ENVIROTHON PRACTICE

AQUATICS GUIDE

2013

Kentucky Division of Water
Nonpoint Source and Basin Team Section
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water.ky.gov

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Introduction

Congratulations on your decision to compete in this year's Kentucky Envirothon Competition! The Kentucky Division of Water has developed this study guide to start you off on your research for the Aquatics Test. Please note: this guide does not contain all the answers to the Envirothon questions. Instead, this handout is a resource guide that contains a lot of information about aquatic topics that might be covered in the aquatics portion of the Envirothon Test. This information comes from a wide variety of sources including Kentucky Division of Water (KDOW), National Oceanic and Atmospheric Administration (NOAA), US Geologic Survey (USGS), US Environmental Protection Agency (US EPA), as well as a wide assortment of other programs and online resources**.**

If you want to excel during the Envirothon, you should do further research on your own. You will be tested on aquatics, wildlife, forestry, soils, and a current issue topic. You can always find out more on the current issue by referencing the Recommended Resources on the Canon North American Envirothon Page at www.envirothon.org. For aquatics, an additional list of helpful websites has been provided at the back of this guide. Be sure to expand your research to include your school or local library, in addition to other *reputable* web resources. We at KDOW hope that this test guide helps you in your journey toward understanding aquatics. Should you have any questions, please contact our Environmental Education Specialist Michelle Shane at Michelle.Shane@ky.gov or 502-564-3410 ext. 4936.

Water Planet Overview

Sources: World Health Organization; World Water Day; NOAA

Of all water on earth, 97.5% is salt water. The remaining 2.5% is fresh water, with some 70% frozen in the polar icecaps. The other 30% of fresh water is mostly present as soil moisture or lies in underground aquifers. In the end, less than 1% of the world's fresh water (or about 0.007% of all water on earth) is readily accessible for direct human uses. It is found in lakes, rivers, reservoirs and in underground sources shallow enough to be tapped at affordable cost. Evaporation and precipitation make this water available on a sustainable basis.

Fresh water resources are unevenly distributed: in terms of precipitation, there is a range from almost no rainfall in deserts to several meters per year in the most humid regions. Most of the flow is in a limited number of rivers: the Amazon carries 16% of global runoff, while the Congo-Zaire river basin carries one third of the river flow in all of Africa. Arid and semi-arid zones of the world, constituting 40% of the land mass, have only 2% of global runoff. River flow, however, varies greatly over time and evaporation plays an important role whether a country can be classified as humid or semi-arid.

Experts have estimated the amount of the world's river flow that is readily accessible for human use at about 2,159 cubic miles a year. They add another 839 cubic miles of river flow that is captured and stored by dams and reservoirs. Currently, humans are using about half of the 2,998 cubic kilometers available. This may seem to leave a lot of room, but in reality water needs to be left in the environment to sustain healthy ecosystems (in particular wetlands and their biodiversity), to permit fisheries, and to keep an adequate amount of water available for recreation, navigation and hydro power generation.

The figures on the following pages illustrate both the natural water cycle and the human water cycle. Can you name all the stages of water movement/usage in each figure?

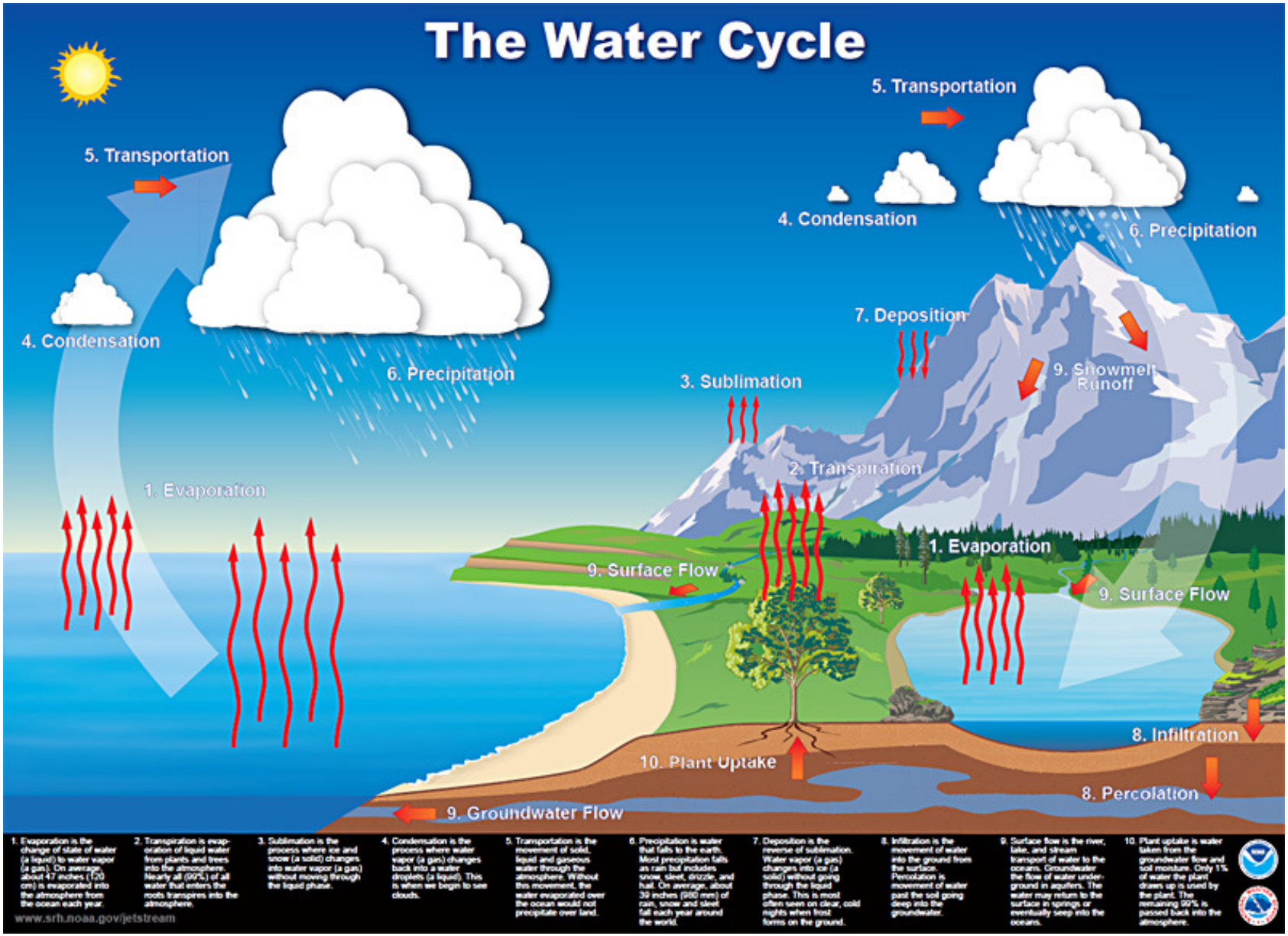


Figure 1: The Natural Water Cycle
Image Credit: www.education.noaa.gov/Freshwater/Water_Cycle.html

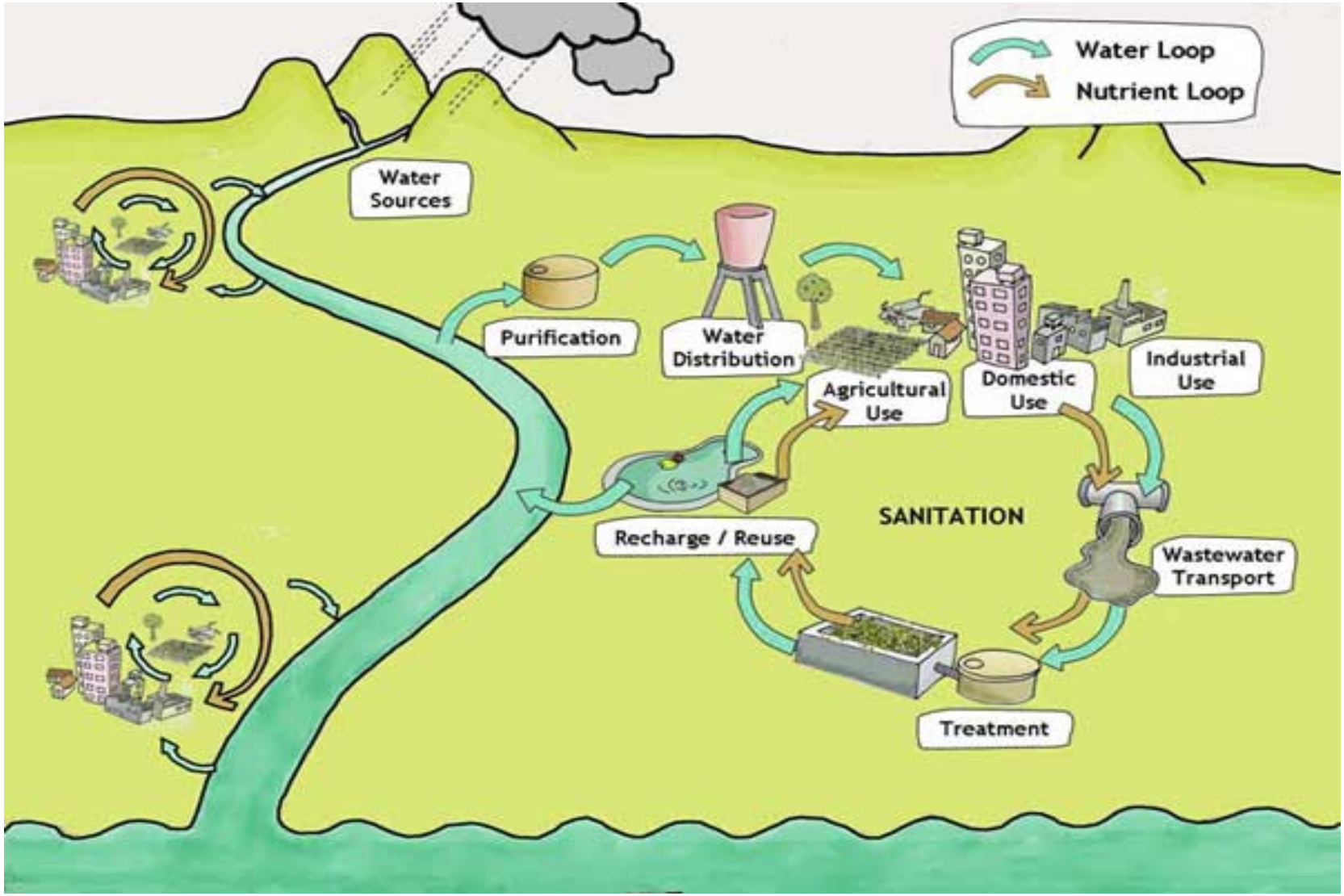


Figure 2: The Human Water Cycle

Image Credit: www.cewas.org/index.php/intro/what-is-sswm/

An Overview of Kentucky's Waters

Water Resources

Average annual rainfall: 40 - 50 inches
Maximum rainfall occurs during winter and spring
Minimum rainfall occurs during late summer and fall

Where the Water Occurs

State surface area: 40,409 square miles
Major drainage basins: 13

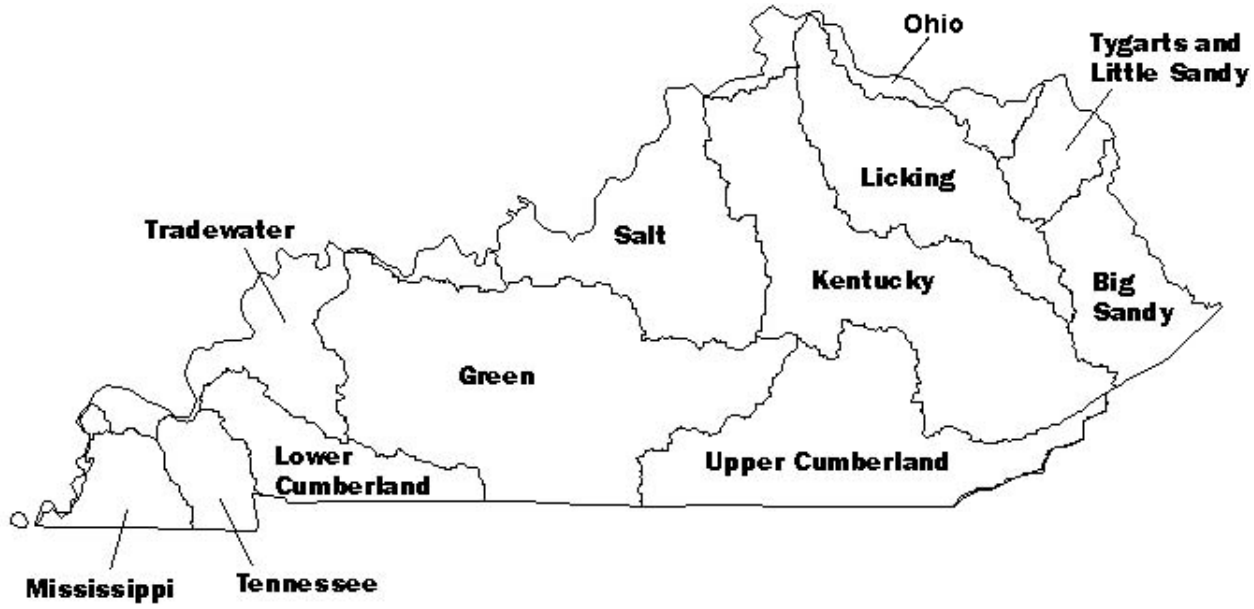


Figure 3: Watersheds in Kentucky

On the surface

Miles of rivers and streams	89,431
Miles of rivers bordering other states	849
Acres of wetlands	637,000
Number of reservoirs more than 1,000 acres in size	18
Acres of publicly owned lakes and reservoirs	228,385

Under the ground

Percent of Kentucky land underlain by karst topography	55
Percent of rural Kentucky population that is self-supplied who rely on groundwater	90
Number of public water supplies that depend on groundwater	283
Population served by public systems supplied by groundwater	618,000

Why Water?

Source: The Water Project and Water.org

So, what's the big deal about water? Well, all living things must have water to survive, whether they get it from a water fountain, a running stream, or a desert oasis. Some organisms live their entire lives in water, like fish and corals. No known living thing can function without water, and there is life wherever there is water on Earth. Water is the one thing we all have in common. Yet without clean water, the ecosystems we live in are damaged and the organisms that live in them (people, plants and animals) may die as a result.

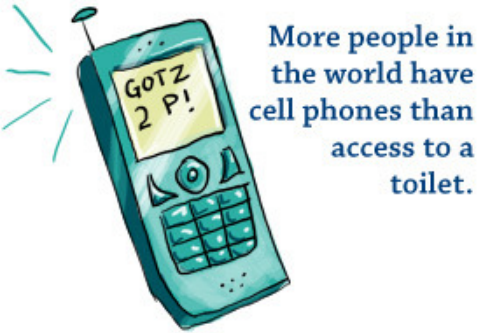


Figure 4: Water Access
Image Credit: water.org/learn-about-the-water-crisis/facts/

Did you know?

- Nearly 1 billion people don't have safe water to drink.
- More than 80% of sewage in developing countries is discharged untreated, polluting rivers, lakes and coastal areas.
- Children in poor environments often carry 1,000 parasitic worms in their bodies at any time.
- The water and sanitation crisis claims more lives through disease than any war claims through guns.
- Children often walk miles every day to collect dirty water to drink, quitting school just so they can gain access to this basic need of life.
- In just one day, more than 200 million hours of women's time is consumed collecting water for domestic use. This lost productivity is greater than the combined number of hours worked in a week by employees at Wal-Mart, United Parcel Service, McDonald's, IBM, Target, and Kroger.
- At home the average American uses between 100 and 175 gallons of water a day, not including the amount of water used to feed and clothe us. Compare that to the less than eight (8) gallons a day someone in a slum may get for all their daily needs.

Conserving water helps to preserve irreplaceable natural resources, and to reduce the strain on wastewater management systems. Wastewater is costly to treat, requireing continuous investment to ensure the water we return to our waterways is as clean as possible.

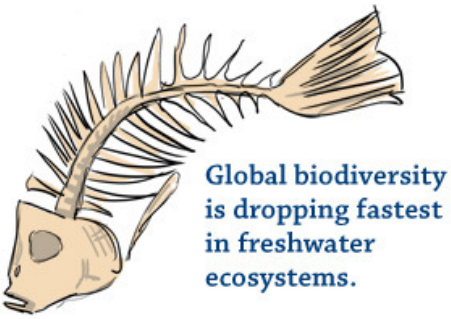


Figure 5: Falling biodiversity
Image Credit: water.org/learn-about-the-water-crisis/facts/

The United States Clean Water Act

Source: EPA websites on CWA

The Clean Water Act (CWA) establishes the basic structure for regulating discharges of pollutants into the waters of the United States and regulating quality standards for surface waters. The basis of the CWA was enacted in 1948 and was called the Federal Water Pollution Control Act, but the act was significantly reorganized and expanded in 1972. "Clean Water Act" became the act's common name with the 1977amendments.

Under the CWA, EPA has implemented pollution control programs such as setting wastewater standards for industry. EPA has also set water quality standards for all contaminants in surface waters.

The CWA made it unlawful to discharge any pollutant from a point source into navigable waters, unless a permit was obtained. EPA's National Pollutant Discharge Elimination System (NPDES) permit program controls discharges. Point sources are discrete conveyances such as pipes or man-made ditches. Individual homes that are connected to a municipal system, use a septic system, or do not have a surface discharge do not need an NPDES permit; however, industrial, municipal, and other facilities must obtain permits if their discharges go directly to surface waters. In Kentucky, we call these permits Kentucky Pollutant Discharge Elimination System (KPDES) permits, because Kentucky runs its own permit program under EPA guidance.

Point Source Pollution

Source: NOAA Ocean Service Education webpages

The legal definition of "point source" in section 502(14) of the Clean Water Act states:

> The term "point source" means any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agricultural storm water discharges and return flows from irrigated agriculture.

Factories and sewage treatment plants are two common types of point sources. Factories, including oil refineries, pulp and paper mills, and chemical, electronics and automobile manufacturers, typically discharge one or more pollutants in their discharged waters (called effluents). Some factories discharge their effluents directly into a waterbody. Others treat it themselves before it is released, and still others send their wastes to sewage treatment plants for treatment. Sewage treatment plants treat human wastes and send the treated effluent to a stream or river.

Another way that some factories and sewage treatment plants handle waste material is by mixing it with urban runoff in a combined sewer system. Runoff refers to stormwater that flows over surfaces like driveways and lawns. As the water crosses these surfaces, it picks up chemicals and pollutants. This untreated, polluted water then runs directly into a sewer system.

When it rains excessively, a combined sewer system may not be able handle the volume of water, and some of the combined runoff and raw sewage will overflow from the system, discharging directly into the nearest waterbody without being treated. This combined sewer overflow (CSO) is considered point source pollution, and can cause severe damage to human health and the environment.

Unregulated discharges from point sources can result in water pollution and unsafe drinking water, and can restrict activities like fishing and swimming. Some of the chemicals discharged by point sources are harmless, but others are toxic to people and wildlife. Whether a discharged chemical is harmful to the aquatic environment depends on a number of factors, including the type of chemical, its concentration, the timing of its release, weather conditions, and the organisms living in the area.

Nonpoint Source Pollution (NPS)

Source: Wikipedia on Nonpoint Pollution; NOAA Ocean Service Education webpages

Non-point source (NPS) pollution is water pollution affecting a water body from diffuse sources, such as polluted runoff from agricultural areas draining into a river, or wind-borne debris blowing out to sea. Nonpoint source pollution can be contrasted with point source pollution, where discharges occur to a body of water at a single location, such as discharges from a chemical factory, urban runoff from a roadway storm drain or from ships at sea.

NPS may derive from many different sources with no specific solution to rectify the problem, making it difficult to regulate. It is the leading cause of water pollution in the United States today, with polluted runoff from agriculture the primary cause.

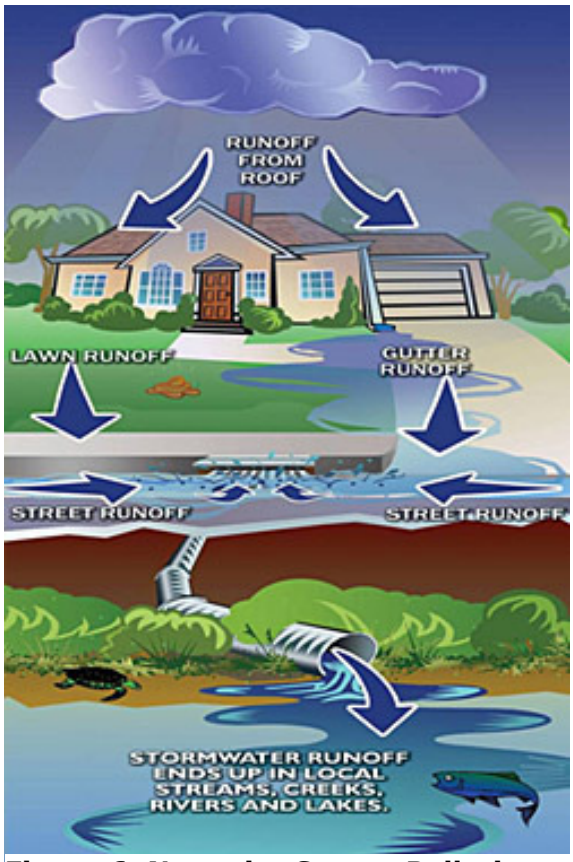


Figure 6: Nonpoint Source Pollution
Image Credit: www.cityftmyers.com/Departments/PublicWorks/Divisions/Engineering/Information/StormwaterInformation/NonpointSourcePollution/tabid/950/Default.aspx

Most nonpoint source pollution occurs as a result of runoff, hence why NPS is also called "runoff pollution". When rain or melted snow moves over and through the ground, the water absorbs any pollutants it comes into contact with. The water collects the pollutants and carries the contaminants as the water travels. Following a heavy rainstorm, for example, water will flow across a parking lot and pick up oil left by cars driving and parking on the asphalt. When you see a rainbow-colored sheen on water flowing across the surface of a road or parking lot, you are actually looking at nonpoint source pollution.

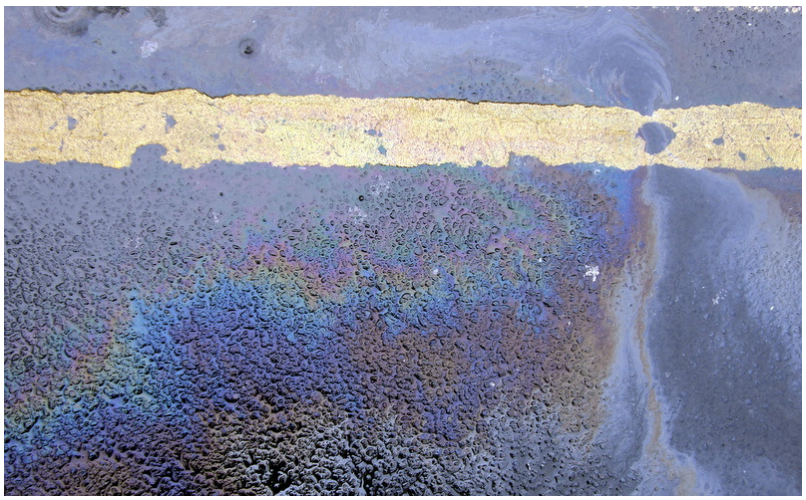


Figure 7: NPS Pollution moves across impervious pavement

Drops of oil or gas from a car runs off a parking lot. Image Credit: http://www.arealninja.com/?tag=puddle

This runoff then runs over the edge of the parking lot, and most likely it eventually empties into a stream. The water flows downstream into a larger stream, and then to a lake, river or ocean. The pollutants in this runoff can be quite harmful. Although the concentration of some pollutants from runoff may be lower than the concentration from a point source, the total amount of a pollutant delivered from nonpoint sources may be higher because the pollutants come from many places.

Nonpoint source pollution not only affects ecosystems; NPS can also have harmful effects on the economy. U.S. Coastal and marine waters support 28.3 million jobs, generate $54 billion in goods and services through activities like shipping, boating, and tourism, and contribute $30 billion to the U.S. economy through recreational fishing alone. If pollution leads to mass die-offs of fish and dirty-looking water, these areas and others like them will experience deep financial losses.

With increased control over point source pollution, scientists have begun to focus on nonpoint source pollution, how it affects the quality of the environment, and, even more importantly, how it can be controlled. NPS is difficult to control because it comes from multiple locations. It also varies over time in terms of the flow and the types of pollutants it contains. Table 1 (next page) lists some possible NPS pollution categories.

There are many types of nonpoint source pollutants. When these accumulate in high enough concentrations in a waterbody, they can seriously affect the environment and the organisms living there. They can also affect human health.

Table 1: Categories of Nonpoint Source Pollution

Agriculture Non-irrigated Crop Production Irrigated Crop Production Specialty Crop Production Pasture Grazing-Riparian and/ or Upland Pasture Grazing-Riparian Pasture Grazing-Upland Range Grazing-Riparian and/ or Upland Range Grazing-Riparian Range Grazing-Upland Animal Feeding Operations (NPS) Aquaculture Animal Holding/Management Areas	**Hydromodification** Channelization Dredging Dam Construction Upstream Impoundment Flow Regulation/Modification **Habitat Modification** (other than hydro-modification) Removal of Riparian Vegetation Streambank Modification/Destabilization Drainage/Filling of Wetlands
Silviculture Harvesting, Restoration, Residue Management Forest Management (pumped drainage, fertilization, and pesticide application) Logging Road Construction/Maintenance Silvicultural Point Sources	**Marines and Recreational Boating** In-water Releases On-land Releases **Erosion from Derelict Land**
Construction Highway/Road/Bridge Construction Land Development	**Atmospheric Deposition** **Highway Maintenance and Runoff Spills** **Contaminated Sediments**
Urban Runoff / Storm Sewers Other Urban Runoff Illicit Connections/Illegal Hook-ups/Dry Weather Flows Highway/Road/Bridge Runoff Erosion and Sedimentation	**Debris and Bottom Deposits** **Internal Nutrient Cycling** (primarily lakes) **Sediment Resuspension**
Resource Extraction Surface Mining Subsurface Mining Placer Mining Dredge Mining Petroleum Activities Mill Tailings Mine Tailings Acid Mine Drainage Abandoned Mining Inactive Mining	**Natural Sources** **Recreational and Tourism Activities** (Non-boating) Golf Courses **Upstream Impoundment** **Salt Storage Sites** **Groundwater Loadings**
Improper Waste Disposal Sludge Wastewater Landfills Inappropriate Waste Disposal/Wildcat Dumping Industrial Land Treatment Onsite Wastewater Systems (Septic Tanks) Hazardous Waste Septage Disposal	**Groundwater Withdrawal** **Other** Source Unknown

The primary nutrients of concern in nonpoint source pollution are nitrogen and phosphorus. Both are essential for plant growth, but if too much of these substances enter a waterbody, it can lead to a condition called eutrophication (pronounced you-tro-fi-kay-shun). Eutrophication results in an overproduction of organic matter, particularly the microscopic plants called algae.

You may have seen green masses of algae growing on a pond or lake. This excess algae blocks the sunlight needed by native bottom-dwelling plants, often killing them. As the algae and bottom-dwelling plants die, they decay, using up oxygen in the water. This leads to a condition called hypoxia -- very low levels of oxygen in the water -- which makes it difficult for aquatic animals like fish and crabs to survive. You may have heard of the hypoxic zone in the Gulf of Mexico, also known as the “dead zone” at the mouth of the Mississippi River.

In addition to hypoxia, eutrophication may be associated with conditions that result in harmful algal blooms (HABs). Harmful algae are often small, single-celled organisms that live in aquatic environments. Although these organisms are not harmful in small quantities, too many of them can negatively affect the environment and people's health. When fish and shellfish feed on HABs, they can accumulate toxins that the algae produce. Consequently, when people eat seafood with algal toxins in it, they may get sick. The distribution, frequency, and intensity of HABs appears to be increasing worldwide.

Nonpoint sources of nutrients often originate from agricultural activities. Excess nutrients applied to crops in the form of fertilizers are washed away in runoff, typically during rainstorms. Nutrients also originate from urban and suburban areas, from sources such as lawn fertilizers, and even pet wastes.

Nitrogen and phosphorus also come from atmospheric inputs. Scientists believe that the combustion of fossil fuels like oil and coal by power plants, large industries, and automobiles is a major source of nutrients in the atmosphere (USGS, 2004). Controlling nutrient inputs is proving to be very difficult because the nutrients frequently originate from multiple sources that are challenging to identify and control.

Other types of pollution from nonpoint sources include, but are not limited to:

- Bacteria and viruses
- Herbicides
- Oil and gas
- Organic Matter
- Pesticides
- Sediment
- Trash
- Other chemicals, including paints, cleaning solutions, solvents, etc.

Because nonpoint source pollution poses many threats to environmental and human health, scientists are working hard to effectively manage this problem. Research, monitoring and assessments of the environment are increasing their knowledge of the causes and effects of nonpoint source pollution, and leading to the development of strategies to reduce and control it.

Controlling Nonpoint Source Pollution

While research, monitoring, and assessment look at the larger environmental effects of nonpoint source pollution, taking measures to stop pollution before it begins is also essential for controlling the problem. This is especially true in coastal communities. According to a NOAA Coastal Population Trends Report, about 153 million people lived in coastal areas in 2003. This is 53 percent of the total U.S. population. Between 1980 and 2003, the total coastal population increased by 28 percent, or 33 million people. If coastal populations continue to grow, the chances for more nonpoint source pollutants such as nutrients, sediments, pesticides, and other toxic chemicals to enter waterbodies via runoff increases.

Even though the exact locations of nonpoint source pollution cannot be identified, scientists know that certain environments and operations produce a high volume of pollution. Experts have developed systems to reduce and even eliminate pollution from these places. Listed below are some strategies to help reduce nonpoint source pollution from some of these high volume areas.

Urban and Suburban Areas

- Buffer strips are strips of grass located between and around impervious paving materials such as parking lots and sidewalks, and a body of water. The buffer strip absorbs soil, fertilizers, pesticides, and other pollutants before they can reach the water.
- Retention ponds capture runoff and stormwater. Sediments and contaminants settle out of the water when they are trapped in the retention pond.
- Constructed wetlands are a recent innovation in which an area is made into a wetland; the land is then used to slow runoff and absorb sediments and contaminants. The constructed wetland also provides habitat for wildlife.
- Porous paving materials are used in parking lots and highways. The porous pavement allows rainwater and stormwater to drain into the ground beneath it, reducing runoff. In some cases, there is also a stone reservoir underneath the pavement to allow filtration of the water before it reaches the groundwater.

- Sediment fences, or knee-high black fabric fences, are often used at construction sites to trap large materials, filter sediment out of rainwater, and slow runoff.
- Grass planting and laying of straw around construction sites help reduce runoff and associated nonpoint source pollution.

Agricultural Operations

- Buffer strips are planted between a farm field and a body of water. The buffer strip absorbs soil, fertilizers, pesticides, and other pollutants before they can reach the water.
- Conservation tillage involves leaving some crop residue from a previous harvest while planting a new crop. Less erosion occurs because the field is not plowed, and nutrients or pesticides are more likely to stay where they are applied.
- Crop nutrient management involves applying fertilizers sparingly to prevent excess nutrient runoff. Prior to the growing season, farmers test the fields to ensure that nutrients are applied only as needed.
- Beneficial insects can be used to control agricultural pests, reducing the need for pesticides. Common predators include ladybugs, praying mantises, and spiders, which feed on aphids, mites, and caterpillars. These natural predators help control infestations on valuable crops such as corn, soybeans, and tomatoes.

Forestry Operations

- The location and design of roads and skid trails (temporary pathways used to shuttle logs out of the forest) are carefully planned prior to any logging operations. Skid trails are designed to follow the contour of the land and reduce erosion.
- Buffer strips are maintained between logging operations and nearby streams, lakes or rivers.
- Trees are replanted after logging to allow for regrowth and less erosion.

Marinas

- Shutoff valves on fuel pumps on docks help limit spillage into the water.
- Pump-out stations at marinas allow boaters to safely empty their sanitary systems without dumping wastes into the water.
- Trash is placed in appropriate waste containers.

What You Can Do to Reduce NPS Pollution

Controlling and preventing nonpoint source pollution is every person's responsibility, including yours. Remember: if it's on the ground, it's in our water! There are many things all of us can do to reduce nonpoint source pollution, including:

- Plant grass, trees and shrubs in bare areas. This is one of the most important things you can do to reduce nonpoint source runoff. The grass, trees and shrubs will reduce and absorb runoff, and their roots will hold the soil together, reducing erosion.
- Properly dispose of motor oil and household chemicals. Never pour chemicals on the ground or in storm drains, where they will eventually make their way into a stream or river. Motor oils and household chemicals can harm, and even kill, aquatic life. Used motor oil should be taken to oil recycling facilities.
- Use fertilizers and pesticides sparingly on lawns and gardens. Excess fertilizer and pesticides can damage your plants. The excess often winds up in runoff and can lead to eutrophication in waterbodies. To reduce the use of pesticides, use beneficial insects such as ladybugs and praying mantises to control unwanted pests in the garden. Try a technique used in agriculture known as "scouting." Go out and survey your yard or garden to see what pests are present and then use pesticides only if natural predators cannot keep the pests in check.
- Put trash in its place. Keep it out of storm drains, where it will clog up the drain or end up in the nearest stream or lake.
- Organize neighborhood cleanups. Go on stream walks in your neighborhood, removing trash and debris as you go. Getting together as a group is fun, a good way to meet your neighbors, and together you can learn a lot about the natural environment.
- Recycle plastic, glass, and paper. Less trash means less material in the waste stream, and reducing the waste stream is the goal of all measures to control nonpoint source pollution.

Low Impact Development (LID)

Source: EPA LID webpages; LID Center; Natural Resources Defense Council

LID is an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible. LID employs principles such as preserving and recreating natural landscape features, minimizing effective imperviousness to create functional and appealing site drainage that treat stormwater as a resource rather than a waste product. There are many practices that have been used to adhere to these principles such as bioretention facilities, rain gardens, vegetated rooftops (See figure, next page), rain barrels, and permeable pavements. By implementing LID principles and practices, water can be managed in a way that reduces the impact of built areas and promotes the natural movement of water within an ecosystem or watershed. Applied on a broad scale, LID can maintain or restore a watershed's hydrologic and ecological functions. LID has been characterized as a sustainable stormwater practice by the Water Environment Research Foundation and others.

Figure 8: Green roof in Louisville, KY

This roof was installed on the American Life & Accident Insurance Co. building.

Image Credit: www.greenroofsolutions.com/about-grs/projects/commercial/

LID stands apart from other approaches through its emphasis on cost-effective, lot-level strategies that replicate predevelopment hydrology and reduce the impacts of development. By addressing runoff close to the source, LID can enhance the local environment and protect public health while saving developers and local governments money.

Seven Benefits of Low Impact Development

- **Effective.** Research has demonstrated LID to be a simple, practical, and universally applicable approach for treating urban runoff. By reproducing predevelopment hydrology, LID effectively reduces runoff and pollutant loads. Researchers have shown LID practices to be successful at removing common urban pollutants including nutrients, metals, and sediment. Furthermore, since many LID practices infiltrate runoff into groundwater, they help to maintain lower surface water temperatures. LID improves environmental quality, protects public health, and provides a multitude of benefits to the community.
- **Economical.** Because of its emphasis on natural processes and micro-scale management practices, LID is often less costly than conventional stormwater controls. LID practices can be cheaper to construct and maintain and have a longer life cycle cost than centralized stormwater strategies. The need to build and maintain stormwater ponds and other conventional treatment practices will be reduced and in some cases eliminated. Developers benefit by spending less on pavement, curbs, gutters, piping, and inlet structures. LID creates a desirable product that often sells faster and at a higher price than equivalent conventional developments.
- **Flexible.** Working at a small scale allows volume and water quality control to be tailored to specific site characteristics. Since pollutants vary across land uses and from site to site, the ability to customize stormwater management techniques and degree of treatment is a significant advantage over conventional management methods. Almost every site and every building can apply some level of LID and integrated management practices that contribute to the improvement of urban and suburban water quality.
- **Adds value to the landscape.** It makes efficient use of land for stormwater management and therefore interferes less than conventional techniques with other uses of the site. It promotes less disturbance of the landscape and conservation of natural features, thereby enhancing the aesthetic value of a property and thus its desirability to home buyers, property users, and commercial customers. Other benefits include habitat enhancement, flood control, improved recreational opportunities, drought impact prevention, and urban heat island effect reduction.
- **Achieves multiple objectives.** Practitioners can integrate LID into other urban infrastructure components and save money. For example, there is a direct overlap between stormwater management and Combined Sewer Overflow (CSO) control such that municipalities can use LID to help remedy both problems. Lot level LID applications and integrated stormwater management practices combine to provide substantial

reductions in peak flows and improvements in water quality for both combined and separated systems.

- **Follows a systems approach.** LID integrates numerous strategies, each performing different stormwater management functions, to maximize effectiveness and save money. By emulating natural systems and functions, LID offers a simple and effective approach to watershed sensitive development.
- **Makes sense.** New environmental regulations geared toward protecting water quality and stabilizing our now degraded streams, rivers, lakes, and estuaries are encouraging a broader thinking than centralized stormwater management. Developers and local governments continue to find that LID saves them money, contributes to public relations and marketing benefits, and improves regulatory expediencies. LID connects people, ecological systems, and economic interests in a desirable way.

Water Quality Parameters

Source: USGS Water Science for Schools; NY DEC

Water quality is the physical, chemical and biological characteristics of water. These different constituent characteristics or parameters of water are used to help determine water quality. The parameters used to test water vary depending on if the water is being monitored under a NPDES or other type of permit, or if the water health is being measured directly. In this section, we discus some basic environmental water quality parameters used to assess the health of streams in Kentucky, including: water temperature; pH; specific conductance; turbidity; dissolved oxygen; hardness, and suspended sediments. Additional parameters, tested to determine what types of pollution may be contaminating a waterbody, include nutrients, pathogens, metals, and emerging contaminants; this list is by no means comprehensive.

Temperature

Water temperature is not only important to swimmers and fisherman, but also to industries and even fish and algae. A lot of water is used for cooling purposes in power plants that generate electricity. They need cool water to start with, and they generally release warmer water back to the environment. The temperature of the released water can affect downstream habitats. Temperature also can affect the ability of water to hold oxygen as well as the ability of organisms to resist certain pollutants.

pH

pH is a measure of how acidic/basic water is. The range goes from 0 - 14, with 7 being neutral. A pH of less than 7 indicates acidity, whereas a pH of greater than 7 indicates a base. pH is really a measure of the relative amount of free hydrogen and hydroxyl ions in the water. Water that has more free hydrogen ions is acidic (< 7), whereas water that has more free hydroxyl ions is basic (> 7). Since pH can be affected by chemicals in the water, pH is an important indicator of water that is changing chemically. pH is reported in "logarithmic units," like the Richter scale, which measures earthquakes. Each number represents a 10-fold change in the acidity/baseness of the water. Water with a pH of 5 is ten times more acidic than water having a pH of six.

Pollution can change water's pH, which in turn can harm animals and plants living in the water. For instance, water coming out of an abandoned coal mine can have a pH of 2, which is very acidic and would definitely affect any fish crazy enough to try to living in it! By using the logarithm scale, this mine-drainage water would be 100,000 times more acidic than neutral water -- so stay out of abandoned mines.

Specific Conductance

Specific conductance is a measure of the ability of water to conduct an electrical current. It is highly dependent on the amount of dissolved solids (such as salt) in the water. Pure water, such as distilled water, will have a very low specific conductance, and seawater will have a high specific conductance. Rainwater often dissolves airborne gasses and airborne dust while it is in the air, and thus often has a higher specific conductance than distilled water. Specific conductance is an important water-quality measurement because it gives a good idea of the amount of dissolved material in the water.

Probably in school you've done the experiment where you hook up a battery to a light bulb and run two wires from the battery into a beaker of water. When the wires are put into a beaker of distilled water, the light will not light. But, the bulb does light up when the beaker contains salt water (saline). In the saline water, the salt has dissolved, releasing free electrons, and the water will conduct an electrical current.

Turbidity

Turbidity is the amount of particulate matter that is suspended in water. Turbidity measures the scattering effect that suspended solids have on light: the higher the intensity of scattered light, the higher the turbidity. Materials that cause water to be turbid include:

- clay
- silt
- finely divided organic and inorganic matter
- soluble colored organic compounds
- plankton
- microscopic organisms

Turbidity makes the water cloudy or opaque. Turbidity is measured by shining a light through the water and is reported in nephelometric turbidity units (NTU). During periods of low flow (base flow), many rivers are a clear green color, and turbidities are low, usually less than 10 NTU. During a rainstorm, particles from the surrounding land are washed into the river making the water a muddy brown color, indicating water that has higher turbidity values. Also, during high flows, water velocities are faster and water volumes are higher, which can more easily stir up and suspend material from the stream bed, causing higher turbidities.

Turbidity can be measured in the laboratory and also on-site in the river. A handheld turbidity meter measures turbidity of a water sample. The meter is calibrated using standard samples from the meter manufacturer. The picture with the three glass vials shows turbidity standards of 5, 50, and 500 NTUs. Once the meter is calibrated to correctly read these standards, the turbidity of a water sample can be taken. State-of-the-art turbidity meters are

beginning to be installed in rivers to provide an instantaneous turbidity reading. These meters read turbidity in the river by shining a light into the water and reading how much light is reflected back to the sensor. The smaller tube contains a conductivity sensor to measure electrical conductance of the water (which is strongly influenced by dissolved solids) and a temperature gauge.

Dissolved Oxygen

Although water molecules contain an oxygen atom, this oxygen is not what is needed by aquatic organisms living in our natural waters. A small amount of oxygen, up to about ten molecules of oxygen per million molecules of water, is actually dissolved in water. This dissolved oxygen is breathed by fish and zooplankton and is needed by them to survive.

Rapidly moving water, such as in a mountain stream or large river, tends to contain a lot of dissolved oxygen, while stagnant water contains little. As the water rolls over obstacles in a stream, such as rocks and logs in riffle areas, the water absorbs oxygen from the air. Bacteria in water can consume oxygen as organic matter decays. Thus, excess organic material in our lakes and rivers can cause an oxygen-deficient situation to occur. Aquatic life can have a hard time in stagnant water that has a lot of rotting, organic material in it, especially in summer, when dissolved-oxygen levels are at a seasonal low. When oxygen levels get too low, aquatic life must migrate from the area or possibly die.

Some of the tests used to measure oxygen levels tell scientists the amount of dissolved oxygen (DO), biological oxygen demand (BOD), carbonaceous biochemical oxygen demand (CBOD), and the chemical oxygen demand (COD).

Hardness

The amount of dissolved calcium and magnesium in water determines its "hardness." Water hardness varies throughout the United States. If you live in an area where the water is "soft," then you may never have even heard of water hardness. But, if you live in Florida, New Mexico, Arizona, Utah, Wyoming, Nebraska, South Dakota, Iowa, Wisconsin, or Indiana, where the water is relatively hard, you may notice that it is difficult to get soap to lather up when washing your hands or clothes. And, industries in your area might have to spend money to soften their water, as hard water can damage equipment. Hard water can even shorten the life of fabrics and clothes! Does this mean that students who live in areas with hard water keep up with the latest fashions since their clothes wear out faster?

Suspended Sediment

Suspended sediment is the amount of soil moving along in a stream. It is highly dependent on the speed of the water flow, as fast-flowing water can pick up and suspend more soil than calm water. During storms, soil is washed from the stream banks into the stream. The

amount that washes into a stream depends on the type of land in the river's drainage basin and the vegetation surrounding the river.

If land is disturbed along a stream and protection measures are not taken, then excess sediment can harm the water quality of a stream. You've probably seen those short, plastic fences that builders put up on the edges of the property they are developing. These silt fences are supposed to trap sediment during a rainstorm and keep it from washing into a stream, as excess sediment can harm the creeks, rivers, lakes, and reservoirs.

Sediment coming into a reservoir is always a concern; once it enters it cannot get out - most of it will settle to the bottom. Reservoirs can "silt in" if too much sediment enters them. The volume of the reservoir is reduced, resulting in less area for boating, fishing, and recreation, as well as reducing the power-generation capability of the power plant in the dam.

Nutrients

Nutrient pollution is one of America's most widespread, costly and challenging environmental problems. Nutrient pollution comes from excess ammonia, nitrogen, phosphorus and sulfates in the air and water. Nutrients are natural parts of aquatic ecosystems. Nitrogen and phosphorus support the growth of algae and aquatic plants, which provide food and habitat for fish, shellfish and smaller organisms that live in water. Nitrogen is also the most abundant element in the air we breathe.

But when too many nutrients enter the environment the air and water can become polluted. These excess nutrients usually come from a wide range of human activities. Too much nitrogen and phosphorus in the water causes algae to grow faster than ecosystems can handle. Significant increases in algae lead to eutrophication. Some algal blooms are harmful to humans because they produce elevated toxins and bacterial growth that can make people sick if they come into contact with polluted water, consume tainted fish or shellfish, or drink contaminated water.

Nutrient pollution in ground water can be harmful, even at low levels. Millions of people in the United States use groundwater as their drinking water source. Infants are vulnerable to a nitrogen-based compound called nitrates in drinking water. Excess nitrogen in the atmosphere can produce pollutants such as ammonia and ozone, which can impair our ability to breathe, limit visibility and alter plant growth. Excess nitrogen in the air can impair our ability to breathe, limit visibility and alter plant growth. When excess nitrogen comes back to earth from the atmosphere, it can harm the health of forests, soils and waterways.

Pathogens

Polluted runoff and untreated sewage released into the water can expose swimmers to bacteria, viruses, and protozoans. These pathogens (disease-causing organisms) can be present

at or near the site where polluted discharges enter the water. Children, the elderly, and people with weakened immune systems are most likely to develop illnesses or infections after swimming in polluted water.

Swimming-related illnesses are typically minor. This means that they require little or no treatment, respond readily to treatment, and have no long-term health effects. The most common illness associated with swimming in water polluted by sewage is gastroenteritis. It occurs in a variety of forms that can have one or more of the following symptoms: nausea, vomiting, stomachache, diarrhea, headache, and fever. Other minor illnesses associated with swimming include ear, eye, nose, and throat infections. In highly polluted water, swimmers may occasionally be exposed to more serious diseases like dysentery, hepatitis, cholera, and typhoid fever.

Agencies monitoring for water pollution usually analyze the water samples they collect for indicator species to assess the water for harmful levels of pathogens. Collecting and measuring the pathogens directly can be difficult and potentially hazardous. Good indicator species are microorganisms that are easy to collect and analyze for, safe to handle, representative of the pathogen of concern for characteristics like growth, and always present when pathogens are present or vice versa.

Metals

The effects of metals in water and wastewater range from beneficial through troublesome to dangerously toxic. Some metals are essential; others may adversely affect water consumers, wastewater treatment systems and receiving waters. Some metals may be either beneficial or toxic, depending on concentration.

The primary mechanism for toxicity to organisms that live in the water column is by absorption to or uptake across the gills: this physiological process requires metal to be in a dissolved form. This is not to say that particulate metal is nontoxic, only that particulate metal appears to exhibit substantially less toxicity than does dissolved metal.

Not all metals are acutely toxic in small concentrations. The "heavy metals" include copper (Cu), iron (Fe), cadmium (Cd), zinc (Zn), mercury (Hg), and lead (Pb) and are the most toxic to aquatic organisms. Some water quality characteristics which affect metal toxicity include temperature, pH, hardness, alkalinity, suspended solids, redox potential and dissolved organic carbon. Metals can bind to many organic and inorganic compounds which reduces the toxicity of the metal.

Emerging Contaminants

Source: www.dec.ny.gov/docs/water_pdf/drugbkgrd_.pdf

In the last two decades, research is documenting with increasing frequency that many chemical and microbial constituents that have not historically been considered as contaminants are present in the environment on a global scale. The presence of these constituents in our waters is an emerging issue, meaning that it has come to light relatively recently as analytical detection methods have improved and researchers have begun looking for these compounds.

"Emerging contaminants" can be broadly defined as any synthetic or naturally occurring chemical or any microorganism that is not commonly monitored in the environment but has the potential to enter the environment and cause known or suspected adverse ecological and(or) human health effects. In some cases, release of emerging chemical or microbial contaminants to the environment has likely occurred for a long time, but may not have been recognized until new detection methods were developed. In other cases, synthesis of new chemicals or changes in use and disposal of existing chemicals can create new sources of emerging contaminants

These emerging contaminants are commonly derived from municipal, agricultural, and industrial wastewater sources and pathways. These newly recognized contaminants represent a shift in traditional thinking as many are produced industrially yet are dispersed to the environment from domestic, commercial, and industrial uses. Hundreds of emerging contaminants have been identified in global waters; most are not filtered out of drinking water, even in the United States.

One example of a class of emerging contaminants is pharmaceuticals and personal care products (PPCPs). Pharmaceuticals in particular are designed to have a biologic consequence. They are intended to cause some effect in the living organism. They may also be resistant to some forms of degradation, in order to retain their biological activity through manufacture, shipping, storage, and retail distribution. Significant portions of some drugs pass through the body unchanged, or are metabolized to a different biologically active substance. These substances may be excreted unchanged, conjugated, or metabolized, and enter municipal waste water (i.e., sewage treatment plants) which are not specifically designed to treat them.

The risk to aquatic life from PPCPs in water is perhaps of greater immediate concern. Fish, other aquatic animals, and invertebrates are exposed continuously to contaminants in water throughout their life including sensitive, developmental life stages. Some PPCPs with certain chemical characteristics (e.g., low water solubility, lipophilic, and resistant to biodegradation) might be bioaccumulated from very low concentrations in water to concentrations in fish tissue capable of stimulating a biological response. PPCPs that are capable of mimicking hormones, known as endocrine-disruptors, are particularly problematic because hormone systems function at very low concentrations. Many different hormone

systems could potentially be impacted by PPCPs, but harmful impacts to fish reproduction have already been attributed to wastewater-derived contaminants (including PPCPs, pesticides, and industrial chemicals) that mimic the hormone estrogen. This mimicry has been shown to cause changes in the reproductive systems of exposed fish. In some instances, 18% or more of the male fish in a population have been found to develop female sexual organs. For more information, research studies completed in the Potomac River in Maryland and Boulder Creek in Colorado.

Stream Habitat Assessment

Source: KDOW Sampling SOP

A stream habitat assessment is a visual-based evaluation. The assessment consists of ten parameters that rate instream habitat, channel morphology, bank stability and riparian vegetation for each sampling reach. A numerical scale of 0 (lowest) to 20 (highest) is used to rate each parameter (Barbour et al. 1999). For each parameter, the investigators will determine which of the following conditions exist at the sampling reach: Optimal, Suboptimal, Marginal, or Poor. A parameter score will then be given within the condition category chosen:

1) Optimal (20-16)
2) Suboptimal (15-11)
3) Marginal (10-6)
4) Poor (5-0)

Note that some of the parameters rate left and right banks individually, reducing the points as outlined in the above categories, but the total score for that parameter still equals 20 points. The investigators will total all of the parameter ratings to obtain a final habitat score out of a total 200 points, with a higher score indicating better habitat.

Parameters for Habitat Assessment

i. These parameters should be evaluated within the sampling reach. All of the areas within the reach should be evaluated together as a composite.

Parameter 1: Epifaunal Substrate/Available Cover

This metric measures the relative quantity and the variety of structures: cobble, boulders, fallen trees, logs, branches, root mats, undercut banks, aquatic vegetation, etc., that provide refugia, feeding opportunities and sites for spawning and nursery functions. See the table on the next page for substrate particle sizes.

1) Optimal: >70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient) (20-16)
2) Suboptimal: 40%-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of new fall, but not yet prepared for colonization (may rate at the high end of the scale) (15-11)
3) Marginal: 20%-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed (10-6)
4) Poor: <20% stable habitat; lack of habitat is obvious; substrate unstable or lacking (5-0)

Table 2: Substrate Particle Size	
Substrate Particle Size	
Categories	**Size (mm)**
Boulders	>256 (= 10 in)
Cobble	64 - 256 (= 2.5 - 10 in)
Pebble	16 - 64 (= .63 - 2.5 in)
Gravel	2 - 16 (=.08 - .63 in)
Fines	<2 (= .08 in)
Exposed Bedrock	--
Hardpan Clay	--
Detritus	--

Parameter 2: Embeddedness

Embeddedness is the extent to which rocks and snags are covered or sunken into the silt, sand, mud or biofilms (algal, fungal or bacterial mats) of the stream bottom. Generally, as rocks become embedded, the surface area available to macroinvertebrates and fish (for shelter, spawning and egg incubation) is decreased; assess in the upstream or central portions of riffles.

1) Optimal: Rocks are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space (20-16)
2) Suboptimal: Rocks are 25%-50% surrounded by fine sediment (15-11)
3) Marginal: Rocks are 50%-75% surrounded by fine sediment (10-6)
4) Poor: Rocks are >75% surrounded by fine sediment (5-0)

Parameter 3: Velocity/Depth Regime

The best streams in most high-gradient regions will have all of the following patterns of velocity and depth: 1) slow-deep (pool), 2) slow-shallow (glide), 3) fast-deep (run), and 4) fast-shallow (riffle); the occurrence of these four patterns relates to the stream's ability to provide and maintain a stable aquatic environment. See figure on the next page for a depiction of these regimes. Investigators may have to scale deep and shallow depending upon the stream size; a general guideline is 0.5 m between shallow and deep.

1) Optimal: All 4 regimes present (20-16)
2) Suboptimal: Only 3 of the 4 regimes present; if fast-shallow is missing, score lower than if missing other regimes (15-11)
3) Marginal: Only 2 of the 4 regimes present; if fast-shallow or slow-shallow are missing, score low (10-6)
4) Poor: Dominated by 1 regime (usually slow-deep) (5-0)

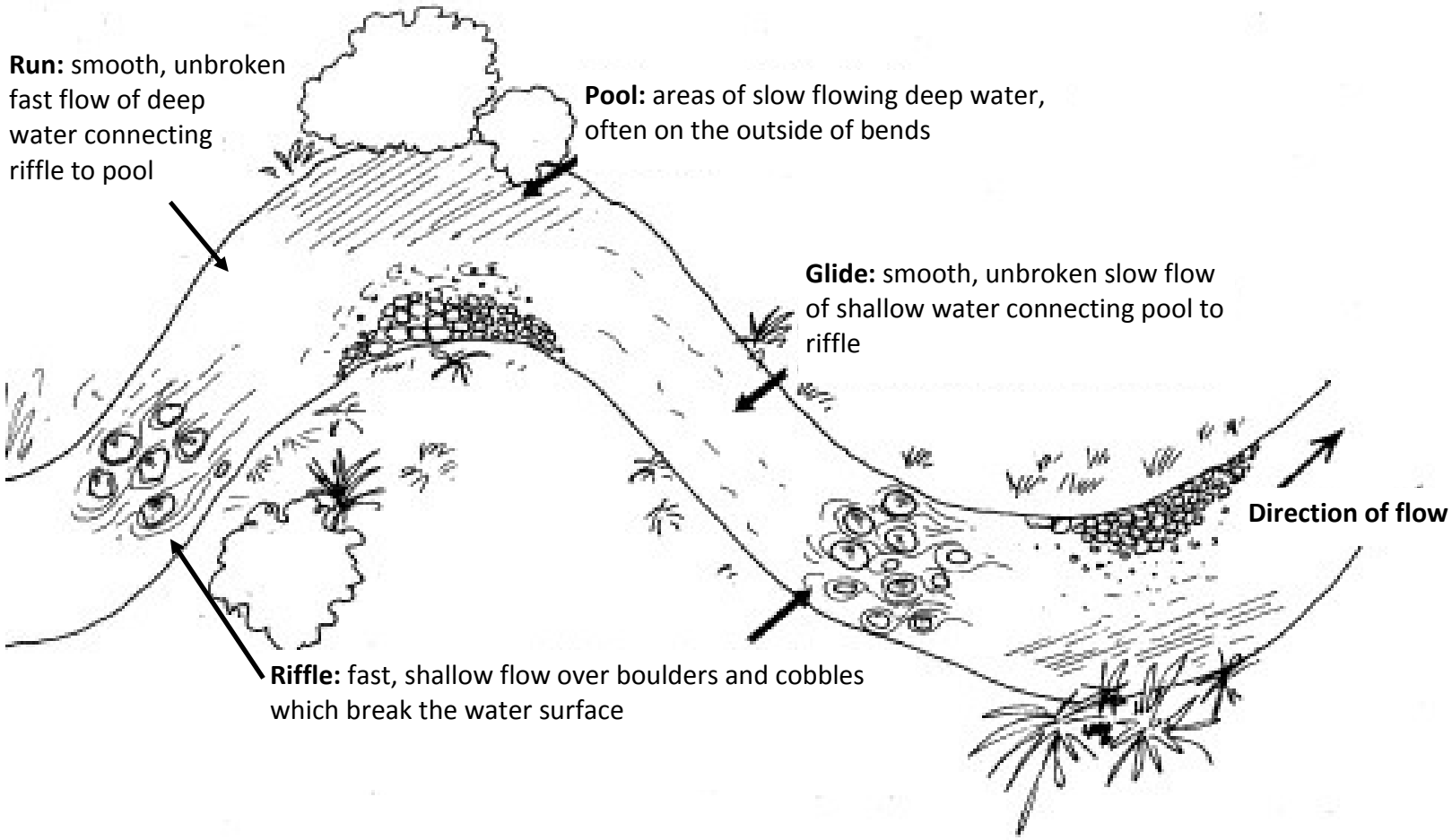


Figure 9: Pools, riffles, runs and glides

Image Credit: share3.esd105.wednet.edu/rsandelin/ees/Resources/Flowing%20water%20concepts.htm

Parameter 4: Sediment Deposition

This metric measures the amount of sediment that has accumulated in pools and changes that have occurred to the stream bottom as a result of deposition. This may cause the formation of islands, point bars (areas of increased deposition usually at the beginning of a meander that increases in size as the channel is diverted toward the outer bank) or shoals, or result in the filling of runs and pools. Sediment is often found in areas that are obstructed and areas where the stream flow decreases, such as bends. Deposition is a symptom of an unstable and continually changing environment that becomes unsuitable for many organisms. See the figure below for different depositional features.

1) Optimal: Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition (20-16)
2) Suboptimal: Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5%-30% of the bottom affected; slight deposition in pools (15-11)
3) Marginal: Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30%-50% of the bottom affected; moderate sediment deposits apparent at most obstructions and slow areas, bends and pools (10-6)
4) Poor: Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition (5-0)

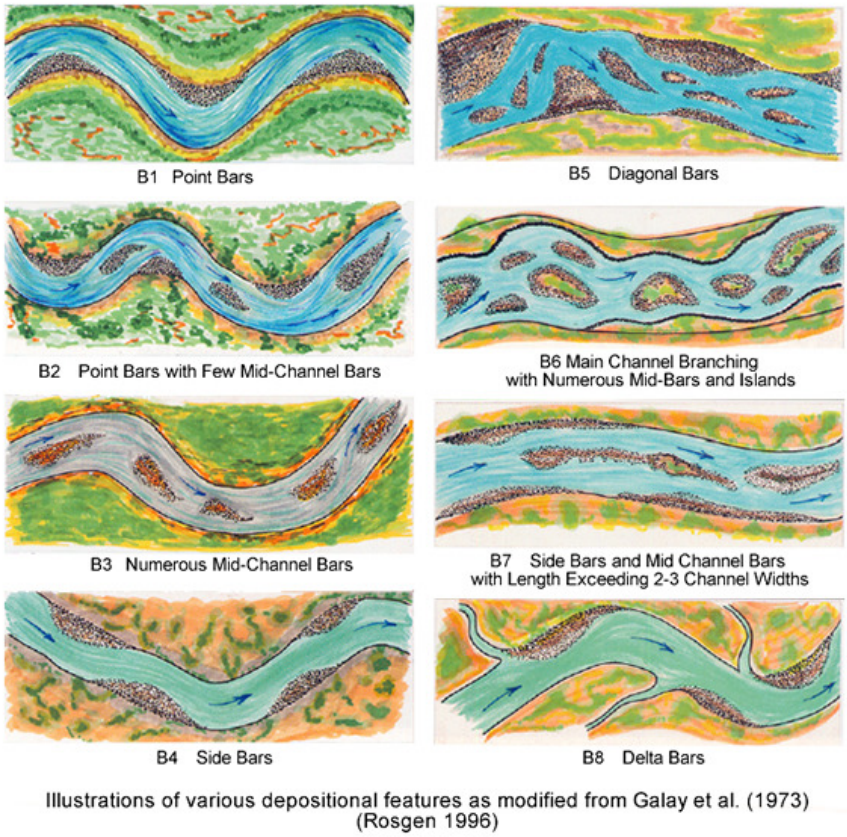


Figure 10: Depositional features

Image Credit: www.fgmorph.com/fg_8_12.php

Parameter 5: Channel Flow Status

This metric measures the degree to which the channel is filled with water; will change with seasons.

1) Optimal: Water reaches base of both lower banks; minimal amount of channel substrate exposed (20-16)
2) Suboptimal: Water fills >75% of the available channel; or <25% of channel substrate exposed (15-11)
3) Marginal: Water fills 25%-75% of the available channel; riffle substrates are mostly exposed (10-6)
4) Poor: Very little water in channel; mostly present in pools (5-0)

ii. The next five (5) parameters should evaluate an area from approximately 100-m upstream of the sampling reach through the sampling reach. This whole area should be evaluated as a composite. When determining left and right bank, orient yourself to look downstream.

Parameter 6: Channel Alteration

This metric measures the large-scale changes in the shape of the stream channel; channel alteration is present when 1) artificial embankments, rip-rap and other forms of bank stabilization or structures are present; 2) the stream is very straight for significant distances; 3) dams and bridges are present; and 4) other such changes have occurred.

1) Optimal: Channelization or dredging absent or minimal; stream with normal pattern (20-16)
2) Suboptimal: Some channelization present, usually in areas of bridge abutments; evidence of past channelization (dredging, etc., >20 past years) may be present, but recent channelization not present (15-11)
3) Marginal: Channelization may be extensive; embankments or shoring structures present on both banks; and 40%-80% of the stream reach channelized and disrupted (10-6)
4) Poor: Banks shored with gabion or cement; >80% of the stream disrupted; instream habitat greatly altered or removed entirely (5-0)

Parameter 7: Frequency of Riffles (or Bends)

This metric measures the sequence of riffles and thus the heterogeneity occurring in a stream. In low gradient areas where riffles seldom occur, the frequency of bends is measured rather than riffles.

1) Optimal: Occurrence of riffles relatively frequent; ratio of distance between riffles divided by the width of the stream <7:1 (generally 5 to 7); variety of habitat is key; in streams where riffles are continuous, placement of boulders or other large, natural obstruction is important (20-16)
2) Suboptimal: Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 and 15 (15-11)
3) Marginal: Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 and 25 (10-6)
4) Poor: Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is >25 (5-0)

Parameter 8: Bank Stability

The Bank Stability metric is a measure of whether the stream banks are eroded or have the potential to erode. The figure below shows several different bank shapes. Each bank is scored independently from 10-0.

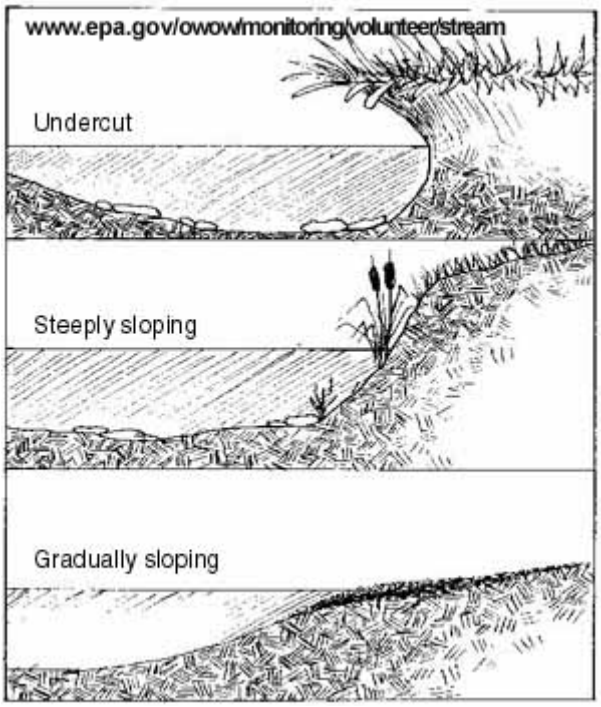


Figure 11: Types of stream bank shapes

Image Credit: water.epa.gov/type/rsl/monitoring/vms41.cfm

1) Optimal: Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems; <5% of bank affected (10-9)
2) Suboptimal: Moderately stable; infrequent, small areas of erosion mostly healed over; 5%-30% of the bank affected (8-6)
3) Marginal: Moderately unstable; 30%-60% of bank in reach has areas of erosion; high erosion potential during floods (5-3)
4) Poor: Unstable; many raw, eroded areas; obvious bank sloughing; >60% of bank has erosional scars (2-0)

Parameter 9: Bank Vegetative Protection

This metric measures the amount of vegetative protection afforded to the stream and the near-stream portion of the riparian zone. Each bank is scored independently from 10-0.

1) Optimal: >90% of the streambank surfaces and immediate riparian zones covered by natural vegetation, including trees, understory shrubs, herbs and nonwoody macrophytes; vegetation disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally (10-9)
2) Suboptimal: 70%-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one half of the potential plant stubble height remaining (8-6)
3) Marginal: 50%-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one half of the potential plant stubble height remaining (5-3)
4) Poor: <50% of the streambank surfaces covered by vegetation; disruption is very high; vegetation has been removed to 5 cm or less in average stubble height (2-0)

Parameter 10: Riparian Vegetative Zone Width

This metric measures the width of the natural vegetation from the edge of the streambank through the riparian zone. See the figure on the next page for a diagram depicting riparian zones. The presence of old fields, paths, walkways, etc., in otherwise undisturbed riparian zones may be judged to be inconsequential to destruction of the riparian zone. Each bank is scored independently from 10-0.

1) Optimal: Width of riparian zone >18 m; human activities (parking lots, roadbeds, clear-cuts, lawns, pastures or crops) have not impacted the zone (10-9)
2) Suboptimal: Width of riparian zone 13-18 m; human activities have impacted the zone only minimally (8-6)
3) Marginal: Width of riparian zone 6-12 m; human activities have impacted the zone a great deal (5-3)
4) Poor: Width of riparian zone <6 m; little or no riparian zone due to human activities (2-0) (Barbour et al. 1999)

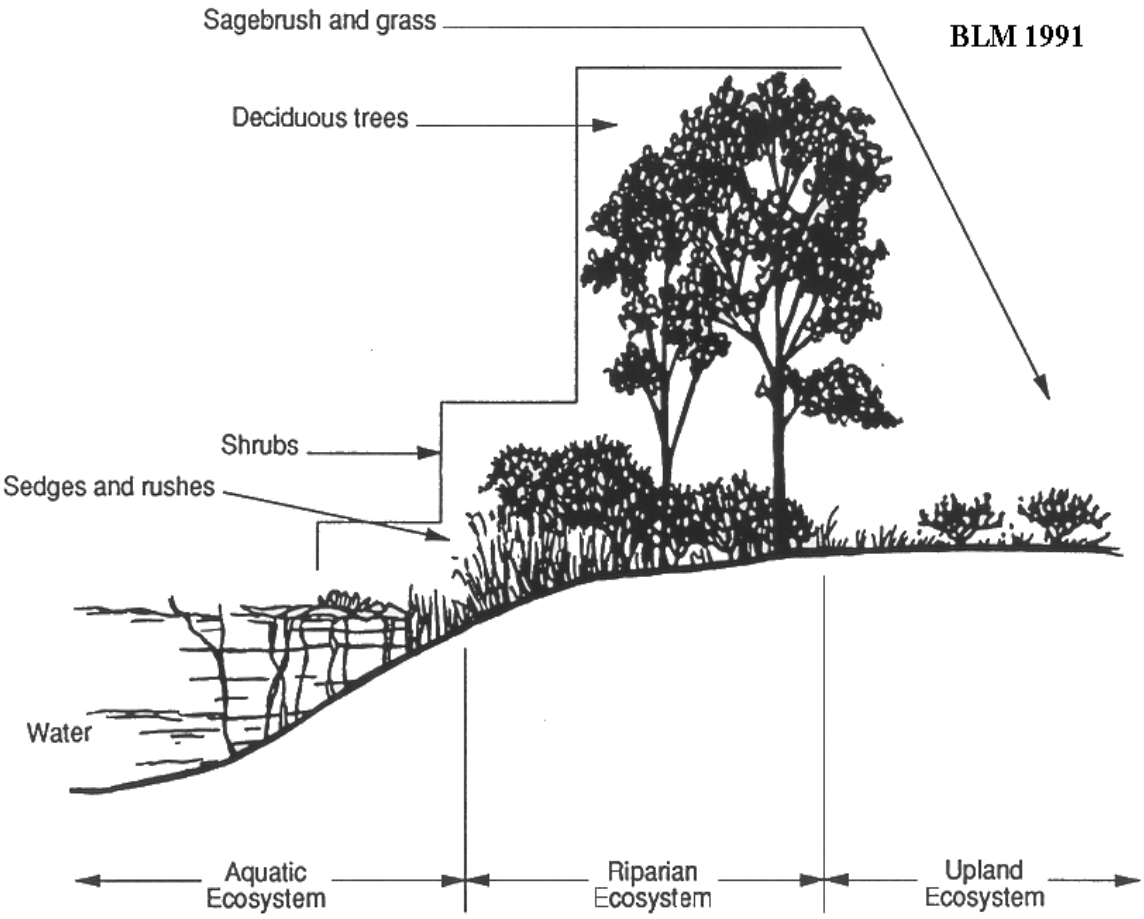


Figure 12: Riparian zone

Image Credit: aces.nmsu.edu/riparian/WHTRIPAREA.html

Stream Order

Source: About.com Geography

Identifying stream order helps hydrologists, biologists, geographers and other scientists in their study and understanding of streams and their ecology. Stream order is an effective way to classify the world's waterways and is a crucial step in understanding and managing the many differences between streams of different sizes. The stream order hierarchy was officially proposed in 1952 by Arthur Newell Strahler, a geoscience professor at Columbia University in New York City, in his article "Hypsometric (Area Altitude) Analysis of Erosional Topology" which appeared in the *Geological Society of America Bulletin*.

When using stream order to classify a stream, the sizes range from a first order stream all the way to the largest, a 12th order stream. A first order stream is the smallest of the world's streams and consists of small tributaries. These are the streams that flow into and "feed" larger streams but do not normally have any water flowing into them. In addition, first and second order streams generally form on steep slopes and flow quickly until they slow down and meet the next order waterway.

First through third order streams are also called headwater streams and constitute any waterways in the upper reaches of the watershed. It is estimated that over 80% of the world's waterways are these first through third order, or headwater streams.

Going up in size and strength, streams that are classified as fourth through sixth order are medium streams while anything larger (up to 12th order) is considered a river. For example, to compare the relative size of these different streams, the Ohio River in the United States is an eighth order stream while the Mississippi River is a tenth order stream. The world's largest river, the Amazon in South America, is considered a 12th order stream.

Unlike the smaller order streams, these medium and large rivers are usually less steep and flow slower. They do however tend to have larger volumes of runoff and debris as it collects in them from the smaller waterways flowing into them.

Going Up in Order

When studying stream order, it is important to recognize the pattern associated with the movement of streams up the hierarchy of strength. Because the smallest tributaries are classified as first order, they are often given a value of one by scientists. It then takes a joining of two first order streams to form a second order stream. When two second order streams combine, they form a third order stream, and when two third order streams join, they form a fourth and so on.

If however, two streams of different order join, neither increases in order. For example, if a second order stream joins a third order stream, the second order stream simply ends by

flowing its contents into the third order stream, which then maintains its place in the hierarchy. See the figure below to help visualize the stream order hierarchy.

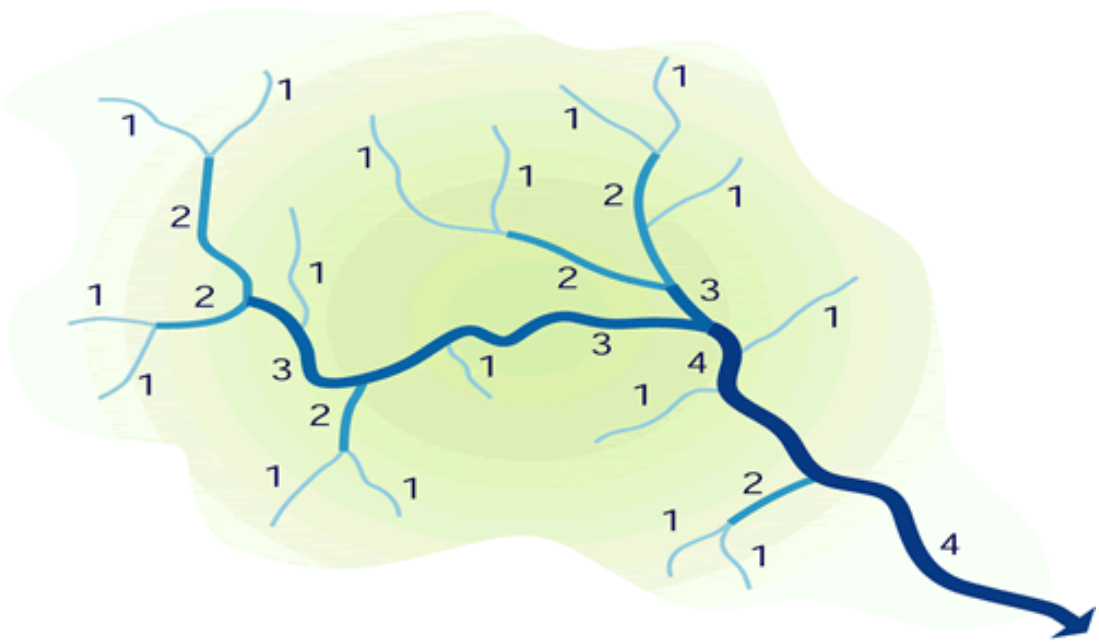


Figure 13: Stream Order

Image credit: www.fgmorph.com/fg_4_8.php

Benthic Macroinvertebrates

Benthic macroinvertebrates are small organisms that live below ("benthic") the water, have no backbone ("invertebrates"), and can be seen with the naked eye ("macro"). In a healthy stream, thousands of these organisms can be found in every square foot of substrate material. Macroinvertebrates are often called "bugs" for short. It is important to note that while many macroinvertebrates are insects, not all of them are; some are worms, snails, crustaceans, bivalves, etc. Benthic macroinvertebrates are also abbreviated as "macros" or "benthics".

Macros spend all or part of their life cycle in the water, and therefore are exposed to contaminants in the stream on a daily basis. Some species are very pollution tolerant and won't be affected by stream contaminants. However, other species are only somewhat pollution tolerant, while still others are very pollution sensitive. Those macroinvertebrates with sensitivities can die when exposed to specific pollutants. So the biotic community make-up can tell us a lot about the year-round water quality.

Scientists sample streams for macroinvertebrates to find out about water conditions. Entomologists examine the samples to determine the species present and the abundance of organisms in each species. The type and number of organisms in the sample are good indicators of stream health. You should take time to become familiar with some of the commonly found macros in Kentucky streams. For an idea of just some of the bugs found in streams in Kentucky, see the macroinvertebrate key on the next page. In one of the following sections, this guide discusses sampling procedures to collect macros. You can also request special training from Watershed Watch in Kentucky. Through their "Phase 2" training, you can learn about biological sampling procedures, types of macroinvertebrates and habitat assessments. Visit water.ky.gov/wsw/pages/default.aspx to learn more!

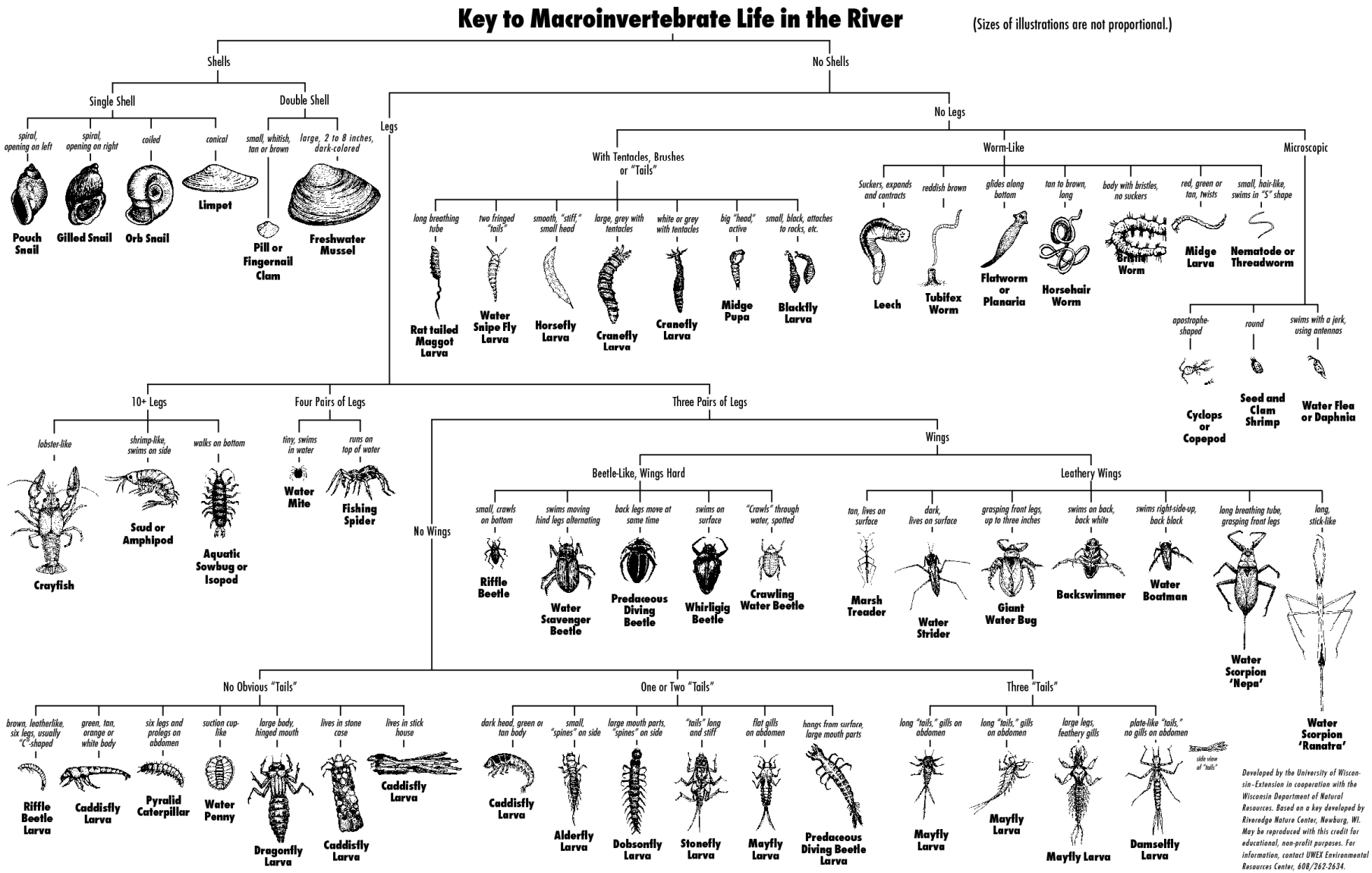


Figure 14: Macroinvertebrate Key Image Credit: www.docstoc.com/docs/104326808/Key-to-Macroinvertebrate-Life-in-the-River (larger version is available at this site)

Bug Metamorphosis

We have established that macros are made up of more than just bugs. However, it is interesting to note that the macros that are insects undergo one of two metamorphic changes. The figure on the next page shows two different types of metamorphosis: incomplete and complete. Incomplete metamorphosis involves three stages: egg, nymph and adult. The juvenile stages look very similar to the adult form. Complete (also called "complex") metamorphosis involves four stages: egg, larva, pupa and adult. The juvenile stages usually look nothing like the adult form. Upon transformation into the adult stage, many bugs become airborne, leaving the water in search of mates to reproduce.

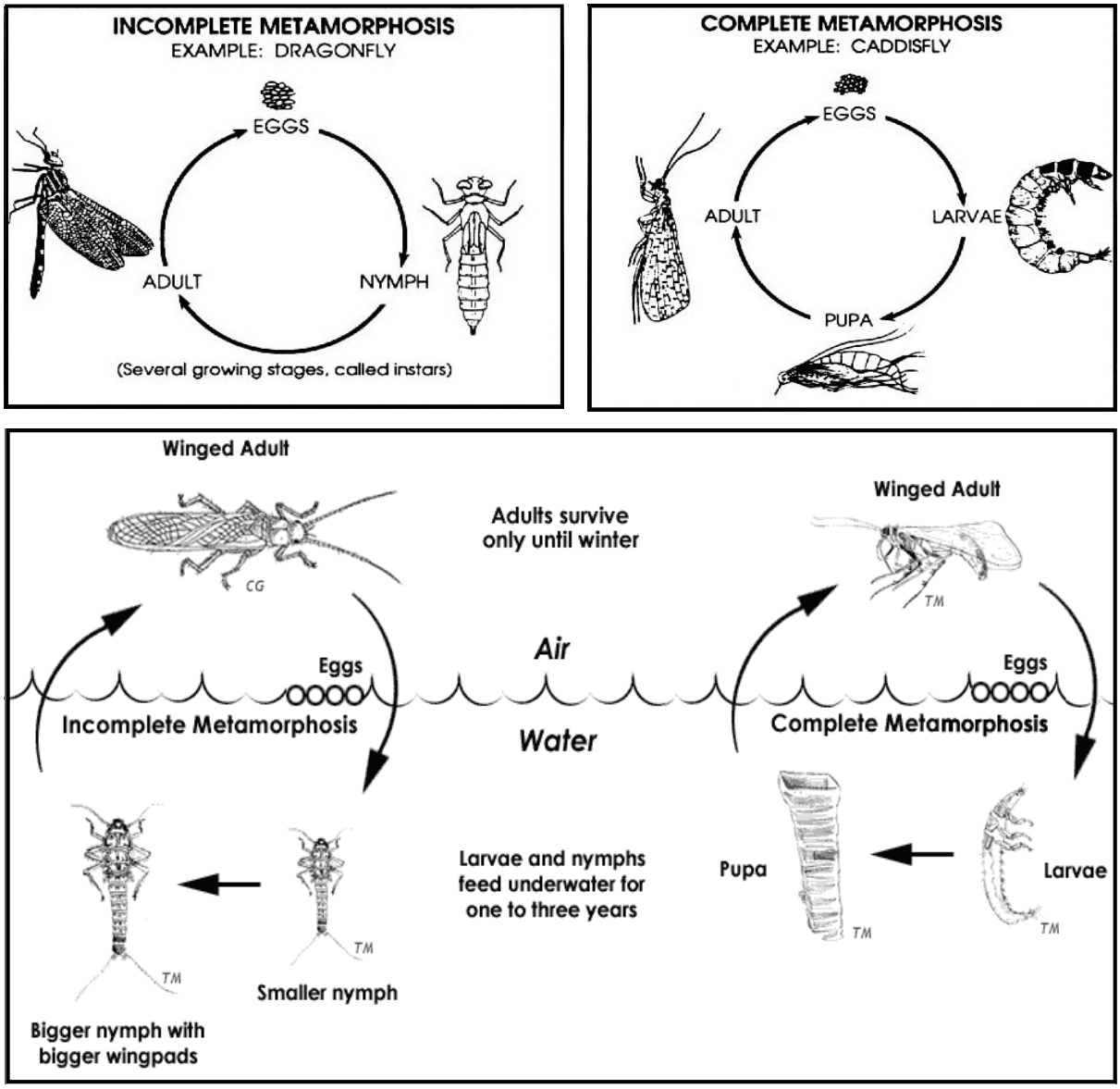


Figure 15: Bug Metamorphosis

Macroinvertebrate Sampling

1) Riffle Sample

This technique (See figure below) samples the most important subhabitat (i.e., riffle) found in moderate to high-gradient streams. It requires using a 600 µm mesh, one meter wide net in moderate to fast current in areas with gravel to cobble substrate. Four (4) 0.25 m^2 samples are taken from mid-riffle or the *thalweg* (path of deepest thread of water), dislodging benthos by vigorously disturbing 0.25 m^2 (20 x 20 in.) in front of the net. Large rocks should be hand washed into the net. The contents of the net are then washed and all four samples are composited into a 600 µm mesh wash bucket. **This sample must be kept separate from all other subhabitat collections.**

Figure 16: Sampling a riffle with a dipnet

Image Credit: www.urbanrivers.org/toolsofascientist/tools.html

2) Multi-Habitat Sample

a) Sweep Sample - This sample involves sampling a variety of non-riffle habitats with the aid of an 800 x 900 µm mesh triangular or D-frame dipnet. Each habitat is sampled in at least three (3) replicates, where possible.

(1) *Undercut banks/root mats* - sampled by placing a large rootwad into the triangular or D-frame dipnet and shaken vigorously. The contents are removed from the dipnet and placed into a mesh wash bucket. *Note: If undercut banks are present in both run and pool areas, each is sampled separately with three replicates*.

(2) *Marginal emergent vegetation* (exclusive of *Justicia americana* beds) - sampled by thrusting (i.e., "jabbing") the dipnet into the vegetation for ca. 1 m, and then sweeping through the area to collect dislodged organisms. Material is then rinsed in the wash bucket and any sticks, leaves and vegetation are thoroughly washed and

inspected before discarding. (*Note: centiare (symbol ca) is a synonym for one square metre.*)

(3) *Bedrock or slab-rock habitats* - sampled by placing the edge of the dipnet flush on the substrate, disturbing approximately 0.1 m^2 of area to dislodge attached organisms. Material is emptied into a wash bucket.

(4) *Justicia americana* (water willow) beds - sampled by working the net through a 1 m section in a jabbing motion. The material is then emptied into a wash-bucket and any *J. americana* stems are thoroughly washed, inspected and discarded.

(5) *Leaf Packs* - preferably "conditioned" (i.e., not new-fall material) where possible; samples are taken from a variety of locations (i.e., riffles, runs and pools) and placed into the wash-bucket. The material is thoroughly rinsed to dislodge organisms and then inspected and discarded.

b) Silt, sand, and fine gravel - Sieving - a U.S. No. 10 sieve is used to sort out larger invertebrates (e.g., mussels, burrowing mayflies, and dragonfly larvae) from silt, sand and fine gravel by scooping the substrate to a depth of ca. 5 cm. A variety of collection sites are sampled in order to obtain three replicates in each substrate type (silt, sand and fine gravel).

c) Aufwuchs sample - Small invertebrates associated with this habitat are obtained by washing a small amount of rocks, sticks, leaves, filamentous algae and moss into a medium-sized bucket half filled with water. The material is then elutriated and sieved with the Nitex™ sampler.

d) Rock Picking - Invertebrates are picked from 15 rocks (large cobble-small boulder size; 5 each from riffle, run and pool). Selected rocks are washed in a bucket half filled with water, and then carefully inspected to remove invertebrates with fine-tipped forceps.

e) Wood Sample - Pieces of submerged wood, adding ranging from roughly 3 to 6 meters (10 to 20 linear feet) and ranging from 5–15 cm (2–6 inches) in diameter, are individually rinsed into the wash-bucket. Pieces of wood are inspected for burrowers and crevice dwellers. Large diameter, well-aged logs should be inspected and hand-picked with fine-tipped forceps.

Definitions of Special Use Waters

Special use waters are rivers, streams and lakes listed in Kentucky Administrative Regulations (KAR) or the Federal Register as being worthy of additional protection. The different kinds of special use waters (discussed below) are Cold Water Aquatic Habitat, Exceptional Waters, Reference Reach Waters, Outstanding State Resource Waters, Outstanding National Resource Waters, State Wild Rivers and Federal Wild and Scenic Rivers. Not included as special use waters are water bodies designated by default as Warm Water Aquatic Habitat, Primary Contact Recreation and Secondary Contact Recreation.

Cold water aquatic habitat (CAH) means surface waters and associated substrate that will support indigenous aquatic life or self-sustaining or reproducing trout populations on a year-round basis. (401 KAR 5:031, Section 4).

Outstanding state resource waters (OSRW) means surface waters designated by the cabinet pursuant to 401 KAR 5:031, Section 7, and includes certain unique waters of the Commonwealth.

Exceptional waters means waterbodies whose quality exceeds that necessary to support propagation of fish, shellfish, and wildlife and recreation in and on the water. (401 KAR 5:030, Section 3).

Federal wild river areas is a classification of the Wild and Scenic Rivers Act (PL 90-542) and means those rivers or sections of rivers that are free of impoundments and generally inaccessible except by trail, with watersheds or shorelines essentially primitive and waters unpolluted. These represent vestiges of primitive America.

Federal scenic river areas is a classification of the Wild and Scenic Rivers Act (PL 90-542) and means those rivers or sections of rivers that are free of impoundments, with shorelines or watersheds still largely primitive and shorelines largely undeveloped, but accessible in places by roads.

Figure 17: Wild and Scenic River

In the Red River Gorge, 19.4 miles of the Red River running through Clifty Wilderness is designated a Kentucky Wild River, and the first National Wild and Scenic River in Kentucky.

Image Credit: www.rivers.gov/wsr-red.html

Outstanding National Resource Waters (ONRW) are waters that meet the requirements for an outstanding state resource water classification and are of national ecological or recreational significance. They are listed in 401 KAR 5:030, Section 3.

Reference Reach Waters are streams representative of a large number of similar streams within a definable geographic area. Reference reach waters are the least impacted within an ecoregion and provide an estimate of attainable conditions for similar streams within the same ecoregion and watershed. These streams are included in the list of exceptional waters in 401 KAR 5:030, Section 3(2).

Wetlands

Source: "Classification of Wetlands and Deepwater Habitats of the United States" (Cowardin, Carter, Golet, LaRoe; December 1979); and EPA

What is a Wetland?

Generally, wetlands are lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface (Cowardin, et al). Wetlands vary widely because of regional and local differences in soils, topography, climate, hydrology, water chemistry, vegetation, and other factors, including human disturbance. There is no single, correct, indisputable, ecologically sound definition for wetlands, primarily because of the diversity of wetlands and because the demarcation between dry and wet environments lies along a continuum (Cowardin, et al). Indeed, wetlands are found from the tundra to the tropics and on every continent except Antarctica.

For regulatory purposes under the Clean Water Act, the term wetlands means "those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas."

Yet, wetlands are much more than the muddy places we once thought of as a barrier to moving from one place to another, or taking up land that could otherwise be farmed. Wetlands were also once thought to be a problem causing flooding in some areas. In the past, they were promptly drained of their water, and streams near them were straightened. Ironically, our harsh treatment of wetlands proved more costly than ever thought. Wetlands commonly provide many important benefits, such as those listed below. Also, see the figure on the next page for a depiction of some of the ways in which wetlands work to our benefit.

- Flood Control. Some wetlands, particularly those on floodplains and in coastal areas, function in flood control by storing and decreasing the velocity of excess water during heavy rainfall. As water flows into wetlands, it naturally loses velocity as it collects and continues to spread out. Wetland vegetation provides another natural barrier to fast moving water and therefore aids in speed reduction of flood waters. The result of wetland activity during floods is often *decreased damage* to surrounding areas.
- Silt Catchers. When flood waters are slowed by wetlands, they drop sediments among the roots and stems of the plants. This protects downstream waterbodies by preventing a dangerous build-up of gill clogging and egg damaging silt.

§ Erosion Control. Wetlands buffer shorelands against erosion because they are often located between water bodies and high ground. The roots of wetland vegetation bind the soil, putting a hold on it, while the plants themselves absorb the impact of waves.

§ Water Cleaners and Suppliers. Wetlands fed by groundwater further transport the water to streams that may otherwise dry up during warm summers or times of drought. Furthermore, wetlands absorb water during the wet seasons and gradually release it during dry seasons, and can thereby refill aquifers and other drinking water supplies. Wetlands not only supply water, but they cleanse it. When water enters a wetland, the wetland acts like a giant kidney, filtering out impurities before allowing the water to leave. The wetland vegetation plays a large role in this filtering system as it uses its roots and stems to trap and gather sediments comprised of both chemicals and nutrients.

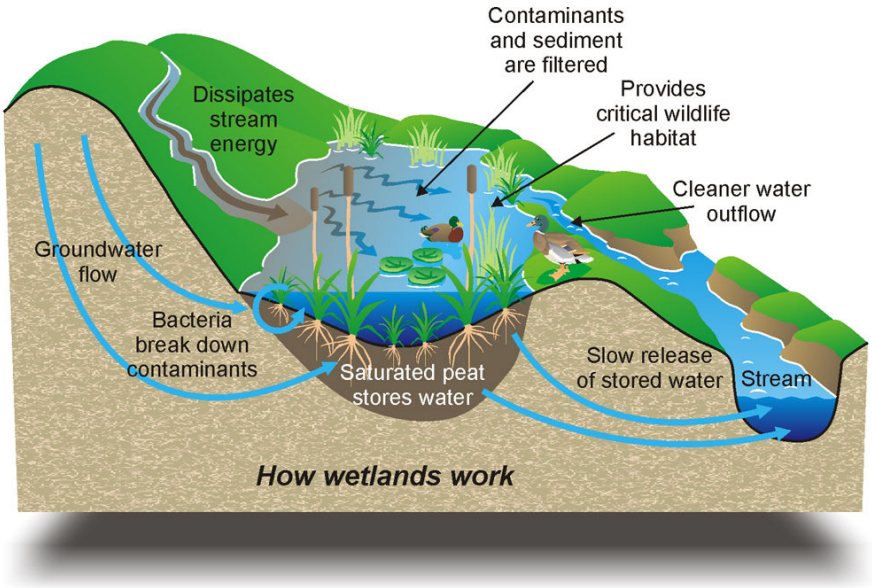


Figure 18: How wetlands work

Image Credit: bragi0.com/Wetlands.dwt

§ Vital Habitats. There is more life in one acre of a healthy wetland than there is in one acre of almost any other kind of habitat. Wetlands are virtual havens for the endangered species of the United States; about 35% of all plants and animals listed as threatened or endangered in the United States either live in wetlands or depend on them in some way.

§ Nature's Nurseries. The thick vegetation found in wetlands provides a safe haven and plentiful food supply for the young of many fish, crabs, and other small creatures who begin life in wetlands, remain safely until they are not so vulnerable, and move to open waters when the time comes.

- Migration Stations. Many migratory birds, including ducks, herons, sandpipers, and eagles, "visit" wetlands in the fall and/or spring to feed while en route to their summer and winter destinations. A large number of birds nest and winter in wetlands as well, but the greatest bird populations are recorded during migration.
- Recreation and Economy. Hunting, fishing, hiking, boating, photographing, and bird watching opportunities are abundant in America's wetlands. According to the Terrene Institute, wetlands support an annual commercial fur and hide harvest of $300-$400 million and the 50 million people who observe and photograph birds and wildlife in wetlands spend close to $10 billion a year supporting their hobby.
- Inspiration. Nature in all forms inspires us to protect our environment and express ourselves through the arts. For centuries, naturalists, artists, photographers, and writers have recorded their experiences with America's wetlands and continue to do so in this, the age of technology through new mediums such as internet web pages and documentaries.

Learn more about wetlands and their value from US EPA's Wetlands Web site feature: America's Wetlands.

Estuaries

Source: National Estuarine Research Reserve System website (March 2011)

What is an Estuary?

In the most general terms, an estuary is an ecosystem, comprising both the biological and physical environment, which has developed in a region where rivers meet the sea and fresh flowing river water mingles with tidal salt water to become brackish, or partly salty. However, there are also several types of wholly freshwater ecosystems that have many similar characteristics to what we think of as traditional brackish estuaries.

For example, along the Great Lakes, river water with very different chemical and physical characteristics mingles with lake water in coastal wetlands that are affected by tides and storms, just as estuaries are along the oceanic coasts. These freshwater "estuaries" also provide many of the ecosystem services and functions that brackish estuaries do, such as serving as natural filters for runoff and serving as nursery grounds for many species of birds, fish, and other animals.

Whether they are salt or fresh, estuaries have certain properties that make them unique and extremely valuable as part of the larger natural system as well as to human health and well-being.

Types of Estuaries

Most estuaries are less than 10,000 years old. Estuaries are typically classified by their existing geology or their geologic origins (in other words, how they were formed). The five major types of estuaries – classified by their geology – are coastal plain, bar-built, delta system, tectonic, and fjord.

Freshwater Estuaries

Although freshwater estuaries do not contain saltwater, they are unique combinations of river and lake water, which are chemically distinct. Unlike brackish estuaries where mixing processes are typically tidally driven, freshwater estuaries are most often storm-driven. In freshwater estuaries the composition of the water is often regulated by storm surges and subsequent seiches (vertical oscillations, or sloshing, of lake water).

Estuarine Benefits

- Estuaries act like huge sponges, buffering and protecting upland areas from crashing waves and storms and preventing soil erosion. They soak up excess water from floods and stormy tidal surges driven into shore from strong winds.
- Estuaries provide a safe haven and protective nursery for small fish, shellfish, migrating birds, and coastal shore animals. In the US, estuaries are nurseries to more than 75% of all fish and shellfish harvested.
- People enjoy living near estuaries and the surrounding coastline. They sail, fish, hike, swim, and enjoy bird watching. An estuary is often the center of a coastal community.

Although estuaries provide many benefits to humans, these unique ecosystems are under threat from human activities. See the figure below for more information.

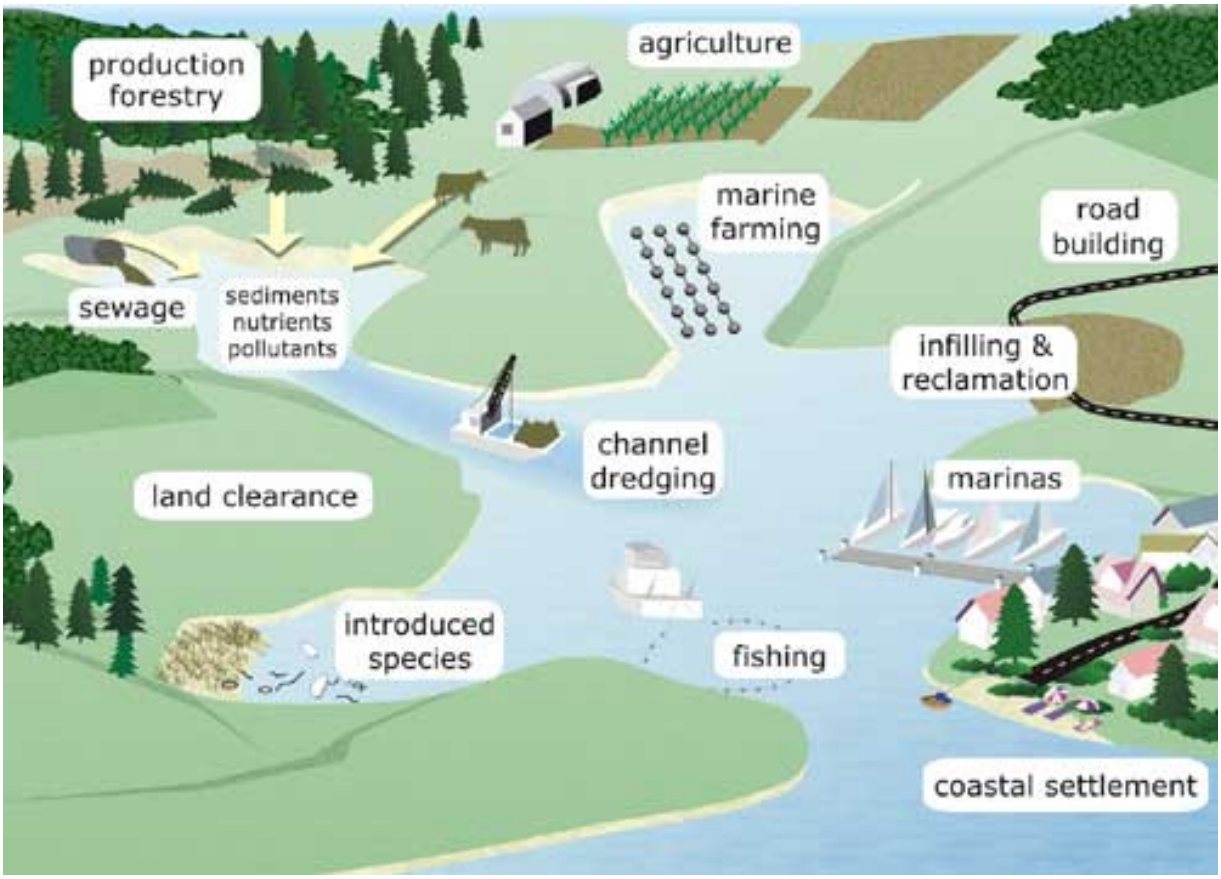


Figure 19: Threats to estuaries

Image Credit: www.ew.govt.nz/environmental-information/Our-coast/Coastal-ecosystems/Estuaries/Threats-to-estuaries/

Water Savers: 50 Ways to Live with Less

Source: Special Report from ConsumerReports.org

Water conservation makes sense for environmental and economic reasons even if your area is not facing a water shortage. The average U.S. household uses 350 gallons of water per day, according to the American Water Works Association. Depending on the region, households use 20 to 62 percent of that total outdoors on lawns, pools, and such. Saving water outdoors, then, can really make a dent. The figure to the right shows water usage inside the average American home. Indoors, homeowners can reduce water use by about 30 percent by installing more-efficient water fixtures and regularly checking for leaks.

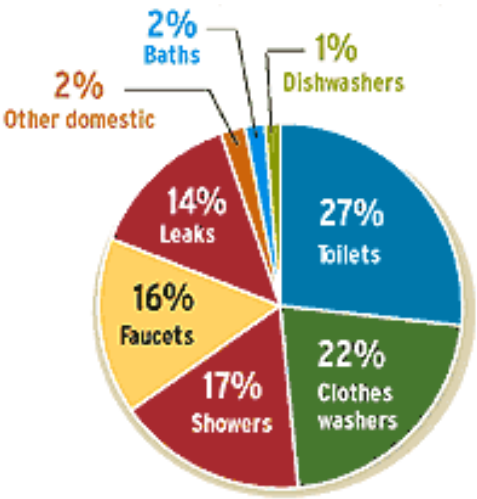


Figure 20: How we use water
Here's where the water goes in our homes (numbers are rounded).
Image Credit: American Water Works Association and AWWA Research Foundation.

Below, Consumer Reports has listed 50 ways to live with less water. Most can be done for little or no cost. Keep in mind that making just one or two changes can make a major difference. Fixing leaky toilets, for instance, can save more than 100 gallons of water a day.

Kitchen and Laundry

No- or low-cost actions

- Run the dishwasher and the washing machine only when they are full.
- Don't prerinse dishes before loading the dishwasher. You'll save as much as 20 gallons a load, or 6,500 gallons per year. Our tests show prerinsing doesn't improve cleaning. Or, use the rinse-and-hold dishwasher feature for a less-than-full load before later in the week running the full load. The rinse-and-hold option uses about 2 gallons of water.
- When your dish load is small, fill the sink or basin and wash dishes by hand. Place soapy dishes on a rack, and spray rinse.
- Wash vegetables and fruits in a bowl or basin using a vegetable brush; don't let the water run.
- Use recycled water on plants. Sources: water left from boiled eggs, tea kettles, and washed vegetables; dehumidifier condensate.

- Investigate using waste water from the washing machine, bathtub, or sink on outdoor, inedible plants. States vary in their approach to so-called gray-water use. New York, for example, bans it out of concern that the byproducts of cleaning, say, can contaminate soil. Check with your state or municipality's department of environmental protection for details. (We don't recommend using gray water to wash the car; small particles in the water may scratch the paint.)
- Steam vegetables instead of boiling. Besides using less water, you'll retain more vitamins in the food.
- Chill drinking water in the refrigerator instead of running the faucet until the water is cold.
- Defrost food in the refrigerator, not in a pan of water on the counter or in the sink. Besides saving water, it's less likely to breed bacteria.

Long-term investments

- Make your next dishwasher a water-saver. The most water-efficient models Consumer Reports has tested use only about 5 gallons per wash--less than half that of the least water-efficient models (see Consumer Reports May 2002 dishwasher report, available to subscribers only).
- Make your next clothes washer a water-saver. The most water-efficient Consumer Reports has tested, the front-loading Kenmore (Sears) Elite HE 3t, uses only about 30 gallons for a large, 20-pound wash load, about the same amount that many machines use for an 8-pound load. (Look for a July 2002 report on washers.)

Bathroom

No- or low-cost actions

- Fix toilet leaks. Plumbing leaks as a whole account for 14 percent of water consumed in the home, according to a study sponsored by the American Water Works Association, an industry trade group. One cause is toilet leaks, which often go unnoticed. To determine whether your older toilet is leaking, add food coloring to the tank water and let it sit 15 minutes. If it appears in the bowl, there's a leak.
- Don't use your toilet as a wastebasket.
- Turn off the faucet when brushing teeth. Faucets can spout 2 to 3 gallons per minute.

- Time your showers to keep them short; this can cut 5 to 7 gallons per minute with an old-style showerhead. Or turn off the water while lathering.
- Displace some water in the toilet tank of an older toilet with a capped plastic liter bottle filled with water.
- Also for older toilets: Consider installing an early-closing flapper valve, which prevents a part of the tank from emptying.
- When taking a bath, close the drain before turning on the water. And fill it half as full as you usually do; you could save 10 to 15 gallons.
- Install new showerheads and low-flow faucets. Showerheads that were made after January 1994 must use no more than 2 1/2 gallons per minute (see Consumer Reports May 1998 remodeling report, available to subscribers only).

Long-term investments

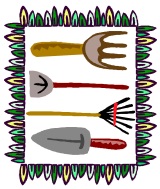
- Replace older toilets with low-flow models. Some of them work very well, and they use less than half as much water as older models (see our May 1998 remodeling report, available to subscribers only). Consumer Reports has more reports on low-flow toilets available.
- Insulate your water heater and all hot-water pipes so you waste less while waiting for the hot water to flow.

Lawn, Patio, Driveway

No- or low-cost actions

- Fix leaky hoses and hose connections.
- Outfit all hoses with automatic shutoff (pistol-style) nozzles.
- Adjust hose attachments and sprinkler heads to emit large drops instead of fine spray, which evaporates more easily.
- Use a sprinkler timer, but don't overwater. Your local Department of Agriculture Cooperative Extension office can advise on what's appropriate for your region.
- Position sprinklers so they're not watering driveways and walkways.
- Hand-water with a hose where possible. Homeowners who water with a handheld hose can use one-third less water outdoors than those who use automatic sprinklers.

- Water during the coolest time of the day to reduce evaporation. Don't water when it's windy.
- Adjust your lawnmower to cut grass to a height of 3 inches or more. Taller grass encourages deeper roots and shades the soil to reduce moisture loss.
- If faced with watering restrictions, concentrate first on shrubs and trees, then perennials, then annuals. Unless your lawn is newly planted, let it grow brown; it will likely perk up as the weather cools.
- Sweep driveways, sidewalks, and steps instead of hosing them down.



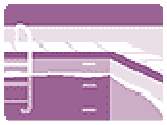
Garden

No- or low-cost actions

- Add compost or peat moss to soil to improve its water-holding capacity.
- Mulch beds to a depth of 2 to 3 inches to reduce evaporation.
- To ensure that potted plants and flowers use water most efficiently, consider adding polymer crystals to soil in flowerpots to make it more absorbent, or buy special patio pots that allow water to reach roots efficiently. Such products are available at garden retailers.
- Choose drought-tolerant plants. Perennials include coneflower, butterfly weed, goldenrod, iris, and daylily. Annuals include verbena, dianthus, and cosmos. Herbs include thyme, rosemary, lavender, aloe, and many species of salvia. As for shrubs, conifers generally use less water in the summer than flowering shrubs. Trees include Japanese pagoda, Kentucky coffee, honey locust, and Eastern red cedar.
- Put off planting major shrubs. Even drought-tolerant varieties need a season or more of intensive watering to properly develop root systems.
- Reduce the size of your vegetable garden. Plant tomatoes and herbs in pots and use recycled water on them.
- Consider buying a rain barrel to catch water from your gutter system to use on plants. A barrel that holds about 60 gallons--and includes a childproof lid--costs about $100. Most have a spigot for easy dispensing on your plants.

Long-term investments

- Consider drip irrigation for flowers and shrubs. These systems, which can be purchased at home-improvement and garden retailers, are lengths of thin plastic tubing perforated at intervals and placed at the base of plants where the water can most efficiently penetrate to the roots.
- Develop a long-term landscaping plan that uses drought-tolerant plants. Wise landscaping can save up to 50 percent of the water you use outdoors. Change the composition of your lawn to drought-tolerant strains.



Recreation

No- or low-cost actions

- If you're allowed to fill your pool, use a cover to reduce evaporation.
- Fill pool a few inches lower than usual.
- Avoid water toys that need a constant stream of water.
- Don't install or use fountains or other water ornaments unless they use recycled water.
- Consider buying a pool filter that uses less water during filter cleaning. Some new filters waste no water at all.

Other Tips

No- or low-cost actions

- Check your home's water meter for system leaks. Turn off all faucets and water-using appliances, then read your meter. Make sure no one uses water for 30 minutes, then take a second reading. If the dial has moved, you have a leak in a toilet or water pipe.
- Participate in water-conservation programs in hotels and motels. Many lodging establishments give you ways to inform the maid that you don't need fresh towels every day, which will save on their laundry-water usage.
- If you use a diaper service for your baby, consider switching to disposables. In regions where water is a bigger issue than landfills, this may be the more ecologically sound choice.

- Patronize commercial car washes that use recycled water. Or, wash at home, if watering restrictions permit, using a bucket of water, not a running hose.
- Investigate further. Check out *www.h2ouse.org*, a web site developed by the California Urban Water Conservation Council in partnership with the Environmental Protection Agency (EPA). Another good source of information: WaterWiser *www.waterwiser.org*, a site of the American Water Works Association in cooperation with the EPA and the Bureau of Reclamation.

Websites for Further Research and Study

Benthic Macro-invertebrates in Our Water	www.epa.gov/bioindicators/html/benthosclean.html
Canon Envirothon	www.envirothon.org
Clean Water Act	www.epa.gov/lawsregs/laws/cwa.html
Common Water Measurements	ga.water.usgs.gov/edu/characteristics.html
Drinking and Ground Water	www.epa.gov/safewater/kids/cycle.html
EPA Student Center for Water	www.epa.gov/gateway/science/water.html
EPA WaterSense	www.epa.gov/WaterSense
EPA NPS Outreach Toolbox	cfpub.epa.gov/npstbx/index.html
EPA Low Impact Development	www.epa.gov/owow/NPS/lid
Georgia Envirothon	www.georgiaenvirothon.org
Globe Hydrology	www.globe.gov/sda/tg/globetg.html
Groundwater Aquifers	ga.water.usgs.gov/edu/earthgwaquifer.html
Groundwater Foundation	www.groundwater.org
H_2ouse – Water Saver Home	www.h2ouse.org
Hydrologic Cycle	ga.water.usgs.gov/edu/watercyclesummary.html
Kentucky Division of Water	water.ky.gov
Kentucky Water fact sheets	water.ky.gov/Pages/FactSheets.aspx
Kentucky Water Laws	water.ky.gov/Pages/Regulations.aspx
Low Impact Development (LID Center)	www.lid-stormwater.net/background.htm
LID (NRDC)	www.nrdc.org/water/pollution/storm/chap12.asp
National Estuarine Research Reserve System	www.nerrs.noaa.gov
NOAA Guide to NPS Pollution	oceanservice.noaa.gov/education/tutorial_pollution
Ohio Watershed Network	ohiowatersheds.osu.edu
Properties of Water	ga.water.usgs.gov/edu/waterproperties.html
Riparian Benefits	www.on.ec.gc.ca/wildlife/factsheets/fs_habitat-e.html#riparian

The Water Project	thewaterproject.org/why_water.asp
USA Water Pollution	www.epa.gov/ebtpages/watewaterpollution.html
USGS Physical & Chemical Properties of H_2O	ga.water.usgs.gov/edu/waterproperties.html
Water Basics	ga.water.usgs.gov/edu/mwater.html
Water Conservation USA	www.waterconservationusa.org
Water Crisis and Facts	water.org
Water Cycle	ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/hyd
Watersheds	www.epa.gov/owow/watershed/whatis.html
Watershed, Locate Yours	cfpub.epa.gov/surf/locate/index.cfm
Water Use USA	ga.water.usgs.gov/edu/wateruse.html
Water Wiser	www.waterwiser.org
Wetlands	www.epa.gov/owow/wetlands