

Chapter 6

A Watershed View

- Introduction to Volunteer Water Quality Monitoring Training Notebook -

“Everything is connected to everything else.” – Aldo Leopold

Knowing Your Watershed

A stream is a reflection of its watershed. Because everything that occurs within a watershed affects water resources, understanding watersheds is essential to the interpretation of stream health and water quality. If we want to preserve and protect our water resources, it is important to know how human actions are directly and indirectly altering watersheds. With this knowledge you can become an educated advocate for Missouri’s streams.

Water is a vital resource. We use it for drinking, bathing, recreation and for growing our food. Since everyone is dependent on water, it is important that we protect our water resources. Before we can protect waterways, we need to understand how watersheds are defined and how they are impacted by natural phenomena and human activities.

Defining Watersheds

A watershed, or drainage basin, is the area of land that drains into a particular body of water. Watersheds can range in size from less than an acre to millions of square miles. At its mouth, the Mississippi River has a drainage area of over 1.2 million square miles. Large drainage basins are made up of many smaller watersheds or sub-watersheds. The Missouri River is a sub-watershed of the Mississippi River. The Gasconade River, a tributary of the Missouri River, is a sub-watershed of the Missouri. This network is almost infinite. We all live, work, and play in a watershed.

The boundaries of a watershed are determined by topography, which is the shape or the physical features of the land’s surface. If the highest points of land surrounding a river were connected (like “connect-the-dots”), this line would form the watershed boundary.

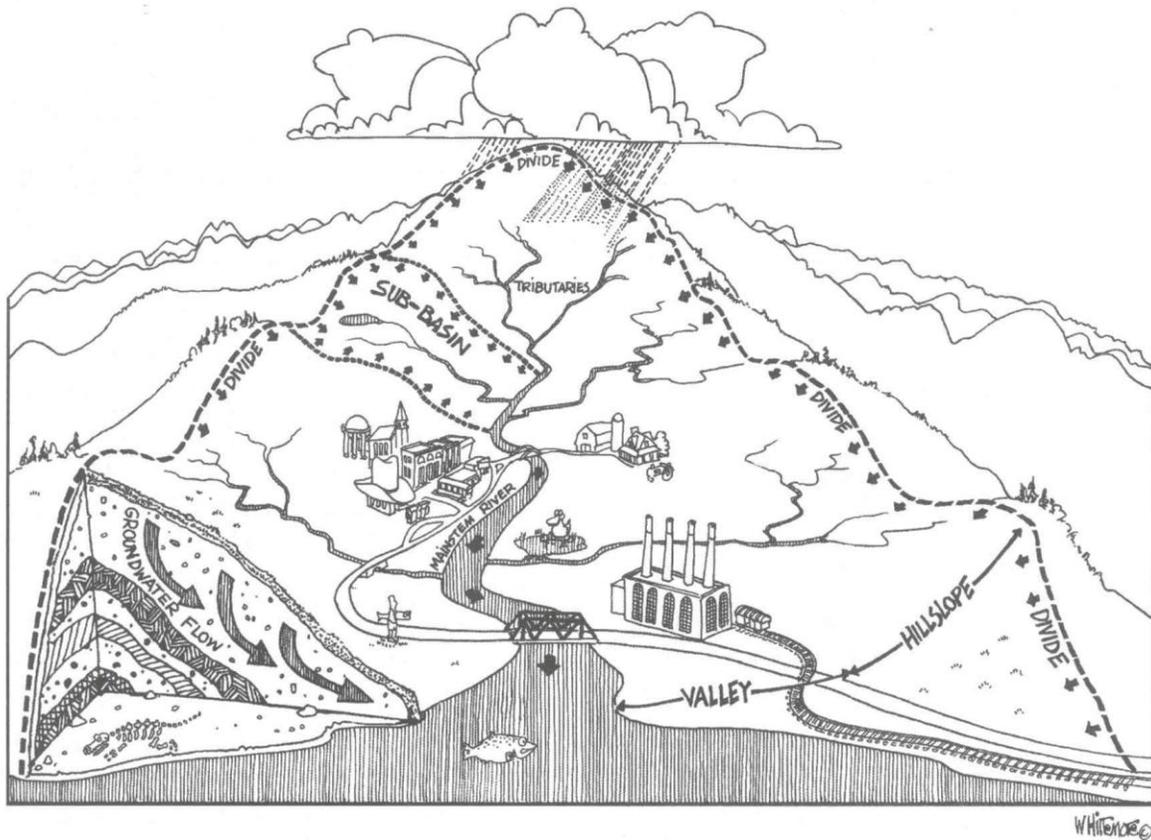


Figure 1. Watersheds are interconnected land-water systems
 (from *The Streamkeeper's Field Guide*)

This boundary is the divide between watersheds (Figure 1.). Precipitation that falls on one side of a divide will drain into that watershed's streams. In a watershed, the system of stream channels that transports water, sediment and other materials is called the drainage network. Stream channels link together like branches of a tree, with each stream draining into a successively larger waterway. Each stream follows a path from the headwaters (highest elevation in the watershed) where the stream originates to the mouth (lowest elevation) where the stream empties into another body of water.

A watershed is the land area that water flows across, or under, on its way to a stream or lake. All parts of a watershed are interconnected. Something that occurs in the headwaters can affect distant areas downstream. As water runs downhill, it picks up whatever is on the ground. As water flows across and through urban areas, fields or pastures, it can pick up silt, pollutants or even heat. These constituents eventually flow into a stream or lake, affecting

the quality of the water you use to drink, swim or fish. Anytime someone flushes the toilet, does laundry, fertilizes the lawn or dumps used oil on the ground, the water quality within the watershed is impacted.

Stream Channel and Watershed Formation

The forces of moving water and the resistance of earth materials are what cause the formation and shape of a watershed. There is a constant “tug of war” between water’s erosive capabilities and the earth’s surface resistance, so when the erosive power of water is greater than the resistive forces, the result can be seen as valleys, canyons, stream channels, and gullies, etc. At the same time, uplift is also occurring in some areas, caused by natural geologic forces. Watersheds are extremely complex and dynamic entities which are constantly undergoing change (Figure 2.).

Water in headwater streams comes from a variety of sources, such as snow melt, surface runoff, groundwater seepage or springs. Tributaries join the small headwater streams and add to the flow. As more tributaries enter the stream, it gets larger and changes physically, chemically and biologically. The shape of the channel, the stream’s gradient or slope, and the substrate all change as the stream flows from its headwaters to its mouth.

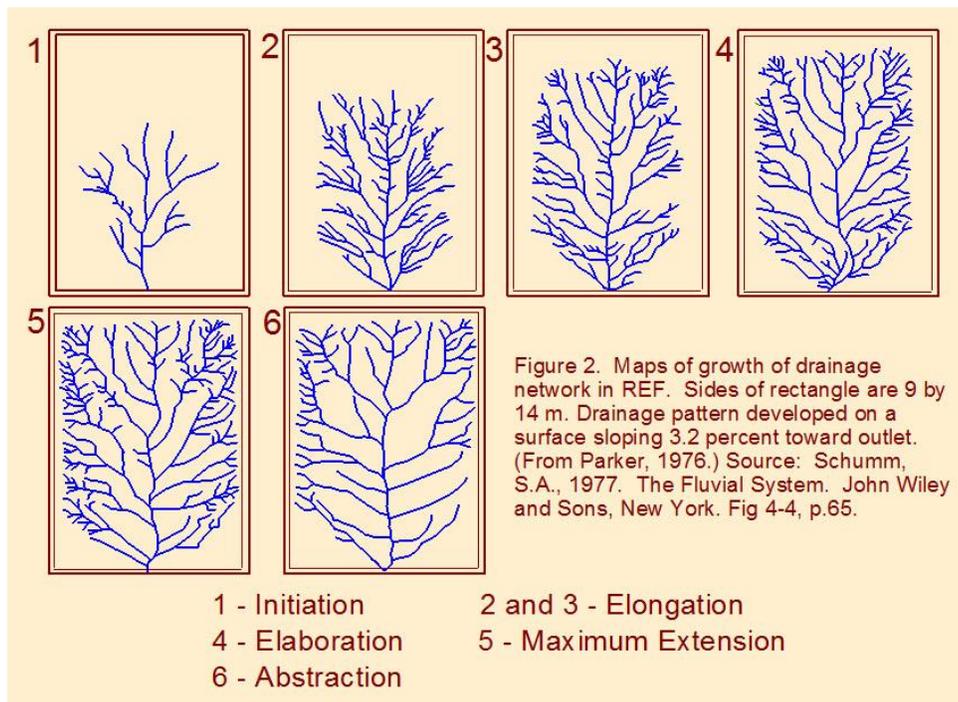


Figure 2. Evolution of a drainage network

Watershed Dynamics

A multitude of variables affect the formation and maintenance of a watershed, including:

- Climate
- Hydrology
- Geology
- Soil types
- Slope/gradient/topography
- Land use/land cover

Climate. Changes in climate have a direct relationship with the erosional and depositional processes which act to form the landscape. Climatic conditions also influence the types of soils and vegetation that are found in a particular watershed. The climate of an area is governed by latitude, elevation, proximity to oceans, and local topographical features. Together these factors determine or modify airflow patterns and weather systems which indicate the ranges of precipitation, temperature, humidity, wind, evaporation, and transpiration that a watershed is subjected to.

Hydrology. Hydrology is the science that deals with the properties, distribution, and circulation of water on the land surface, in the soil and underlying rocks, and in the atmosphere. The circulation of water from ocean to atmosphere, to land, and then back to ocean is known as the hydrologic cycle. The amount of precipitation and in particular the amount occurring in a watershed plays a principal role in sculpting and changing the land surface.

Geology. The geology of a watershed determines the foundation materials on which various soil types form. Geologic characteristics determine the nature and extent of groundwater storage, the type of material available for erosion and transport, and the chemical quality of the water. The physical and chemical weathering of rock is the process that breaks down the underlying rock of a watershed and creates the sediments available for erosion, and is the primary natural source of calcium, magnesium, potassium, and sodium in streams. In Missouri, the limestone geology provides good buffering capacity that neutralizes naturally

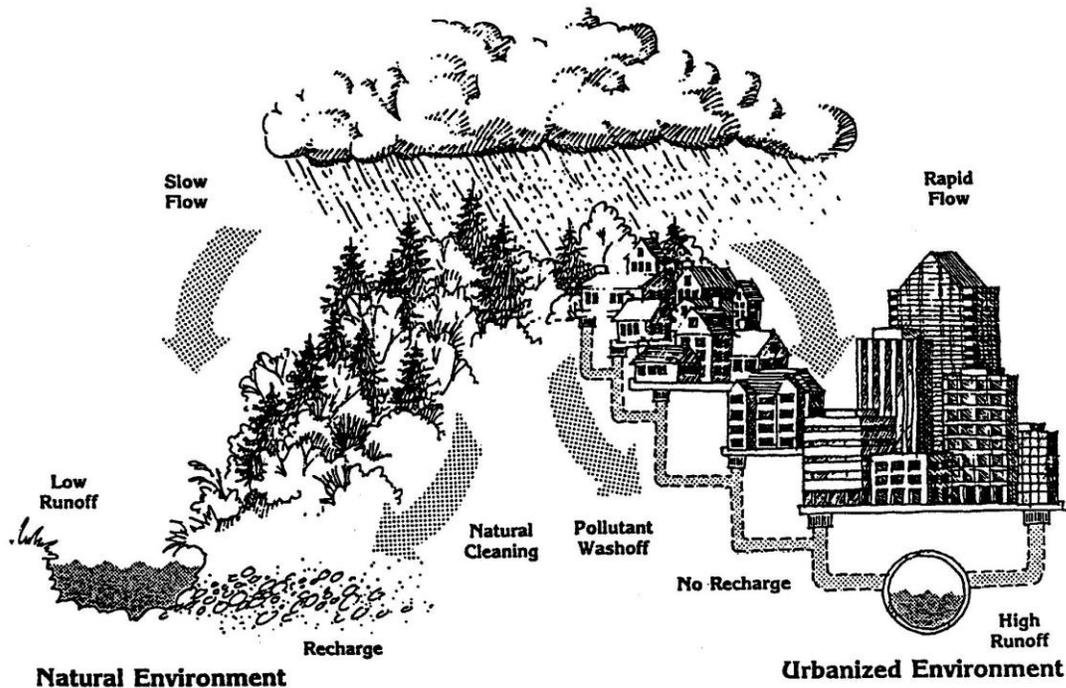
acidic rain water as it flows over the underlying bedrock and transports the carbonate-rich limestone sediment through the stream system.

Soil Type. The quality of a soil is determined by a combination of physical, chemical, and biological properties such as texture, water-holding capacity, organic matter content, porosity, and depth. Infiltration rates are dependent on the structure and texture of the surface soils, vegetative cover, and land-use practices. Soil types exhibit a wide range of vulnerability to erosion, and also have a direct bearing on the types of vegetation that can be supported in a watershed. Small particles such as silt are more easily eroded than coarse materials, such as sand or gravel.

Slope/Gradient/Topography. The steepness of the land surface and the gradient at which streams flow has a significant influence on discharge and how it affects the watershed. As slope increases, so does potential energy and erosive power of water as it flows downward in the watershed. Steep slopes have a high degree of runoff and are more susceptible to erosion.

Land Use/Land Cover. These are of special interest because they are important factors affecting runoff and erosion. The amount and type of vegetative cover established on the land surface is extremely significant in controlling runoff and erosion. Vegetation creates a barrier that reduces raindrop impact on the soil surface, reduces the velocity of water flow, and allows for greater infiltration of water into the soil surface.

Human uses of land and water also impact water quality. One way that humans influence watersheds is by constructing impervious surfaces, which are non-porous so that water cannot penetrate them. Examples of impervious surfaces are streets, parking lots and rooftops. Impervious surfaces increase the amount of runoff and therefore the potential for erosion. In undisturbed areas, features such as wetlands, uncompacted soils and vegetation are able to absorb water runoff and reduce erosion. If these natural sponges are replaced by impervious surfaces, less water is absorbed and a larger volume of water flows more quickly to waterways through ditches or storm drainage pipes. This increased runoff adds to stream volume and velocity, which can cause stream bank erosion, sedimentation and flooding (Figure 3.).



drawing courtesy City of Bellevue Utilities Department

Figure 3. Effects of urbanization and impervious surfaces on a watershed

(from *The Streamkeeper's Field Guide*)

The most pervasive threat to water quality in the United States is increased siltation due to runoff and erosion. The average soil erosion rate in Missouri for cropland is approximately 4.5 tons (9,000 pounds) per acre. In 1995 it was estimated that 95 million tons of soil eroded from Missouri's cropland. That is enough to bury all four lanes of I-70 between St. Louis and Kansas City under thirty feet of soil.

Industrial and agricultural activities can also alter watersheds and impact a stream through point and nonpoint sources of pollution. Point source pollution can be traced to a specific source. Examples include a pipe discharging pollutants from an industrial plant or sewage treatment facility. All point discharges should have a "State Operating Permit" issued from the Missouri Department of Natural Resources' Water Protection Program. Since the State of Missouri has primacy (authority) over clean water law in this state, EPA defers to Missouri's State Operating permits. Nonpoint source pollution (NPS) arises not from one specific source, but from a number of diffuse sources. Because the source of nonpoint pollution is harder to identify, it is difficult to control.

Nonpoint source pollution, generated by human activities throughout a watershed, usually reaches waterbodies via surface runoff. Agriculture and urban runoff are the greatest sources of nonpoint pollutants. Soil erosion, animal waste, fertilizer and pesticides from cropland can seriously degrade streams. Heat and pollutants from street and parking lot runoff, fertilizer and pesticides from lawns, parks and golf courses, sediment from construction sites, cleaning products and pet waste can all reach streams and rivers through nonpoint runoff, contributing to the degradation of our water supply.

Watershed Elements

Every watershed can, and should be, viewed as a system of elements. Any factor or event that alters the environmental conditions within the watershed, or within one of the watershed's elements, is likely to trigger an adjustment or series of adjustments within the watershed. The five main parts of a watershed are:

- Uplands
- Floodplains
- Riparian Corridor
- Stream Channel
- Aquifer/Groundwater

Uplands. Uplands provide the initial slope for energy of the system and the first sediment input to stream systems. A headwater stream often has no clearly defined channel and is dry except during and shortly after rain events. Water flow from these “temporary” or ephemeral streams moves nutrients from the uplands towards the stream channel and is the very beginning of a complex and inter-connected stream system. The water entering a stream gets its first filtration, organic input, sediment, and potential pollution from the uplands. Human activities in the uplands that impact the amount of water and sediment entering the stream can greatly impact the health of the entire watershed. These types of activities include urbanization, timber harvest, mining, and agriculture.

Floodplains. Floodplains can be defined as “areas that are periodically inundated by the lateral overflow of rivers or lakes, and/or by direct precipitation or groundwater” (Junk et al 1989). One of their primary functions is to serve as storage areas for floodwaters. The

floodplain of a stream also serves a very important function in dissipating energy of flowing water as it passes through the stream channel. The ability for floodplains to dissipate energy and reduce velocities is directly related to the vegetative condition of the riparian corridor, or the “hydraulic roughness” of the floodplain. The presence of trees in the riparian corridor and floodplain will decrease the velocity of the water, allowing sediment to drop out into the floodplain and store organic material and nutrients that are important to both aquatic and terrestrial biota inhabiting the floodplain. Human alterations of the floodplain such as the construction of levees, clearing of vegetation, urban development, or building dams upstream can negatively impact the floodplain’s ability to filter pollutants and sediment, reduce velocities, and prevent flooding downstream.

Riparian Corridor. The riparian corridor, or riparian area, consists of the vegetation growing directly adjacent to a stream. It is part of the floodplain and functions in a similar way to the floodplain, but is given special consideration as it is the area of a floodplain that experiences regular flooding. A healthy riparian corridor serves as a filter for excess nutrients and sediment, regulates water temperatures by providing shade from the sun, reduces velocities, provides wildlife habitat, and helps to stabilize banks. Riparian corridors are crucial to maintaining healthy watersheds. Activities such as clearing, grazing, and urbanization in the riparian corridor of a stream can have detrimental impacts on water quality by increasing sediment, pollutants, temperatures, velocities, and erosion into the stream system.

Stream Channel. The stream channel is the path of water and sediment flowing within the stream banks, and functions as a conduit for the movement of water, sediment, and organic materials. Geology, topography, the types of soils and vegetation, and the amount of water flowing into a system determine the size and shape of the stream channel. A stream is constantly working towards a natural balance among its primary components: water, sediment, energy, and vegetation. This balance is called dynamic equilibrium, and streams constantly adjust to balance the water and sediment loads they carry. Everything we do in a watershed that changes one of the primary components will ultimately be reflected in the stream channel as it changes to adapt to that watershed alteration. Activities such as channelization (straightening) of a stream and dam construction can compromise the balance

among these primary components by changing one or more of the variables. The stream will work to gain back the balance, often at the expense of important stream, riparian, and wetland habitats.

Aquifer/Groundwater. This is water held within the interconnected openings of saturated rock and sediment beneath the land surface. Water that moves from the land surface and percolates through the ground to replenish the groundwater is called recharge. Water returning from the groundwater to the land surface to streams, lakes, ponds, or wetlands is called discharge. Discharge into the stream provides the **base flow** of the stream, meaning the stable flow between runoff events that provides near-constant temperatures and wetted habitat for aquatic organisms. When water is not given the opportunity to infiltrate through the ground, but instead runs off directly to a stream as it would in a situation with a high amount of impervious surfaces, recharge does not occur, reducing base flows and habitat availability for aquatic life.

Mapping Watersheds and Understanding Maps

“Expanses unknown to deed or map are known to every dawn.” – Aldo Leopold

Your goal is to construct a map that will show watershed boundaries, topography and land use. Land use information can be gathered from a variety of sources such as government agencies, businesses, environmental and civic groups, or by using online mapping tools such as CARES (www.cares.missouri.edu). After collecting land use information, you will be able to assess the health of your watershed and monitor changes.

This exercise is designed to educate about the importance of taking a watershed view. By mapping your watershed, you will become familiar with the impacts in your watershed. The Watershed Mapping Activity does these things:

1. Helps to identify potential sources of pollution
2. Helps to identify monitoring sites
3. Provides information to educate the local community about potential pollution sources and the stressors affecting your stream and its watershed

4. Provides a blueprint for possible community restoration efforts such as cleanups and tree plantings
5. Provides a sense of the value of the stream and its watershed

Equipped with this knowledge, you will have the ability to make informed decisions about current and proposed activities in your watershed.

Since the goal is to know your watershed thoroughly, it is important to select an area that is of manageable size. If you are working on a stream that has a large watershed, you may want to map a limited portion of the stream and watershed. When selecting your area, you should also consider personal connections you may have to a particular watershed.

NOTE: Watershed boundary and land use maps you choose to create for your adopted stream are for your personal use. You **do not** have to submit them to the Program with your sampling data.

Interpreting a USGS Topographic Map

The United States Geological Survey (USGS) publishes topographic maps traditionally used for this activity. Some of the sources for USGS “topo” maps are listed in Chapter 10, *Appendix*. We suggest that if you choose to obtain a USGS map, have your map laminated to protect it during field use. Also, if you use water-soluble markers, a laminated map can be wiped off and notes changed as needed.

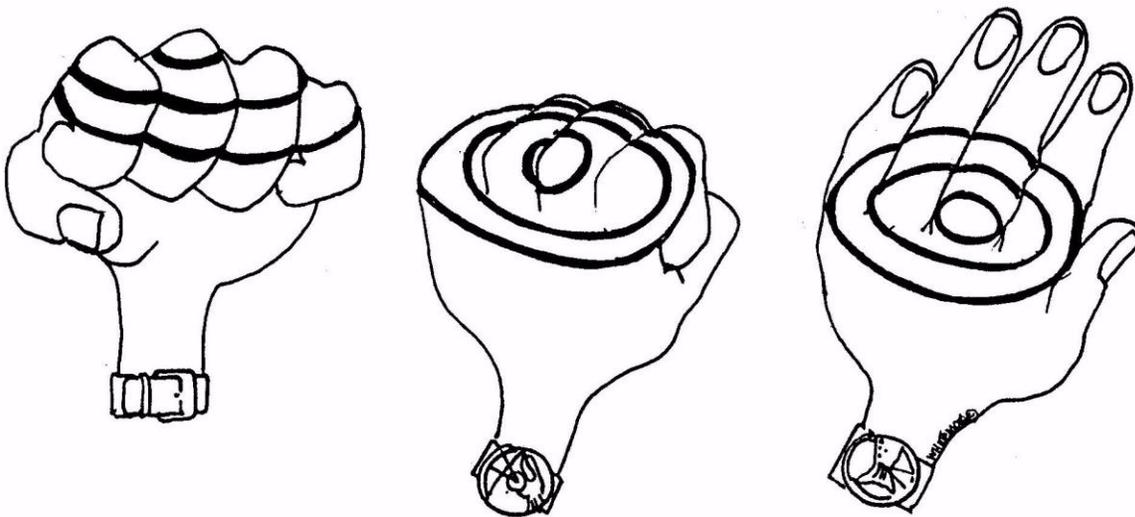
You will need at least one USGS topographic map to complete this project. To determine which map or maps you need, see the instructor to find your watershed on the *Index Map of Published Topographic Sheets* in Missouri. The index map shows the boundaries of the USGS quadrangle maps. They are called quadrangles or “quads” because each map has four equal sides in terms of degrees of latitude and longitude. We use the most detailed maps from USGS – the “7.5-minute” series. These quads show 7.5 minutes of longitude (~7 miles) by 7.5 minutes of latitude (~8 miles).

To use these maps effectively, it is important to understand their language. Maps cannot be as large as the area they represent so they must be drawn to scale. Scale is written as a ratio. For example, scale on 7.5-minute maps is “1:24,000.” This means that one unit of measure

on the map is equal in 24,000 of the same units on the Earth's surface. Another way to understand the scale is to imagine that a map with a scale of 1:24,000 is 1/24,000 the size of the area it represents on the Earth. On a 1:24,000 scale map, 1 inch = 24,000 inches, which is 2,000 feet. [Note that a mile = 5,280 feet.]

Since all maps use symbols to represent features, you must be able to interpret the symbols in order to read the map. Different types of maps use different symbols so each one has a specific key or guide to the symbols and their meanings.

Topographic maps are the best type of reference map to use because the map illustrates the shape and elevation of features using contour lines or shaded relief. It takes practice, but once you become familiar with using topographic maps, you will be able to visualize your watershed in three dimensions. USGS topo maps show relief using contour lines. **Relief** is the variation in elevation of the Earth's surface. **Elevation** is the height in feet (or meters) above sea level of a particular point or line. An individual **contour line**, seen in brown on topo maps, connects points of equal elevation. The thicker brown lines will always have an elevation number on them somewhere along the line. The lighter brown lines may or may not have numbers. If they don't have a number displayed, you will need to determine the elevation using the **contour interval** -- the vertical difference in elevation between two adjacent contour lines. This can be illustrated using a fist and hand (reference Figure 4.).



(from *The Streamkeeper's Field Guide*)

Figure 4. Contour lines can be illustrated by using a fist and hand.

This interval varies from map to map depending on local relief. Flat areas in Florida may only have 2 feet between lines, where an 80-foot contour interval will be found on maps of the Rocky Mountains west of Denver, Colorado. It is important to know the contour interval for the map you use, so look for it on the bottom, center of each map.

When using contour lines to determine watershed boundaries, it is important to remember four rules:

- 1.) a contour line *never* goes up or down hill,
- 2.) contour lines *never* cross each other,
- 3.) the closer together the contour lines, the steeper the slope, and
- 4.) the rule of the “V”s.

When contour lines cross a river or stream, they make a “V” shape. **Knowing the tip of the “V” always points upstream will help you to determine the direction of flow.** The rule of the “V”s also applies to ridge tops. On a topographic map, hills or ridge tops are shown as a closed circle (not necessarily a round one). As contour lines extend out from the hill or ridge top (going downhill), they often form rows of parallel “V”s (Figure 5.). These “V”s, when seen rippling outwards from a ridge top, point downhill toward lower elevations.

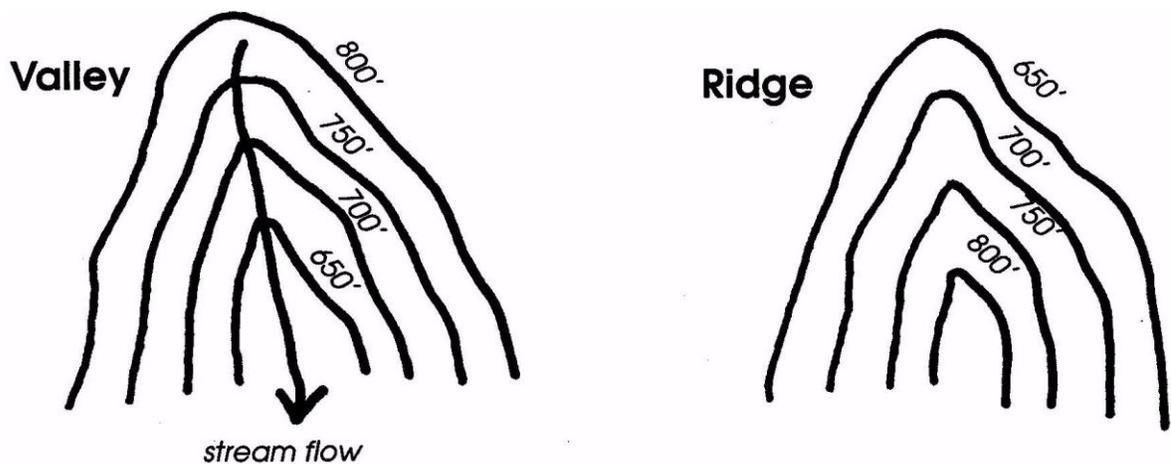
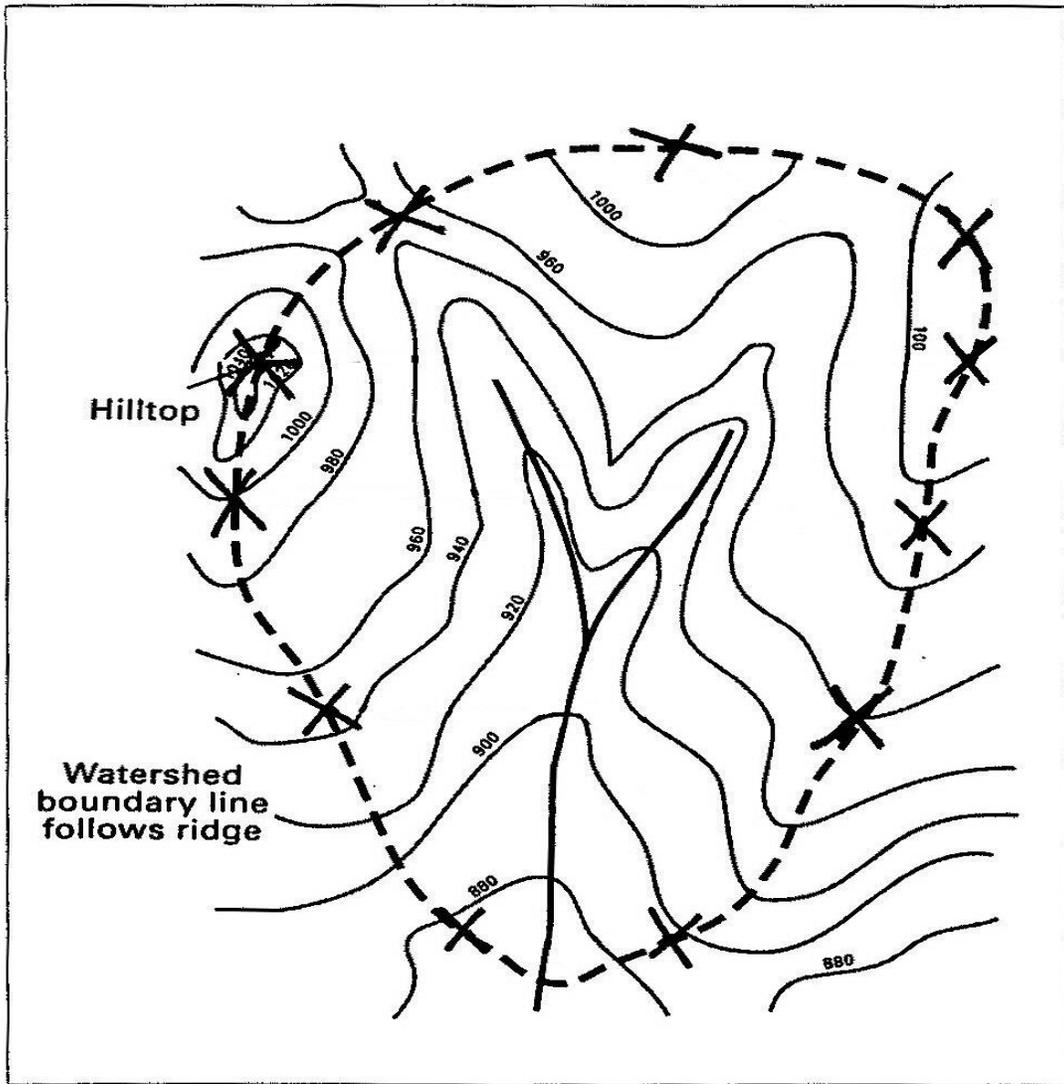


Figure 5. Topographic map with a 50-foot contour interval.
(from *The Streamkeeper's Field Guide*)

Creating a Watershed Map Using a USGS Topographic Map

1. Once you know how to interpret maps, you will be ready to create a map of your stream's watershed. On your USGS quad map(s), mark the furthest downstream point you will evaluate. All waterways upstream from this point are in your watershed. If you are mapping a segment of a large stream and watershed, mark the upstream and downstream points of your segment on the topo map(s). Use a blue marker to trace your stream and all its tributaries. Use arrows to mark the direction of flow if it helps you read the map.
2. With a pencil, mark the highest points of elevation surrounding your stream and its tributaries with "X"s (Figure 6.). One way to find high points is to look for hill tops or ridge tops, represented by closed circles (like hamburgers). If the high spot is a peak, the circle will look more round (like hot dogs). If the high area is a ridge top, the closed circle may be elongated in shape.
3. Connect the highest points of elevation to outline the boundary of your watershed. Note that roads are often built along ridge tops, and watershed boundaries never cross a stream (at least not in the headwaters). Keep in mind that every drop of water that falls within these boundaries will eventually drain into the stream you have adopted.
4. Note every confluence (the point where one stream joins another) and any known point source pollution discharge. You may want to monitor water quality above and below these particular sites (see the *Site Selection and Identification* chapter in this notebook).



Idealized Watershed Boundary. Adapted from Method for the Comparative Evaluation of Nontidal Wetlands in New Hampshire.

Figure 6. Idealized Watershed Boundary. Adapted from Method for the Comparative Evaluation of Nontidal Wetlands in New Hampshire.

5. Conduct a “visual assessment” of your watershed by driving, walking and/or floating through the watershed and along the stream. This will provide an overall picture of the land that drains into your adopted stream. This will also give you first-hand knowledge of the conditions of your watershed and stream. Look for the following as you drive or walk through your watershed.
 - a) Look at the lay of the land. Become familiar with the hills, valleys and low areas along the stream that frequently flood (this is the floodplain).

- b) Look for evidence of how the community has dealt with the stream and its potential for flooding. Are portions of the stream flowing through concrete channels? Has riprap been placed along the banks? Is it dammed, diverted, leveed or straightened? Is there evidence of erosion at the bridges and road crossings?

- c) Look for activities and land-use practices that might affect the stream. In particular, look for construction sites, parking lots, golf courses, manicured lawns, gullies in row crop fields, cattle with unrestricted access to the stream, mining, industrial and sewage treatment plant discharges, open dumps and landfills. Look for outfalls you identified in your background investigation. Also look for forested land, healthy riparian corridors and undisturbed wetlands.

Aerial Photograph Maps

Aerial photograph maps are based on photographs taken from airplanes. They show details that cannot be represented on other maps. These maps can be an aid in determining land use in your watershed. Chapter 10 of this notebook, *Appendix*, provides possible sources of aerial maps for your area. Be sure to check the date on aerial maps, because land use changes rapidly so the photograph may or may not represent the current conditions.

Online Watershed Profiles

One of the newer methods for obtaining a watershed map is the Missouri Watershed Evaluation and Comparison Tool offered by the University of Missouri's Center for Applied Research and Environmental Systems, or CARES, which can be found at www.cares.missouri.edu (Figure 7.).

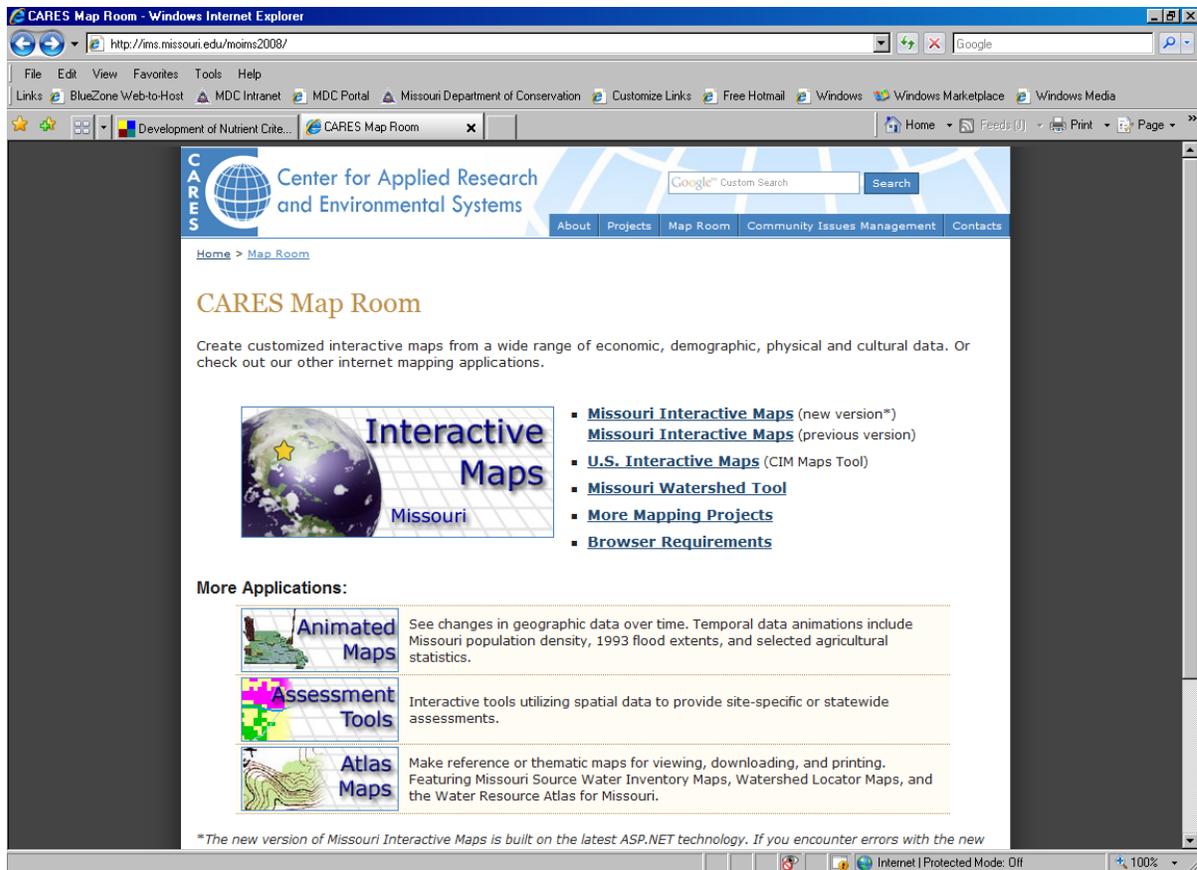


Figure 7. CARES Map Room

In the CARES Map Room, you have several different choices in how to map your watershed. Your three main options for building a watershed map include:

- Missouri Interactive Maps
- Missouri Watershed Tool
- Atlas Maps

Missouri Interactive Maps. With this option, you have the ability to narrow down your mapping area to County, City, 7.5 USGS Quadrangle, River Basin, or even use the Address feature if your stream is near your home. Once you set your Map Area (Step 1), then you can choose the Data Layers to go onto your map (Step 2). It is helpful to choose Base Data such as Cities and Towns, County Boundaries, Roads and Highways, and Administrative Data such as Public Lands, depending on where your adopted stream is located. You will also want to choose “Water Resources”, which will open another menu that includes “Hydrography”, and this will provide options to choose any or all of the Hydrological

features within your data set (Figure 8.). Once you have verified your selections (Step 3), simply click “Make Map” and you can manipulate the map to your choosing using the tools provided on the map page. You can also label your chosen features using the Layer and Label controls on the right hand side of the screen and print your map to your specifications.



Figure 8. Choosing Data Layers for your Interactive Map

If you choose the 7.5 minute USGS Topographical Map under “Imagery”, you will have the ability to focus in closer to your stream site, print map, and outline the watershed boundary using the method mentioned earlier in this chapter to feature your stream’s sub-watershed within your digitally mapped area. The Hydrological Unit Codes (HUCS) provided may cover a much larger area than what directly drains into your adopted stream site, so using topographical features to outline your sub-watershed can be very helpful on a more localized scale.

Missouri Watershed Tool. Another way to create a watershed profile is by using the Missouri Watershed Tool. After visiting the Introduction page and clicking “Start”, you can

choose how large of a watershed you would like CARES to feature, first searching by county and then choosing 8, 10, 12, or 14-digit Hydrological Unit Codes (HUCs) within that county. As the digits of the HUC increase, the sizes of the watersheds decrease. Once you have chosen your watershed, for example Hurricane Creek in Bollinger County (Figure 8.), you are given a number of options on what features to display, including land use, elevation, soils, slope, historical precipitation, and even Confined Animal Feeding Operations (CAFOs) within the watershed, just to name a few of the choices available. It is a useful tool in understanding the natural features as well as human activities in the watershed.

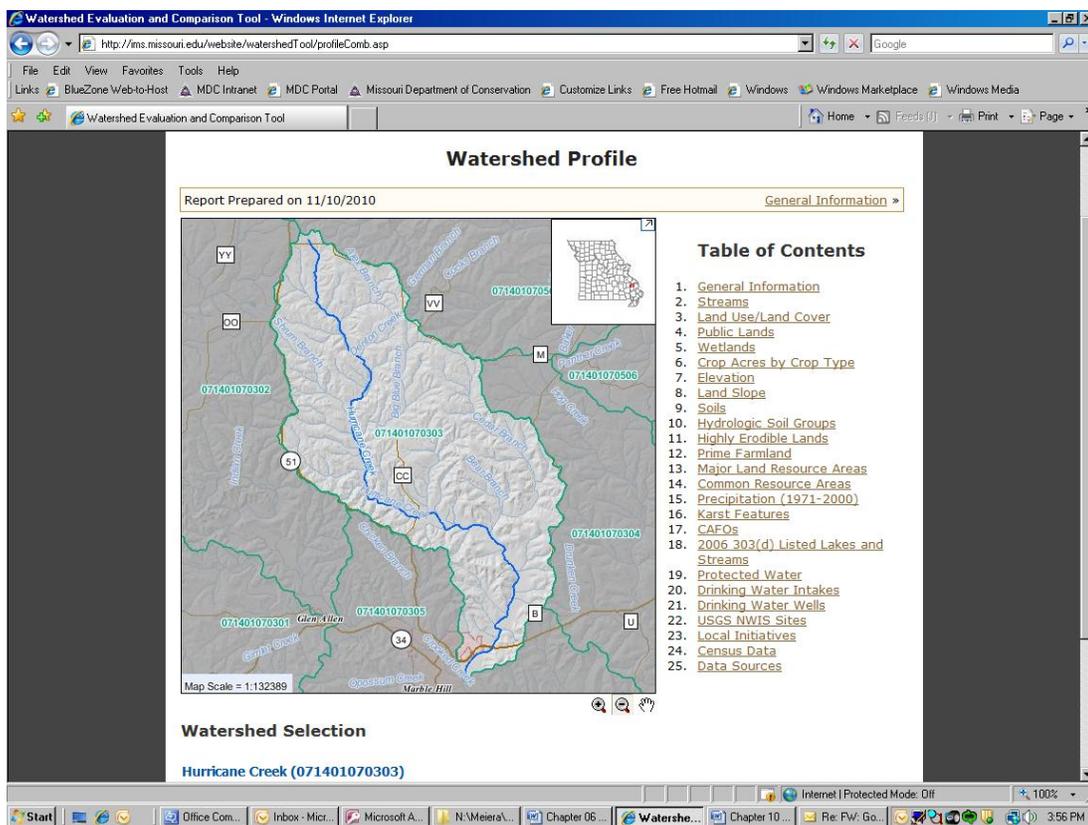


Figure 9. Hurricane Creek Watershed Profile

Atlas Maps. Under the Atlas Maps option, you can choose “Watershed Maps” to get a generalized image of a watershed, also divided into 8, 10, 12, and 14-digit HUCs. It will generate a printable .JPEG or .PDF image of the watershed with a legend for quick reference. It is not as versatile as the previous options but provides accurate, basic watershed profile information (Figure 10.).

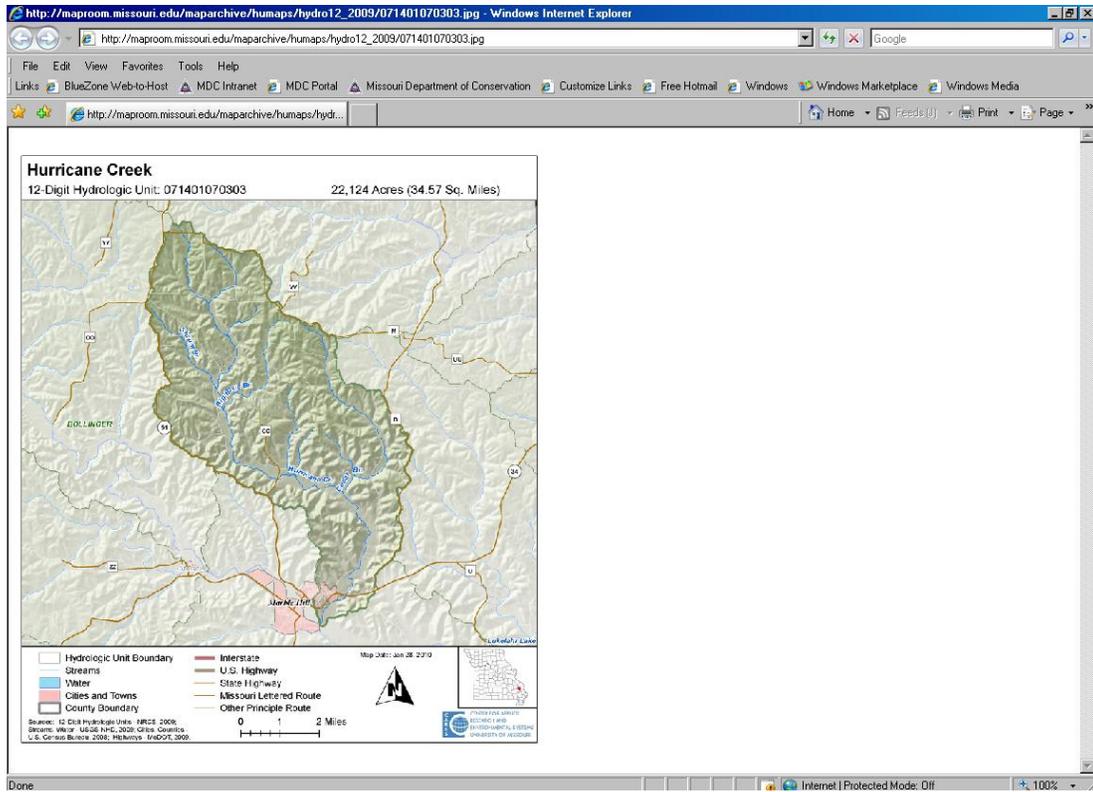


Figure 10. Atlas Map of Hurricane Creek, Bollinger County

Again, watershed and land-use maps you create are for your own information and use. You do not have to submit the map to the program. However, if you see a change in the watershed that you feel has affected your sampling results, be sure to make a note of that fact on all of the data sheets you submit.

Land Ethics

“That land is a community is the basic concept of ecology, but that land is to be loved and respected is an extension of ethics.” – Aldo Leopold

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