This chapter is divided into three sections. The first section provides a review of basic concepts concerning watersheds, the water cycle, stream habitat, and water quality. This background information is essential for designing a stream monitoring program that provides useful data.

Section 2.2 presents the 10 critical questions that should be answered by program planners. These include: Why is monitoring taking place? Who will use the monitoring data? and What parameters or conditions will be monitored? The last section discusses the importance of safety in the field and laboratory.

2.1 Basic Concepts

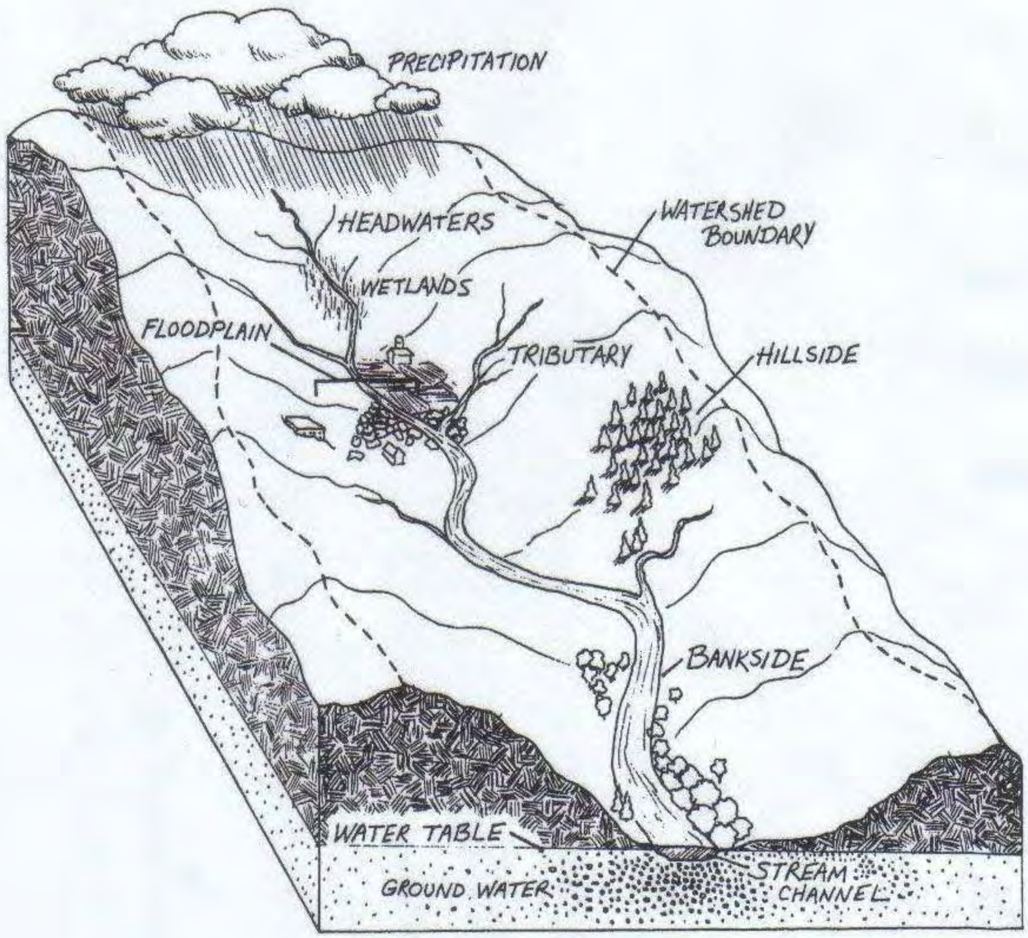
Watersheds

A watershed is the area of land from which runoff (from rain, snow, and springs) drains to a stream, river, lake, or other body of water (Fig. 2.1). Its boundaries can be identified by locating the highest points of lands around the waterbody. Streams and rivers function as the "arteries" of the watershed. They drain water from the land

Figure 2.1

Cross section of a watershed

Volunteers should get to know the watersheds of their study streams.



as they flow from higher to lower elevations.

A watershed can be as small or as large as you care to define it. This is because several watersheds of small streams usually exist within the watershed of a larger river. The watershed of the Mississippi River, for example, is about 1.2 million square miles and contains thousands of smaller watersheds, each defined by a tributary stream that eventually drains into a larger river like the Ohio River or Missouri River and to the Mississippi itself.

The River System

As streams flow downhill and meet other streams in the watershed, a branching network is formed (Fig. 2.2). When observed from the air this network resembles a tree. The trunk of the tree is represented by the largest river that flows into the ocean or large lake. The "tip-most" branches are the headwater streams. This network of flowing water from the headwater streams to the mouth of the largest river is called the river system.

Water resource professionals have developed a simple method of categorizing the streams in the river system. Streams that have no tributaries flowing into them are called first-order streams. Streams that receive only first-order streams are called second-order streams. When two second-order streams meet, the combined flow becomes a third-order stream, and so on.

The Water Cycle

The water cycle is the movement of water through the environment (Fig. 2.3). It is through this movement that water in the river system is replenished. When precipitation falls to earth in a natural (undeveloped) watershed in the mid-Atlantic states, for example, about 40 percent will be returned to the atmosphere by evaporation or transpiration (loss of water vapor by plants). About 50 percent will percolate into the soil. The remaining 10 percent of the precipitation moves across the land as runoff and drains into streams, wetlands, and other bodies of water (Fig. 2.4, left panel).

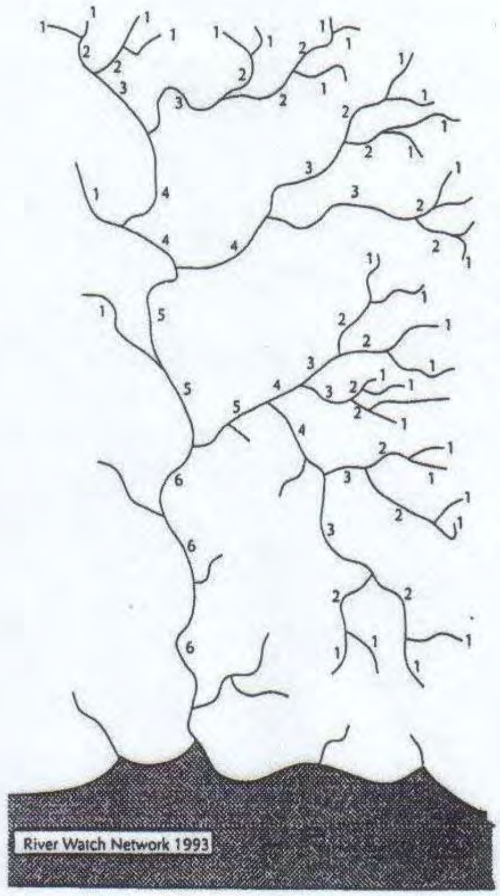


Figure 2.2

A representation of a river network with stream order marked

The water that soaks into the ground is important for maintaining streamflow in the river network during dry weather. Percolating water slowly moves downward through the soil until it drains into an area where all the pores and cracks in the rock are saturated with water. The top of this zone is known as the water table.

Water in this saturated zone moves laterally, following the laws of gravity and/or water pressure from above. If the path of this moving ground water intercepts a

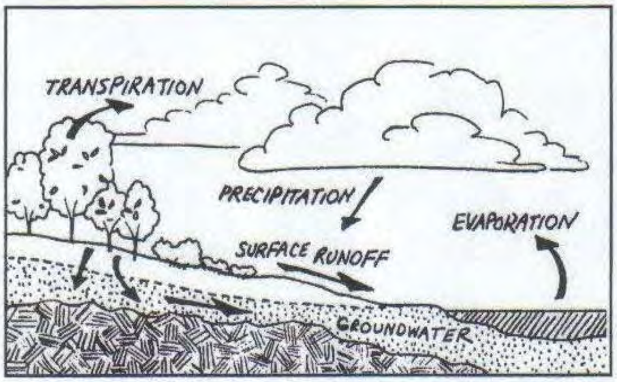


Figure 2.3

The water cycle

Water moving through the water cycle replenishes streams in the watershed.

stream channel, the ground water is discharged into the stream as a spring. The combination of ground water discharges to a stream is defined as its baseflow. At times when there is no surface runoff, the entire flow of a stream might actually be baseflow from ground water (Fig. 2.5).

Some streams, on the other hand, constantly lose water to the ground water. This occurs when the water table is below the bottom of the stream channel. Stream water percolates down through the soil until it reaches the zone of saturation. Other streams alternate between losing and gaining water as the water table moves up and down according to the seasonal conditions or pumpage by area wells.

The interactions between the watershed, soils, and water cycle define the natural water flow (hydrology) of any particular stream. Most significant is the fact that developed land is more impervious than natural land. Instead of percolating into the ground, rain hits the hard surfaces of buildings, pavement, and compacted ground and runs off into a storm drain or other artificial structure designed to move water quickly away from developed areas and into a natural watercourse. These conditions typically change the fate of precipitation in the water cycle (See Fig. 2.4, right panel). For example:

- Less precipitation is evaporated back to the atmosphere. (Water is transported rapidly away via storm drains and is not allowed to stand in pools.)
- Less precipitation is transpired back to the atmosphere from plants. (Natural vegetation is replaced by buildings, pavement, etc.)
- Less precipitation percolates through the soil to become ground water. (This can result in a lower water table and can affect baseflow.)
- More surface runoff is generated and transported to streams. (Streamflow becomes more intense during and immediately after storms.)

Chapter 3, Watershed Survey Methods, is designed to help volunteers learn about their watershed. Using the watershed survey approach, they will become familiar with their watershed's boundaries, its hydrologic features, and the human uses of land and water that might be affecting the quality of the streams within it.

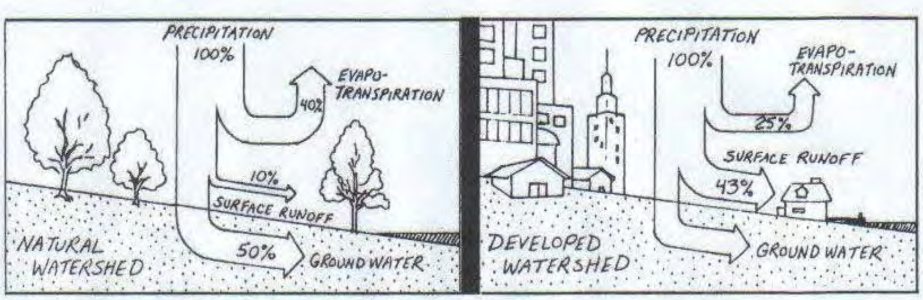
The Living Stream Environment

A healthy stream is a busy place. Wildlife and birds find shelter and food near and in its waters. Vegetation grows

Figure 2.4

The fate of precipitation in undeveloped vs. developed watersheds

Surface runoff increases and ground water recharge decreases as watersheds become developed.



along its banks, shading the stream, slowing its flow in rainstorms, filtering pollutants before they enter the stream, and sheltering animals. Within the stream itself are fish and a myriad of insects and other tiny creatures with very particular needs. For example, stream dwellers need dissolved oxygen to breathe; rocks, overhanging tree limbs, logs, and roots for shelter; vegetation and other tiny animals to eat; and special places to breed and hatch their young. For many of these activities, they might also need water of specific velocity, depth, and temperature.

Human activities shape and alter many of these stream characteristics. We dam up, straighten, divert, dredge, dewater, and discharge to streams. We build roads, parking lots, homes, offices, golf courses, and factories in the watershed. We farm, mine, cut down trees, and graze our livestock in and along stream edges. We also swim, fish, and canoe in the streams themselves.

These activities can dramatically affect the many components of the living stream environment (Fig. 2.6). These components include:

1. The *adjacent watershed* includes the higher ground that captures runoff and drains to the stream. For purposes of this manual, the adjacent watershed is defined as land extending from the riparian zone to 1/4 mile from the stream.
2. The *floodplain* is the low area of land that surrounds a stream and holds the overflow of water during a flood.
3. The *riparian zone* is the area of natural vegetation extending outward from the edge of the stream bank. The riparian zone is a buffer to pollutants entering a stream from runoff, controls erosion, and provides stream habitat and nutrient input into the stream. A healthy stream system generally has a healthy riparian zone. Reductions and impairment of riparian zones occur when roads, parking lots, fields, lawns, and other artificially cultivated areas, bare soil, rocks, or buildings are near the stream bank.
4. The *stream bank* includes both an upper bank and a lower bank. The lower bank normally begins at the normal water line and runs to the bottom of the stream. The upper bank extends from the break in the normal slope of the surrounding land to the normal high water line.
5. The *streamside cover* includes any overhanging vegetation that offers protection and shading for the stream and its aquatic inhabitants.
6. *Stream vegetation* includes emergent, submergent, and floating plants. Emergent plants include plants with true stems, roots, and leaves with most of their vegetative parts above the water. Submergent plants also include some of the same types of plants, but they are completely immersed in water. Floating

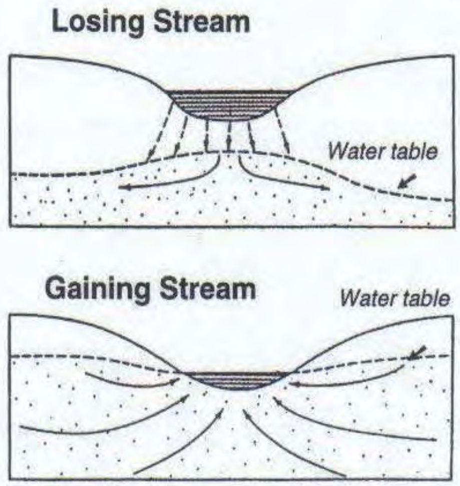


Figure 2.5

Streams losing and gaining water

The position of the water table sometimes plays a role in determining the amount of streamflow.

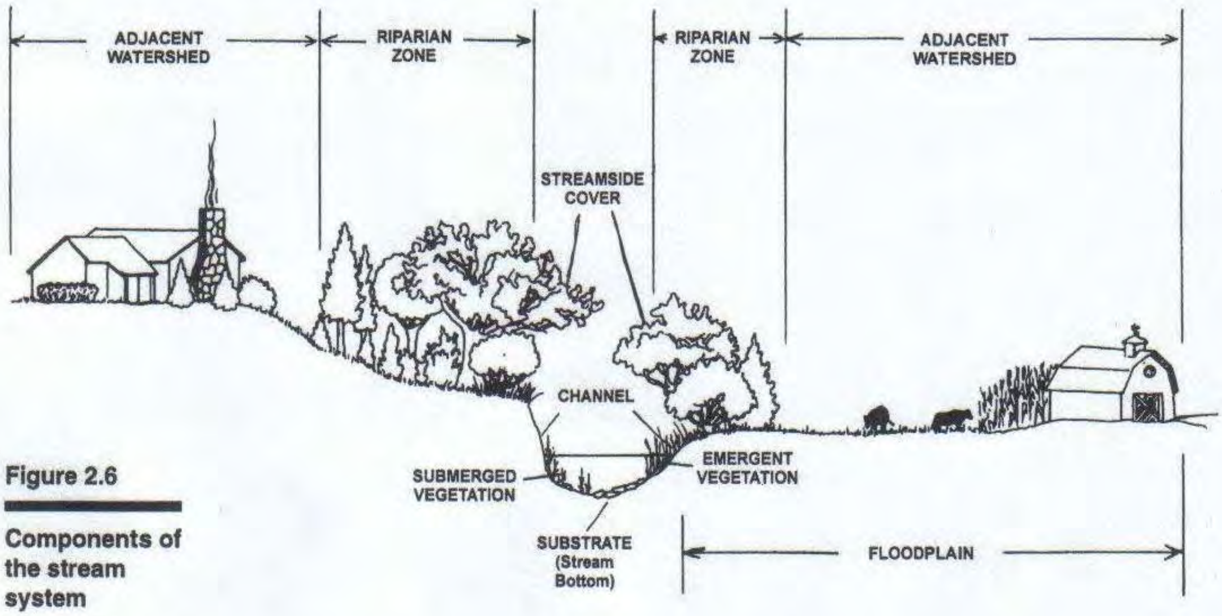


Figure 2.6

Components of the stream system

Volunteers should be aware that the surrounding land affects stream habitat.

plants (e.g., duckweed, algae mats) are detached from any substrate and are therefore drifting in the water.

7. The *channel* of the streambed is the zone of the stream cross section that is usually submerged and totally aquatic.
8. *Pools* are distinct habitats within the stream where the velocity of the water is reduced and the depth of the water is greater than that of most other stream areas. A pool usually an has soft bottom sediments.
9. *Riffles* are shallow, turbulent, but swiftly flowing stretches of water that flow over partially or totally submerged rocks.
10. *Runs* or *glides* are sections of the stream with a relatively low velocity that flow gently and smoothly with little or no turbulence at the surface of the water.
11. The *substrate* is the material that makes up the streambed, such as clay, cobbles, or boulders.

Whether streams are active, fast-moving, shady, cold, and clear or deep, slow-moving, muddy, and warm —or something in between—they are shaped by the land they flow through and by what we do to that land. For example, vegetation in the stream's riparian zone protects and serves as a buffer for the stream's streamside cover, which in turn shades and enriches (by dropping leaves and other organic material) the water in the stream channel.

Furthermore, the riparian zone helps maintain the stability of the stream bank by binding soils through root systems and helps control erosion and prevent excessive siltation of the stream's substrate. If human activities begin to degrade the stream's riparian zone, each of these stream components—and the aquatic insects, fish, and plants that inhabit them—also begins to degrade.

Chapter 4 includes methods that volunteers can use to assess the stream's living environment—specifically, the insects that live in the stream and the physical components of the stream (the habitats) that support them.

Water Quality

The water in a stream is always moving and mixing, both from top to bottom and from one side of the stream to the other. Pollutants that enter the stream travel some distance before they are thoroughly mixed throughout the flow. For example, water upstream of a pipe discharging wastewater might be clean. At the discharge site and immediately downstream, the water might be extremely degraded. Further downstream, in the recovery zone, overall quality might improve as pollutants are diluted with more water. Far downstream the stream as a whole might be relatively clean again. Unfortunately, most streams with one source of pollution often are affected by many others as well.

Pollution is broadly divided into two classes according to its source. Point source pollution comes from a clearly identifiable point such as a pipe which discharges directly into a waterbody. Examples of point sources include factories, wastewater treatment plants, and illegal straight pipes from homes and boats.

Nonpoint source pollution comes from surface water runoff. It originates from a broad area and thus can be difficult to identify. Examples of nonpoint sources include agricultural runoff, mine drainage, construction site runoff, and runoff from city streets and parking lots.

Nationally, the pollutants most often found in the stream environment are not toxic substances like lead, mercury, or oil and grease. More impacts are caused by sediments and silt from eroded land and nutrients such as the nitrogen and phosphorus found in fertilizers, detergents, and sewage treatment plant discharges. Other leading pollutants include pathogens such as bacteria, pesticides, and organic enrichment that leads to low levels of dissolved oxygen. Common sources of pollution to streams include:

- *Agricultural activities* such as crop production, cattle grazing, and maintaining livestock in holding areas or feedlots. These contribute pollutants such as sediments, nutrients, pesticides, herbicides, pathogens, and organic enrichment.
- *Municipal dischargers* such as sewage treatment plants which contribute nutrients, pathogens, organic enrichment, and toxicants.
- *Urban runoff* from city streets, parking lots, sidewalks, storm sewers, lawns, golf courses, and building sites. Common pollutants include sediments, nutrients, oxygen-demanding substances, road salts, heavy metals, petroleum products, and pathogens.

Other commonly reported sources of pollutants are mining, industrial dischargers (factories), forestry activities, and modifications to stream habitat and hydrology.

Chapter 5 describes methods volunteers can use to monitor water quality and detect pollutants from these sources.