

Chapter 8

Understanding Water Quality

The term water quality can be interpreted in a number of ways. One definition from the U.S. Geological Survey (USGS) is that water quality is a term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose. When the average person asks about water quality, they probably want to know if the water is good enough to use at home, to play in, to serve in a restaurant, etc., or if the quality of our natural waters is suitable for aquatic plants and animals.

Water quality is also the *study* of the chemical, physical and biological characteristics of surface water and groundwater. As such, it is one of five river basin sciences. The other four river basin sciences are hydrology, fluvial morphology, ecology and hydraulics. Hydrology is the study of precipitation, infiltration, surface runoff, stream flow rates, water storage in wetlands, detention basins, plus water use and diversions. Fluvial morphology is the study of a stream channel's geologic origin, alignment, slope, shape, size, sediments and floodplains. Ecology is the study of plants, animals and their environment, with emphasis on aquatic systems, wetlands and riparian forests. And finally, hydraulics is the study of the stream's water velocity, flow depth, flood elevations, channel erosion, storm drains, culverts, bridges and dams.

To fully understand and implement the actions proposed in the Lower Coosa River Basin Water Quality Improvement Strategy (Part IV), first water quality, as both a descriptive term and a river basin science, must be understood. The two most significant parts of understanding water quality are the balance and interrelationship between the river basin sciences and the balance and interrelationship between a water body (stream or river) and the land surrounding it.

The matrix in Figure 100 demonstrates the interaction of the five river basin sciences by showing how the subject of each of the river basin sciences is also a subject matter of the other river basin sciences. This matrix can be utilized to determine impacts on or from other river basin sciences as issues are identified. The interrelationship between streams and the surrounding land uses is explained in the section on the Watershed Equation and discussed even more in the sections on Beneficial Ecosystem Services. First, however, the stream network is explained as a foundation to understand how and where water quality originates.

Figure 100:

Interrelationship of River Basin Sciences					
	Hydrologic	Hydraulic	Ecologic	Fluvial Morphology	Water Quality
Hydrologic		Channel encroachments Dams Bridges Culverts Alter peak flows	Vegetation effects Evapotranspiration Infiltration Runoff	Floodplains and wetlands Detain water Groundwater discharge Create baseflow	
Hydraulic	Instream flows Flood flows Flood frequency Droughts		Vegetative roughness Friction Woody debris Barriers Beaver dams	Channel size, shape, slope, alignment Bedform roughness Sediment sources	
Ecologic	Flow duration Flow variations Growth Fish	Size and type of aquatic habitats Flow depth, velocity and scour		Substrate type and diversity Pools Riffles Shelters Migratory barriers Spawning sites	Toxics Turbidity Temperature Dissolved Oxygen Levels Salinity pH
Fluvial Morphology	Groundwater recharge Soil moisture Springs and seeps	Velocity Flow Deposition Shear stresses Tractional forces Waves Sediment transport	Aquatic and riparian vegetation traps sediment		Temperature Affects Settling
Water Quality	Base flow Dilution Pollutants	Pollution transport Mixing Aeration Stratification	Respiration Nutrients Solar exposure Oxygen demand Photosynthesis Fine and coarse	Sediment yields Dissolved solids Turbidity Color	

The Stream Network

The stream network is the organizational structure of surface water flowing into a body of water, be it a stream, a lake or a river. In other words, it is the structure of an identified drainage area. In general terms, there are three types of streams based on the level of water flow, i.e., how much running water is contained in the stream bed. *Ephemeral* streams are streams that only flow on the surface periodically, usually during a rainfall event. *Intermittent* streams flow for several periods during the year, such as a season or several months. And, *perennial* streams are streams that flow year-round.

Each stream network begins with a headwater, which is the point at which water begins to flow in a certain direction, or drain into a basin. It is often perceived that “headwater” refers to a small, clear and often cool stream in a shaded area from which the water flows downstream. Instead, the term headwater actually encompasses many other types of small streams, including intermittent streams that flow briefly during precipitation events and that during dry periods may sink into disconnected pools of water or disappear below a “dry stream bed”. Typically, spring fed headwaters, or ground seeps, have clear water with a relatively steady temperature and flow. In contrast, headwaters originating in marshy meadows may have tea colored water and experience less stability in temperature and flow.

For more scientific research and studies, the U.S. Geological Stream Order Numbering System is used, which was developed by the U.S. Geological Survey. This system designates a stream by a number, or order, based on how many times it has converged with another stream. The following are the definitions for the USGS stream order numbering system:

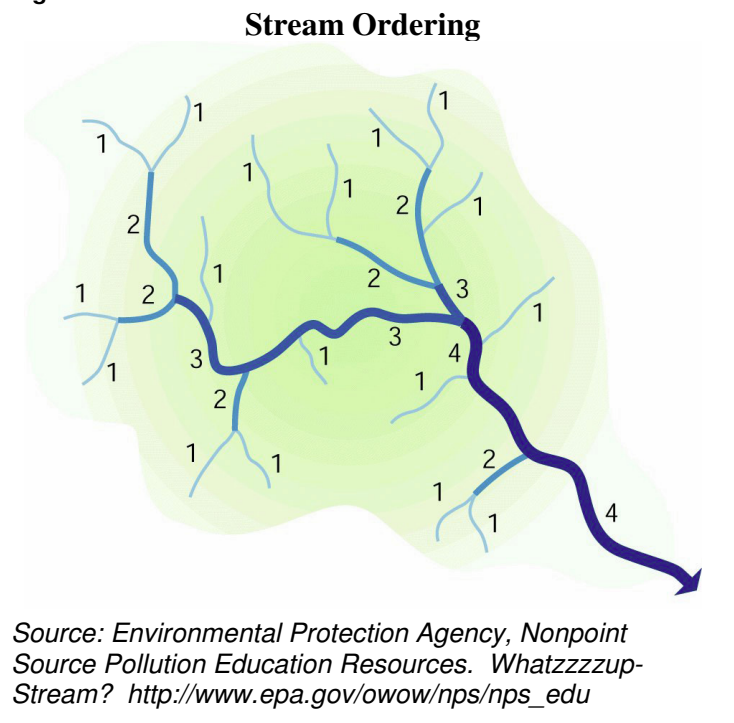
Zero-Order Streams: swales, hollows and other formations that lack defined stream banks, but serve as important conduits of water, sediment, nutrients, and other materials during precipitation events

First-Order Streams: streams having the smallest distinct channel such as rivulets of water that flow from hillside springs and form a channel

Second-Order Streams: streams formed when two first-order channels combine

Third-Order Streams: streams formed by the combination of two second-order streams.

Figure 101:



The system then continues based on the intersection of similar order streams to form higher order streams. Nationwide, it is estimated that only about half of the first-order streams intersect other first-order streams and flow into second-order streams. The other half of first-order streams drain directly into larger order streams, rivers, estuaries and oceans. The term “headwater” is often used in the stream order system to refer to the smallest streams in a stream network including zero, first and second-order streams. It is estimated that half of the total length of channels in a stream network can be first-order streams.¹ Stream networks are often mapped showing creeks or, at most, east and west branches or unnamed tributaries flowing into a creek. The low order streams (the ephemeral and intermittent streams), however, are largely unmapped. Since the mapped stream, or creek, is actually formed by the upstream perennial streams, groundwater seeps, intermittent and ephemeral streams, and sheet flow, the concept of the headwaters of a watershed is frequently misunderstood and improperly defined.

Based on available topographic maps from the USGS, it has been estimated that three-fourths, or more, of the total length of streams and channels in the United States are first and second-order streams. For example, field surveys of streams in the Chattooga River watershed in Georgia found thousands of streams, representing over 80 percent of the stream length in the watershed system, were not shown on the USGS topographic maps. In addition, some small streams that were mapped as intermittent were actually perennial. In Georgia’s Etowah River Basin, the National Elevation Data detailed about 40 percent of the headwater streams and 60 percent were not captured. The Ohio Environmental Protection Agency found similar conditions in their studies. These studies show that the ultimate origination source of a stream network in the headwater area is significant, but invisible.¹

Even limited studies such as the above indicate that the foundations of our nation’s rivers originate in vast networks of unnamed and underappreciated headwater streams that have not been located and mapped. In addition, the lack of a comprehensive inventory of streams in this category hinders the ability to determine the real importance of these streams. Based on other scientific data and knowledge, however, it is reasonable to assume that these areas and small streams are critical to the health of the entire stream network including the downstream river and lakes into which the named tributary creek eventually flows.

These example studies, documenting the extent of unmapped small streams, indicate that similar streams are likely to be significantly underestimated in the Lower Coosa River Basin. It implies that streams shown on existing stream network maps are not detailed enough to serve as a basis for complete stream management and protection. Therefore, for purposes of this study and to understand where a stream network begins the definition of a *watershed* can be recalled as *the surrounding land area that drains into a body of water, i.e., a drainage area*.

The Watershed Equation

It is commonly understood that the aquatic system is linked. The middle segments of a stream network obviously connect the upstream and downstream segments. In contrast, the relationship between the surrounding land and water is often misunderstood or ignored. The

general belief is that the land, or terrestrial ecosystem, only surrounds and confines the water or aquatic ecosystem. For purposes of watershed management, of which water quality is a part, this fundamental relationship between the land and the water must be addressed and the benefits understood. Examples of two of the functions and processes critical to human well being that come from the relationship of ground and water are the natural purification of water and the processing of waste. Benefits that humans receive from the functioning interrelationship of these ecosystems are scientifically referred to as *ecosystem services* (discussed later in this chapter).

Much of the exchange between land and water occurs in the transition zone along the edges of the stream, or the channel, and the adjacent land called the *riparian zone*. The types of land cover and activity occurring in the riparian zone have a distinct effect on the water in the stream channel. For example, during a rainstorm the runoff carries various materials, bits of soil, parts of trees and insects from the land area between streams in the network to downstream channels. As the rain and flow increases, potentially to flood conditions, the amount and size of material transported downstream increases.

Water quality is a result of the relationship between the surrounding land and the stream and can be expressed in a *watershed equation*. There are three key variables in the watershed equation: (1) the amount of runoff, (2) the quality of the runoff, and, (3) the capacity of the receiving stream channel. When the landscape in a watershed is altered it is very likely that the runoff rate will increase. When this occurs, the maximum capacity of the associated stream is reached at a faster rate and more frequently. Less rain will fill the stream at a faster rate during an individual rain event because there is more runoff. Likewise, because there is more runoff the frequency at which the stream is filled increases because less water is absorbed by the adjacent land. Regardless of the reason for the increase in runoff, the additional volume of water flowing in the channel provides the power to alter the channel.

Figure 102:

The Watershed Equation

$$\begin{array}{c} \text{Amount of Runoff} \\ + \\ \text{Quality of Runoff} \\ + \\ \text{Stream Channel Capacity} \\ \hline \text{Quality of Water} \end{array}$$

Typically, changes in land use are thought of in terms of drastic modifications such as changing undeveloped land to urban uses. Changes in the landscape, however, do not have to be nearly that drastic to have an impact on water quality. Even a forested area that experiences a forest fire changes the landscape and increases the runoff in the burned portion of the watershed. When land is converted from natural vegetation to agricultural fields the same thing occurs. A study in Wisconsin determined that when forested watersheds were converted to agricultural fields the size of floods increased. The cultivation removed larger sized vegetation that previously absorbed more of the rainfall. Cultivation also destroyed the near surface characteristics including natural air spaces created in the soil by animal burrows and the root systems of the larger vegetation. The resulting collapse of the near surface layer of soil caused more runoff as opposed to soaking into undisturbed, vegetated ground.¹

Urbanization has a similar effect. Previously vegetated or farmed areas are converted to roof tops and paving that generate greater storm water runoff. The amount of impermeable surface (roofs, roads and parking lots) increases the volume of runoff to the extent that it is several times greater than the amount of rainwater runoff from undeveloped or agricultural land.

The location of the change in land activity within the watershed is also important. If the land activity changes occur in the upper portions of the watershed the effects are felt over a longer distance of the stream network. In addition, if the land activity change occurs in the headwater area of the watershed the impact is different because more of the small order streams are modified. The loss of the beneficial water quality ecosystem services provided by streams is discussed in more detail later in this chapter.

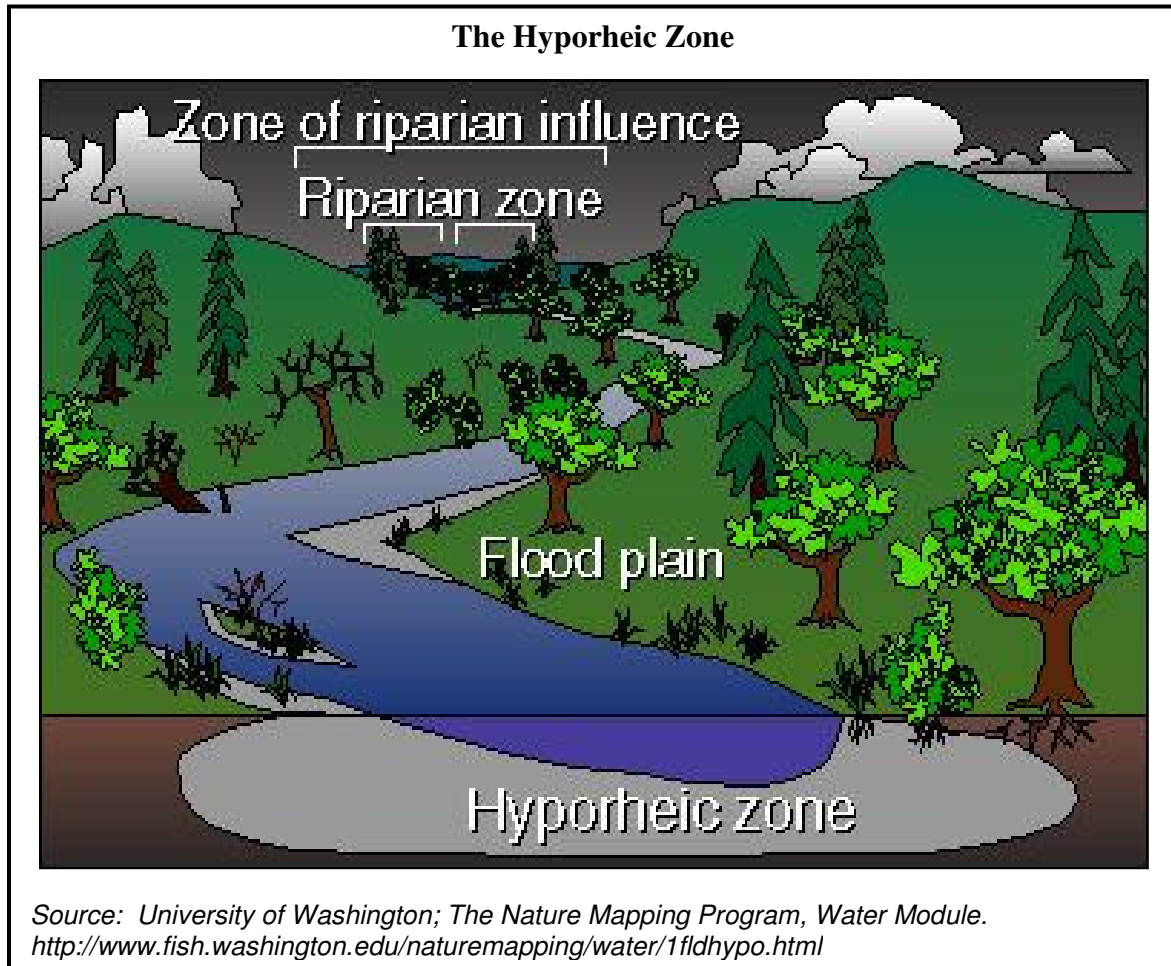
Any change in land activity that results in more runoff will, over time, result in changes in the stream channel. The added water volume increases the speed of the stream because deeper water has less friction with the bottom of the stream. Thus, the volume of water and rate of flow immediately increases the capacity of the receiving stream. Over time the physical changes in the stream channel may include smoothing of the streambed creating faster flows, incising the channel deeper, and straightening of the channel through bank erosion. The channel changes caused by the added volume and rate of flow enable the modified stream to carry larger volumes of water downstream more quickly. This decreases the amount of water that the channel itself can absorb so a proportionately larger amount of the already increased runoff volume is diverted downstream.

As a watershed becomes more urbanized, stormwater runoff is handled in a significantly different manner. Natural streams are replaced by storm sewers and other artificial conduits. When several smaller, rough streambeds are replaced with fewer and larger smooth surfaced conduits, a greater water volume is concentrated at a single downstream location at a faster rate. Additionally, increased outfall flow from an urban storm system results in less water soaking into the ground. One effect of this type of change is increased downstream flooding. When the urban area is located high in the watershed the effect is magnified downstream because the downstream waterway receives water from multiple other headwater areas and influences a longer distance of the stream network. Typically the downstream portions of the stream network experience bigger and more frequent flooding. A case study of the Watts Branch Creek watershed in Maryland showed that three decades of urban growth (storm sewers and paved surfaces) tripled the number of floods and increased the size of the average annual flood by 23 percent.¹

Water and land also meet in the saturated ground adjacent to the channel and the sediments or streambed beneath the water. This area is scientifically referred to as the *hyporheic zone*. It is in this zone where the stream water makes the most intimate contact with the streambed and channel banks. It is also in this zone where much of the cleansing action and nutrient processing within a stream network occurs. This is also the zone where ground and surface water are in direct contact. Ecosystem services that occur in the hyporheic zone significantly affect water quality. Streams with extensive hyporheic zones retain and process nutrients (treat waste) efficiently. This has a positive effect on water quality and the riparian zone.

When human actions alter the extent of this relationship, including eliminating it by encasing streams in pipes and concrete channels that sever the connection between water and land, the result is poorer water quality and degraded fish habitat downstream. In addition, other ecosystem services are altered or eliminated. Also, as urban land is developed, many small streams in the overall stream network are replaced by pipes and paved drainage ditches resulting in fewer and shorter streams. For example, as the Rock Creek watershed in Maryland was urbanized it was determined that more than half the small streams were eliminated.¹

Figure 103:



The watershed equation is essentially the linkage of the aquatic ecosystem with the terrestrial ecosystem. How they interact, or impact each other, is the resulting sum which is the quality of the water in the stream. And, the water quality of a stream has a direct impact on the level of beneficial ecosystem services that the stream is capable of providing. Humans are dependent upon those ecosystem services to maintain an environment that is conducive to the use of natural resources while decreasing the need for extreme treatment of resources prior to consumption or use. Ecosystems services received from the relationship of land and water affect both water quantity and water quality. Within a stream network, the ecosystem services effecting water quantity include storing water, exchanging water between ground

and surface water, reducing the intensity of flow, and providing continuous flow by augmenting base flow, especially during drought periods. Within the same stream network, the ecosystem services affecting water quality include processing and the slow release of nutrients, transforming organic material, and trapping and retaining sediment.

Beneficial Water Quality Ecosystem Services

The natural processes that occur in a stream network can provide several beneficial ecosystem services for the entire watershed and aquatic system. In order to receive the ecosystem services that sustain the water quality and health of any waterway, the other stream sciences - hydrologic, hydraulic, morphology and ecologic - that interrelate with the water quality of the stream must be intact and reasonably balanced.

Materials that wash into streams include, but are not limited to, soils, leaves, dead insects and runoff from various riparian land uses such as agricultural fields, animal pastures and urban areas. One of the key water quality ecosystem services that a stream network can provide is the filtering and processing of many of these materials. Healthy aquatic systems, including balanced stream sciences, can transform many materials such as these into less harmful substances.

Processing and Slowly Releasing Nutrients. Inorganic nitrogen and phosphorous are essential nutrients for all living organisms. In excess or in the wrong proportions, however, these nutrients (chemicals) can harm both natural systems and humans. Eutrophication is the enrichment of waters by excess nutrients. Again, nitrogen and phosphorous, are two of the primary chemical causes of eutrophication. The result of eutrophication is reduced water quality in streams, rivers, lakes and other downstream water bodies such as estuaries. Typically, once eutrophication begins in a river system it moves downstream, including being transmitted through impoundments such as those present on the Coosa River, until action is taken to significantly reduce the source of excess nutrients in the stream network.

An indicator of eutrophication is the excessive growth of algae. Algal blooms reduce visibility and light, and lower the amount of dissolved oxygen in the water body. Some of the algae species that grow in eutrophic waters generate bad taste, odor or are toxic. These are clear problems for water systems using eutrophic water sources to supply drinking water systems. Nitrogen can also harm people and animals. Excess nitrogen, in the form of nitrate, has been linked to methemoglobinemia (“blue baby syndrome”) in infants and has toxic effects on some animals. The depletion of oxygen, if severe enough, can cause fish kills.

When compared to large streams, small streams, especially shallow ones, have proportionately more water in contact with the stream channel. More water contact with the streambed allows more natural processing or cleansing to occur. Bacteria, fungi and other microorganisms living on the bottom of the stream consume inorganic nitrogen and phosphorous and convert them into less harmful and biologically beneficial compounds. The result is that the average distance traveled by a nutrient before it is removed from the water column is shorter in a smaller stream than in larger streams. As a consequence, when small streams are lost more nutrients can enter and travel farther in the stream network. When the

nutrients get into larger streams and rivers the processing rate is much slower because there is less contact between the volume of water and the stream channel. Therefore, the downstream system, particularly in larger streams and rivers, retains higher nutrient levels for longer periods. Another likely consequence is the further eutrophication of downstream rivers and lakes.

Some research examples supporting these findings include the following. One study conducted in small headwater streams in the southern Appalachian Mountains found that both phosphorous and the nitrogen containing compound ammonium traveled less than 65 feet downstream before being removed from the water. In another study, based on research in 14 headwater streams across the United States, it was shown that nitrogen entering a small stream in the headwater portion of a stream network was either retained or transformed within 1,000 yards.¹

Based on the above principles and examples, channel shape and size play an important role in transforming excess nutrients. This was also shown in studies conducted in Pennsylvania. When forests surrounding small streams were cleared it allowed both the warming of the water and the additional light enabled meadows and grass along the stream bank. The grasses trapped sediment and created sod along the stream bank that effectively narrowed the stream channel to about one-third of the original width. The narrowing reduced the amount of streambed available for microorganisms that process nutrients. As a result, the nitrogen and phosphorous traveled downstream somewhere between five and ten times farther than they did prior to the removal of the tree cover.¹

Wetlands also remove pollutants from surface water. A study of eight watersheds in the northeast determined that wetlands associated with first-order streams were responsible for 90 percent of the phosphorous removal in the upper watershed area.¹

Streams do not have to be perennial (year round) to make significant contributions to water quality. Pollutants, such as fertilizers, enter stream networks during rain events producing runoff. This is the same time that ephemeral and intermittent streams are most likely to have water and be able to process nutrients in the area in contact with the ground. Although these streams are less efficient for nutrient processing, as seen in the Pennsylvania study, they still are effective for processing nutrients because large ground areas are involved. Failure to maintain the processing capacity of ephemeral and intermittent streams will reduce the ability to control nonpoint source pollution.

Transforming Organic Material. Small streams and wetlands perform another ecosystem service by transforming or recycling organic carbon contained in dead plants and animals. In freshwater ecosystems, such as those located in the Lower Coosa River Basin, much of the carbon recycling starts in wetlands and small streams in headwater areas. Like nitrogen and phosphorous, carbon is essential, but harmful if present in the wrong form or excess quantities. If all organic material went downstream in large quantities, the decomposing material would deplete the dissolved oxygen in downstream waters. This would kill fish and other aquatic life.

The natural ecological process converts inorganic carbon into organic carbon. Organic carbon is the basis for every food web on earth. The conversion provides aquatic food for many organisms including mayflies. The mayfly was one of the indicator species evaluated by the USGS sampling for baseline data in the Lower Coosa River Basin. Either due to the presence of other harmful pollutants, or the lack of proper processing in the food chain, the mayfly has disappeared from sampling sites in watersheds with higher degrees of urbanization. (See Chapter 10.)

Trapping and Retaining Sediment. Runoff from precipitation events and receding floodwaters wash soil, leaves and various other materials into the stream network. Within the stream some of the material is broken into smaller pieces. Depending on the size of the material and characteristics of the water flow, smaller parts of the sediment begin to settle out. If the natural vegetation and soil cover are disturbed by fires, farming or construction, the amount of runoff increases and more material is washed into the stream. The increased amount of runoff also increases the amount of erosion within the stream bed and banks. The increased flow and volume of water tends to carry larger pieces and volumes of sediment farther downstream. Both actions contribute additional sediment to the total stream network.

Grassy areas, small streams and wetlands in a stream network can trap and retain sediment that washes into them. The amount of sediment accrued in the stream network is dependent on the kinds of landscape cover, land uses and how the overall watershed is managed. The movement of sediment, like water flow, takes place throughout the stream network. Natural material obstructions and the bumpy bottom of the stream bed cause sediment to settle out of the water column. Therefore, intact stream networks moderate, not eliminate, the amount of sediment that is delivered to downstream portions of the stream network.

A Pennsylvania study showed that in a one year period, the urbanization of a 160 acre headwater area increased channel erosion over a one-quarter mile stretch of stream that generated an additional 50,000 cubic feet of sediment. This quantity of sediment is sufficient to fill 25 rooms approximately sized 13 feet by 19 feet with 8-foot ceilings. The same study estimated that in a non-urbanized watershed it would take about five years to produce the same amount of sediment. Such studies show that landscape and land cover changes, such as farming and urbanization, without the protection of the headwater streams and their riparian zones, cause much more sediment to travel downstream.¹

Wetlands, whether or not they are connected to surface water, provide areas where runoff slows or stops and allows the debris it is carrying to drop out. Because headwater streams and wetlands represent a significant percentage of total stream length they can retain a substantial amount of sediment and prevent it from flowing into downstream rivers and lakes. Ephemeral streams can also retain significant amounts of sediment. These small streams expand in response to the intensity of rain. During expansion the stream flows over dry to damp ground. The leading edge of the stream, called the *trickle front*, soaks into the expanded area of the stream bed and settles out sediment at the same time.

Sediment suspended in the water column makes the water murkier and decreases the amount of sunlight that underwater plants and animals receive. In many cases the plants no longer

receive adequate light to grow. Fish that depend on visual signals to mate may be less likely to spawn in murky water. High levels of sediment suspended in the water can even cause fish kills. As sediment settles on the bottom it continues to cause problems because it fills the holes and spaces between gravel and rocks and smothers the aquatic animals that live on the bottom of stream beds. This disturbs the food web. And, if heavy sediment settlement occurs during a spawning season the fish eggs are smothered.

Once sediment moves farther downstream it becomes a more expensive problem. Too much sediment fills reservoirs and navigation channels, constructs sand bars that prohibit access to tributaries from the main channel, eliminates recreational and sport fishing, harms aquatic habitats (including associated plants and animals) and increases water filtration and purification costs for municipalities and industries.

The ability of small streams and wetlands, especially in headwater areas, to process and transform organic matter helps to maintain water quality and healthy downstream ecosystems. By maintaining these same attributes and managing the riparian zone, the amount of sediment can be controlled to maintain the health of the stream network.

Beneficial Water Quantity Ecosystem Services

As stated earlier, the four beneficial ecosystem services related to water quantity that streams and wetlands can provide include storing water or flood control, reducing the intensity of flow, exchanging water between ground and surface water, and providing base flow augmentation or continuous flow. Although the focus of this plan is the water quality of the Lower Coosa River Basin, water quantity within the basin has a direct impact on water quality.

Flood Control. Occasional flooding is a natural function of every stream network. Floodwaters perform beneficial services such as carrying sediment and nutrients downstream to other parts of the watershed. While providing some positive benefits, floods can also destroy farms, structures (houses, businesses and others), roads and bridges.

Human impacts in the watershed, including the landscape of the riparian zone or changes in the stream channel, can result in larger and more frequent flooding. As discussed earlier in the Watershed Equation section of this chapter, stream channels that carry low volumes of water, especially if the flowing water is shallow, and having slower rates of flow afford the greatest opportunity for the ground or streambed to absorb the most water. When small streams, including ephemeral and intermittent streams and wetlands are in their natural state they absorb significant amounts of rainwater and runoff before they overflow themselves. This is especially true in the upper portions of a watershed where significant lengths of small streams are located.

Reducing the Intensity of Flow. A natural streambed does not have a smooth surface like a concrete drainage ditch or pipe. The roughness of a natural streambed slows the passage of water. In smaller streams the friction produced by the streambed (gravel, rocks, pools and dams composed of natural materials) slows the flow of water as it moves downstream.

Slower moving water also causes less erosion and carries less sediment and debris downstream.

Exchanging Ground and Surface Water. During wet and dry periods the exchange of water between ground and surface water resources reverses. During wet periods the exchange is from surface water to groundwater. In dry periods the exchange is from groundwater to surface water. This latter process is more fully discussed in the next section – Providing Flow Augmentation.

Small streams and wetlands in a stream network play an important role in groundwater recharge. As discussed, the smaller, upstream components of a network collectively have the largest area of surface contact between land and water. This expansive area of contact provides the greatest opportunity for surface water, whether from precipitation or stream flow, to recharge groundwater. During periods of rainfall when ephemeral and intermittent streams contain water, the contact area between land and water increases. This increases the opportunity to recharge groundwater during rainstorms. In addition, the elevation of streams located in the headwater area is typically higher than the water table, thereby providing the opportunity for water to easily flow through the soil or channel bed and recharge groundwater.

Slower moving water is more likely to seep into a stream's natural storage system of banks and channel beds (hyporheic zone) and recharge the groundwater. Wetlands that have permanent water and ephemeral wetlands that retain water for a period of time also provide opportunities to recharge groundwater. When a change occurs in the landscape, such as timber harvesting or structural construction, in the riparian zone, it typically increases the amount of precipitation runoff into a stream as opposed to infiltrating to groundwater. The consequence is less overall groundwater recharge and, in essence, the recharge process gets short circuited.

Providing Flow Augmentation. During dry periods, the exchange is from groundwater to stream water. Groundwater is returned to local streams through the streambed to sustain a relatively continuous flow in moderately dry periods and to augment the base flow during periods of drought. Because of these interchanges, groundwater can provide a significant portion of surface water flow in streams and rivers. In fact, the USGS estimates that, nationwide, 40 to 50 percent of water in large streams and rivers comes from groundwater.¹ In dry seasons or during drought periods as much as 95 percent of stream flow may come from groundwater.

Small streams and wetlands in a stream network play a crucial role in providing a continual flow of water. As previously noted, water in streams and rivers comes from several sources: precipitation, other streams, groundwater and water held in soil. During dry periods, the small streams in the headwater areas provide the opportunity to recharge groundwater supplies that can be released to the stream flow. Wetlands associated with surface water bodies can also directly release water from the larger geographic areas they cover to maintain stream flow as wetland water levels decline. Even wetlands, without an apparent connection to surface water, are involved in providing a continual flow of water by storing and slowly

releasing water into groundwater that eventually resurfaces through springs and stream channels.

Because of the role of small streams and wetlands in maintaining continuous and base flow it is important to protect them. By maintaining water levels in local streams throughout the watershed, the aquatic ecosystems are properly supported and water is supplied for various beneficial uses located in the watershed. When groundwater recharge is short circuited, there is less water available to recharge stream flow during dry to drought periods. The effect in the watershed is offset in time. Typically, the shortage of surface water is not associated with the earlier actions that reduced the ability to recharge groundwater resources.

The recharge process of stream networks that are functionally intact moderates flooding in times of high water and maintains flow during dry periods. Likewise they can reduce the intensity of stream flow. Alterations to stream networks and wetlands can disrupt the present and future quantity of water available in the stream and river system.

In this chapter, water quality has been discussed and explained in terms of a scientific discipline, as part of a system or network, as a factor in a equation, and as a provider of beneficial ecosystem services. By now, it should be clear that water quality is much more than an adjective or descriptive noun. It is a result of the integration of numerous processes and systems. Because of this integration, it should also now be clear that maintaining the water quality of the Lower Coosa River Basin cannot be solved with one or two remedial actions. Instead, maintaining good water quality will only occur as the result of the integration of numerous initiatives by the inhabitants of the basin acting in their own watersheds.

Source Documents:

1. American Rivers and Sierra Club, with funding from The Turner Foundation. *Where Rivers Are Born: The Scientific Imperative for Defending Small Streams and Wetlands*. Judy L. Meyer, PhD, Louis A Kaplan, PhD, Denis Newbold, PhD, David L. Strayer, PhD, Christopher J. Woltemade, PhD, Joy B. Zedler, PhD, Richard Beilfuss, PhD, Quentin Carpenter, PhD, Ray Semlitsch, PhD, Mary C. Watzin, PhD, Paul H. Zedler, PhD. September 2003.

