is an area of land located at a higher elevation above a waterbody that does not or very rarely experiences flooding. The upland areas of a watershed are important habitat for mammals, birds, reptiles, and amphibians. Upland vegetation stabilizes the soil surface, minimizes surface erosion, and filters and retains dissolved and suspended matter carried by surface water runoff from the surrounding land.

The **floodplain** is the flat area of land surrounding a body of water that is subject to periodic flooding. After heavy rainfalls, the floodplain holds excess water, allowing it to be slowly released into the river system or seep into groundwater aquifers. Floodplains also help to settle or filter out sediment from floodwaters, thereby keeping it out of water bodies. Floodplains often support an abundance of aquatic life and are used as recreation areas.



**Figure 2.9.** Riparian buffer zones capture and filter runoff. (Photo credit: Alabama Low Impact Development Handbook)



The word *riparian* means “of the river.” The **riparian zone** is the transition zone between the water and the dry uplands, or the natural, noncultivated, vegetated land that touches and immediately surrounds a stream, river, lake, or other body of water (figure 2.9).<sup>14</sup>

The riparian zone often includes wetlands, which are areas of land that are regularly saturated with water for at least part of the year, have hydric or wetland soils, and contain vegetation adapted to living in saturated conditions. Wetlands and other components of the riparian zone perform vital functions that help to maintain the health of the watershed.<sup>4</sup> Riparian zones help to do the following:

- **Stabilize slopes and streambanks.** The roots of trees and plants hold streambank soil in place so that ground is not lost to erosion.
- **Filter pollutants.** Vegetated riparian buffers along the water’s edge can help to filter pollutants from agricultural, urban, suburban, and other land cover through natural processes such as deposition, infiltration, adsorption, filtration, biodegradation, and plant uptake. The vegetation in the riparian area slows the flow of water, traps sediment and other pollutants, and absorbs nutrients from the watershed before they can reach the water.<sup>4</sup>
- **Maintain proper water temperatures within the stream or river.** Trees and plants hanging over the water shade it and help keep it cool all summer. This is critical to fish life, as some fish become stressed, or even die, when temperatures increase even a few degrees.
- **Supplement nutrients.** As leaves and insects fall into the water, they provide food for animals living in the stream.
- **Provide habitat and food for wildlife.** Many birds (great blue herons, kingfishers, eagles, osprey, etc.) and other animals rely on vegetation near water for their homes and resting places.
- **Provide a “transitional zone” from streambank to floodplain to watershed slope.** This is critical for flood mitigation, as it slows floodwater and allows it to soak in or enter the stream with less energy.

A **waterbody** refers to any stream, river, pond, lake, estuary, or ocean. Water bodies can be flowing (lotic) systems (streams and rivers) or nonflowing (lentic) systems (ponds and lakes).

The flow of water in these systems, particularly in rivers and streams, is greatly affected by the natural features of the watershed, including the topography, slope, soils, and vegetation. For example, as a stream meanders or curves, it helps to slow down the flow of water and control flash flooding (figure 2.10). A severe, rapid release of water will occur in straight channels with little resistance to water.



**Figure 2.10.** Vegetation creates a riparian buffer along a creek.



**Figure 2.11.** Streams are classified according to size and location in a watershed. (Photo credit: South Carolina Forestry Commission)

## STREAM TYPES & STREAM ORDER

Streams often are classified in a stream order according to their size and location in a watershed. Stream types include **perennial**, **intermittent**, and **ephemeral** (figure 2.11).

**Perennial** streams typically flow continuously during a normal year, have well-defined channels, have little to no vegetation growing in the channel, and may pool or dry up during drought years.

They typically are associated with a water table in the localities through which they flow.<sup>14</sup>

**Intermittent** streams flow for at least 30 days during parts of the year, depending on when the area receives water from springs, rainfall, or snow melts.<sup>14</sup> They may have well-defined channels and vegetation reflective of permanent water influence, such as the presence of willow, box elder, or similar trees.

**Ephemeral** streams flow only in direct response to precipitation. They appear immediately or shortly after a rain event, but their channels are above the water table at all times.<sup>14</sup> Of Alabama’s rivers and streams, about 61 percent flow permanently throughout the year, while 39 percent flow only intermittently during wetter times.<sup>12</sup>



The idea of stream orders has been important in developing the river continuum concept (figure 2.12), which is a way of describing how aquatic communities change from headwaters to larger streams.<sup>19</sup> Stream order is a useful tool for managing and protecting waterways by considering the many differences that exist between streams of different sizes.

When we know the order of a stream, we are able to make several useful predictions about the stream's physical and biological environments.<sup>16</sup> The following outlines the differences between stream orders. You can learn more online at the Environmental Protection Agency's Watershed Academy (<https://www.epa.gov/watershedacademy>).

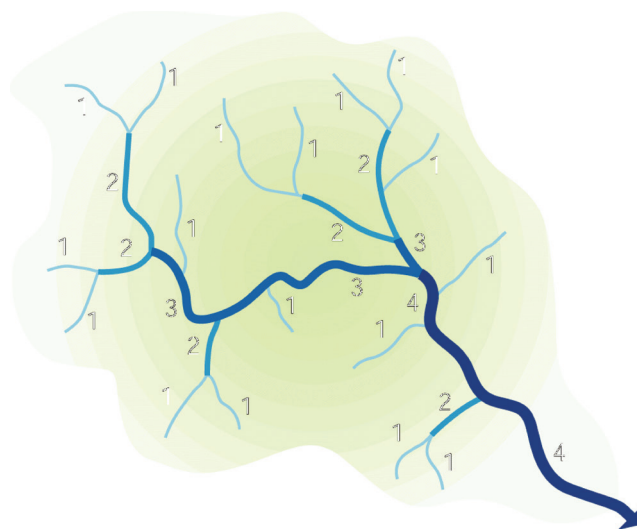
**Headwater streams** (stream orders 1 to 3) are usually small, steep gradient streams with fast flows and cool temperatures. Headwater streams usually have thick vegetation along their banks that shade most of the stream, keep water cooler, and limit the potential for photosynthesis within the stream.<sup>5</sup>

Leaves and organic debris from overhanging vegetation are primary sources of organic inputs into headwater streams, providing the basis for the food pyramid involving microorganisms (microscopic organisms, such as bacteria, viruses, or fungi), invertebrates (animals without a backbone, such as arthropods, mollusks, annelids, etc.), and fish.

First-order streams may have large substrata, such as boulders, tree roots, and logs, in them, which can obstruct the flow of water, creating plunge pools, high water turbulence, and highly oxygenated water. Second- and third-order streams generally have a repeating pattern of pools (deep, still waters), riffles (shallow, swift, and turbulent water), and runs (intermediate stretches that are neither pools nor riffles).<sup>16</sup>

**Middle-reach streams** (stream orders 4 to 6) are further down the watershed. The smaller headwater streams converge to form larger stream channels that become wider, deeper, and generally have lower gradients. This causes the flow of water to be slower, less turbulent, and often less oxygenated.

The stream channel still may have large, woody debris, such as stumps and partially submerged logs. In the middle reaches, less of the stream channel is shaded by bank vegetation, allowing more primary production to occur within the stream channel.<sup>5</sup> Photosynthesis becomes increasingly important as the primary source of oxygen in the water. Because the stream is wider, organic input from leaves and bank debris is relatively less important than it is for headwater streams.



**Figure 2.12.** Stream ordering in a drainage network. 1 = first order stream 2 = second order stream, etc. Knowing the order of a stream allows us to make useful predictions about the stream's physical and biological environments. (Photo credit: Stream Corridor Restoration: Principles, Processes, and Practices, 10/98, by the Federal Interagency Stream Restoration Working Group (FISRWG).)

**Lower-reach streams** (stream orders 7 and above) continue to converge and form channels that are larger, deeper, and have slower-moving water. The food source from streamside vegetation is relatively insignificant compared to primary production that occurs within the water column.<sup>5</sup>

The land is flatter and the floodplain is clearly visible. The channel may split into large, meandering channels and wetlands, and marshes are present. Often, these large channels carry large amounts of sediment. Oxygen in the water is the result primarily of photosynthesis occurring in the river channel and not due to physical mixing. The typical sequence of pools and riffles found in middle reaches are not common here, although pools and riffles still may be found.

Understanding stream order is an effective tool to use to manage and protect our waterways of varying sizes. As water travels from headwater streams toward the mouths of larger rivers, lakes, or the ocean, the width, depth, and velocity of the waterways gradually increase, as does the amount of water discharged. These physical characteristics dictate the types of aquatic organisms that can thrive in them.

Both natural factors and human-induced impacts influence stream size, shape, and gradient as well as substrate type, water quality, water quantity, and streamside vegetation.



### Did you know?

- Intermittent or ephemeral streams flow only part of the year or after rains.
- First-order streams flow year-round and do not have any tributaries.
- Second-order streams are formed by the union of two first-order streams.
- Third-order streams are formed by the union of two second-order streams. If a second-order stream is joined by a first-order stream, it remains a second-order stream.
- All other higher-order streams form when two streams of lower order join<sup>5</sup>.
- The Cahaba River in Alabama is a sixth-order stream, and the Mississippi River in the United States is a tenth-order stream.

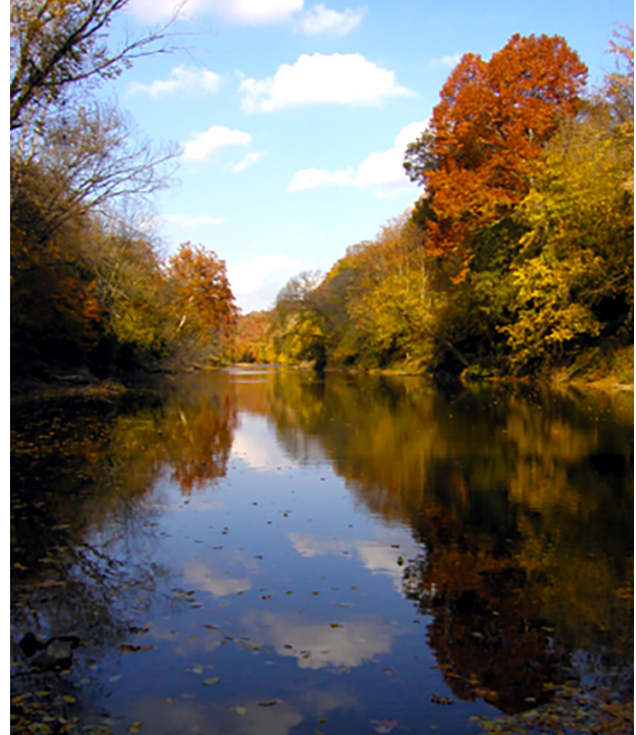
The health of a watershed and its water bodies depends on many factors: the soils and vegetation surrounding the waterbody, the use of the stream, the location of the water within the watershed, and much more.

## HOW DOES ALABAMA USE WATERSHEDS?

How we use the water in our watersheds can significantly impact the water quality. Alabama has sixty-seven counties with an estimated 4,874,747 people<sup>17</sup>, all living within and relying on Alabama's sixteen river basins. Alabama uses the water in its watersheds for a variety of purposes.

Keep in mind that watershed boundaries span state lines (for example, approximately 15 percent of all surface water flowing through the lower 48 states flows through Alabama<sup>8</sup>). How we use water in our watersheds can impact other watersheds as well (figure 2.13).

Water in river and reservoir systems can be used in-stream for hydroelectric power generation, navigation, recreation, and wastewater assimilation and to maintain minimum stream flows to support fish and wildlife habitat. Groundwater, meanwhile, contributes to base flow in streams and rivers. Water also can be withdrawn from rivers, reservoirs, and aquifers to meet off-stream needs for public drinking water, self-supplied residential drinking water, irrigation, livestock drinking water, aquaculture, and self-supplied industrial, mining, and thermoelectric power generation.<sup>11</sup>

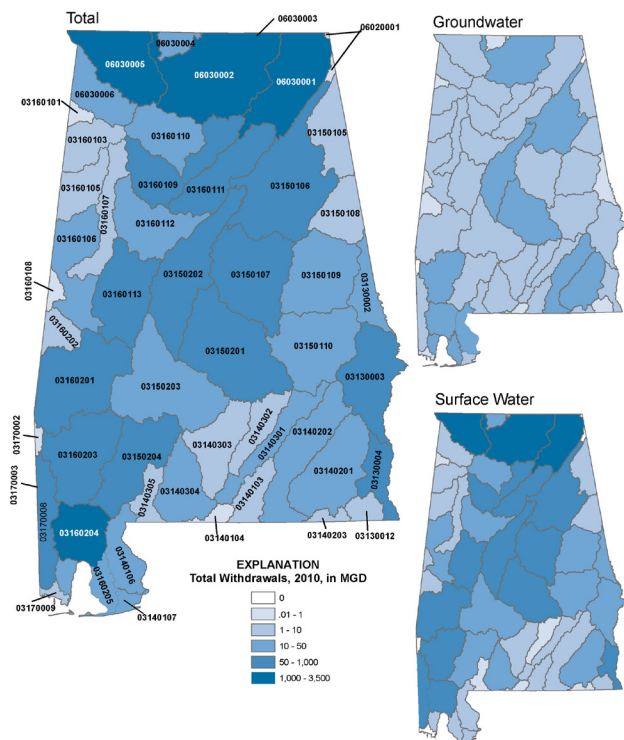


**Figure 2.13.** Perennial streams flow year round.  
(Photo credit: Alabama Water Watch)

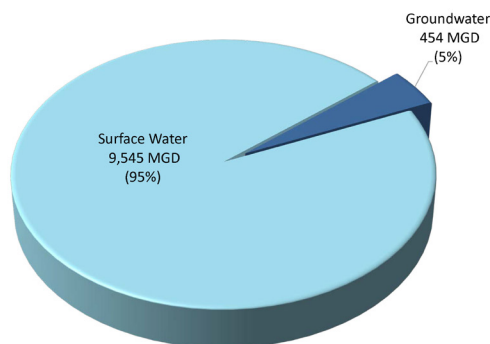
**Table 2.1. Human Uses of a Watershed**

Human Uses of a Watershed	Examples
Recreation	Boating, fishing, swimming, water skiing, hiking, rock climbing, camping, hunting, etc.
Water consumption	Drinking, irrigation, gardening and lawns, channeling of water
Transportation	Bridges, railroads, roads, etc.
Industrial	Thermal cooling, waste treatment
Extraction of natural resources	Ore and mineral mining, rock quarrying, logging, commercial fishing
Agriculture	Crops, forage production, irrigation, etc.
Housing Development	Houses, sidewalks, roads, etc.
Commercial development	Large buildings, retail stores, roads, sidewalks, etc.





**Figure 2.14.** Total Alabama water withdrawals by source in 2010. (Photo credit: Alabama Department of Economic and Community Affairs, Office of Water Resources)



**Figure 2.15.** Total Alabama water withdrawals by source in 2010. (Photo credit: Alabama Department of Economic and Community Affairs, Office of Water Resources)

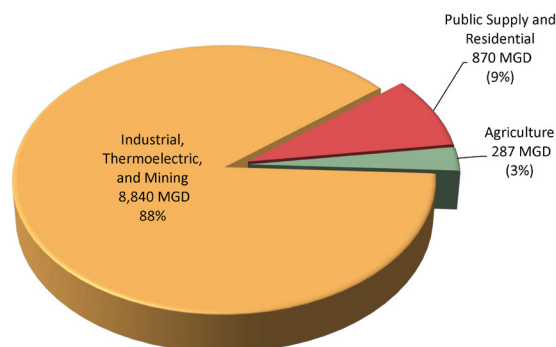
According to the *2017 Alabama Surface Water Assessment Report* by the Office of Water Resources in the Alabama Department of Economic and Community Affairs, Alabamians used about 9,999 million gallons per day (MGD) during 2010 (the latest data available). Estimates of withdrawals by source indicate that total surface water withdrawals were approximately 9,545 MGD (95 percent of the total withdrawals), and the remaining 454 MGD (5 percent) were from groundwater (figures 2.14, 2.15).

Water withdrawals have more than doubled in Alabama from 1960 to 2010, from approximately 4,220 MGD to 9,999 MGD.<sup>11</sup> Following are estimated 2010 withdrawals by category (figure 2.16) and in descending order:

- 3. Thermoelectric power, 8,840 MGD.** All of the thermoelectric power water use was from surface water. Nearly all of the water (98 percent) was used for once-through cooling, and most of that water was returned to a surface water source.
- 4. Public supply and residential sector, 870 MGD.** Public supply groundwater withdrawals were approximately 58 percent of total groundwater withdrawals for Alabama.
- 5. Agriculture, 287 MGD.** Irrigation and other agricultural withdrawals accounted for roughly 3 percent of withdrawals.<sup>2</sup>

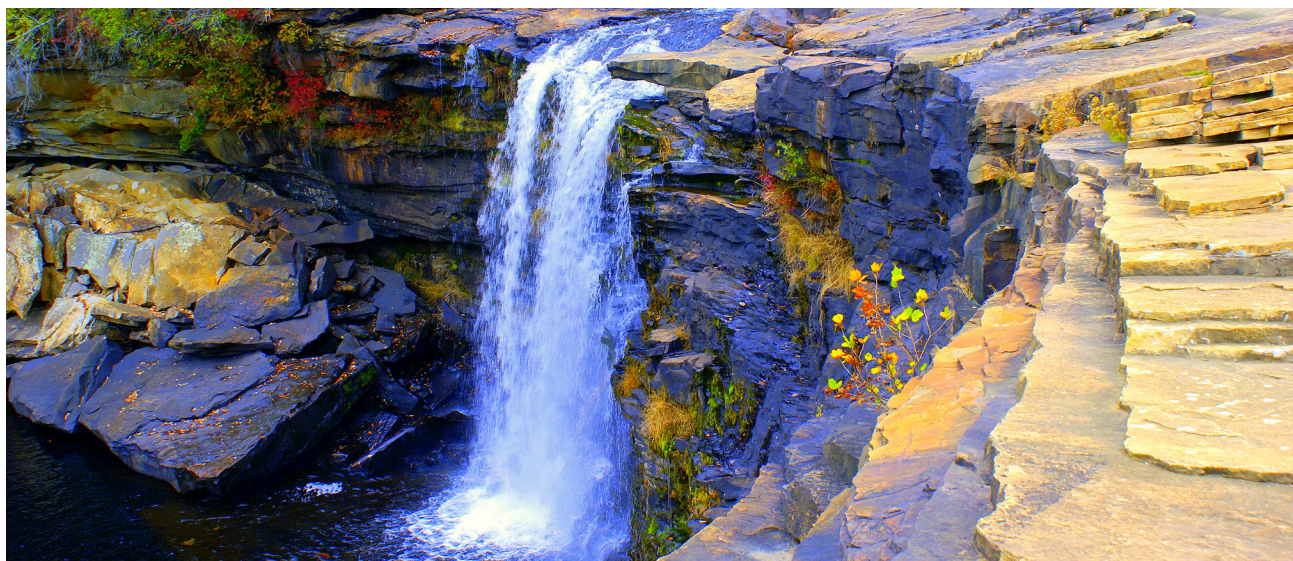
Approximately 65 percent of the water used is obtained from surface sources, such as lakes, rivers, and streams, and provided with full treatment (coagulation, sedimentation, filtration, and disinfection). Twenty-seven south Alabama counties receive all of their public water supplies from groundwater sources.<sup>11</sup> Alabama has twenty major aquifers that supply water from the land surface to depths approaching 3,000 feet.<sup>11</sup>

Although plentiful, clean water is a valuable resource worth preserving in Alabama.



**Figure 2.16.** Total Alabama withdrawals by sector in 2010. (Photo credit: Alabama Department of Economic and Community Affairs, Office of Water Resources)





**Figure 2.17.** An Alabama water treasure is DeSoto Falls in Mentone.

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