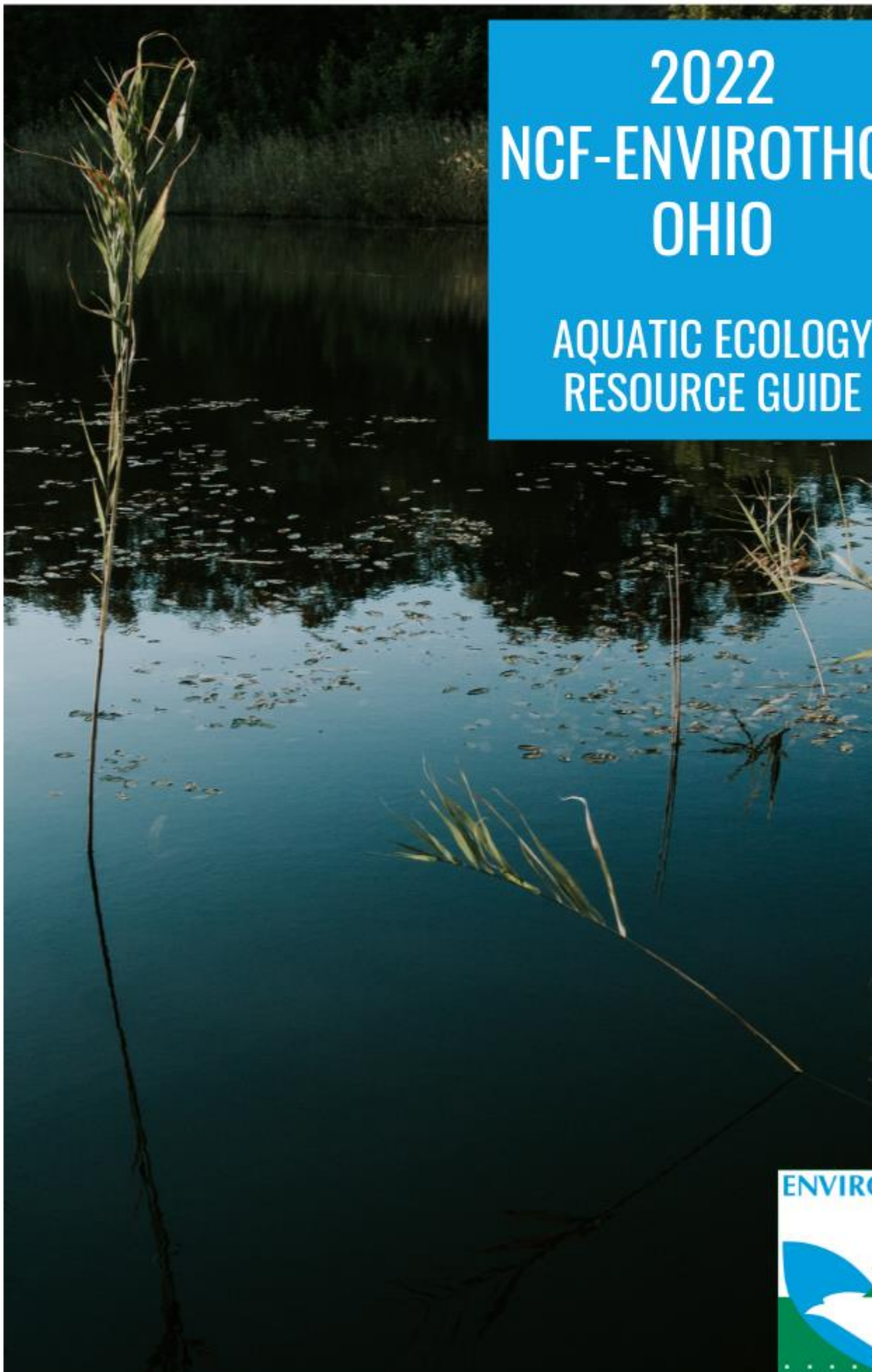

2022 NCF-ENVIROTHON OHIO

AQUATIC ECOLOGY RESOURCE GUIDE

ENVIROTHON

OHIO 2022

2022 NCF-Envirothon Ohio

Aquatic Ecology Study Resources

Key Topic 1: Aquatic Species

1. Categorize different types of aquatic plants based on their adaptations.
2. Describe the role of cyanobacteria in aquatic ecosystems and their role in harmful algal blooms.
3. Identify the ecological niches of organisms.
4. Identify common aquatic macroinvertebrates and their pollution tolerances and complete a Pollution Tolerance index.
5. Identify aquatic invasive species.

Study Resources

Resource Title	Source	Located on
Wetland Plant Adaptations	*Erin Dorset, 2022*	Pages 3-4
Harmful Algal Blooms in Ohio Waters	*Ohio Sea Grant, 2010*	Pages 5-8
Biological Monitoring Instructions for Stream Monitors	*Izaak Walton League of America, 2022*	Page 9-16
Ohio Field Guide to Aquatic Invasive Species	*Tory Gabriel, John Navarro, and Eugene Braig, 2018*	Pages 17-20

Study Resources begin on the next page! →

Wetland Plant Adaptations

by Erin Dorset, Wetland Monitoring & Assessment Program

Saltmarsh Cordgrass (***Spartina alterniflora***)

Wetland plants live a tough life. They are often under water for significant periods of time, meaning that they are frequently deprived of oxygen. Wetland plants also need to remain stable in the soil if they deal with fast moving water that ebbs and flows. Those that live in marine or estuarine areas are under even more stress simply because they need to be able to deal with saltwater! So how are wetland plants able to survive and reproduce under these difficult conditions? If you've ever seen a saltmarsh in Delaware, then you've probably seen saltmarsh cordgrass. It grows in the areas in saltmarshes that are relatively low in elevation, meaning that they are flooded at every high tide. This plant has to deal with saltwater, and lots of it! It is also what's known as a halophyte, which is a plant that can tolerate saltwater conditions. This grass actually has salt glands so that it can secrete all of the excess salt out (Figure 2). If you look carefully at its leaves, you can sometimes actually see the salt crystal secretions! Some other saltmarsh plants have this ability too, such as spike saltgrass (*Distichlis spicata*).

Arrow Arum (*Peltandra virginica***)**

The name of this plant is fitting, because its leaves look like large arrowheads. Arrow arum likes to live in tidal freshwater marshes, lakes, and ponds where the water is shallow. This plant has evolved an interesting and effective way of reproducing while living in the water. The fruits, which look like greenish berries, fall into the water when they are ripe. Once they are in the water, the coating around the fruits swells and eventually bursts. After the coating bursts, the berries are capable of floating on the surface of the water. The berries can then release seeds, which sink to the ground below the water to eventually germinate and grow new plants. Because the berries can float on the water, seeds can disperse for plants to grow in new areas. Arrow arum knows how to work with the water!

Bald cypress (*Taxodium distichum***)**

Bald cypress trees are deciduous conifers that grow in swamps and in floodplains along rivers and streams. They are southern trees, so Delaware is the farthest north that they grow naturally! How is it that a big tree can withstand so much water? Well, bald cypress trees have specialized root structures called pneumatophores—commonly called "knees"—that grow vertically out of the ground and water (Figure 4). Scientists believe that these knees help get air to roots that are under water. They might also help stabilize the tree in very watery conditions.

Cattails (*Typha* species)

Cattails are one of the most well-known wetland plants because they are widespread and easily recognizable with their brown, “tail-like” flowering structures There are two species of cattail; the broadleaf cattail is native (*Typha latifolia*), while the narrowleaf cattail (*Typha angustifolia*) is invasive. Both species are commonly found in marshes, shallow ponds, ditches, and wet meadows.

These areas often have standing water, and cattails have evolved a way to cope with that. Cattails have something called aerenchyma in their leaves, stems, and roots. Aerenchyma are basically open spaces that allow oxygen to travel from the air, to the leaves and shoots, and down to the roots and rhizomes (underground root-like stems) that are underwater. This keeps the parts of the plant that are submerged happy! They also help keep cattails upright in water because they keep the leaves fairly stiff. If you cut a cattail leaf open, you can actually see the aerenchyma in the leaves! Many other herbaceous wetland plants share this same adaptation to survive in wetland environments.

Ohio Sea Grant Fact Sheets

Harmful Algal Blooms in Ohio Waters

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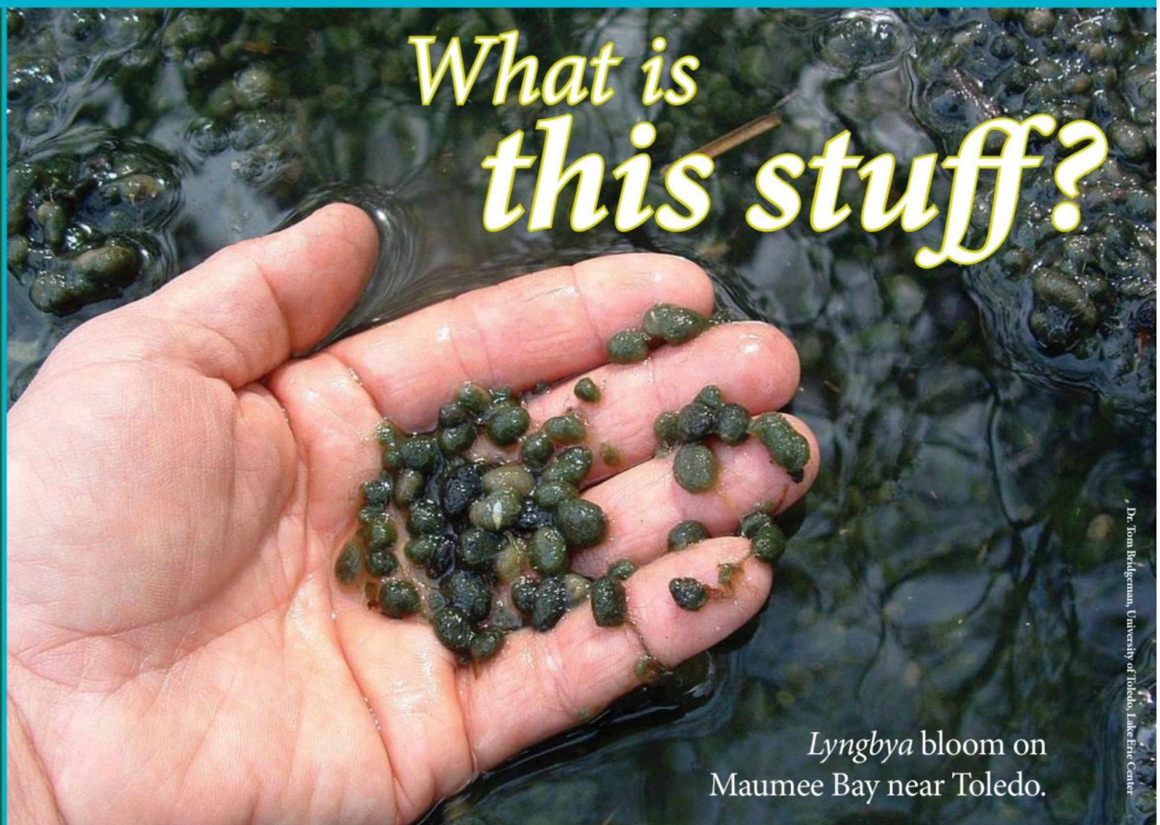


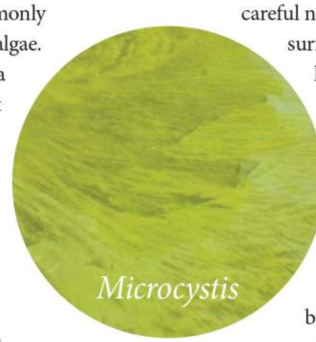
Lyngbya bloom on Maumee Bay near Toledo.

Harmful algal blooms (HABs) are so named because many produce poisons (or toxins) that can cause illness or irritation—sometimes even death—in pets, livestock, and humans. An algal **bloom** is an abundant or excessive growth of algae. Most HABs are caused by **planktonic** bacteria, which are suspended in the water and rely on currents to move them. The term "algal" is a little misleading because the organisms that normally make up HABs are actually **cyanobacteria**, which are commonly referred to as "blue-green algae," and are not true algae.

Like plants and true algae, cyanobacteria have a pigment called **chlorophyll** that captures sunlight to **photosynthesize** sugars for energy. Aquatic plants and algae require nutrients, especially phosphorus and nitrogen, from the water or sediment to grow. Unlike most plants and true algae, many cyanobacteria are able to pull and use (or **fix**) nitrogen from the atmosphere using specialized cells called **heterocytes**.

Cyanobacteria can be distributed throughout the water or they can float to form scums on or near the surface. The cells of many cyanobacteria group together to grow in **colonies**. Blooms can look like slicks of opaque, bright green paint, but closer inspection often reveals the grainy appearance of individual colonies. While most HABs in Ohio will appear greenish or sometimes black, cyanobacterial blooms can have a wide variety of appearances; some may appear blue-green, purple, red, white, or brown.

Not all algal blooms or surface scums are HABs. Be careful not to confuse cyanobacterial surface scums with the small and harmless aquatic plants called duckweeds. Some true algae like *Cladophora* can also create large blooms with the right nutrient and light conditions. Such blooms can be a serious nuisance and cause environmental problems but do not generate the toxins associated with many cyanobacteria. Nuisance blooms of green algae are not addressed in this fact sheet.



Microcystis

This project was funded in part through the Lake Erie Protection Fund. The LEPF is supported by the voluntary contributions of Ohioans who purchase the Erie… Our Great Lake *license plate featuring the Marblehead Lighthouse:* ***lakeerie.ohio.gov***

Many HAB-forming organisms are native to Ohio but only cause problems when environmental conditions—often human-induced conditions—favor them. Lake Erie's most prevalent HAB-forming organisms include *Anabaena*, *Aphanizomenon*, and *Microcystis* (this trio is sometimes known as "Annie, Fannie, and Mike"). There are several common, often visible cyanobacteria that make up HABs in Ohio:

Microcystis

- Globular colonies that can adjust their buoyancy to move up and down through the water column
- Cannot fix nitrogen from the atmosphere
- Most dominant cyanobacteria in Ohio's Lake Erie waters

Anabaena

- Colonies of hair-like filaments that can be planktonic or form mats along the bottom or near shore
- Can fix nitrogen from the atmosphere using specialized cells

Aphanizomenon

- Colonies of planktonic filaments that often bundle together
- Can fix nitrogen from the atmosphere using specialized cells
- Sometimes sold as a dietary supplement. Consuming could be dangerous because this supplement is not regulated and may contain cyanobacterial toxins. *Consumers beware!*

Cylindrospermopsis

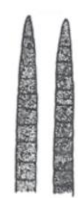
- Colonies of planktonic filaments that distribute through the water
- Can fix nitrogen from the atmosphere using specialized, teardrop-shaped cells
- A recent invader to Ohio's Lake Erie waters and Buckeye Lake

Lyngbya

- Colonies of clustered filaments, usually visible to the naked eye that often form dense mats along the bottom that float to the surface later in the growing season
- Lacks specialized cells but still fixes nitrogen from the atmosphere
- One of Ohio's recently problematic species (specifically *Lyngbya wollei*, also known as *Plectonema wollei*), especially on Maumee Bay near Toledo

Nostoc

- Colonies of filaments that usually clump into a green, gelatinous, "marble-like" ball
- Can fix nitrogen from the atmosphere using specialized cells
- Sold as a dietary supplement. Consuming could be dangerous because this supplement is not regulated and may contain cyanobacterial toxins. *Consumers beware!*



Planktothrix (also known as *Oscillatoria*)

- Colonies of planktonic filaments that distribute through the water
- Lacks specialized cells but still fixes nitrogen from the atmosphere
- Dominates recent HABs on Grand Lake St. Marys and is very common to Ohio's inland lakes and reservoirs

What causes HABs to form?

Extensive HABs have been observed in Lake Erie, the Ohio River, and many inland Ohio water bodies. They can occur almost anywhere there is water: lakes, ponds, stormwater retention basins, rivers, streams, or reservoirs.

Knowing what triggers HABs is key to reducing their occurrence and impacts. HABs may be minimized, and some completely avoided, by reducing the nutrients and pollutants added to the water.

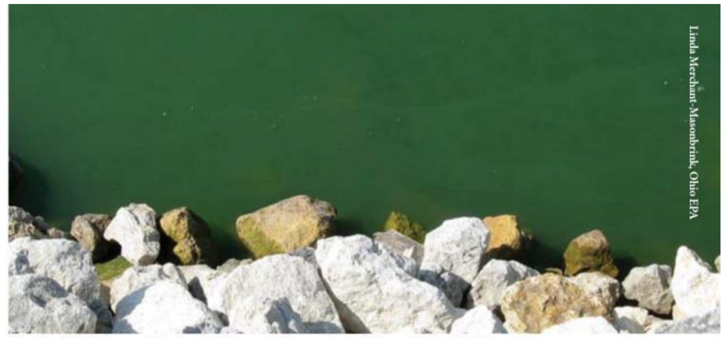
Factors that can contribute to HABs include:

- excess nutrients (phosphorus or nitrogen),
- sunlight,
- low-water or low-flow conditions,
- calm water (low-wind conditions),
- warmer temperatures,
- low salinity, and
- selective grazing (avoiding cyanobacteria) by zooplankton or zebra/quagga mussels.

Many of these factors can occur simultaneously in Lake Erie and Ohio's inland waters. Nutrients that contribute to HABs and other algal blooms (mostly phosphorus and nitrogen) come from many sources, including agriculture, lawn fertilizers, wastewater treatment plants, sewer overflows, leaking septic systems, and precipitation. Forests and wetlands are natural filtering and buffering zones. As wetlands have been depleted, pollutants and excessive nutrients have more easily entered our waters, where they potentially fuel algal blooms. Low oxygen and some biological activities can also recycle nutrients stored by the system and thus fuel blooms.

Because many HAB-forming species can use nitrogen from the atmosphere, they are often very successful in systems with low nitrogen concentrations where plants and true algae might not do so well. When a resource or nutrient is scarce enough that growth is directly linked to its abundance, that nutrient is considered **limiting**. Lake Erie algal growth, for example, is phosphorus—rather than nitrogen—limited. In Maumee Bay, *Microcystis* growth over the summer is closely related to the summer flow of the Maumee River, which presumably is because it brings more phosphorus into the lake to fertilize blooms. Low light availability (because of sediment input from the river and resuspended lake sediment) protects *Microcystis* from too much sunlight (which can kill it). Low light minimizes competition from other algal species by shading them out (see Dr. Tom Bridgeman's work in *Twine Line* Vol. 31, No. 3 at ***ohioseagrant.osu.edu/_documents/twineline/v31i3.pdf***).

So, what's the problem?



Linda Merchant-Masonbrink, Ohio EPA

Planktothrix bloom distributed through the water of Grand Lake St. Marys.

Harmful algal blooms can cause taste and odor problems in drinking waters, pollute beaches with scums, reduce oxygen levels for fish and other animals, cause processing problems for public water supplies, and may generate toxic chemicals. Cyanobacteria can cause a range of problems for recreation and the environment, but at their worst they can cause health problems because of their ability to produce toxins.

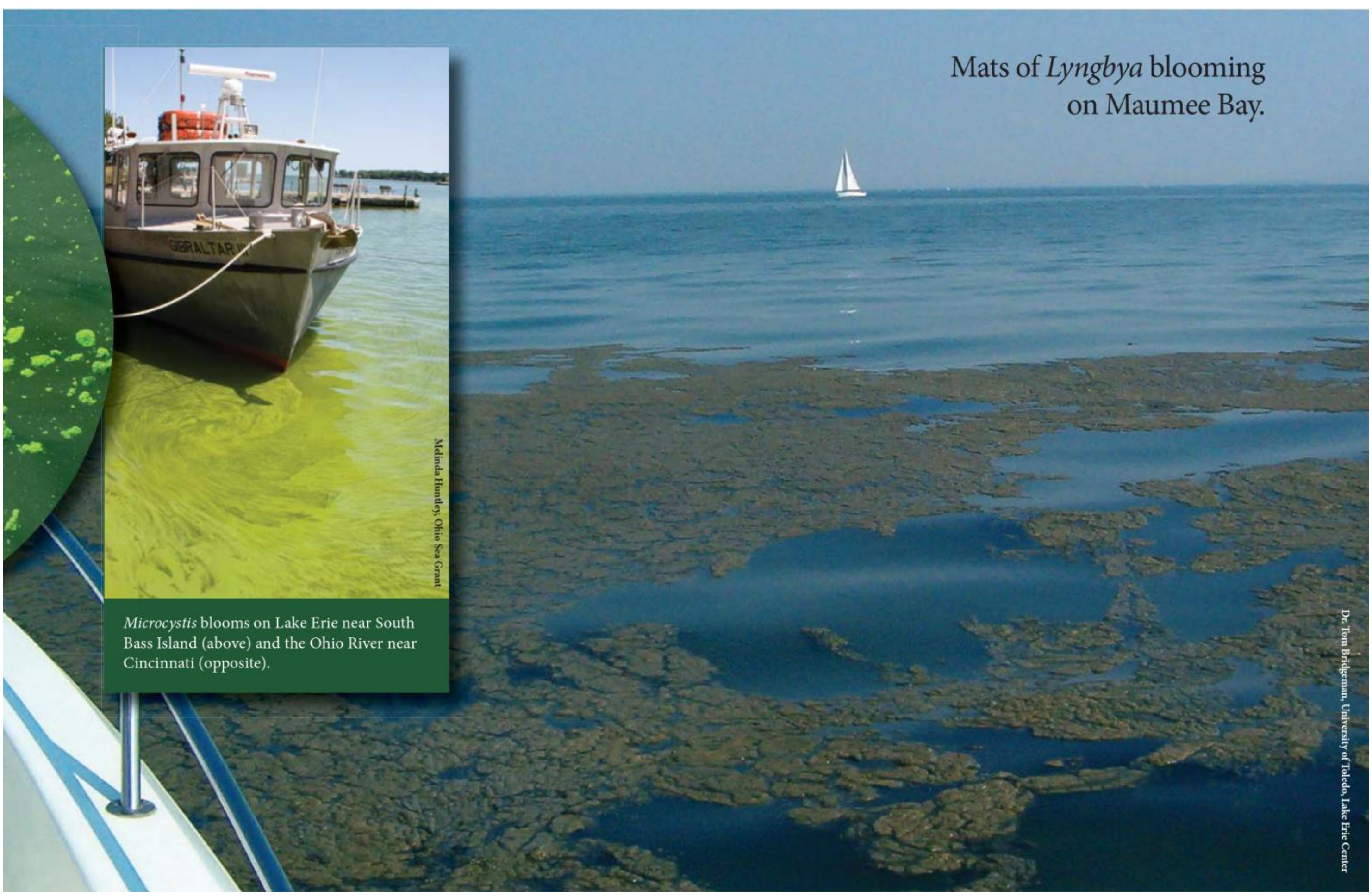
More than 40 freshwater species of HAB-forming cyanobacteria are known to make toxins. The three main classes of toxins produced by cyanobacteria are: 1) nerve toxins (or **neurotoxins**); 2) liver toxins (or **hepatotoxins**); and 3) skin toxins (or **dermatotoxins**), which may cause itching, rashes, or other allergic reactions.

The presence of cyanobacteria does not necessarily mean that toxins are being produced. The level of toxicity depends on the strains present and environmental factors (i.e., the amount of nutrients, light, temperature, stress, etc.). HAB toxicity also depends on the sensitivity, the age, and the sex of the animal or person that consumes or comes into contact with the toxin.

The World Health Organization (WHO) has developed provisional guidelines for HABs that may impact human health (Table 1). Microcystin, a hepatotoxin produced by *Microcystis* and some other cyanobacteria, is the only HAB toxin for which sufficient information exists to formulate a guideline. Increased monitoring of public drinking water should occur whenever microcystin levels reach 1 part per billion (ppb). Potential risk to human health from recreational contact is considered low at microcystin concentrations up to 4 ppb and moderate at 20 ppb.

Table 1. *World Health Organization (2003) provisional guidelines for threats to human health from recreational contact with cyanobacteria.*

Human-health risk	Cell concentration (per milliliter)	Chlorophyll *a* concentration
Low	< 20,000 cells	1-10 ppb
Moderate	20,000-100,000 cells	10-50 ppb
High	> 100,000 cells	Visible scums



Mats of *Lyngbya* blooming on Maumee Bay.

Dr. Tom Bridgeman, University of Toledo, Lake Erie Center

Melinda Huntley, Ohio Sea Grant

Microcystis blooms on Lake Erie near South Bass Island (above) and the Ohio River near Cincinnati (opposite).

What can I do about it?

How do I keep my family and pets safe?

- Avoid contact with waters that have HAB advisories posted or anywhere the water is pea green, has a floating bright green scum, or is generally discolored. *When in doubt, stay out!*
- Immediately rinse family members, pets, and yourself after swimming in natural waters. HABs cannot always be seen, smelled, or tasted.
- Never allow your family members or pets to drink lake or river water. Besides HABs, natural waters can contain other pathogens that cause illness.
- It is not advisable to use natural waters as a residential water source. Lax attention to residential filtration systems can cause periodic exposure to HABs and other pathogens.
- Never cook with natural water from areas suspected to have a HAB. Boiling water will not eliminate HAB toxins!
- Consider minimal consumption of fish fillets from water bodies experiencing a HAB event. Research has indicated toxins are greatest in internal organs but also can be found in fillets. At a minimum, remove the skin from the fillets and wash thoroughly prior to cooking, being sure not to use natural water as the source.
- If anyone becomes ill after swimming, seek medical attention immediately! Seek veterinary assistance if a pet appears ill.
- Know the signs of HAB poisoning:
    - o Humans: numbness of lips, tingling in fingers and toes, dizziness, headache, rash or skin irritation, abdominal pain, diarrhea, and vomiting.
    - o Pets: weakness, staggering, convulsions, difficulty in breathing, and vomiting.

Watch for posted HAB warnings!

How can I help prevent HABs and toxin release?

- Excess nutrients like phosphorus and nitrogen from watershed sources are major contributing factors to HABs. You can limit the addition of nutrients by:
    - o Using lawn and plant fertilizers sparingly. Do not over-fertilize or over-water after applying fertilizer. If possible, use a phosphorus-free fertilizer.
    - o Regularly checking and maintaining your septic system, as damaged or improperly working systems can cause nutrient loading to nearby waters.
    - o Preventing surface runoff from agricultural and livestock areas.
    - o Not allowing large concentrations of Canada geese to set up residence. Their waste can cause excessive nutrients to enter waters.
    - o Maintaining native plants along the shoreline and in as much of the watershed as possible. These plants are excellent filters of nutrients and are essentially maintenance-free.
- Do not treat established HABs with algaecides (like copper sulfate) because toxins can be released from the dying cells.
- In small lakes and ponds experiencing annual HABs or that are at high risk for such blooms, install a bottom aeration system. These systems reduce the amount of phosphorus recycled by a pond and can reduce the severity of and sometimes prevent HABs.

How can I report a HAB?

- Contact the Ohio Department of Health: ***www.odh.ohio.gov***
- Contact the Ohio Environmental Protection Agency (EPA)
    - o Inland Lakes/HAB Program Coordinator: ***www.epa.ohio.gov/dsw*** or 614.644.2001
- Contact your local watershed coordinator: ***ohiowatersheds.osu.edu/groups***

What are additional sources of HAB information?

- Ohio EPA HAB information for Ohio Lakes: ***www.epa.ohio.gov/dsw/inland_lakes/index.aspx***
- National Oceanic and Atmospheric Administration, Great Lakes HAB Web page: ***www.glerl.noaa.gov/res/Centers/HABS***
- U.S. Centers for Disease Control and Prevention, Harmful Algal Blooms Web page: ***www.cdc.gov/hab***
- World Health Organization, a guide to toxic cyanobacteria in water: ***www.who.int/water_sanitation_health/resourcesquality/toxicyanbact***
- U.S. Geological Survey, guidelines for sampling cyanobacteria in lakes and reservoirs: ***water.usgs.gov/owq/FieldManual/Chapter7/7.5.html***

Note: Numerous states have factsheets and/or web pages on cyanobacteria or blue-green algae.

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Biological Monitoring Instructions for Stream Monitors

ROCKY BOTTOM SAMPLING

The Rocky Bottom Sampling method is intended for volunteers sampling streams that have rocky bottoms or riffles. A kick-seine net – a finely meshed net with supporting poles on each side – is the best tool to use for collecting macroinvertebrates in rocky bottom streams. The League's Rocky Bottom Sampling method recommends using a kick seine net that is 3-feet square with 1/32-inch mesh. The 1/32-inch mesh net will provide you with a large sample because it captures younger, and therefore smaller, organisms of each species, and some state and local government agencies require use of the 1/32-inch mesh.

Select a riffle that is a shallow, fast-moving area of water with a depth of 3 to 12 inches and cobble-sized stones (2 to 10 inches) or larger. Before entering the stream, record observations about riffle composition on the back of the Biological Monitoring Data Form.

Place the kick-seine net at the downstream edge of the riffle. Place rocks on the bottom edge of the net to secure it tightly against the streambed so that no organisms escape under the net. Don't allow any water to flow over the top of the net either — organisms can escape over the net. Also, if water is flowing over the top of the net, the water level is too high for safe monitoring.

Monitor the streambed for a distance of three feet upstream of the kick-seine and across the width of the net. Firmly and thoroughly rub your hands over all rock surfaces to dislodge any attached insects for 40 seconds. After you have rubbed off any macroinvertebrates, carefully place each large rock outside of your three-foot sampling area. Stir up the bed with your hands and feet until the entire area has been searched. All exposed and detached organisms will be carried into the net. Then, for 20 seconds, use the toe of your shoe to jab the streambed with a shuffling motion, moving towards the net. Disturb the first few inches of sediment to dislodge burrowing organisms.

Before removing the net, rub any rocks that you used to anchor the net to the stream bottom and remove the rocks from the bottom. Firmly grab the bottom of the net so that your sample does not fall from the net, and then remove it from the water with a forward-scooping motion. The idea is to remove the net without allowing any insects to be washed under or off it.

Placing a white trash bag or white sheet under the net before separating the sample will catch any tiny organisms that may crawl through the net. Use a watering can or spray bottle to periodically water your net. The organisms will stop moving as the net dries out. Occasionally wetting the net will cause the organisms to move, making them easier to spot. Watering the net is especially important on hot, dry days. Place the net on a flat, bright area, out of direct sunlight. Using tweezers or your fingers, separate all the organisms from the net and place them in your collecting container, which should be half full of water from the stream.

ROCKY BOTTOM SAMPLING EQUIPMENT

- Kick-seine
- “Field Guide to Aquatic Macroinvertebrates”
- A Guide to Aquatic Insects and Crustaceans
- Biological Monitoring Data Form
- Fahrenheit thermometer
- Two small magnifier boxes (optional)
- Magnifying glass (optional)
- Shallow plastic pan l Specimen jars or ice cube trays for sorting organisms
- Tweezers or forceps (optional)
- White sheet or plastic trash bag (optional) l Clipboard (optional)
- Camera (optional)
- Squirt bottle (optional)
- Glass vials for collecting macro invertebrate samples
- 70-percent alcohol for specimen preservation (optional)
- Old sneakers or sandals that secure to your feet
- Waders may be preferred in cold weather or for additional leg protection when water is cloudy

BIOLOGICAL MONITORING INSTRUCTIONS FOR STREAM MONITORS

Sort organisms into similar groups as you separate your sample. This will make your identification quicker when you are ready to record results. Plastic ice cube trays are helpful when sorting the catch. For example, put all organisms with legs in one section and all organisms with no legs in another section. Any organism that moves, even if it looks like a worm, is part of the sample. Look closely, since most aquatic macroinvertebrates are only a fraction of an inch long.

IDENTIFICATION

Once organisms are collected through either the Rocky Bottom or Muddy Bottom Sampling methods, they are sorted and identified. You can use IWLA’s “Field Guide to Aquatic Macroinvertebrates” or A Guide to Aquatic Insects and Crustaceans, both of which can be purchased through links on the Save Our Streams equipment page on the League’s website: iwla.org/sos. The League’s free Aqua Bugs app provides easy-to-follow instructions to help you identify your macroinvertebrates. Search for it in the Apple Store and Google Play Store.

Izaak Walton League macroinvertebrate guides provide a general overview of the macroinvertebrate types found across the United States. The composition of macroinvertebrate populations varies depending on local geography and geology. Try contacting your local environmental protection agency or universities for more information about local macroinvertebrates. Local experts might be able to share additional field guides that are specifically designed for your area.

Not all organisms in your stream are listed in the guides. For instance, macroinvertebrates such as whirligig beetles, water striders, and predaceous diving beetles are not included on the survey sheet. They are surface breathers and do not provide any indication of water quality.

When beginning your identification, ask yourself the following questions:

- How large is the organism?
- Is the body long and slender, round, or curved?
- Does the organism have any tails? How many?
- Does the organism have any antennae?
- Does the organism have legs? How many? Where?
- Is the body smooth and all one section, or is it segmented (two or more distinct sections)?
- Does the organism have any gills (fluffy or plate-like appendages)? Where are the gills located? Sides, back, underside, under its legs?
- Does it have pinching jaws like a beetle larva?
- Are any legs or antennae missing because they were broken off in the net?
- What color is the organism?
- Does the organism swim underwater or remain on the surface?

When using the macroinvertebrate guides, read the descriptions for each organism. Sizes are provided for reference. However, if you catch a young macroinvertebrate that has just hatched and has not yet reached full size, it may be smaller than indicated in the guides. Specimens can be put into magnifying boxes to ease identification.

During identification of macroinvertebrates, tally/record your results on the biological monitoring tally sheet. Make sure you have collected at least 100 individual macroinvertebrates. If you did not, complete a second sampling. Once all collected macroinvertebrates have been identified and counted, check off each species in the Biological Monitoring Data Form table and add the total of each species found. Add the number of check marks in each column — Sensitive, Less Sensitive, and Tolerant — and multiply by the index value at the bottom of that column. Add the subtotal for each column to arrive at your total index value, which provides the final water quality rating. Include information relating to habitat and physical parameters of the stream. Return the organisms to the stream after sampling is completed.

You will notice that neither the number of each macroinvertebrate identified nor the total number of macroinvertebrates found affects the final water quality rating. This is because the stream health survey is based primarily on the diversity, not the numbers, of individual organisms found. However, changes in the numbers of each macroinvertebrate can indicate changes in stream health over time, which is why it is important to monitor a site over the entire year.

The League updates the sensitivity rankings for macroinvertebrates based on the most recent scientific research.

BIOLOGICAL MONITORING DATA FORM QUESTIONS

The Biological Monitoring Data Form also includes questions about the land and vegetation surrounding the stream. These questions help characterize the quality of stream habitat and its ability to support a healthy population of stream organisms. The land use information also paints a picture of the stream for other people who might review your data. Guidelines for correctly answering these questions are given below. Record the answers based on the area that is upstream from your monitoring site; generally, you should record the data for the area you can see. For land use information, include uses for one mile upstream from your site or the section of stream you have adopted. If necessary, take a walk or consult a map for this information.

<u>Fish populations:</u> Different fish have different tolerances to pollution. The type of fish present may indicate the type of water quality expected. If you collect fish but don't recognize the type, write a description of the fish on the data form or take a picture to use for later reference. You can find fish identification charts or experts to help with fish identification at local schools, agencies, libraries, or online.

<u>Barriers to fish movement:</u> The absence of certain fish types may be due to a dam or other large obstacle, not because of water quality. Note on your survey form if the dam is upstream or downstream from your monitoring site and how far away. Waterfalls should only be recorded if they are large enough that a fish could not reasonably jump over them or swim around them. Usually, waterfalls of a few feet or less are not impediments to the upstream movement of fish.

<u>Surface water appearance:</u> You may check more than one of the colors listed but not all of them. Note if strange colors are present throughout the stream or only in one section, such as immediately below a discharge pipe or highway culvert.

<u>Streambed deposit (bottom):</u> Record the over-all appearance of the stream bottom. If the streambed does not have any apparent coating, you may note it as "other" and write in "normal." Odor: Note any unusual odors. Odors may come from natural processes or may indicate potential water quality problems.

<u>Stability of streambed:</u> An unstable streambed can mean that soil is eroding from the bottom of the stream and may indicate water quality problems. When standing in the stream, determine how frequently the bed sinks beneath your feet.

<u>Algae color:</u> Algae feels slimy. You will notice it as you rub rocks during monitoring. A great deal of algae may indicate too many nutrients in the water. Sometimes more algae will appear in the spring after snowmelt releases extra nutrients into the stream. However, take note of the percent and type of algae present in the stream to make sure it is not increasing over time.

<u>Algae located:</u> Estimate the percentage of stream bed that is covered by algae. Algae is often present in small quantities in healthy streams. Excess algae may indicate water quality problems.

<u>Stream channel shade:</u> Over the course of the day, estimate what percentage of the stream channel is shaded by streamside trees, shrubs, and grasses. Shading helps keep water cool and can be beneficial for aquatic life.

Streambank composition: Remember to look at both sides of the stream's banks. When questions ask for a percentage, use the information for both the left and right bank and combine values. For instance, if one side of the bank is completely bare due to erosion while the other side is well vegetated, you should record the percent of bank coverage as 50 percent. When recording total percentages of shrubs, grasses, and trees, you should also look at both sides of the bank. However, if one side has artificial structures such as rock riprap or concrete, you will have to account for such ground cover. For instance, if the left side of the bank is not vegetated, you cannot have more than 50 percent of shrubs, grasses, and trees total when those values are added together.

Streambank erosion: Again, look at both sides of the bank to determine the percentage of soil erosion.

Riffle composition: This question refers to the 3x3-foot area of the stream sampled for Rocky Bottom Sampling techniques with a kick-seine net. Do not fill out this question when using the muddy bottom sampling technique. If you used a kick-seine to conduct the Rocky Bottom Sampling method, answer this question before you disturb the site. The organisms you collect are most abundant in riffles composed of predominantly cobble-sized stones (more than 70 percent cobbles is a good riffle habitat). Start with the largest rocks first when recording bed composition. If you don't have any boulders (rocks larger than 10 inches), record cobble-sized stones and continue until your percentages equal 100 percent. A typical riffle in a medium-gradient stream might be recorded as 5 percent boulders, 65 percent cobbles, 15 percent gravel, 10 percent sand, and 5 percent silt. Ranges are given on the survey form for the rock sizes. For the smaller rock sizes, remember that silt feels like talcum powder and sand feels gritty. If your riffle had 40 percent silt, 6 10 percent gravel, and no cobbles, you should either find another station to monitor or switch to the Muddy Bottom Sampling method.

Land uses in the watershed: The survey form asks if land use impacts within a one-mile radius of your sampling site are high (H), moderate (M), slight (S), or none (N). Although these questions are somewhat subjective, determining the impact is easy and straightforward.

- Note "H" for a land use if it: — Comprises the majority of land in the watershed and is polluting the stream, such as a stream traveling through land that is being strip mined for coal. — Has a severe impact on stream quality even though the land use does not utilize a great deal of land, such as a construction site that has caused the stream to be full of silt.
- Note "M" if the land use is definitely contributing to stream degradation, but is not the major cause for degradation (or is one of many causes). For example, parking lot runoff and trash from a shopping mall may contribute significantly to stream pollution, but they may not be the only causes of stream degradation.
- Note "S" for a land use if its impacts only slightly pollute the stream. For example, although a farm may be present, good farming practices and conservation measures may mean the pollution impact is negligible.
- Note "N" if the land use is present but causing no pollution.
- If the land use is not present, do not write anything. Take the time to drive or walk through your watershed before filling out this section to determine if these land uses are present and impacting the stream.

When considering land use as the controlling factor in stream quality, look not just at the area visible from the stream but at all the land draining into the stream – the watershed. If the stream collects water from an intensely developed or agricultural area, do not be surprised if no organisms are found. Should this be the case, consider visiting a forested stream of the same size in the same watershed for sampling comparison. You might be surprised by the different types of organisms you find. You can identify a pollution source by sampling the stream at quarter-mile intervals upstream from the initial sampling point (where a pollution impact is suspected) until quality improves. The pollution sources should be identified somewhere between the point where degraded conditions were first found and the point where water quality improves. Comments: Use this space to record observations that are not noted elsewhere on the data form. This may include current and potential future threats to the stream's health.

STREAM PROBLEMS AND THEIR EFFECTS ON STREAM ORGANISMS

1. Physical Problems may include excessive sediment from erosion, street runoff, or discharge pipes. Sediment can create poor riffle characteristics, contribute to excessive flooding, reduce flow, change water temperature, and smother aquatic life. The result is usually a reduction in the number of macroinvertebrates in the study area.
2. Organic Pollution is from excessive human or livestock wastes or high nutrient enrichment from farm or yard runoff. The result is usually a reduction in the diversity of insects.
3. Toxic Pollution includes chemical pollutants such as chlorine, acids, metals, pesticides, and oil. The result is usually a reduction in the number of insects.

Observations:

- High diversity, high numbers; many sensitive species such as stoneflies, caddisflies, and mayflies - No problem; good water quality
- High diversity, low numbers - Possibly due to poor habitat conditions
- Low diversity, high numbers - Organic pollution (nutrient enrichment) or sedimentation; excessive algae growth from nutrient enrichment
- Low diversity, low numbers; or no bugs found but the stream appears clean - Toxic pollution (e.g., chlorine, acids, heavy metals, oil, herbicides, insecticides)

Biological Monitoring Data Form for Stream Monitors

MACROINVERTEBRATE COUNT

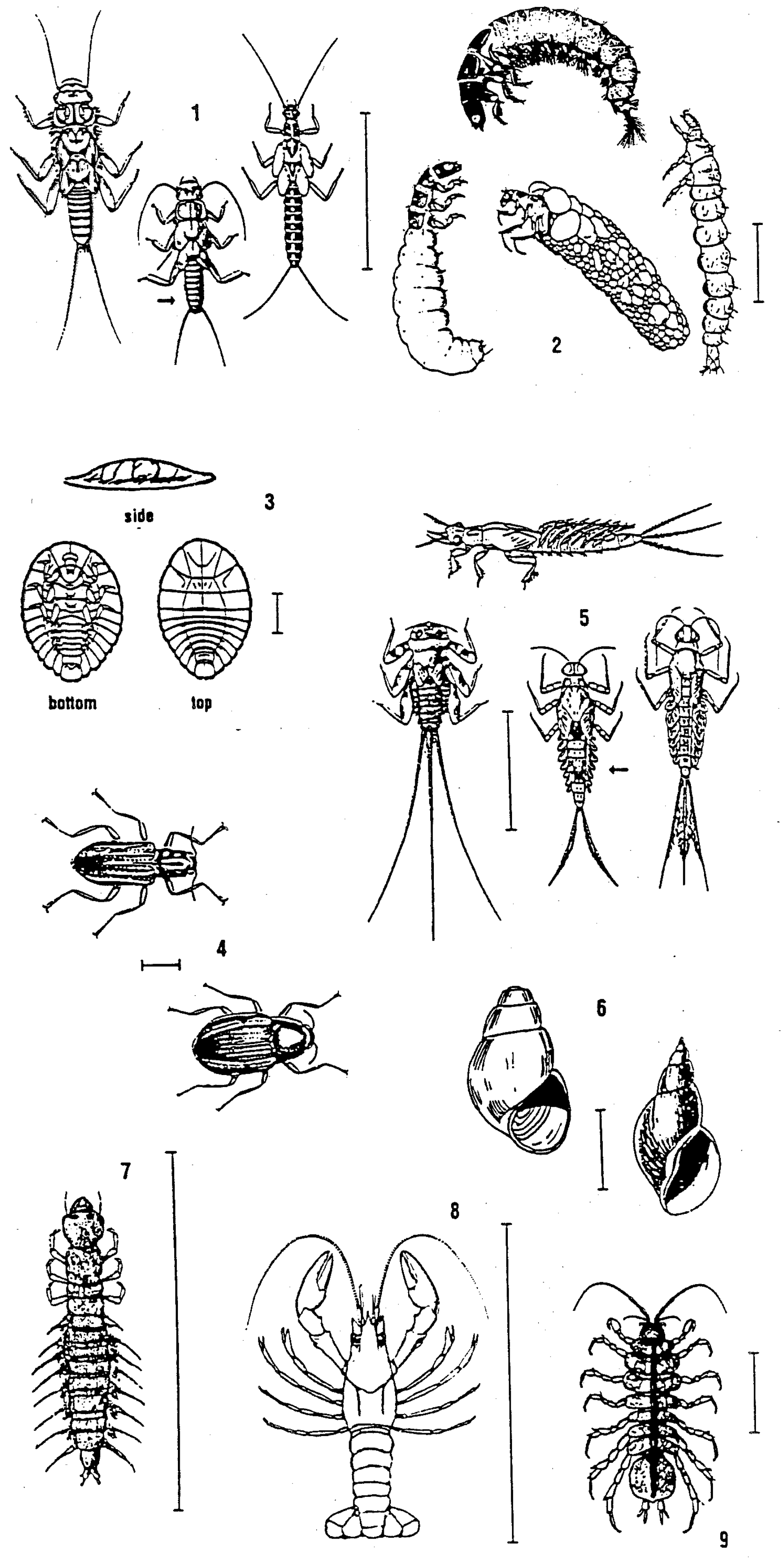
Please consult biological monitoring instructions on how to conduct the macroinvertebrate count. Use the attached tally sheet to track numbers of each macroinvertebrate found. Once sampling and identification are complete, place a check mark next to each type of macroinvertebrate identified and list the total number found. Add up the number of check-marks in each category (sensitive, less sensitive, tolerant) and multiply those numbers by the indicated index value.

Sensitive (Ex: ☑ 10 Caddisflies)	**Less Sensitive** (Ex: ☑ 2 Dobsonflies)	**Tolerant** (Ex: ☑ 3 Leeches)
☐ ________ Caddisflies (except net spinners) ☐ ________ Mayflies ☐ ________ Stoneflies ☐ ________ Watersnipe flies ☐ ________ Riffle beetles ☐ ________ Water pennies ☐ ________ Gilled snails	☐ __ Dobsonflies ☐ __ Fishflies ☐ __ Crane flies ☐ __ Damselflies ☐ __ Dragonflies ☐ __ Alderflies ☐ __ Crayfish ☐ __ Scuds ☐ __ Aquatic sowbugs ☐ __ Clams ☐ __ Mussels ☐ __ Common net spinning Caddisflies	☐ ________ Aquatic worms ☐ ________ Black flies ☐ ________ Midge flies ☐ ________ Leeches ☐ ________ Lunged snails
___# of check marks multiplied by 3 = ___	___# of check marks multiplied by 2 = ___	___# of check marks multiplied by 1 = ___
Now add the three totals from each column for your stream's index value. Total index value = ________________________ Total number of macroinvertebrates in sample: ________________________		

Compare the final index value to the following ranges of numbers to determine the water quality of the stream sample site.

WATER QUALITY RATING

_________ Excellent (> 22) _________ Good (17-22) _________ Fair (11-16) _________ Poor (< 11)



Bar lines indicate relative size

Stream Insects & Crustaceans

GROUP ONE TAXA

Pollution sensitive organisms found in good quality water.

1 *Stonefly: Order Plecoptera.* 1/2" - 1 1/2", 6 legs with hooked tips, antennae, 2 hair-like tails. Smooth (no gills) on lower half of body. (See arrow.)

2 *Caddisfly: Order Trichoptera.* Up to 1", 6 hooked legs on upper third of body, 2 hooks at back end. May be in a stick, rock or leaf case with its head sticking out. May have fluffy gill tufts on lower half.

3 *Water Penny: Order Coleoptera.* 1/4", flat saucer-shaped body with a raised bump on one side and 6 tiny legs on the other side. Immature beetle.

4 *Riffle Beetle: Order Coleoptera.* 1/4", oval body covered with tiny hairs, 6 legs, antennae. Walks slowly underwater. Does not swim on surface.

5 *Mayfly: Order Ephemeroptera.* 1/4" - 1", brown, moving, plate-like or feathery gills on sides of lower body (see arrow), 6 large hooked legs, antennae, 2 or 3 long, hair-like tails. Tails may be webbed together.

6 *Gilled Snail: Class Gastropoda.* Shell opening covered by thin plate called operculum. Shell usually opens on right.

7 *Dobsonfly (Hellgrammite): Family Corydalidae.* 3/4" - 4", dark-colored, 6 legs, large pinching jaws, eight pairs feelers on lower half of body with paired cotton-like gill tufts along underside, short antennae, 2 tails and 2 pairs of hooks at back end.

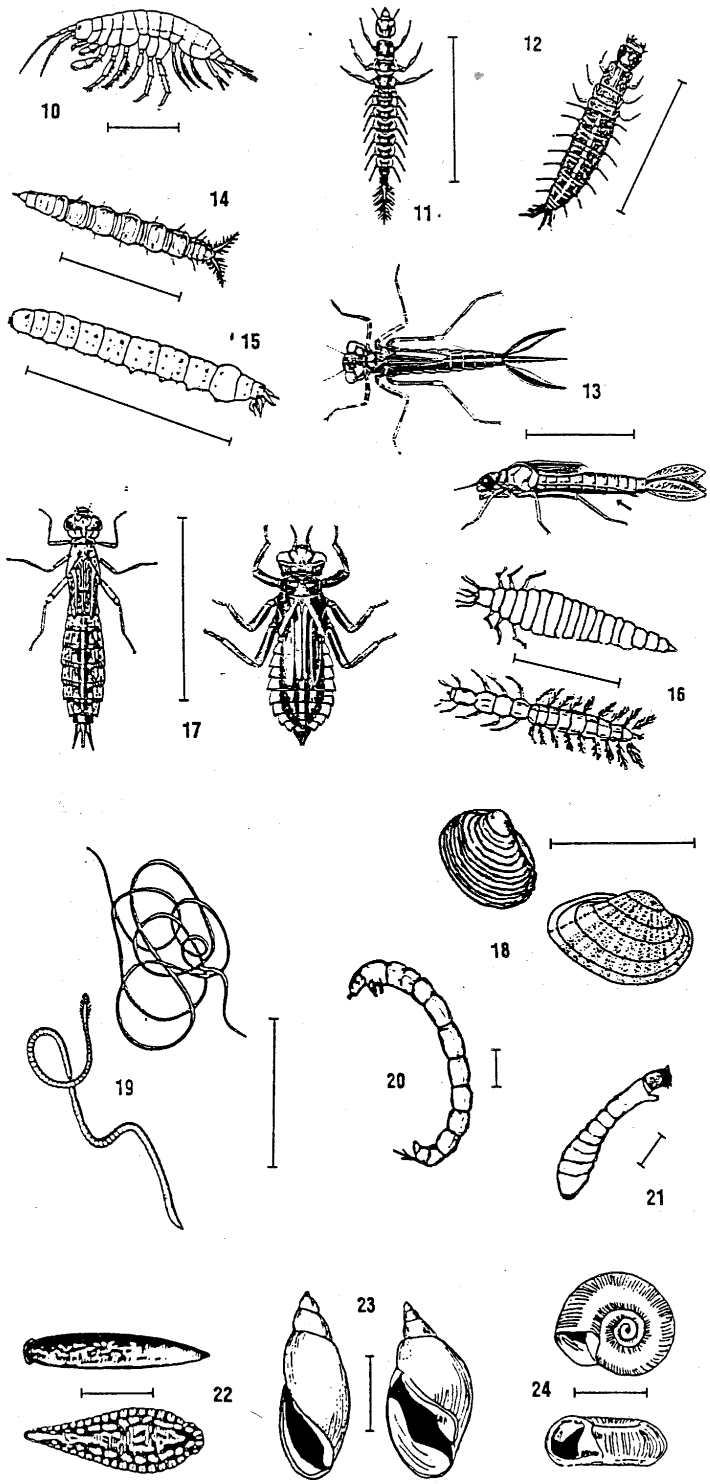
GROUP TWO TAXA

Somewhat pollution tolerant organisms can be in good or fair quality water.

8 *Crayfish: Order Decapoda.* Up to 6", 2 large claws, 8 legs, resembles small lobster.

9 *Sowbug: Order Isopoda.* 1/4" - 3/4", gray oblong body wider than it is high, more than 6 legs, long antennae.

Save Our Streams
Izaak Walton League of America
1401 Wilson Blvd. Level B
Arlington, VA 22209



Bar lines indicate relative size

GROUP TWO TAXA continued

10 *Scud: Order Amphipoda.* 1/4", white to grey, body higher than it is wide, swims sideways, more than 6 legs, resembles small shrimp.

11 *Alderfly larva: Family Sialidae.* 1" long. Looks like small hellgrammite but has 1 long, thin, branched tail at back end (no hooks). No gill tufts underneath.

12 *Fishfly larva: Family Corydalidae.* Up to 1 1/2" long. Looks like small hellgrammite but often a lighter reddish-tan color, or with yellowish streaks. No gill tufts underneath.

13 *Damselfly: Suborder Zygoptera.* 1/2" - 1", large eyes, 6 thin hooked legs, 3 broad oar-shaped tails, positioned like a tripod. Smooth (no gills) on sides of lower half of body. (See arrow.)

14 *Watersnipe Fly Larva: Family Athericidae (Atherix).* 1/4" - 1", pale to green, tapered body, many caterpillar-like legs, conical head, feathery "horns" at back end.

15 *Crane Fly: Suborder Nematocera.* 1/3" -2", milky, green, or light brown, plump caterpillar-like segmented body, 4 finger-like lobes at back end.

16 *Beetle Larva: Order Coleoptera.* 1/4" 1", light-colored, 6 legs on upper half of body, feelers, antennae.

17 *Dragon Fly: Suborder Anisoptera.* 1/2" - 2", large eyes, 6 hooked legs. Wide oval to round abdomen.

18 *Clam: Class Bivalvia.*

GROUP THREE TAXA

Pollution tolerant organisms can be in any quality of water.

19 *Aquatic Worm: Class Oligochaeta.* 1/4" - 2", can be very tiny; thin worm- like body.

20 *Midge Fly Larva: Suborder Nematocera.* Up to 1/4", dark head, worm-like segmented body, 2 tiny legs on each side.

21 *Blackfly Larva: Family Simulidae.* Up to 1/4", one end of body wider. Black head, suction pad on end.

22 *Leech: Order Hirudinea.* 1/4" - 2", brown, slimy body, ends with suction pads.

23 *Pouch Snail and Pond Snails: Class Gastropoda.* No operculum. Breathe air. Shell usually opens on left.

24 *Other snails: Class Gastropoda.* No operculum. Breathe air. Snail shell coils in one plane.

Creeping Water-primrose - *Ludwigia peploides*

Species at a Glance: Creeping water-primrose, also called floating primrose-willow, is an herbaceous, perennial, wetland plant whose sprawling stems usually grow flat along mud or a water surface. Although native to parts of North America, this species has become invasive outside of its native range, including Washington State where it is listed as a Class A noxious weed because of its ability to form dense floating mats that can displace native aquatic plants and wetland grasses. Identification Leaves: Alternately arranged leaves are clustered together and vary in size and shape from long and slender to round or egg shape. They are up to 9 cm (3.5 in) long. Leaf bases taper to a stalk that ranges from 2.5–4 cm (1–1.5 in) long. The leaves have smooth margins and are either hairless or have long, soft hairs. The leaves are dark green with light green pinnate veins. Flowers: Showy flowers have five bright yellow petals that are 1–1.5 cm (0.4–0.6 in) long and bloom late July to August. The flowers occur on long stalks arising from the leaf axils. Fruit/Seeds: Capsules contain many small (1 mm) seeds. Stems/Roots: Flowering stems are either floating or lying on the ground. Sprawling stems, which can reach a length of 2.7 m (9 ft), are fleshy, reddish in color, and either hairless or slightly hairy.

Moneywort - *Lysimachia nummularia*. Species at a Glance: Moneywort, also called pennywort and creeping jenny, is an herbaceous low growing perennial that is part of the primrose family. It forms a thick creeping ground cover with stems that can reach up to 0.6 m (2 ft) long and form a mat-like growth about 5–10 cm (2–4 in) tall. Identification Leaves: Evergreen to semi-evergreen leaves are simple, opposite, and oval in shape, resembling small coins that typically reach 0.6–4 cm (0.25–1.5 in) in length. Upper surfaces of the leaves have widely scattered, glandular, red to black dots. Flowers: Small, cup-shaped, yellow flowers have five petals and small dark reddish to black spots. They are hermaphroditic and typically solitary in the leaf axils. Blooming usually occurs from June to August, but some may not bloom at all. Fruit/Seeds: Small seeds are located within capsular fruits that are about as long as the sepals. Stems/Roots: Smooth stems are thin, reddish, and creep along the ground, rooting where the leaf nodes come in contact with the soil. The stems branch frequently and often form mats.

Narrowleaf and Hybrid Cattails *Typha angustifolia, Typha x glauca*

Species at a Glance: Cattails are aquatic perennials that grow in wetland areas and produce distinct velvety brown spikes of flowers. The two most widespread species in the United States are the native common cattail, also called the broadleaf cattail (*Typha latifolia*) and the non-native narrowleaf cattail (*Typha angustifolia*). The hybrid cattail is produced when these two species cross, giving it characteristics of both species. Identification Leaves: Long, narrow (5–15 mm [0.2–0.6 in]), flat leaves originate at the base of the stem from each shoot and spread outward as they rise into the air, reaching 0.9–1.8 m (3–6 ft) in height. Flowers: Dense, fuzzy, cylindrical spikes are located at the end of the stem. The flower spike is divided into two distinct male and female inflorescences, separated by a 3–10 cm (1.2–3.9 in) gap. Lighter brown male flowers (staminate) are located above the female (pistillate) flowers, which are often green during bloom, turning dark brown during seed maturation. Fruits: Cigar-shaped fruits about 5–15 cm (2–5.9 in) long contain soft, downy seeds about 1 mm (0.04 in) in size. Stems: The flowering stalks are light green, stiff, round in cross-section, and grow up to 3 m (10 ft) tall.

Purple Loosestrife *Lythrum salicaria*

Species at a Glance: Purple loosestrife is an upright perennial herb that can grow 0.9–3 m (3–10 ft) high, depending on environmental conditions. While gardeners might enjoy the brilliant purple display, its attractiveness doesn't outweigh the serious threat it poses to ecosystems in Ohio. Identification Leaves: The body of the leaf is lance-shaped or oblong, while the base is usually heart-shaped or rounded. Leaves are stalkless with smooth edges and are sometimes covered in fine, downy hairs. They reach 4–10 cm (1.6–3.9 in) in length and are usually paired and opposite each other down the stem, but can also be whorled in groups of three. Flowers: Paired, or clustered into 10–40 cm (3.9–16 in) long magenta-colored spikes. Each flower is complete, containing five to seven petals that can range in color from pink to purple-red, and blooms from June to September. Fruits: Two valve-shaped capsules that burst at maturity release seeds usually in late July or August. Stems/Roots: Mature plants can have 1–50 square, woody stems arising from a large central taproot. Stems are 4–6 sided, green to purple in color, and are often branching, giving the plant a bushy or woody appearance.

Yellow Iris *Iris pseudacorus*

Species at a Glance: This exotic member of the iris family, also called the yellow flag, is commonly found in wetlands in many regions of the United States. It is an emergent aquatic perennial with showy yellow petals that can grow on average 0.3–0.9 m (1–3 ft) tall, although some can reach up to 2.1 m (7 ft). Identification Leaves: Long, broad, flattened, and sword-shaped; usually dark green in color, pointed at the ends and overlapped at the base. Can grow up to 2.5 cm (1 in) wide. Flowers: There are usually 2–3 flowers on each stalk that have bright yellow to cream-colored petals with sepals outlined in purple and brown. They are 8–10 cm (3.1-3.9 in) in diameter and bloom June through August. Seeds: Numerous smooth, flattened seeds grow in small oblong shaped capsules, roughly 5 cm (2 in) long. Capsules grow in clusters at the base of the flower and have the ability to float. Roots: Fleshy and form from a single-branched stem. They are 10–30 cm (3.9–12 in) long.

Asian Clam - *Corbicula fluminea*

Species at a Glance: The Asian clam, also called the Asiatic clam, pygmy clam, or gold clam, is a small freshwater bivalve with two thick-hinged shells that rarely exceed the size of a quarter. It was first introduced to the west coast of the United States in 1924, possibly as a food item. By the 1970s, it occupied most of the Mississippi River Basin, the Gulf Coast, and the eastern United States. Identification: The shell is typically yellow-green to brown; however, darker morphs exist, usually in the southwestern United States. While the small shell averages 2.5 cm (1 in), it can reach up to 6.5 cm (2.6 in) long. The shell is thick, triangular in shape, and displays coarse, concentric growth rings. The inside of the shell is layered with white to light purple polished nacre and the teeth are finely serrated. Microscopic juveniles called veligers appear under a microscope in a D-shape less than 1 mm (0.04 in) in length.

Zebra Mussel - *Dreissena polymorpha*

Species at a Glance: The zebra mussel is a small, fingernail-sized, freshwater mollusk that attaches to hard objects and costs billions of dollars to control and remove. Since its discovery in the Great Lakes, it has quickly spread to become one of the most intrusive, prolific, and costly aquatic invaders in North America. In many open-water environments, they can be virtually impossible to eradicate once established. They are closely related to the invasive quagga mussel as both belong to the genus *Dreissena*, which makes them unrelated to our native mussels. Identification: Although the zebra mussel is named for the alternating light and dark bands present on the shell, color patterns can vary between black, brown, beige, and tan with white to yellow stripes or zigzagged patterns. The shell is triangular or D-shaped, with a straight midventral line and a prominent ridge on each valve that allows the mussel to sit upright on its ventral margin. While size is typically 2–2.5 cm (0.8–1 in) in length, some mussels can reach up to 5 cm (2 in). The sticky, thread-like projections, called byssal threads, are located toward the middle of the shell and help it attach to hard substrates. Eggs develop into round, microscopic larvae called veligers that free-float in the water column for up to five weeks before settling. Under polarized light, veligers appear to be marked with a dark “X”.

Common Carp - *Cyprinus carpio*

Species at a Glance: The common carp, which can live up to 50 years, is omnivorous, has a voracious appetite, and is one of the largest members of the minnow family. Varieties of common carp include mirror carp, leather carp, and koi, which is a type of common carp popular in small ponds and water gardens. Identification: These bronze, brassy, or yellow fish have spine-like rays at the front of the dorsal and anal fins, and are easily identified by two pairs of barbells on each side of the upper jaw. The body is heavy and stout, with large scales usually outlined in black. The head is short, with a rounded snout and a toothless, sucker-like mouth. Their average length is 25–55 cm (10–22 in) and they typically weigh 1–10 lbs., although some can reach up to 122 cm (48 in) long and weigh up to 40 lbs. or more.

2022 NCF-Envirothon Ohio
Aquatic Ecology Study Resources

Key Topic 2: Aquatic Ecosystems

6. Describe the structure of an aquatic ecosystem, including species, communities, and abiotic components.
7. Interpret results of water quality monitoring measures (such as dissolved oxygen, turbidity, *E coli* counts, pH, nutrient levels) and provide recommendations for best management practices.

Study Resources

Resource Title	Source	Located on
Lentic & Lotic Ecosystems	*Joan Reinbold, 2018*	Page 22
The Mississippi/Atchafalaya River System	*USEPA, 2021*	Pages 23-24
Types of Aquatic Plants and Animals in the Mississippi River	*G.D. Palmer, 2017*	Page 25
Abiotic Factors in Natural Wetlands	*Donald Miller, 2018*	Pages 26-27
Swamps	*New Hampshire PBS, 2021*	Pages 28-29
What is a Wetland?	*Ohio Wetlands, 2021*	Pages 30-31
Vernal Ponds	*Greg Lipps, 2021*	Page 32
Rivers and Streams: Life in Flowing Water	*Declan McCabe, 2011*	Pages 33-34
A Primer on Water Quality	*US Geological Survey, 2021*	Pages 35-36
Glossary of River Terminology	*Texas Parks and Wildlife, 2022*	Pages 37-42
Water: Monitoring and Assessment	*US EPA, 2021*	Pages 43-47
What Level of E. coli is Acceptable?	*New Hampshire Department of Environmental Services, 2021*	Page 48

<u>Study Resources begin on the next page!</u> ➡

Lentic & Lotic Ecosystems Updated March 13, 2018 *By Joan Reinbold*

Lentic ecosystem (also called the lacustrine ecosystem or the still water ecosystem) and lotic ecosystem (also called the riverine ecosystem) are two types of water ecosystems, the first dealing with still water ecosystems and the second dealing with flowing water ecosystems. Together, they are the two ecosystems that make up the study of freshwater ecology.

Lentic Features
A lentic ecosystem entails a body of standing water, ranging from ditches, seeps, ponds, seasonal pools, basin marshes and lakes. Deeper waters, such as lakes, may have layers of ecosystems, influenced by light. Ponds, due to their having more light penetration, are able to support a diverse range of water plants.

Lotic Features
A lotic ecosystem can be any kind of moving water, such as a run, creek, brook, river, spring, channel or stream. The water in a lotic ecosystem, from source to mouth, must have atmospheric gases, turbidity, longitudinal temperature gradation and material dissolved in it.
Lotic ecosystems have two main zones, rapids and pools. Rapids are the areas where the water is fast enough to keep the bottom clear of materials, while pools are deeper areas of water where the currents are slower and silt builds up.

Considerations
Like any ecosystems, lentic and lotic ecosystems can be destroyed through natural or human interaction. Lentic and lotic systems may succumb to such things as climate change, being dammed, drained, filled or undergo an invasive species invasion.

The Mississippi/Atchafalaya River Basin (MARB)

History

The Mississippi River originates as a tiny outlet stream from Lake Itasca in northern Minnesota. During a meandering 2,350-mile journey south to the Gulf of Mexico, the Mississippi River is joined by hundreds of tributaries, including the Ohio and Missouri Rivers. Water from parts or all of 31 states drains into the Mississippi River, and creates a drainage basin over 1,245,000 square miles in size. Before reaching the Gulf, the Mississippi meets up with its distributary, the Atchafalaya River.

This map of the MARB shows major tributaries to the Mississippi River and the general area of the hypoxic zone at its mouth.

The Mississippi/Atchafalaya River Basin (MARB), which encompasses both the Mississippi and the Atchafalaya River Basins, is the third largest in the world, after the Amazon and Congo basins. Parts or all of 31 states plus two Canadian provinces drain into the Mississippi River, totaling 41% of the contiguous United States and 15% of North America. Along with being the largest U.S. drainage basin, the Mississippi also creates borders for 10 states. The Mississippi River provides necessary resources to the United States and the world and has helped to shape American history and commerce, including tourism and the fishing industry. According to U.S. Census data, nearly 30% of Americans live in the MARB.

Prior to the Louisiana Purchase, the Mississippi River acted as the western border for the United States. The water way was first used for trade with Indian tribes when fur pelts were floated down the river from Ohio. Once steamboats were invented, the Mississippi River became an important mode of transportation that revolutionized river commerce. Manmade locks and dams were created to control flooding and create deeper waters for steamboats. However, this system made it more difficult for water to be absorbed and made flooding even more detrimental. The convenience of a trustworthy mode of transportation and a constant water supply encouraged agriculture, industries, and cities to spread to areas along the river. Productivity from these areas resulted in large amounts of nutrients being discharged from the river system into the Gulf of Mexico. These nutrients have contributed to hypoxia.

Image courtesy of The Historic New Orleans Collection Accession No. 1999.111.34

The natural capacity of the MARB to remove nutrients has been diminished by a range of human activities. The Mississippi is one of the most heavily engineered rivers in the United States. Over time, the character of the old river meanders and floodplains have been modified for millions of acres of agriculture and urbanization. Many of the original freshwater wetlands, riparian zones and adjacent streams and tributaries along the Mississippi have been disconnected from the river by levees and other engineering modifications. This has caused a loss of habitat for native plants and animals and has reduced the biological productivity of the entire river basin. Historically, the coastal marshes of Louisiana have provided a natural barrier against the erosion caused by the fierce storms which often come from the Gulf by neutralizing some of the flow energy of the water. This capacity has been reduced by channelization.

Over the years, traffic on the river has caused increased bank erosion, turbidity, sediment resuspension, and disruption of native species habitats. The increased amount of river dredging, levee building, and construction that comes along with this traffic impairs aquatic life in many ways by disturbing their habitat.

Types of Aquatic Plants and Animals in the Mississippi River Updated July 21, 2017

By G.D. Palmer

The Mississippi River is home to a variety of aquatic plants and animals in a complex, interconnected ecosystem. Aquatic plants provide food and shelter to many different species in the river, and can be as small as the single-celled algae. The Mississippi River features a range of animals, from invertebrates to fish, frogs and others.

Algae

According to the Iowa Department of Natural Resources, the Mississippi plays host to two major types of algae: green and blue-green. Green algae are the basic biological component of any healthy ecosystem; they create large colonies that can give the water a greenish cast. Blue-green algae are less desirable and are considered a nuisance algae. They're associated with stressed ecosystems and can cause unpleasant flavors in fish or kill entire populations.

Duckweed

This common free-floating plant has a single tiny leaf and roots that dangle in the water to suck up nutrients. As indicated by its name, duckweed is an important food source for many waterfowl.

Waterlilies

White waterlilies are a common site in the Mississippi River, and are composed of large, floating leaves with a leathery texture. They produce large white flowers on top of the leaves, and are rooted in the mud below.

Crayfish

Also called crawfish or crawdads, these crustaceans resemble small lobsters. They are primarily bottom feeders, and consume leavings from other animals, carrion and small animals. Both native and invasive crayfish live in the Mississippi River.

Catfish

Channel catfish are a common sight in the Mississippi River. They are the most numerous type of catfish. These fish can grow to surprising sizes, and stick primarily to the river bottom. They're notable for their tendency to strike many different kinds of bait, but they should be eaten rarely due to the danger of PCB (polychlorinated biphenyl) contamination.

Leopard Frog

These spotted frogs are also called meadow frogs. They live in and around the Mississippi River. They often serve as an environmental indicator species due to their susceptibility to pollutants and contaminants. They spend most of their time along the margins of streams and other bodies of water, and eat mostly insects, arthropods and other invertebrates.

Abiotic Factors in Natural Wetlands (Updated March 13, 2018)

By Donald Miller

A natural wetland is a complex ecosystem. Like other ecosystems, whether land- or water-based, many factors affect the form and function of the wetlands. Both biotic and abiotic factors and processes are integral to the natural wetland ecosystem. The term "biotic" refers to living things. The term "abiotic" refers to the materials, processes or factors that are nonliving.

Water

Water itself is perhaps the quintessential abiotic factor in natural wetlands. Although essential to virtually all biological processes, water itself is nonliving and it can occur independently of living things. In natural wetlands, water is the medium in which the entire ecosystem exists and functions. Wetlands in regions that have been glaciated in the past -- in the form of massive ice sheets -- may owe their early beginnings to the powerful carving effects of the glacier. So, even water in that dramatically different form was a significant factor in the development of the wetlands.

Air

Unlike water, air is composed of more than one chemical compound. Oxygen, nitrogen, carbon dioxide and several other gaseous substances form air's chemical composition. Air, especially the oxygen contained within it, is another critical abiotic factor in natural wetlands. Virtually any wetland ecosystem features many kinds of plants and animals. Green plants make use of carbon dioxide from the air; in turn, they release oxygen as a waste product. Animals do the inverse; they take in and use oxygen and give off carbon dioxide as a waste product. Although there are organisms that can and do live and grow in the absence of oxygen, the vast majority of life forms in a natural wetland -- both under the water and above its surface -- require oxygen from the air.

Sunlight

Light from the sun is an essential abiotic factor in natural wetlands. Sunlight provides the energy that plants need to carry out photosynthesis. That same energy is transmitted to other organisms in the wetland through the food chain or food web. And temperature, of course, is an abiotic factor directly related to the amount of energy the wetland receives from the sun.

Minerals

Beneath the water, at the bottom of a natural wetland, are sedimentary materials of various kinds. Much of this material is organic or biotic and arises from the decomposing remains of living organisms in the wetland. But there is also a mineral component to this sedimentary material. Mineral particles of various kinds and sizes intermix with the organic material. Just as in terrestrial ecosystems, plants in the natural wetland must obtain abiotic mineral nutrients in order to live and grow. And minerals are not limited to the bottom sediments; they can be dissolved directly into the water, where they form a complex natural chemical mix that has a bearing on factors like pH, a measure of the acidity in the water.

Rocks
In addition to the relatively small particles of mineral sediments, there are often larger rocks of various sizes and kinds in wetlands. Whether a massive, continuous layer of bedrock underlying the wetland and forming its foundation, or relatively smaller rocks that are under the water or that protrude above the surface, rocks are a significant abiotic factor in many wetlands. Besides providing substrates for plants and animals to either grow on or perch on, rocks -- through natural weathering processes -- gradually break down and provide mineral nutrients to the wetland ecosystem.

Swamps

Zoom Image Credit: US Fish and Wildlife

Swamps are forested wetlands. Like marshes, they are often found near rivers or lakes and have mineral soil that drains very slowly. Unlike marshes, they have trees and bushes. They may have water in them for the whole year or for only part of the year. Swamps vary in size and type. Some swamps have soil that is nutrient rich; other swamps have nutrient poor soil. Swamps are often classified by the types of trees that grow in them.

Conifer Swamps

Trees like white cedar, northern white cedar, eastern hemlock, eastern white pine, pitch pine, loblolly pine, and black spruce are common in conifer swamps.

Hardwood Swamps

Hardwood swamps have trees like red maple, black willow, aspen, cottonwood, ashes, elms, swamp white oak, pin oak, tupelo, and birches.

Shrub Swamps

Shrub swamps have small trees and bushes like buttonwood, willow, alders, and dogwood.

Cypress Swamps

Zoom Image Credit: Ned Trovillion US Fish and Wildlife

Cypress swamps are found in the southern United States. They are named for the bald cypress tree. Bald cypress trees are deciduous trees with needle-like leaves. They have very wide bases and “**knees**" that grow from their roots and stick up out of the water. Bald cypress trees can grow to 100 to 120 feet tall.

Zoom Image Credit: Ryan Haggerty US Fish and Wildlife

Fire plays an important role in the establishment of bald cypress swamps. Cypress trees grow very quickly after a fire and re-establish themselves before other trees have a chance to grow! Many of the bald cypress trees in cypress swamps in the U.S. were cut down in the late 1800s and the early 1900s. The wood from the bald cypress is resistant to rot and was a popular wood for building. Other trees and shrubs like pond cypress, black gum, red maple, wax myrtle, and buttonwood are also be found in cypress swamps. Animals like white-tailed deer, minks, raccoons, pileated woodpeckers, purple gallinules, egrets, herons, alligators, frogs, turtles, and snakes are often found in cypress swamps.

From Lake to Swamp

Swamps start out as lakes, ponds or other shallow bodies of water. Over time, trees and shrubs begin to fill in the land. Plants die and decay, and the level of the water gets lower and lower. Eventually, the original body of water becomes a swamp.

Zoom Image Credit: US Fish and Wildlife

Zoom Image Credit: S. Bournique US Fish and Wildlife

The Great Dismal Swamp

The **Great Dismal Swamp** is located in northeastern North Carolina and southern Virginia. It is a mixture of waterways, swamps, and marshes. Unlike most swamps, it is not located near a river. It is a **coastal plain swamp**. Trees like cypress, black gum, juniper, and water ash are common. Animals commonly found in the Great Dismal Swamp include black bears, white-tailed deer, opossums, raccoons, and cottonmouth snakes.

Zoom Image Credit: Ryan Haggerty US Fish and Wildlife

Okefenokee Swamp

The **Okefenokee Swamp** is located in southeastern Georgia and northern Florida. It is about 25 miles wide and 40 miles long. Not all of the Okefenokee is a swamp; part of it is a bog. In fact, Okefenokee is a Hitchiti word that means "*Land of the Trembling Earth.*" Parts of the swamp are so boggy that you can shake the trees by stomping on the ground!

Zoom Image Credit: Ryan Haggerty US Fish and Wildlife

Trees in the Okefenokee swamp includes giant tupelo and bald cypress. Mammals like the raccoon, black bear, white-tailed deer, bobcat, red fox and river otter make the swamp their home. Reptiles in the swamp include the eastern diamondback rattlesnake, cottonmouth, eastern coral snake, copper head, alligator, and snapping turtle. Birds like the barred owl, anhinga, great egret, great blue heron, and sandhill crane are also found in the swamp. Plants like the pitcher plant, water lily, and Spanish moss that grow in the swamp can survive in the nutrient poor and acidic soil of the Okefenokee swamp.

WHAT IS A WETLAND?

According to the Ramsar Convention on Wetlands;

“Wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters."

For regulatory purposes in the United States, under the Clean Water Act, the term wetlands means "those areas that are inundated or saturated by surface or groundwater 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."

Marshes A marsh is possibly the most beloved of all wetlands. They have a broad vista, often extending out to open waters. They are busy and vibrant places populated by an intriguing variety of birds that are marsh dependent. Herons and egrets wade in the shallow waters, while ducks seasonally descend in epic numbers. Plants grow from spongy bottoms, some remain submerged, while others like the white water lily float at the surface. Others, including pickerel weed and cattail are emergent, rise above the surface, providing seclusion for secretive birds and insects. Possibly one of the most productive ecosystems on the planet, marshes convert the essential elements of water, mineral and sunlight into living tissue at a higher rate than a mature forest or prairie. Fish often use the submerged complexity as nurseries where the many layers of vegetation provide refuge and nutrition.

Wet Meadows commonly occur in poorly drained areas such as shallow lake basins, low-lying depressions, and the land between shallow marshes and upland areas. Precipitation serves as their primary water supply, so they are often dry in the summer.

Wet Prairies are similar to wet meadows but remain saturated longer. Wet prairies may receive water from intermittent streams as well as ground water and precipitation.

Vernal Pools have either bedrock or a hard clay layer in the soil that helps keep water in the pool. They are covered by shallow water for variable periods from winter to spring, but may be completely dry for most of the summer and fall. Many vernal pools fill with water in fall or spring.

Swamps are fed primarily by surface water inputs and are dominated by trees and shrubs. Swamps occur in either freshwater or saltwater floodplains. They are characterized by very wet soils during the growing season and standing water during certain times of the year. Well-known swamps include Georgia’s Okefenokee Swamp and Virginia’s Great Dismal Swamp. Swamps are classified as forested, shrub, or mangrove.

Forested swamps are found in broad floodplains of the northeast, southeast, and south-central United States and receive floodwater from nearby rivers and streams. Common deciduous trees found in these areas include bald cypress, water tupelo, swamp white oak, and red maple.

Shrub swamps are similar to forested swamps except that shrubby species like buttonbush and swamp rose dominate.

WETLAND BENEFITS

- **Erosion control**. Wetland vegetation reduces erosion along lakes and stream banks by reducing forces associated with wave action.
- **Fisheries habitat**. Many species of fish utilize wetland habitats for spawning, food sources, or protection.
- **Flood control**. Wetlands can slow runoff water, minimizing the frequency streams and rivers reach catastrophic flood levels.
- **Ground water recharge and discharge**. Some wetlands serve as a source of ground water recharge. By detaining surface waters that would otherwise quickly flow to distant lakes or rivers, the water can percolate into the ground and help ensure long-term supplies of quality ground water. Some wetlands are ground-water discharge areas; they receive ground water even during dry periods. This helps reduce the impact of short-term droughts on rivers and streams.
- **Natural filter.** By trapping and holding water, wetlands store nutrients and pollutants in the soil, allowing cleaner water to flow in to the body of water beyond or below the wetland. Vegetation, like cattails, can absorb some of the pollutants that remain in the soil. Wetlands also moderate water flows, providing time for sediments to settle out before the water is released to other wetlands, lakes, or streams. Less sediment means clearer waters and a better environment for aquatic life.
- **Drinking water quality**. Wetlands improve water quality in nearby rivers and streams, and thus have considerable value as filters for future drinking water
- **Rare species habitat**. 43 per cent of threatened or endangered species in the U.S. live in or depend on wetlands. This includes plants and animals.
- **Source of income**. Wetlands provide economic commodities such as cranberries and fish and provide spatial amenities to developments.
- **Recreation**. Wetlands are inviting places for recreational activities including hiking, fishing, bird watching, hunting and boating. Wetlands are great places to canoe, hunt, fish, or explore and enjoy nature.
- **Shoreline stabilization**. Wetlands that occur along the shoreline of lakes or along the banks of rivers and streams help protect the shoreline soils from the erosive forces of waves and currents. The wetland plants act as a buffer zone by dissipating the water's energy and providing stability by binding the soils with their extensive root systems.
- **Wildlife habitat**. Many animals depend on wetlands for homes and resting spots. Fish, amphibians, reptiles, aquatic insects and certain mammals need wetlands as a place for their young to be born and grow.
- **Education**. Wetlands provide ideal locations for classroom ecological studies and a focus for art.

Vernal ponds (also called ephemeral, temporary, or seasonal ponds, pools, or wetlands) are areas that do not contain water year-round. Instead, these areas fill with water seasonally, usually with the onset of spring (vernal) or fall rains, and then dry up in the late summer. Vernal ponds are one of the most critical amphibian habitats.

Many predators of amphibians live in permanent bodies of water, including fish, invertebrate predators, and even other amphibians, such as American Bullfrogs and Northern Green Frogs. Many of Ohio's amphibian species rely on the relative safety that temporary pools offer for egg-laying and the development of their larvae.

Habitat destruction is the major threat to vernal ponds. Often, people mistake seasonally wet areas as "wasteland," and proceed to fill in or drain these critical habitats. Sometimes landowners mistakenly believe that by making a vernal pond permanent (by digging it bigger and deeper) they are increasing the value of the area for wildlife.

What can you do to protect vernal ponds? Do not alter the vernal pond to make it deeper. Do not introduce fish or other predators of amphibians to the pond. Keep a buffer around the pond. Buffers are areas of natural vegetation (not turf grass) that help filter the water flowing into the pond and provide areas for the terrestrial amphibians to live.

Rivers and Streams: Life in Flowing Water

Declan McCabe, Nature Education Knowledge, 2011

What lies beneath? Rivers: diverse habitats with broadly varying niches. Communities reflect and influence local, upstream, downstream, and broader landscape conditions.

Introduction

Water current pervades every facet of existence for life in **lotic** (flowing water) habitats. Maintaining position in the face of flow can be energetically costly, but provides access to a conveyer belt-like food-delivery system. Stream and river organisms reflect their localized niche, and surrounding landscape both upstream and downstream. River organisms have evolved in diverse and fascinating ways in the varied environments between river source and mouth.

Glossary

Aquifer: Underground water that exists in the interstitial space between substrate particles or porous rock.
Benthos: The community of organisms inhabiting the solid floor, or *benthic zone* of any water body.
Biomes: Large biogeographical regions characterized by a particular community type. They are broadly defined by climatic variables including temperature and precipitation. Examples include desert, rain forest, and tundra.
Catchment: The area that drains to a single stream or river. Frequently referred to as a *river basin*. Synonymous with *watershed* in North American usage.
Collectors: A macroinvertebrate functional feeding group using small organic particles as a primary food source. *Filtering collectors* accumulate this material from the water column. *Gathering collectors* accumulate this material from the benthic zone.
Discharge: The quantity of water passing a certain river or stream location per unit time. Expressed as units of volume per unit time (e.g., cubic meters per second).
Functional feeding groups: Feeding guilds of aquatic macroinvertebrates. These include grazers (commonly called *scrapers*), shredders, collectors, and predators.
Grazers: Also called scrapers, a macroinvertebrate functional feeding group that consumes attached periphyton as its primary food source
Hyporheic zone: A zone of saturated substrate beneath and spreading laterally from a river bed. It is the zone of active water and organism exchange between the river water and ground water.
Lentic: Referring to standing-water habitats including lakes, ponds, and swamps (contrast with *lotic*).
Lotic: Referring to flowing-water habitats including rivers, springs, and streams (contrast with *lentic*).

Periphyton: The community of primary producers and heterotrophic microorganisms attached to submerged surfaces. In streams this would include algae, cyanobacteria, bacteria, and fungi and their associated extra-cellular secretions. Periphyton serves as the food base utilized by *grazers*.
Pool: An area of low gradient water in a stream. See also *riffle*.
Predators: Organisms whose primary food source is other animals.
Riffle: A high-gradient bar of deposited substrate, usually spanning the width of a stream. Typically found as part of a riffle-pool repeating sequence in streams of medium gradient. Not to be confused with ripple.
Ripple: Small-scale undulations on the surface unconsolidated fine substrates such as silt and sand. These features are shaped by the action of flowing water in low-gradient rivers.
Riparian zone: The area of terrestrial habitat adjacent to and most directly influenced by or stream.
River Continuum Concept: A model of longitudinal change in physical habitat, and the biological communities in rivers.
Shredders: A benthic macroinvertebrate functional feeding group that utilizes leafy detritus as their primary food source. Although the leaves are consumed, nutritional value is derived from the attached community as well as the leaves themselves.
Species-area relationship: The frequently-confirmed observation that as one increases the area from which a community sample is taken, one typically samples an increasing number of species.
Species-discharge relationship: An analogous concept to the species-area concept applied to rivers. As river size (as measured by *discharge*) increases, one usually finds more fish species.
Step pools: A series of stream pools separated by areas of high-gradient water flow. These pools can be visualized by analogy to the step surfaces on stairs separated by the stair risers that support those steps.
Watershed: European usage: the boundary between two catchments; water is shed to one stream on one side of this line and in the opposite direction and to a different stream on the other side. North American usage: a synonym of *catchment*.

A Primer on Water Quality

What is in the water? Is it safe for drinking? Can fish and other aquatic life thrive in streams and lakes that are affected by human activities? What is the water quality? To answer these questions, it is helpful to understand what "water quality" means, how it is determined, and the natural processes and human activities that affect water quality.

What do we mean by "water quality"? Water quality can be thought of as a measure of the suitability of water for a particular use based on selected physical, chemical, and biological characteristics. To determine water quality, scientist's first measure and analyze characteristics of the water such as temperature, dissolved mineral content, and number of bacteria. Selected characteristics are then compared to numeric standards and guidelines to decide if the water is suitable for a particular use.

How is water quality measured? Some aspects of water quality can be determined right in the stream or at the well. These include temperature, acidity (pH), dissolved oxygen, and electrical conductance (an indirect indicator of dissolved minerals in the water). Analyses of individual chemicals generally are done at a laboratory.

Why do we have water-quality standards and guidelines? Standards and guidelines are established to protect water for designated uses such as drinking, recreation, agricultural irrigation, or protection and maintenance of aquatic life. Standards for drinking-water quality ensure that public drinking-water supplies are as safe as possible. The U.S. Environmental Protection Agency (USEPA) and the States are responsible for establishing the standards for constituents in water that have been shown to pose a risk to human health. Other standards protect aquatic life, including fish, and fish-eating wildlife such as birds.

How do natural processes affect water quality? Natural water quality varies from place to place, with the seasons, with climate, and with the types of soils and rocks through which water moves. When water from rain or snow moves over the land and through the ground, the water may dissolve minerals in rocks and soil, percolate through organic material such as roots and leaves, and react with algae, bacteria, and other microscopic organisms. Water may also carry plant debris and sand, silt, and clay to rivers and streams making the water appear "muddy" or turbid. When water evaporates from lakes and streams, dissolved minerals are more concentrated in the water that remains. Each of these natural processes changes the water quality and potentially the water use.

What is naturally in the water? The most common dissolved substances in water are minerals or salts that, as a group, are referred to as dissolved solids. Dissolved solids include common constituents such as calcium, sodium, bicarbonate, and chloride; plant nutrients such as nitrogen and phosphorus; and trace elements such as selenium, chromium, and arsenic. In general, the common constituents are not considered harmful to human health, although some constituents can affect the taste, smell, or clarity of water. Plant nutrients and trace elements in water can be harmful to human health and aquatic life if they exceed standards or guidelines. Dissolved gases such as oxygen and radon are common in natural waters. Adequate oxygen levels in water are a necessity for fish and other aquatic life. Radon gas can be a threat to human health when it exceeds drinking water standards.

How do human activities affect water quality? Urban and industrial development, farming, mining, combustion of fossil fuels, stream-channel alteration, animal-feeding operations, and other human activities can change the quality of natural waters. As an example of the effects of human activities on water quality, consider nitrogen and phosphorus fertilizers that are applied to crops and lawns. These plant nutrients can be dissolved easily in rainwater or snowmelt runoff. Excess nutrients carried to streams and lakes encourage abundant growth of algae, which leads to low oxygen in the water and the possibility of fish kills. Chemicals such as pharmaceutical drugs, dry-cleaning solvents, and gasoline that are used in urban and industrial activities have been found in streams and ground water. After decades of use, pesticides are now widespread in streams and ground water, though they rarely exceed the existing standards and guidelines established to protect human health. Some pesticides have not been used for 20 to 30 years, but they are still detected in fish and streambed sediment at levels that pose a potential risk to human health, aquatic life, and fish-eating wildlife. There are so many chemicals in use today that determining the risk to human health and aquatic life is a complex task. In addition, mixtures of chemicals typically are found in water, but health-based standards and guidelines have not been established for chemical mixtures.

What about bacteria, viruses, and other pathogens in water? The quality of water for drinking cannot be assured by chemical analyses alone. The presence of bacteria in water, which are normally found in the intestinal tracts of humans and animals, signals that disease-causing pathogens may be present. Giardia and cryptosporidium are pathogens that have been found occasionally in public-water supplies and have caused illness in a large number of people in a few locations. Pathogens can enter our water from leaking septic tanks, wastewater-treatment discharge, and animal wastes.

How can I find out more about my water quality? Contact your local water supplier and ask for information on the water quality in your area. The USEPA requires public-water suppliers to provide water-quality data to the public on an annual basis in an understandable format. State agencies that deal with health, environmental quality, or water resources also can provide information on the quality of your water. Additional resources can be found on the Internet at: http://water.usgs.gov/nawqa
http://www.epa.gov/safewater

Glossary of River Terminology

Alluvial - Deposited by running water.
Aquatic ecosystem - Any body of water, such as a stream, lake, or estuary, and all organisms and nonliving components within it, functions as a natural system.
Aquatic habitat - Habitat that occurs in free water.
Armoring - A natural or artificial process where an erosion-resistant layer of relatively large particles is established on the surface of the streambed through the removal of finer particles by stream flow. A properly armored streambed generally resists movement of the bed material at discharges up to approximately "three fourths" bank-full depth.
Average annual runoff - For a specified area, it is the average value of annual runoff amounts calculated for a whole hydrologic cycle of record that represents average hydrologic conditions.
Backwater - (1) A small, generally shallow body of water attached to the main channel, with little or no current of its own, or (2) A condition in subcritical flow where the water surface elevation is raised by downstream flow impediments.
Bank-full channel depth - the maximum depth of a channel within a rifle segment when flowing at a bank-full discharge.
Bank-full channel width - The top surface width of a stream channel when flowing at a bank-full discharge.
Bank-full discharge - The stream discharge corresponding to the water stage that first overtops the natural banks. This flow occurs, on average, about once every 1 or 2 years.
Bank-full width - the width of a river or stream channel between the highest banks on either side of a stream.
Bar - an accumulation of alluvium (usually gravel or sand) caused by a decrease in sediment transport capacity on the inside of meander bends or in the center of an overwide channel.
Barrier - A physical block or impediment to the movement or migration of fish, such as a waterfall (natural barrier) or a dam (man-made barrier).
Base flow - The sustained portion of stream discharge that is drawn from natural storage sources, and not affected by human activity or regulation.
Base level - The elevation to which a stream-channel profile has developed.
Basin - The total area of land from which water drains into a specific river
Bed - The bottom of a channel.
Benthic invertebrates - Aquatic animals without backbones that dwell on or in the bottom sediments of fresh or salt water. Examples: clams, crayfish, and a wide variety of worms.
Benthos - All plants and animals living on or closely associated with the bottom of a body of water.
Best management practice (BMP) - Conservation measures intended to minimize or mitigate impacts from a variety of land-use activities.
Boulder - A large substrate particle that is larger than cobble, 256 mm in diameter. **Braided channel** - A stream characterized by flow within several channels, which successively meet and divide. Braiding often occurs when sediment loading is too large to be carried by a single channel.
Buffer strip - A barrier of permanent vegetation, either forest or other vegetation, between waterways and land uses such as agriculture or urban development, designed to interrupt and filter out pollution before it reaches the surface water resource.
Canopy - A layer of continuous foliage in a forest stand. This most often refers to the upmost layer of foliage, but it can be used to describe lower layers in a multistoried stand. Leaves, branches and/or water that provide shade and cover for fish and wildlife.

Catchment - (1) the catching or collecting of water, especially rainfall. (2) A reservoir or other basin for catching water. (3) The water thus caught. (4) A watershed.
Channel - An area that contains continuously or periodically flowing water that is confined by banks and a streambed.
Channelization - The process of changing (usually straightening) the natural path of a waterway.
Clay - (1) Substrate particles that are smaller than silt and generally less than 0.003 mm in diameter. (2) A soil textural class containing > 40% clay, < 45% sand, and < 40 % silt.
Cobble - Substrate particles that are smaller than boulders and larger than gravels, and are generally 64-256 mm in diameter. Can be further classified as small and large cobble. **Drainage Confluence** - (1) The act of flowing together; the meeting or junction of two or more streams; also, the place where these streams meet. (2) The stream or body of water formed by the junction of two or more streams; a combined flood.
Contaminate - To make impure or unclean by contact or mixture.
Cubic feet per second (cfs) - A unit used to measure water flow. One cubic foot per second is equal to 449 gallons per minute.
Culvert - A buried pipe that allows flows to pass under a road.
Cut bank - The outside bank of a bend, often eroding opposite a point bar.
Daylight - In the restoration field, a verb that denotes the excavation and restoration of a stream channel from an underground culvert, covering, or pipe.
Discharge - The volume of water passing through a channel during a given time, usually measured in cubic feet per second.
Drainage area - The total surface area upstream of a point on a stream that drains toward that point. Not to be confused with watershed. The drainage area may include one or more watersheds.
Dredging - Removing material (usually sediments) from wetlands or waterways, usually to make them deeper and wider.
Effluent - (1) Something that flows out or forth, especially a stream flowing out of a body of water. (2) (Water Quality) Discharged wastewater such as the treated wastes from municipal sewage plants, brine wastewater from desalting operations, and coolant waters from a nuclear power plant.
Ephemeral streams - Streams that flow only in direct response to precipitation and whose channel is at all times above the water table.
Erosion - Wearing away of rock or soil by the gradual detachment of soil or rock fragments by water, wind, ice, and other mechanical, chemical, or biological forces.
Eutrophic - Usually refers to a nutrient-enriched, highly productive body of water.
Eutrophication - The process of enrichment of water bodies by nutrients and the subsequent depletion of dissolved oxygen it produces.
Fill - (1) (Geology) Any sediment deposited by any agent such as water so as to fill or partly fill a channel, valley, sink, or other depression. (2) (Engineering) Soil or other material placed as part of a construction activity.
Floodplain - Land built of sediment that is regularly covered with water as a result of the flooding of an adjacent stream.
Floodplain (100-year) - The area adjacent to a stream that is on average inundated once a century.
Flood stage - An above average elevation for the water level at high flows.
Floodway - A regulatory floodplain under the National Flood Insurance Program that includes the channel and that portion of the adjacent floodplain that is required to pass flood flows (normally the one-in-100-year flood) without increasing the water surface elevation more than a designated height (1 foot in most areas).
Flow - The amount of water passing a particular point in a stream or river, usually expressed in cubic feet per second (cfs).

Gauging station - A particular site in a stream, lake, reservoir, etc., where hydrologic data are obtained.
Gallons per minute (gpm) - A unit used to measure water flow.
Geographic information system (GIS) - A computer system capable of storing and manipulating spatial data.
Geomorphology - A branch of both physiography and geology that deals with the form of the earth, the general configuration of its surface, and the changes that take place due to erosion of the primary elements and the buildup of erosional debris.
Glide - A section of stream that has little or no turbulence.
Gradient - Vertical drop per unit of horizontal distance.
Gravel - An unconsolidated natural accumulation of rounded rock fragments, mostly of particles larger than sand (diameter greater than 2 mm), such as boulders, cobbles, pebbles, granules, or any combination of these.
Groundwater - Subsurface water and underground streams that can be collected with wells, or that flow naturally to the earth's surface through springs.
Groundwater table - The upper surface of the zone of saturation, except where the surface is formed by an impermeable body.
Headwater - Referring to the source of a stream or river.
Hydrograph - A curve showing stream discharge over time.
Meander - The winding of a stream channel, usually in an erodible alluvial valley. A series of sine-generated curves characterized by curved flow and alternating banks and shoals.
Hydrologic unit - A distinct watershed or river basin defined by an eight-digit code.
Hydrology - The scientific study of water of the earth, its occurrence, circulation, and distribution.
Hyporheic zone - The area under the stream channel and floodplain where groundwater and the surface waters of a stream are exchanged freely
Impermeable channel - A material that has properties preventing movement of water through it. Nonporous.
Infiltration (soil) - The movement of water through the soil surface into the soil.
Inflow - Water that flows into a stream, lake, reservoir, or Forebay during a specified period.
Instream cover - The layers of vegetation, like trees, shrubs, and overhanging vegetation, that are in the stream or immediately adjacent to the wetted channel.
Instream flows - (1) Portion of a flood flow that is contained by the channel. (2) A flow or flow regime needed to maintain ecological health in a river/stream.
Intermittent stream - Any nonpermanent flowing drainage feature having a definable channel and evidence of scour or deposition. This includes what are sometimes referred to as ephemeral streams if they meet these two criteria.
Large woody debris (LWD) - Pieces of naturally occurring wood larger than 10 ft long and 6 in. in diameter, in a stream channel.
Limiting factor - A requirement such as food, cover, or another, physical, chemical, or biological factor that is in shortest supply with respect to all resources necessary to sustain life and thus "limits" the size or retards production of a population.
Loading - The influx of pollutants to a selected water body.
Lotic - Meaning or regarding things in running water.
Macroinvertebrate - Invertebrates visible to the naked eye, such as insect larvae and crayfish.
Macrophytes - Aquatic plants that are large enough to be seen with the naked eye.
Main stem - The principal channel of a drainage system into which other smaller streams or rivers flow.
Maximum contaminant level (MCL) - The highest concentration of a constituent in drinking water permitted under federal and State Safe Drinking Water Act regulations.

Mean annual discharge - Daily mean discharge averaged over a period of years. Mean annual discharge generally fills a channel to about one-third of its bank-full depth.
Mean velocity - The average cross-sectional velocity of water in a stream channel. Surface values typically are much higher than bottom velocities. May be approximated in the field by multiplying the surface velocity, as determined with a float, times 0.8.
Meander - The winding of a stream channel, usually in an erodible alluvial valley. A series of sine-generated curves characterized by curved flow and alternating banks and shoals.
Morphology - the form, shape, or structure of a stream or organism.
Riffle - A reach of stream that is characterized by shallow, fast-moving water broken by the presence of rocks and boulders.
Run (in stream or river) - A reach of stream characterized by fast-flowing, low turbulence water.
Thalweg - (1) The lowest thread along the axial part of a valley or stream channel. (2) A subsurface, groundwater stream percolating beneath and in the general direction of a surface stream course or valley. (3) The middle, chief, or deepest part of a navigable channel or waterway.
National Pollutant Discharge Elimination System (NPDES) - A provision of Section 402 of the Federal Clean Water Act of 1972 that established a permitting system for discharges of waste materials to watercourses.
Natural flow - The flow past a specified point on a natural stream that is unaffected by stream diversion, storage, import, export, return flow, or change in use caused by modifications in land use.
Overbank flow - Water flow over the top of the bankfull channel onto the floodplain.
Outfall - The mouth or outlet of a river, stream, lake, drain or sewer.
Oxbow - An abandoned meander in a river or stream, caused by cutoff. Used to describe the U-shaped bend in the river or the land within such a bend of a river.
Percolation - The downward movement of water through the soil or alluvium to a groundwater table.
Perennial streams - Streams that flow continuously.
Point bar - The convex side of a meander bend that is built up due to sediment deposition.
Point Source (PS) - (1) A stationary or clearly identifiable source of a large individual water or air pollution emission, generally of an industrial nature. (2) Any discernible, confined, or discrete conveyance from which pollutants are or may be discharged, including (but not limited to) pipes, ditches, channels, tunnels, conduits, wells, containers, rolling stock, concentrated animal feeding operations, or vessels. Point source is also legally and more precisely defined in federal regulations. Contrast with non-point source (NPS) pollution.
Point source (PS) pollution - Pollutants discharged from any identifiable point, including pipes, ditches, channels, sewers, tunnels, and containers of various types. See non-point source (NPS) pollution.
Pollutant - (1) Something that pollutes, especially a waste material that contaminates air, soil, or water. (2) Any solute or cause of change in physical, chemical, or biological properties that renders water unfit for a given use.
Pollution (of water) - The alteration of the physical, chemical, or biological properties of water by the introduction of any substance into water that adversely affects any beneficial use of water.
Pool - A reach of a stream that is characterized by deep, low-velocity water and a smooth surface.
Rapid - A reach of stream that is characterized by small falls and turbulent, high-velocity water.
Restoration - The return of an ecosystem to a close approximation of its condition prior to disturbance.
Riffle - A reach of stream that is characterized by shallow, fast-moving water broken by the presence of rocks and boulders.
Riparian area - An area of land and vegetation adjacent to a stream that has a direct effect on the stream. This includes woodlands, vegetation, and floodplains.
Riparian habitat - The aquatic and terrestrial habitat adjacent to streams, lakes, estuaries, or other waterways.

Riparian - Located on the banks or a stream or other body of water.
Riparian vegetation - The plants that grow adjacent to a wetland area such as a river, stream, reservoir, pond, spring, marsh, bog, meadow, etc., and that rely upon the hydrology of the associated water body.
Ripple - (1) A specific undulated bed form found in sand bed streams. (2) Undulations or waves on the surface of flowing water.
River channels - Large natural or artificial open streams that continuously or periodically contain moving water, or which form a connection between two bodies of water.
River miles - Generally, miles from the mouth of a river to a specific destination or, for upstream tributaries, from the confluence with a main river to a specific destination.
River reach - Any defined length of river.
River stage - The elevation of the water surface at a specified station above some arbitrary zero datum (level).
Rock - A naturally formed mass of minerals.
Rootwad - The mass of roots associated with a tree adjacent to or in a stream that provides refuge for fish and other aquatic life.
Run (in stream or river) - A reach of stream characterized by fast-flowing, low turbulence water.
Runoff - Water that flows over the ground and reaches a stream as a result of rainfall or snowmelt.
Sand - Small substrate particles, generally from 0.6 to 2.0 mm in diameter. Sand is larger than silt and smaller than gravel.
Sediment - Soil or mineral material transported by water or wind and deposited in streams or other bodies of water.
Sedimentation - (1) The combined processes of soil erosion, entrainment, transport, deposition, and consolidation. (2) Deposition of sediments.
Sediment load - The soil particles transported through a channel by stream flow.
Silt - Substrate particles smaller than sand and larger than clay (3 to 60 um).
Siltation - the deposition or accumulation of fine soil particles.
Slope - The ratio of the change in elevation over distance.
Snag - Any standing dead, partially dead, or defective (cull) tree at least 10 in. in diameter at breast height and at least 6 ft tall. Snags are important riparian habitat features.
Soil bioengineering - Also referred to as biotechnical slope protection. Involves the use of live and dead woody cuttings and poles or posts collected from native plants to revegetate watershed slopes and stream banks. The cuttings, posts, and vegetative systems composed of bundles, layers, and mats of the cuttings and posts provide structure, drains, and vegetative cover to repair eroding and slumping slopes.
Stone - Rock or rock fragments used for construction.
Stream - A general term for a body of water flowing by gravity; natural watercourse containing water at least part of the year. In hydrology, the term is generally applied to the water flowing in a natural narrow channel as distinct from a canal.
Stream bank - The side slopes of an active channel between which the streamflow is normally confined.
Stream channel - A long narrow depression shaped by the concentrated flow of a stream and covered continuously or periodically by water.
Stream gradient - A general slope or rate of change in vertical elevation per unit of horizontal distance of the bed, water surface, or energy grade of a stream.
Stream morphology - The form and structure of streams.
Stream order - A hydrologic system of stream classification. Each small unbranched tributary is a first-order stream. Two first-order streams join to make a second-order stream. A third-order stream has only first and second-order tributaries, and so forth.
Stream reach - An individual segment of stream that has beginning and ending points defined by identifiable features such as where a tributary confluence changes the channel character or order.

Streambank erosion - The removal of soil from streambanks by flowing water.
Streambed - (1) The unvegetated portion of a channel boundary below the baseflow level. (2) The channel through which a natural stream of water runs or used to run, as a dry streambed.
Streamflow - The rate at which water passes a given point in a stream or river, usually expressed in cubic feet per second (cfs).
Substrate - (1) The composition of a streambed, including either mineral or organic materials. (2) Materials that forms an attachment medium for organisms.
Surface water - All water whose surface is naturally exposed to the atmosphere, for example, rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc., and all springs, wells, or other collectors directly influenced by surface water.
Toe - The break in slope at the foot of a stream bank where the bank meets the bed.
Tributary - A stream that flows into another stream, river, or lake.
Turbidity - A measure of the content of suspended matter that interferes with the passage of light through the water or in which visual depth is restricted. Suspended sediments are only one components of turbidity.
Urban runoff - Storm water from city streets and gutters that usually carries a great deal of litter and organic and bacterial wastes into the sewer systems and receiving waters.
Velocity - In this concept, the speed of water flowing in a watercourse, such as a river.
Wash - (1) To carry, erode, remove, or destroy by the action of moving water. To be carried away, removed, or drawn by the action of water. Removal or erosion of soil by the action of moving water. (2) A deposit of recently eroded debris.
Washout - (1) Erosion of a relatively soft surface, such as a roadbed, by a sudden gush of water, as from a downpour or floods. (2) A channel produced by such erosion.
Water pollution - Generally, the presence in water of enough harmful or objectionable material to damage the water quality.
Water quality - A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.
Watershed management - the analysis, protection, development, operation, or maintenance of the land, vegetation, and water resources of a drainage basin for the conservation of all its resources for the benefit of its residents.
Watershed project - A comprehensive program of structural and nonstructural measures to preserve or restore a watershed to good hydrologic condition. These measures may include detention reservoirs, dikes, channels, contour trenches, terraces, furrows, gully plugs, revegetation, and possibly other practices to reduce flood peaks and sediment production.
Watershed restoration - Improving current conditions of watersheds to restore degraded habitat and provide long-term protection to aquatic and riparian resources.
Woody debris - Generally referring to naturally occurring wood in streams.

Water: Monitoring & Assessment – US EPA, 2021

Nitrogen

What are nitrates and why are they important?

Nitrates are a form of nitrogen, which is found in several different forms in terrestrial and aquatic ecosystems. These forms of nitrogen include ammonia (NH3), nitrates (NO3), and nitrites (NO2). Nitrates are essential plant nutrients, but in excess amounts they can cause significant water quality problems. Together with phosphorus, nitrates in excess amounts can accelerate eutrophication, causing dramatic increases in aquatic plant growth and changes in the types of plants and animals that live in the stream. This, in turn, affects dissolved oxygen, temperature, and other indicators. Excess nitrates can cause hypoxia (low levels of dissolved oxygen) and can become toxic to warm-blooded animals at higher concentrations (10 mg/L) or higher) under certain conditions. The natural level of ammonia or nitrate in surface water is typically low (less than 1 mg/L); in the effluent of wastewater treatment plants, it can range up to 30 mg/L.

Sources of nitrates include wastewater treatment plants, runoff from fertilized lawns and cropland, failing on-site septic systems, runoff from animal manure storage areas, and industrial discharges that contain corrosion inhibitors.

Nitrate in Public Drinking Water

Nitrate (NO3) is an inorganic chemical composed of nitrogen and oxygen. Nitrate contamination of drinking water usually results from runoff of agricultural fertilizers or from human or animal wastes, such as livestock feedlots or faulty septic systems.
How much nitrate is allowed in drinking water? The maximum contaminant level (MCL) for nitrate in drinking water is 10 milligrams per liter (mg/L). This is the maximum allowable level of nitrate that may be present in drinking water without a high risk of causing health problems.

What are the health effects of nitrate? Nitrate is essentially harmless to most people, but is considered an acute toxin to infants less than six months of age. In infants, it causes a condition known as methemoglobinemia, or "blue-baby syndrome," which can be fatal. The most obvious symptom is a bluish skin coloring, especially around the eyes and mouth. Other symptoms can include shortness of breath, nausea, vomiting and dizziness. An infant with bluish skin should be taken immediately to a medical facility for treatment. Blue-baby syndrome is caused when bacteria in the digestive tract of infants change the nitrate into nitrite, a much more harmful substance. The nitrite then enters the bloodstream, where it can lower the blood's ability to carry oxygen to the body, causing a blueness to the skin. Infants under six months of age are at higher risk than others because their digestive tract is not fully developed. By six months of age, the hydrochloric acid in the stomach increases to a level that kills most of the bacteria which change nitrate to nitrite, significantly reducing the risk of methemoglobinemia. Healthy adults and older children can consume higher levels of nitrate than infants because of their fully developed digestive systems. It is recommended that women who are pregnant or nursing consult with their physicians about limiting nitrate consumption. People with medical conditions that may make them more susceptible to methemoglobinemia, such as reduced stomach acidity, should also consult their physicians.

Phosphorus

Why is phosphorus important?

Both phosphorus and nitrogen are essential nutrients for the plants and animals that make up the aquatic food web. Since phosphorus is the nutrient in short supply in most fresh waters, even a modest increase in phosphorus can, under the right conditions, set off a whole chain of undesirable events in a stream including accelerated plant growth, algae blooms, low dissolved oxygen, and the death of certain fish, invertebrates, and other aquatic animals.

There are many sources of phosphorus, both natural and human. These include soil and rocks, wastewater treatment plants, runoff from fertilized lawns and cropland, failing septic systems, runoff from animal manure storage areas, disturbed land areas, drained wetlands, water treatment, and commercial cleaning preparations.

Forms of phosphorus

Phosphorus has a complicated story. Pure, "elemental" phosphorus (P) is rare. In nature, phosphorus usually exists as part of a phosphate molecule (PO_4). Phosphorus in aquatic systems occurs as organic phosphate and inorganic phosphate. Organic phosphate consists of a phosphate molecule associated with a carbon-based molecule, as in plant or animal tissue. Phosphate that is not associated with organic material is inorganic. Inorganic phosphorus is the form required by plants. Animals can use either organic or inorganic phosphate.

Both organic and inorganic phosphorus can either be dissolved in the water or suspended (attached to particles in the water column).

Phosphorus cycles through the environment, changing form as it does so. Aquatic plants take in dissolved inorganic phosphorus and convert it to organic phosphorus as it becomes part of their tissues. Animals get the organic phosphorus they need by eating either aquatic plants, other animals, or decomposing plant and animal material.

As plants and animals excrete wastes or die, the organic phosphorus they contain sinks to the bottom, where bacterial decomposition converts it back to inorganic phosphorus, both dissolved and attached to particles. This inorganic phosphorus gets back into the water column when the bottom is stirred up by animals, human activity, chemical interactions, or water currents. Then it is taken up by plants and the cycle begins again.

In a stream system, the phosphorus cycle tends to move phosphorus downstream as the current carries decomposing plant and animal tissue and dissolved phosphorus. It becomes stationary only when it is taken up by plants or is bound to particles that settle to the bottom of pools.

In the field of water quality chemistry, phosphorus is described using several terms. Some of these terms are chemistry based (referring to chemically based compounds), and others are methods-based (they describe what is measured by a particular method).

The term "orthophosphate" is a chemistry-based term that refers to the phosphate molecule all by itself. "Reactive phosphorus" is a corresponding method-based term that describes what you are actually measuring when you perform the test for orthophosphate. Because the lab procedure isn't quite perfect, you get mostly orthophosphate but you also get a small fraction of some other forms.
More complex inorganic phosphate compounds are referred to as "condensed phosphates" or "polyphosphates." The method-based term for these forms is "acid hydrolysable."

Monitoring Phosphorus

Monitoring phosphorus is challenging because it involves measuring very low concentrations down to 0.01 milligram per liter (mg/L) or even lower. Even such very low concentrations of phosphorus can have a dramatic impact on streams. Less sensitive methods should be used only to identify serious problem areas.
While there are many tests for phosphorus, only four are likely to be performed by volunteer monitors.

1. The *total orthophosphate* test is largely a measure of orthophosphate. Because the sample is not filtered, the procedure measures both dissolved and suspended orthophosphate. The EPA-approved method for measuring total orthophosphate is known as the ascorbic acid method. Briefly, a reagent (either liquid or powder) containing ascorbic acid and ammonium molybdate reacts with orthophosphate in the sample to form a blue compound. The intensity of the blue color is directly proportional to the amount of orthophosphate in the water.
2. The *total phosphorus* test measures all the forms of phosphorus in the sample (orthophosphate, condensed phosphate, and organic phosphate). This is accomplished by first "digesting" (heating and acidifying) the sample to convert all the other forms to orthophosphate. Then the orthophosphate is measured by the ascorbic acid method. Because the sample is not filtered, the procedure measures both dissolved and suspended orthophosphate.
3. The *dissolved phosphorus* test measures that fraction of the total phosphorus which is in solution in the water (as opposed to being attached to suspended particles). It is determined by first filtering the sample, then analyzing the filtered sample for total phosphorus.
4. *Insoluble phosphorus* is calculated by subtracting the dissolved phosphorus result from the total phosphorus result.

All these tests have one thing in common they all depend on measuring orthophosphate. The total orthophosphate test measures the orthophosphate that is already present in the sample. The others measure that which is already present and that which is formed when the other forms of phosphorus are converted to orthophosphate by digestion.

Fecal Bacteria

What are fecal bacteria and why are they important?

Members of two bacteria groups, coliforms and fecal streptococci, are used as indicators of possible sewage contamination because they are commonly found in human and animal feces. Although they are generally not harmful themselves, they indicate the possible presence of pathogenic (disease-causing) bacteria, viruses, and protozoans that also live in human and animal digestive systems. Therefore, their presence in streams suggests that pathogenic microorganisms might also be present and that swimming and eating shellfish might be a health risk. Since it is difficult, time-consuming, and expensive to test directly for the presence of a large variety of pathogens, water is usually tested for coliforms and fecal streptococci instead. Sources of fecal contamination to surface waters include wastewater treatment plants, on-site septic systems, domestic and wild animal manure, and storm runoff.

In addition to the possible health risk associated with the presence of elevated levels of fecal bacteria, they can also cause cloudy water, unpleasant odors, and an increased oxygen demand.

Indicator bacteria types and what they can tell you

The most commonly tested fecal bacteria indicators are total coliforms, fecal coliforms, *Escherichia coli*, fecal streptococci, and enterococci. All but *E. coli* are composed of a number of species of bacteria that share common characteristics such as shape, habitat, or behavior; *E. coli* is a single species in the fecal coliform group.

Total coliforms are a group of bacteria that are widespread in nature. All members of the total coliform group can occur in human feces, but some can also be present in animal manure, soil, and submerged wood and in other places outside the human body. Thus, the usefulness of total coliforms as an indicator of fecal contamination depends on the extent to which the bacteria species found are fecal and human in origin. For recreational waters, total coliforms are no longer recommended as an indicator. For drinking water, total coliforms are still the standard test because their presence indicates contamination of a water supply by an outside source.

Fecal coliforms, a subset of total coliform bacteria, are more fecal-specific in origin. However, even this group contains a genus, *Klebsiella*, with species that are not necessarily fecal in origin. *Klebsiella* are commonly associated with textile and pulp and paper mill wastes. Therefore, if these sources discharge to your stream, you might wish to consider monitoring more fecal and human-specific bacteria. For recreational waters, this group was the primary bacteria indicator until relatively recently, when EPA began recommending *E. coli* and enterococci as better indicators of health risk from water contact. Fecal coliforms are still being used in many states as the indicator bacteria.

E. coli is a species of fecal coliform bacteria that is specific to fecal material from humans and other warm-blooded animals. EPA recommends E. coli as the best indicator of health risk from water contact in recreational waters; some states have changed their water quality standards and are monitoring accordingly.

Fecal streptococci generally occur in the digestive systems of humans and other warm-blooded animals. In the past, fecal streptococci were monitored together with fecal coliforms and a ratio of fecal coliforms to streptococci was calculated. This ratio was used to determine whether the contamination was of human or nonhuman origin. However, this is no longer recommended as a reliable test.

Enterococci are a subgroup within the fecal streptococcus group. Enterococci are distinguished by their ability to survive in salt water, and in this respect they more closely mimic many pathogens than do the other indicators. Enterococci are typically more human-specific than the larger fecal streptococcus group. EPA recommends enterococci as the best indicator of health risk in salt water used for recreation and as a useful indicator in fresh water as well.

Which Bacteria Should You Monitor?

Which bacteria you test for depends on what you want to know. Do you want to know whether swimming in your stream poses a health risk? Do you want to know whether your stream is meeting state water quality standards?

Studies conducted by EPA to determine the correlation between different bacterial indicators and the occurrence of digestive system illness at swimming beaches suggest that the best indicators of health risk from recreational water contact in fresh water are *E. coli* and enterococci. For salt water, enterococci are the best. Interestingly, fecal coliforms as a group were determined to be a poor indicator of the risk of digestive system illness. However, many states continue to use fecal coliforms as their primary health risk indicator.

If your state is still using total or fecal coliforms as the indicator bacteria and you want to know whether the water meets state water quality standards, you should monitor fecal coliforms. However, if you want to know the health risk from recreational water contact, the results of EPA studies suggest that you should consider switching to the *E. coli* or enterococci method for testing fresh water. In any case, it is best to consult with the water quality division of your state's environmental agency, especially if you expect them to use your data.

What level of E. coli is acceptable?

New Hampshire Department of Environmental Services, 2021

The acceptable level of E. coli is determined by risk analysis based on statistics to protect human health. Drinking water should have no E. coli after treatment. E. coli levels at designated swimming beaches should not exceed 88 per 100 milliliter (mL) in any one sample, or exceed a three-sample geometric mean average over a 60-day period of 47/100 mL. Recreational waters that are not designated beaches should not have more than 406 E. coli/100 mL in any one sample, or more than 126/100 mL in a 60-day, three-sample geometric mean average. Occasional higher numbers are not unusual, particularly after storm events and where urban or agricultural runoff occurs. These levels are generally not considered unsafe unless investigation indicates the source to be sewage.

2022 NCF-Envirothon Ohio
Aquatic Ecology Study Resources

Key Topic #3 Hydrosphere

8. Differentiate the types of wetlands, describe their characteristics, and identify common species found in each.
9. Identify the global distribution of water (saltwater, freshwater, ice, etc.).
10. Identify the characteristics of estuaries and explain the importance of brackish water systems.

Study Resources

Resource Title	Source	Located on
Four Types of Freshwater Wetlands	*Pattee Creek Watershed, University of Montana, 2021*	Page 50
Wetland Functions and Values	*US EPA, 2021*	Pages 51-56
Wetland Delineation	*US EPA, 2021*	Page 57
3 Steps to Delineate a Wetland on a Site Visit	*Tobyhanna Creek/Tunkhannock Creek Watershed Association, 2021*	Page 58
Climate Impact on Water Resources	*US EPA, archived 2017*	Pages 59-61
Estuaries	*National Geographic, 2021*	Pages 62-64
How is Brackish Groundwater Being Used?	*US Geologic Survey, 2021*	Pages 65-66
What is Brackish Water and How Do You Treat It?	*John Woodard, 2021*	Pages 67-68

Study Resources begin on the next page! ➡

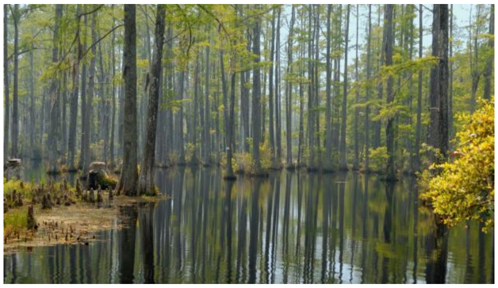
Four Types of Freshwater Wetlands

There are 4 main types of **Freshwater Wetlands** in North America; Ponds, Marshes, Swamps, and Peat bogs.

1) A **Pond** is a well-defined basin that is filled with stagnant water and ringed by vegetation. It is fed mainly by rainstorms and snowmelt, and loses most of its water through seepage and evaporation. In hot, dry months, parts of a Pond may dry out, exposing mud flats. In shallow Ponds, bottom rooted plants such as water lilies can reach the surface, while milfoils, pondweeds and other submergent plants thrive below the water's surface

2) A **Marsh** is usually found near a river, lake or tidal waters. Marshes are subject to periodic flooding, and the water level can change drastically in a short amount of time. The boundaries of a marsh are not well defined, and in draught, a marsh can completely dry up. Marshes are overgrown with coarse grasses, sedges and rushes.

3) A **Swamp** is essentially a wooded marsh. Unlike Marshes, Swamps can support trees, tall shrubs, herbs and mosses. Swamps are covered with still or gently flowing water during wet seasons.



4) A **Peat bog** is a poorly drained area that is covered by mats of moss, which slowly decompose in successive layers and eventually form a material called peat. There are 2 types of peat bogs; Bogs and Fens. The water of a Bog is much more acidic than that of a Fen, due to the larger quantities of sphagnum moss and the more advanced process of decomposition in a Bog. The vegetation of a Peat bog is mainly Sedges, Spruce and low-growing members of the Heath family.

Wetland Functions and Values

Wetlands can be thought of as “biological supermarkets.” They produce great quantities of food that attract many animal species. The complex, dynamic feeding relationships among the organisms inhabiting wetland environments are referred to as food webs. The combination of shallow water, high levels of inorganic nutrients, and high rates of primary productivity (the synthesis of new plant biomass through photosynthesis) in many wetlands is ideal for the development of organisms that form the base of the food web -- for example, many species of insects, mollusks, and crustaceans. Some animals consume the above-ground live vegetation (herbivore-carnivore food web); others utilize the dead plant leaves and stems, which break down in the water to form small, nutrient-enriched particles of organic material called detritus. As the plant material continues to break down into smaller and smaller particles, it becomes increasingly enriched (nutritious) due to bacterial, fungal and protozoan activity. This enriched proteinaceous material, including the various microbes that colonize it, feeds many small aquatic invertebrates and small fish. Many of these invertebrates and fish then serve as food for larger predatory amphibians, reptiles, fish, birds, and mammals. Numerous species of birds and mammals rely on wetlands for food, water, and shelter, especially while migrating and breeding.

Spotted salamander

Figure 6 Photo credit: Matt Perry

Many animals need wetlands for part or all of their life-cycles. In late winter and early spring, for example, adult tiger salamanders migrate from uplands to vernal pools for breeding and egg deposition (Figure 6). The gilled larvae resulting from their fertilized eggs then develop further, eventually producing lungs. Therefore, they must leave the vernal pools for adjacent upland, generally forested, habitat as adults, where they are mainly subterranean. In this instance, a complex of wetlands within a forest matrix is important as the life-cycle requirements of the tiger salamanders change. Thus, for the existence of the tiger salamander, both wetlands and uplands are important and essential. This can similarly be said of other amphibians like the spotted salamander as well as many other animals.

The diversity of habitats in a watershed (Figure 7) or larger landscape unit is also important for other ecological functions associated with wetlands. One such function, biogeochemical cycling, involves the biologic, physical, and chemical transformations of various nutrients within the biota, soils, water, and air. Wetlands are very important in this regard, particularly relating to nitrogen, sulfur, and phosphorous. A good example of this occurs in anaerobic (non-oxygenated) and chemically reduced wetland soils and the muddy sediments of aquatic habitats like estuaries, lakes, and streams, which support microbes that function in nitrogen and sulfur cycling. Upon death and decay, the nitrogen and sulfur in plant and animal biomass is released through mineralization. Much of this is eventually transformed into gaseous forms and released into the atmosphere, where it once again becomes available to certain plants and their associated nitrogen-fixing bacteria in the soil. This is literally a major defense for mud, since it is the anaerobic and chemically reducing conditions in the substrate, in conjunction with various microbes that ensure the gaseous release of the nitrogen and sulfur. On the other hand, phosphorous does not have a gaseous form, but vascular plants in wetlands transform inorganic forms of phosphorus (that might otherwise be shunted into undesirable algal blooms) into organic forms in their biomass as they grow. Thus, wetlands provide the conditions needed for the removal of both nitrogen and phosphorus from surface water.

> **A watershed is a geographic area in which water, sediments, and dissolved materials drain from higher elevations to a common low-lying outlet or basin at a point on a larger stream, lake, underlying aquifer, or estuary.**

Figure 7

Scientists also point out that atmospheric maintenance is an additional wetland function. Wetlands store carbon within their live and preserved (peat) plant biomass instead of releasing it to the atmosphere as carbon dioxide, a greenhouse gas affecting global climates. Therefore, wetlands world-wide help to moderate global climatic conditions. On the other hand, filling, clearing and draining wetlands releases carbon dioxide. Wetlands also play an important role in the hydrologic cycle -- a cycle we all experience quite readily, for example, with the precipitation from a thunderstorm and the evaporation of ponded water from a puddle or bird bath. Wetlands can receive, store, and release water in various ways -- physically through ground water and surface water, as well as biologically through transpiration by vegetation -- and therefore function in this very important global cycle. Some specific examples of the benefits of wetlands to society are elaborated below. In addition, since wetlands play an integral role in the ecology of watersheds, two related Watershed Academy Web modules, Watershed Ecology (http://www.epa.gov/watertrain/ecology/) and Wetlands and Watersheds (under development), are also pertinent. These additional modules will be very helpful in understanding the ecology of watersheds and the role of wetlands in a watershed context.

Habitat for Fish, Wildlife, and Plants

Fish and wildlife use wetlands to varying degrees depending upon the species involved. Some live only in wetlands for their entire lives; others require wetland habitat for at least part of their life cycle; still others use wetlands much less frequently, generally for feeding. In other words, for many species wetlands are primary habitats, meaning that these species depend on them for survival; for others, wetlands provide important seasonal habitats, where food, water, and cover are plentiful.

For example, wetlands are essentially the permanent habitat of the beaver, muskrat, wood duck, clapper rail, mud minnow, wild rice, cattail, broadleaf arrowhead and swamp rose. For other species, such as largemouth bass, chain pickerel, woodcock, hooded warbler, otter, black bear, raccoon, and meadow vole, wetlands provide important food, water, shelter, or nesting habitat.

Numerous birds -- including certain shorebirds, wading birds and raptors, and many songbirds -- feed, nest, and/or raise their young in wetlands. Migratory waterfowl, including ducks, geese, and swans, use coastal and inland wetlands as resting, feeding, breeding, or nesting grounds for at least part of the year. For example, in the Chesapeake Bay Region (a major wintering area for waterfowl), coastal wetlands supported an annual average of nearly 79,000 wintering black ducks over a 45-year period (1950-1994); over the same period, it supported an annual average of about 14,000 wintering pintails. Most of these ducks rely on the prairie potholes (depressional wetlands) in upper mid-western United States and adjacent Canada and interior wetlands in northeastern North America for nesting. Indeed, an international agreement to protect wetlands of international importance was developed because some species of migratory birds are completely dependent on certain wetlands and would become extinct if those wetlands were destroyed (read on for the economic values associated with these resources.)

The U.S. Fish and Wildlife Service estimates that up to 43% of the federally threatened and endangered species rely directly or indirectly on wetlands for their survival (e.g., the wood stork, Florida panther, whooping crane, swamp pink, and Canby's dropwort). Many others use wetlands at some point in their lives. Because they produce so much plant biomass and invertebrate life, estuaries and their coastal marshes serve as important nursery areas for the young of many game (recreational) and commercial fish and shellfish. Menhaden, flounder, sea trout, spot, croaker, and striped bass are among the more familiar fish that depend on coastal wetlands. Such areas are also critical nursery habitat for young commercial shrimp along the Southeast and Gulf Coasts. Freshwater fish, such as the chain pickerel and northern pike, use well-flooded or ponded wetlands as breeding and nursery areas. Some fish, like the brown bullhead and mud minnow, even subsist in wetlands that have natural low dissolved oxygen concentrations that unadapted species cannot endure. In the Pacific Northwest, some wetlands release cooler water to salmon-bearing streams and rivers; in places this is critical to the health of coldwater fish populations.

Improving Water Quality and Hydrology

Wetlands are valuable to us because they greatly influence the flow and quality of water (Figure 18). They help improve water quality, including that of drinking water, by intercepting surface runoff and removing or retaining inorganic nutrients, processing organic wastes, and reducing suspended sediments before they reach open water. For example, as the runoff water passes through wetlands, they retain or process excess nitrogen and phosphorus, decompose organic pollutants, and trap suspended sediments that would otherwise clog waterways and affect fish and amphibian egg development. In performing this filtering function, wetlands save us a great deal of money. A 1990 study showed that, the Congaree Bottomland Hardwood Swamp in South Carolina, removes a quantity of pollutants that would be equivalent to that removed annually by a $5 million waste water treatment plant. Another study at a 2,500-acre wetland in Georgia, indicated that it saves $1 million in water pollution abatement costs annually. Wetlands also reduce environmental problems, such as algal blooms, dead zones, and fish kills, that are generally associated with excess nutrient loadings. However, the capacity of wetlands to function this way is not unlimited, and too much surface runoff carrying sediments, nutrients, and other pollutants can degrade wetlands and thus the societal services they provide. In addition to improving water quality through filtering, some wetlands maintain stream flow during dry periods; others replenish groundwater. Many Americans, of course, depend on groundwater for drinking. The Floridian aquifer system, for instance, is one of the more productive ground water sources in the United States. It occurs across the entire state of Florida, and into southern Georgia, and portions of South Carolina and Alabama. This huge subsurface reservoir produces some of the cleanest water in the nation. Its primary source is rainwater that filters through hundreds of feet of sand and rock. One calculation for 5-acre Florida cypress swamp recharging groundwater was that, if 80 percent of swamp was drained, available ground water would be reduced by an estimated 45 percent.

Flood Protection

Because of their low topographic position relative to uplands (e.g., isolated depressions, floodplains), wetlands store and slowly release surface water, rain, snowmelt, groundwater and flood waters. Trees and other wetland vegetation also impede the movement of flood waters and distribute them more slowly over floodplains (Figure 18 and figure 19 on the next page). This combined water storage and slowing action lowers flood heights and reduces erosion downstream and on adjacent lands. It also helps reduce floods and prevents waterlogging of agricultural lands. Wetlands within and downstream of urban areas are particularly valuable in this regard, counteracting the greatly increased rate and volume of surface-water runoff from pavement and buildings. Preserving and restoring wetlands, together with other water retention, can often provide the level of flood protection otherwise provided by expensive dredging operations and levees. The preservation of wetlands also results in many other benefits to society, such as the protection of ecologically significant fish and wildlife habitat. A good example of this is the Mississippi River's bottomland hardwood-riparian wetlands, which once stored at least 60 days of floodwater and represented significant fish and wildlife habitat. They now store only 12 days of floodwater because most have been filled, leveed, or drained, with substantial loss of fish and wildlife habitat. Another good example is Minnesota, where the cost of replacing the natural flood control function of 5000 acres of drained wetlands was found to be $1.5 million annually.

To quote Henry Wessman, the mayor of Grand Forks, ND: "The total cost of flood damage is born by taxpayers again and again as the flood waters come. I offer as a suggestion to compensate farmers within the area to actually retain natural wetlands. If you look at the costs of compensating farmers for such activities as opposed to the almost annual cost of flood protection and flood fighting within a city such as Grand Forks, you would realize that over the long haul, you are doing yourself a much greater service by retaining that water rather than by continually paying for flood damage."

Therefore, in addition to their fish and wildlife values, wetlands reduce the likelihood of flood damage to homes, businesses, and crops in agricultural areas. They also help control increases in the rate and volume of runoff in urban areas. This protection results in less monetary flood damage (and related insurance costs), as well as protection of human health, safety, and welfare.

Shoreline Erosion

Because of their position on the landscape, wetlands at the margins of lakes, rivers, bays, and the ocean help protect shorelines and stream banks against erosion. Wetland plants hold the soil in place with their roots, absorb the energy of waves, and break up the flow of stream or river currents. The ability of wetlands to control erosion is so valuable that some states (e.g., Florida) are restoring wetlands in coastal areas to buffer the storm surges from hurricanes and tropical storms by dissipating wave energy before it impacts roads, houses, and other man-made structures.

Economic Benefits of Wetland Resources

We use many natural products from wetlands, including mammals and birds, fish and shellfish, and timber. For example, wetlands supporting timber totals about 55 million acres, two-thirds of which occurs east of the Rocky Mountains. Similarly, various plants like blueberries, cranberries, mints, and wild rice, are produced in wetlands. We also derive medicines from wetland soils and plants.

Many of the nation's fishing and shellfishing industries harvest wetland-dependent species (e.g., striped bass and brown shrimp). In fact, the fish and shellfish that depend on wetlands for food or habitat constitute more than 75% of the commercial and 90% of the recreational harvest. In the Southeast, fish and shellfish species dependent upon coastal and estuarine wetlands comprise almost all of the commercial catch. The coastal marshes of Louisiana alone produce a commercial fish and shellfish harvest amounting to 1.2 billion pounds annually, which was worth $244 million in 1991. In this region, 96% of the commercial harvest and more than 50% of the recreational catch are estuary-coastal wetland dependent fish and shellfish. The United States commercial fisheries harvest is worth more than $2 billion annually. This harvest is the basis for a $26.8 billion fishery processing and sales industry. Overall, including commercial and recreational endeavors, seafood is a $50 billion industry.

Wetlands are habitats for commercial fur-bearers like muskrat, beaver, otter, and mink, as well as reptiles such as alligators. The nation's harvest of muskrat pelts alone valued at over $70 million annually, while the alligator industry is valued at $16 million.

Recreation, Education, and Research

Wetlands provide many recreational, educational, and research opportunities. In the United States, more than half of all the adults (98 million) hunt, fish, birdwatch or photograph wildlife, annually spending a total of $59.5 billion in the process. Coastal areas themselves attract at least 100 million Americans each year. At least $18 billion in economic activity is generated annually from coastal wetland-dependent recreational fishing by 17 million Americans. Nature-related recreation is the fastest growing activity of the tourism industry – with an annual increase of about 30% since 1987. In 1996, 160 million Americans spent $29.2 billion to observe, photograph or feed wildlife. Much of this nature-based tourism involves birds, many of which are wetland-dependent. Each year, about $20 billion are spent on seed, travel and equipment by birders. Birding has increased more quickly than other outdoor recreation activities, such as biking, pleasure walking, skiing and golf. In fact, participation has tripled from 1982-83 (21 million) in to 1997 (63 million in 1997). The birding public is quite active – 24.7 million people took trips away from home to partake in birding, spending $5.2 billion in goods and services in 1991. This high level of participation by Americans in bird-related recreation is a clear indicator of the societal value of birds. An inordinate amount of this recreational birding is associated with wetlands and aquatic habitats. This undoubtedly relates to the fact that birds in particular tend to gravitate towards wetlands and aquatic habitats, which in turn attracts natural history and outdoor enthusiasts.

Nationally, economic activity directly associated with non-consumptive enjoyment of birds generated 191,000 jobs and more than $895 million in sales and income tax revenues in 1991. In addition, 3 million migratory bird hunters generated $1.3 billion in retail sales, with a total economic multiplier effect of $3.9 billion, associated with 46,000 additional jobs and sales and income tax revenues of $176 million.

Regional statistics on birding activity are also impressive. A prime example is the Delaware Bay shore and Cape May peninsula of New Jersey, which realizes more than $40 million annually from birders. In addition, artists and writers capture the beauty of wetlands on canvas and paper, or through cameras, and video and sound recorders. Others appreciate wetlands by hiking, boating, and other recreational activities. Almost everyone likes being on or near the water; part of the enjoyment is the varied, fascinating life forms (Figure 27) found in these biologically rich areas.

The recreational benefits associated with wetlands, of course, also serve to educate. Wetlands are studied in conjunction with environmental programs at adult continuing education facilities and at environmental centers. Furthermore, many school systems at the grammar, middle, and high school levels use these valuable ecosystems as out-of door laboratories for environmentally related courses, since they serve as excellent study sites to learn about vegetative structure (e.g., the density and cover of the vegetation) and ecological functions (e.g., nutrient cycling), natural ecological processes (e.g., plant succession), biodiversity, and plant-animal interactions. For more advanced students, particularly those at the high school and college levels, and professionals seeking to learn more about wetlands, they serve as excellent research sites.

WETLAND DELINEATION

Jurisdictional Determinations

Jurisdictional Determinations are issued by the Army Corps of Engineers, and determine whether a water will be regulated under Section 404 of the Clean Water Act. These are often determined by performing a jurisdictional delineation of waters on a property.

Jurisdictional Delineations are performed on a property in order to delineate which waters are Waters of the U.S. and are therefore subject to CWA (Clean Water Act) Section 404. Most often, a preliminary jurisdictional delineation is submitted to the Army Corps by the permit applicant, which the Corps then verifies. The applicant can decide whether they would like a final approved delineation or would like to proceed with an application with only a verified preliminary delineation, which makes for a shorter process.

Wetlands have the following general diagnostic environmental characteristics:

1) **Vegetation.** The prevalent vegetation consists of macrophytes that are typically adapted to areas having hydrologic and soil conditions described in a above. Hydrophytic species, due to morphological, physiological, and/or reproductive adaptation(s), have the ability to grow, effectively compete, reproduce, and/or persist in anaerobic soil conditions.
2) **Soil.** Soils are present and have been classified as hydric. Hydric soils form under conditions of water saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions in the upper part. These soils are typically grey to dark grey or black. They possess characteristics that are associated with reducing soil conditions.
3) **Hydrology.** The area is inundated either permanently or periodically at mean water depths <6.6 ft, or the soil is saturated to the surface at some time during the growing season of the prevalent vegetation. Except in certain situations, evidence of a minimum of one positive wetland indicator from each parameter (hydrology, soil, and vegetation) must be found in order to make a positive wetland determination.

3 Steps to Delineate a Wetland on a Site Visit:

Tobyhanna Creek/Tunkhannock Creek Watershed Association, 2021

- Hydrology Station: Search for indicators of hydrology: Standing water, channels, water-stained leaves, buttressed (heavily exposed) tree roots, or any other clue that indicates the presence of water can be considered indicators of hydrology. Dig a soil pit to see if it fills with water or to check for the formation of water beads. Try to determine the source and movement of the water. Record their findings.
- Hydric Soil Station: Examine a soil pit previously dug in order to understand a little about soils and where they should be taking their soil samples (which is approximately 12-15 inches down, or at the interface between the A and B soil horizon). Take soil samples in wetland and upland sites to determine soil colors utilizing a soil chart, such as the Munsell soil color chart. Determine whether or not the soils located at their station are hydric. Record information on data sheets.

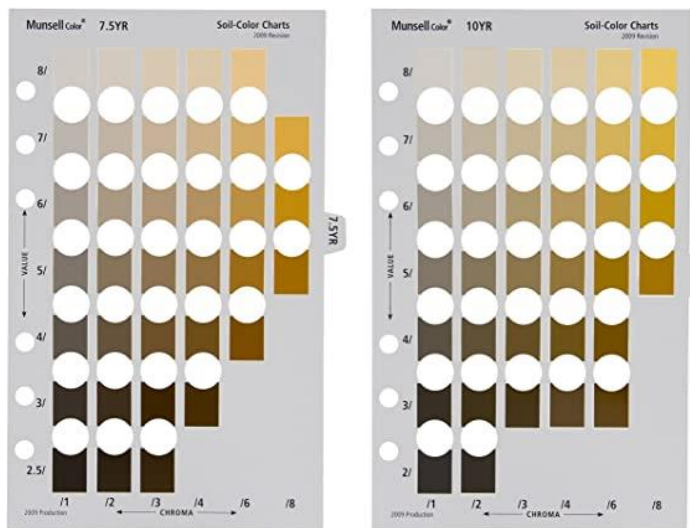


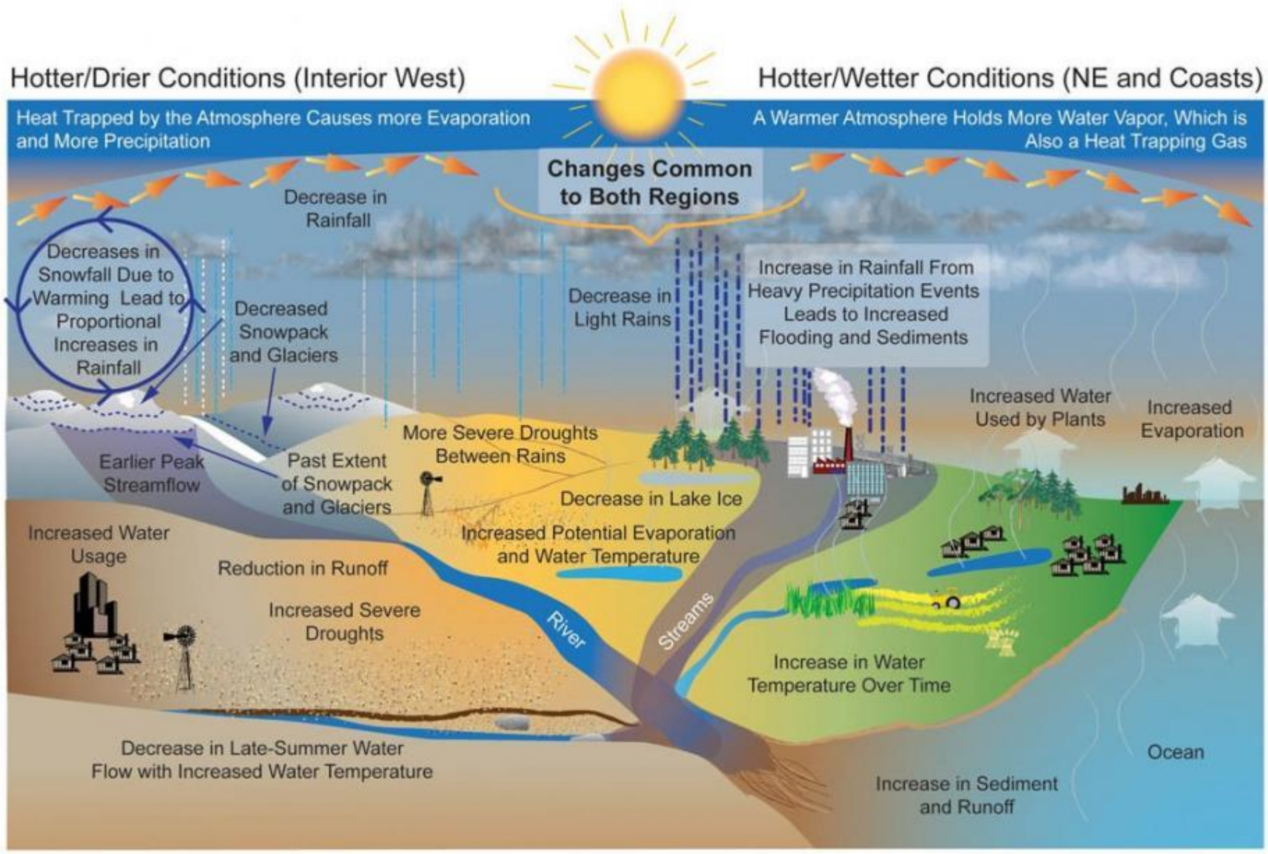
Figure: Munsell color book page layout. Pages from 7.5 and 10 yrs and are each of different hues with color chips of different values aligned vertically on the page and chroma arranged horizontally on the page. Source: https://enviro-soil.com/soils101/includes/soil_color.html

- Status of the vegetation: Determine what the dominant plant types (with status) are present at the site and if they are in an upland or wetland plants.

Use information to answer the following: (1) What, if any, indicators of hydrology were observed at the stations and if observed, what the source and movement of the water at the site was (2) How the conclusion was made if a soil was hydric or not (3) What types of vegetation were identified, how they were classified, and where they were located and (4) based on their findings if they believed they were in an upland or wetland.

Climate Impacts on Water Resources

Key Points



- Warming temperatures, changes in precipitation and runoff, and sea level rise have affected and will likely continue to affect water supply and quality.
- Changes will vary in different regions of the United States; potential effects include increased flooding and drought, water quality impairment, and salt water intrusion to coastal water supplies.
- Changes to our water resources affect many sectors, including energy production, infrastructure, human health, agriculture, and ecosystems.

Water resources are important to both society and ecosystems. We depend on a reliable, clean supply of drinking water to sustain our health. We also need water for agriculture, energy production, navigation, recreation, and manufacturing. Many of these uses put pressure on water resources, stresses that are likely to be exacerbated by climate change.

In many areas, climate change is likely to increase water demand while shrinking water supplies. This shifting balance would challenge water managers to simultaneously meet the needs of growing communities, sensitive ecosystems, farmers, ranchers, energy producers, and manufacturers. In some areas, water shortages will be less of a problem than increases in runoff, flooding, or sea level rise. These effects can reduce the quality of water and can damage the infrastructure that we use to transport and deliver water.

Water Cycle and Water Demand

The water cycle (shown in the following figure) is a delicate balance of precipitation, evaporation, and all of the steps in between. Warmer temperatures increase the rate of evaporation of water into the atmosphere, in effect increasing the atmosphere's capacity to "hold" water.[1] Increased evaporation may dry out some areas and fall as excess precipitation on other areas.

Changes in the amount of rain falling during storms provide evidence that the water cycle is already changing. Over the past 50 years, the amount of rain falling during very heavy precipitation events has increased for most of the United States. This trend has been greatest in the Northeast, Midwest, and upper Great Plains, where the amount of rain falling during the most intense 1% of storms has increased more than 30%.[1] Warming winter temperatures cause more precipitation to fall as rain rather than snow. Furthermore, rising temperatures cause snow to begin melting earlier in the year. This alters the timing of streamflow in rivers that have their sources in mountainous areas.[1]
As temperatures rise, people and animals need more water to maintain their health and thrive. Many important economic activities, like producing energy at power plants, raising livestock, and growing food crops, also require water. The amount of water available for these activities may be reduced as Earth warms and if competition for water resources increases.[1]
Projected changes in the water cycle. Source: USGCRP 2009

Colorado River Water Supply[1][2]

The Colorado River system is a major source of water supply for the Southwest. It supplies water for 33 million people in the cities of Los Angeles, Phoenix, Las Vegas, and Denver. Recent droughts, reductions in winter precipitation and snow pack, and warmer, drier springs have caused water supplies in Colorado River reservoirs to decrease. Expected climate change impacts on Colorado River water supply include:

- Increased year-to-year changes in water storage in reservoirs are possible, even under current conditions.
- Decreased hydropower. For every 1% decrease in streamflow in the Colorado River Basin, there is a 3% decrease in hydroelectric power generation for the region.
- Reductions in river discharge and runoff from snowmelt. Annual snowmelt runoff could also shift to earlier in the spring.

Water Supply Matching satellite images show the decline in Lake Powell and the Colorado River between 1999 and 2014. NASA (2014)Many areas of the United States, especially the West, currently face water shortages. The amount of water available in these areas is already limited, and demand will continue to rise as population grows. Many areas in the West have experienced less rain over the past 50 years, as well as increases in the severity and length of droughts; this has been especially of concern in the Southwest.[1][3]

In the western part of the United States, less total annual rainfall, less snowpack in the mountains, and earlier snowmelt mean that less water will likely be available during the summer months when demand is highest. This will make it more difficult for water managers to satisfy water demands throughout the course of the year.[2][5]

Water Quality

Water quality could suffer in areas experiencing increases in rainfall. For example, in the Northeast and Midwest increases in heavy precipitation events could cause problems for the water infrastructure, as sewer systems and water treatment plants are overwhelmed by the increased volumes of water.[1] Heavy downpours can increase the amount of runoff into rivers and lakes, washing sediment, nutrients, pollutants, trash, animal waste, and other materials into water supplies, making them unusable, unsafe, or in need of water treatment.[2] For information about how climate change and water quality affect public health, visit the Health Impacts & Adaptation page.

Heavy rain in 2004 damaged the city water system in Asheville, North Carolina. Source: USGCRP (2009)Freshwater resources along the coasts face risks from sea level rise. As the sea rises, saltwater moves into freshwater areas. This may force water managers to seek other sources of fresh water, or increase the need for desalination (or removal of salt from the water) for some coastal freshwater aquifers used as drinking water supply.[1] In addition, as more freshwater is removed from rivers for human use, saltwater will move farther upstream. Drought can cause coastal water resources to become more saline as freshwater supplies from rivers are reduced. Water infrastructure in coastal cities, including sewer systems and wastewater treatment facilities, faces risks from rising sea levels and the damaging impacts of storm surges.[2]

Coastal Water Supply [1][4][5][6][7]

The quality of water supply in coastal and island regions is at risk from rising sea level and changes in precipitation. Rising sea level and the occurrence of drought can increase the salinity of both surface water and ground water through salt water intrusion.

For example, the freshwater Everglades currently recharge Florida's Biscayne aquifer, a natural underground area that collects water and is the primary water supply to the Florida Keys. If rising sea levels submerge low-lying areas of the Everglades, portions of the aquifer would become saline. Sea level rise can also push salty water upstream in coastal areas, threatening surface water supplies. Aquifers in New Jersey east of Philadelphia are recharged by fresh portions of the Delaware River, which become saline during severe droughts.

Freshwater resources on some islands, especially small islands and atolls, can be limited, as supply depends on shallow aquifers, which are recharged by precipitation. These freshwater lenses float on top of the saltwater, and rising sea level diminishes the area above sea level in which the lens can reside. (For more detailed information, see the illustration on page 158 of this Climate Change Science Program Report(320 pp, 7.6 M, About PDF)). Sea level rise can turn these shallow aquifers brackish through saltwater intrusion and droughts reduce the water available from other sources, further stressing these limited water supplies.

ESTUARIES

An estuary may also be called a bay, lagoon, sound, or slough. An estuary is an area where a freshwater river or stream meets the ocean. When freshwater and seawater combine, the water becomes brackish, or slightly salty. Water continually circulates into and out of an estuary. Tides create the largest flow of saltwater, while river mouths create the largest flow of freshwater.

When dense, salty seawater flows into an estuary, it has an estuarine current. High tides can create estuarine currents. Saltwater is heavier than freshwater, so estuarine currents sink and move near the bottom of the estuary. When less-dense freshwater from a river flows into the estuary, it has an anti-estuarine current. Anti-estuarine currents are strongest near the surface of the water. Heated by the sun, anti-estuarine currents are much warmer than estuarine currents. In estuaries, water level and salinity rise and fall with the tides. These features also rise and fall with the seasons. During the rainy season, rivers may flood the estuary with freshwater.

During the dry season, the outflow from rivers may slow to a trickle. The estuary shrinks, and becomes much more saline. During a storm season, storm surges and other ocean waves may flood the estuary with saltwater. Most estuaries, however, are protected from the ocean's full force. Geographical features such as reefs, islands, mud, and sand act as barriers from ocean waves and wind.

Types of Estuaries

There are four different kinds of estuaries, each created a different way:

<u>1) Coastal plain estuaries</u>

Coastal plain estuaries are created when sea levels rise and fill in an existing river valley. The Chesapeake Bay, on the East Coast of the United States, is a coastal plain estuary. Chesapeake Bay was formed at the end of the last ice age. Massive glaciers retreated, leaving a carved-out landscape behind. The Atlantic Ocean rushed to fill in the wide coastal plain around the Susquehanna River, creating a large estuary known as a ria: a drowned river mouth.
Tectonic activity, the shifting together and drifting apart of the Earth's crust, creates tectonic estuaries (2). California's San Francisco Bay is a tectonic estuary.

<u>2) Tectonic Estuaries</u>

The San Francisco Bay lies at the junction of the San Andreas fault and the Hayward fault. The complex tectonic activity in the area has created earthquakes for thousands of years. The San Andreas fault is on the coastal side of the bay, where it meets the Pacific Ocean at a strait known as the Golden Gate. The Hayward fault lies on the East Bay, near where the Sacramento and San Joaquin Rivers enter the estuary. The interaction of the San Andreas and Hayward faults contributes to downwarping, the process of an area of the Earth sinking. Like the Chesapeake, the San Francisco Bay was only filled with water during the last ice age. As glaciers retreated, land around the bay experienced post-glacial rebound—without the massive weight of the glacier on top of it, the land gained elevation. The Pacific Ocean rushed in through the Golden Gate to flood the downwarped valley.

<u>3) Bar-built Estuaries</u>

When a lagoon or bay is protected from the ocean by a sandbar or barrier island, it is called a bar-built estuary. The Outer Banks, a series of narrow barrier islands in North Carolina and Virginia, create sandy, bar-built estuaries.

The Outer Banks protect the region's coast from waves and wind brought by Atlantic Ocean hurricanes. The islands and sandbars also protect the delicate, brackish ecosystems created by the outflow of many rivers, such as the Roanoke and Pamlico. For these reasons, engineers monitor the shifting sandbars of the Outer Banks, and constantly work to maintain them.

4) Fjord Estuaries

Fjord estuaries are a type of estuary created by glaciers. Fjord estuaries occur when glaciers carve out a deep, steep valley. Glaciers retreat and the ocean rushes into fill the narrow, deep depression. Puget Sound is a series of fjord estuaries in the U.S. state of Washington. Like fjords found in Alaska and Scandinavia, the fjord estuaries of Puget Sound are very deep, very cold, and very narrow. Unlike many of those fjords, Puget Sound's fjord estuaries also have inflows from local rivers and streams. Many of these streams are seasonal, and fjord estuaries remain mostly salty.

Freshwater Estuaries

Some estuaries not located near oceans. These freshwater estuaries are created when a river flows into a freshwater lake. Although freshwater estuaries are not brackish, the chemical composition of lake and river water is distinct. River water is warmer and less dense than lake water. The mixing of the two freshwater systems contributes to lake turnover—the mixing of the waters of a lake. Freshwater estuaries are not affected by tides, but large bodies of water do experience predictable standing waves called seiches. Seiches, sometimes nicknamed sloshes, rhythmically move back and forth across a lake. The Great Lakes, in the United States and Canada, experience seiches and have many freshwater estuaries. Old Woman Creek National Estuarine Research Center, in Huron, Ohio, was established to study the habitat created by a natural freshwater estuary. At the research center, Old Woman Creek empties into Lake Erie.

Estuary Ecosystems

Many plant and animal species thrive in estuaries. The calm waters provide a safe area for small fish, shellfish, migrating birds and shore animals. The waters are rich in nutrients such as plankton and bacteria. Decomposing plant matter, called detritus, provides food for many species.

Estuaries and People

Estuaries are excellent sites for community living. They provide freshwater for drinking and hygiene. Access to both rivers and oceans helps the development of trade and communication. In fact, the earliest civilizations in the world developed around estuaries. Ur, in what is now Iraq, developed around 3800 BCE near the estuary of the Euphrates River where it met the Persian Gulf. Ur was a sophisticated urban area, with a population of more than 60,000 at its height. Its estuary was the most important port on the Persian Gulf. All ships carrying trade goods from places such as India and the Arabian Peninsula had to pass through Ur. The estuary's wetlands and flood plains provided a rich source of wild game and allowed for the development of irrigation and agriculture. Today, Ur is an archaeological site well inland from the Persian Gulf coast. The landscape has changed, and the estuary of the Euphrates is more than 300 kilometers (186 miles) away. Many modern cities have grown around estuaries, including Jakarta, Indonesia, New York City, New York; and Tokyo, Japan. These urban areas have undergone rapid change, and put their estuaries at environmental risk through land reclamation, pollution, and overfishing.

Land Reclamation
Communities have filled in the edges of estuaries for housing and industry since the times of Ur. This process is called land reclamation. Jakarta's 10 million residents have one of the highest population densities in the world. To create more space for homes and businesses, Indonesian officials have dredged the Ciliwung River and Java Bay. The sand and silt dredged from the river bottom and seafloor fortify the city's beaches and create new land. Land reclamation comes at a price, however. Jakarta's fisheries are disrupted by the dredging. This reduces the potential profits for restaurants and markets, as well as fishers. Destroying the estuary also creates the conditions for flooding. Estuaries provide a natural barrier to ocean waves, which can erode the shoreline and destroy coastal homes and businesses. Jakarta is particularly at risk for tsunami damage, as the area experiences frequent earthquakes.

Pollution
Pollution accumulates in estuaries. The Hudson-Raritan Estuary, where the Hudson and Raritan rivers meet the Atlantic Ocean, is one of the most-trafficked and most-polluted estuaries in the world. Pollution from ships routinely spills into the Hudson-Raritan Estuary, just south of New York City. Debris in the estuary, including fuel, garbage, sewage, and ballast, remained unregulated for decades. Runoff from agriculture and industry in New York and New Jersey also contributed a toxic estuarine environment. Industrial waste and pesticides travel downstream and settle in the water and sediment of the estuary. Today, strict regulations and community activities are working to protect and restore the Hudson-Raritan Estuary. The restoration of oyster beds is an important part of many projects. Oysters are a keystone species in the estuary, filter feeders that naturally help regulate toxins in the water. Millions of oyster beds greeted Henry Hudson when he entered the river in 1609. By the middle of the 20th century, however, the few remaining oysters were too toxic for human consumption. Today, several environmental groups are establishing oyster beds to repopulate the region's native species and reduce pollution in the estuary.

Overfishing
Many estuaries have been overfished. Pacific bluefin tuna are not endangered, but their range has been drastically reduced. Japan provides one of the largest markets for bluefin tuna, and the fish used to swim in the estuary of Tokyo Bay. Bluefin tuna are large, predatory fish. They require an expansive habitat and many kilograms of food every day. As Tokyo's population grew and technology made it easier to catch more fish with less time and money, Tokyo Bay's bluefin tuna population shrank. Today, there is not a bluefin tuna population in Tokyo Bay. However, Japanese scientists have established a successful tuna fish farming technique. Farm-raised tuna does not have a direct environmental impact on the Tokyo Bay estuary. Indonesian, American, and Japanese governments and environmental groups struggle to promote sustainable development in estuaries. Sustainable development aims to preserve the environment while satisfying people's economic standard of living.

How is Brackish Groundwater Being Used?

Industry and public drinking-water suppliers are increasingly turning to brackish groundwater to supplement or replace the use of freshwater. Brackish groundwater is either directly used or treated.

Direct Use:

Brackish groundwater is directly used for purposes such as cooling water for power generation, aquaculture, and for a variety of uses in the oil and gas industry such as drilling, enhancing recovery, and hydraulic fracturing.

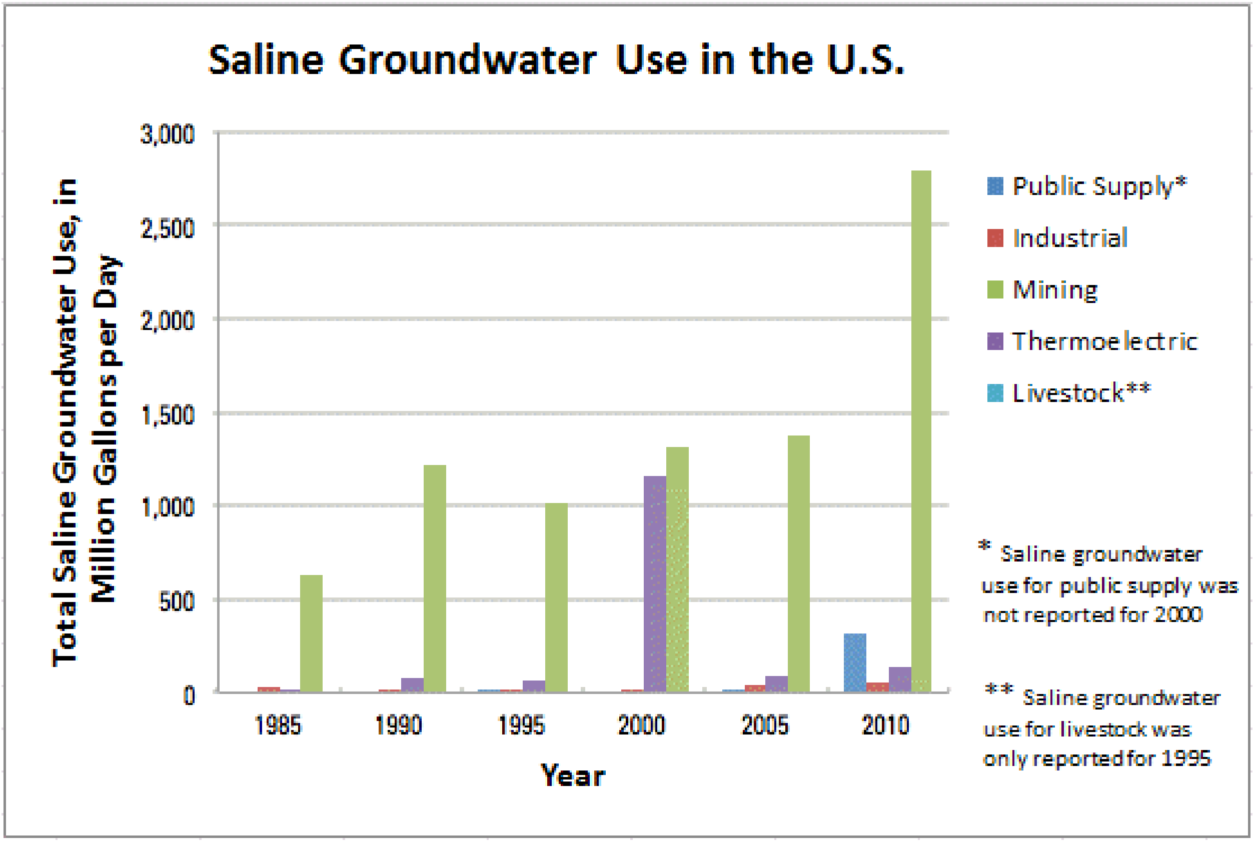
Treated Use:

For purposes requiring lower dissolved-solids content, especially drinking water, brackish water is treated through reverse osmosis or other desalination processes. In 2010, there were 649 active desalination plants in the United States with a capacity to treat 402 million gallons per day (Shea, 2010). Of the desalination plant capacity in the United States, 67 percent was for municipal purposes, 18 percent for industry, 9 percent for power, and the remaining 6 percent for other uses (Mickley, 2010). A total of 314 desalination facilities are used for municipal purposes, 49 percent of which were in Florida, 16 percent in California, 12 percent in Texas, and the remaining 23 percent dispersed among other states. More than 95 percent of the desalination facilities in the United States are inland (Mickley, 2010), and most facilities are designed to treat groundwater with dissolved-solids concentrations in the brackish range (Shea, 2010). Recent advances in technology have reduced the cost and energy requirements of desalination, making treatment of brackish groundwater a more viable option for drinking-water supplies (National Research Council, 2008).

Brackish water desalination facility in Harlingen, Texas. The plant was built in 2007 and has a capacity of 2.25 million gallons per day. Source: North Cameron Regional Water Supply Corporation

Source: Mickley & Associates, written commun., 2013. Survey of municipal desalination plants.

The USGS Water Use Program has published information about saline water use since 1985. The reports include estimates of water withdrawals by State, source of water, and category of use. *Saline water for purposes of that program is defined as water with a dissolved-solids concentration greater than 1,000 milligrams per liter and includes the brackish concentration range.



Graph Source: https://water.usgs.gov/ogw/gwrp/brackishgw/use.html

What is Brackish Water and How Do You Treat It?

Posted by John Woodard on April 22, 2021

Access to safe drinking water is one of the great challenges of modern times. According to the World Health Organization (WHO), 1 in 3 people worldwide don't have access to safe drinking water, and a global population expected to reach 8 billion by 2023 will further exacerbate the problem. Water comprises 71 percent of earth's surface, but only three percent is fresh water, and only about one percent is suitable for drinking. Evidently, there is no shortage of salt water on our planet, and a solution to the global water crisis may lie in the treatment of slightly salty brackish water. Brackish water has salinity levels between fresh water and seawater and is considerably easier to desalinate than the latter. Below you will learn about brackish water, how it is treated, and how it may provide a solution to the world's growing demand for drinking water.

What is brackish water?

Brackish water is water with salinity levels between fresh water and seawater. Salinity refers to the concentration of dissolved salts in a body of water, so brackish water is saltier than fresh water, but less salty than seawater. Brackish water has a salt concentration of 1,000 – 10,000 parts per million (PPM). In contrast, fresh water has a salt concentration of less than 1,000 PPM and seawater has a salt concentration of 30,000 – 40,000 PPM. Also, the total dissolved solids (TDS) level of brackish water far exceeds that of drinking water. The Environmental Protection Agency's guideline for drinking water is less than 500 PPM, while brackish water is between 3,000 and 10,000 PPM.

The easiest way to visualize brackish water is to picture where a river meets an ocean. The transition of fresh river water to salty seawater creates brackish water. These areas are called estuaries and are home to a wide array of plants and animals that have adapted to brackish water, such as mangrove trees and oysters.

Where is brackish water found?

Brackish water is found in estuaries, in lakes, in man-made pools and streams, and even underground in aquifers. Brackish water sources are present across the globe, and estuaries are the most common. For example, as the Thames River in London meets the North Sea, as the Hudson River in New York City meets the New York Bay, and as the Amazon River in Brazil meets the Atlantic Ocean, estuaries are formed. Also, the Caspian Sea (which despite the name is the world's largest lake) contains brackish water because of an ancient ocean that once existed between Europe and Asia. Similar brackish lakes are found around the world, with five in India alone!

Man-made sources of brackish water include intentionally flooded marshlands for prawn farming and ensuing pools and streams from the construction of dikes, which are walls built to control the flow of water from rivers and seas.

Lastly, brackish groundwater exists underground in deep fossil aquifers. Groundwater can be brackish as the result of ancient seas, due to saltwater intrusion in coastal areas, or if water absorbs an excess of minerals, such as sodium and chloride, as it percolates into the ground. In fact, about 75 percent of all the groundwater in New Mexico is brackish. Private well water can even be brackish it draws from a brackish groundwater source. In this case, the water needs to be treated before it can be used.

How do you treat brackish water?

Brackish water is treated through desalination. Desalination is a process that removes dissolved mineral salts from saline water and converts it into fresh, drinkable water. Reverse osmosis and distillation are the primary desalination technologies used to treat brackish water. Seawater can also be desalinated through reverse osmosis and distillation, but due to a higher salt content, not as efficiently as brackish water.

1. **Reverse osmosis : <u>Reverse osmosis</u>** is the leading desalination technology globally. A reverse osmosis system applies pressure to saline water and forces it through a semipermeable membrane. The membrane's small pores block the passage of dissolved salts and other contaminants but allow water to flow through, converting brackish water into fresh water. One of the largest reverse osmosis desalination plants is in Israel and it can produce about 165 million gallons of fresh water each day.
3. **Distillation: <u>Distillation</u>** is a desalination method that mimics evaporation in the atmosphere. Brackish water is heated until it evaporates into steam. Salts and minerals cannot evaporate as water can, so once the water condenses and resumes its liquid form, it is transformed into fresh water. There are two primary distillation methods used to desalinate brackish water: multistage flash distillation and solar distillation. Multistage flash distillation is used in large-scale operations, while solar distillation is used in small-scale operations and in small communities.
   - *Multistage flash distillation*
     In multistage flash distillation, brackish water is passed through multiple chambers where it is heated and compressed under high pressure. In each successive chamber, the pressure is reduced, causing the water to rapidly boil. The vapor produced in each chamber is then condensed and collected as fresh water. Saudi Arabia is home to one of the largest multistage flash distillation systems, and it produces about 200 million gallons of fresh water each day.
   - *Solar distillation*
     In solar distillation, a pool of brackish water is covered by a transparent glass or plastic dome. Sunlight streams through the covering, evaporating the water and condensing it on the cover. The condensation, which is fresh water, then flows from the cover into a collecting trough.

2022 NCF-Envirothon Ohio

Aquatic Ecology Study Resources

Key Topic #4 Aquatics and Society

11. Identify how major legislation protects water resources.
12. Identify organizations that oversee water resource protection.
13. Identify the causes of hypoxia and anoxia in aquatic ecosystems, how these conditions impact the function of the ecosystem, and best management practices for prevention and treatment.
14. Distinguish between point and non-point source pollution and give examples and management strategies for each.
15. Explain the history of human impact on water quality and water resources.

Study Resources

Resource Title	Source	Located on
Overview: Key Federal Environmental Laws	*FindLaw editors, 2016*	Pages 70-72
Hypoxia 101	*US EPA, 2021*	Pages 73-74
Happening Now: Dead Zone in the Gulf 2021	*NOAA, 2021*	Page 75
Point Source and Nonpoint Sources of Pollution	*National Geographic, 2021*	Page 76
Ground Water Contamination	*US EPA, 2021*	Pages 77-78
How to Read a Topographic Map and Delineate a Watershed	*USDA-NRCS, 2021*	Pages 79-80

Study Resources begin on the next page! →

Overview: Key Federal Environmental Laws

Created by FindLaw's team of legal writers and editors | Last updated June 20, 2016

At least 10 major federal laws deal with protecting the environment and the health and safety of U.S. residents. This is in addition to the multitude of other federal acts, rules, and administrative environmental regulations. There are also scores of environmental laws that have been enacted by state and local government. The following is a summary of the major federal environmental laws.

The Clean Water Act

The Clean Water Act was passed in 1977 and is enforced by the EPA, with assistance in particular matters from state agencies or entities. The Act makes it unlawful for any person to discharge any pollutant from a source point into navigable waters of the United States unless they have obtained a special permit allowing such activity from the EPA. Ten years after its enactment, the Clean Water Act was amended to include provisions which focused on toxic pollutants, authorized citizen suits (as opposed to just government enforcement actions), and funded sewage treatment plants.

The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)

In 1980, Congress passed CERCLA for the purpose of addressing how uncontrolled or abandoned hazardous waste sites, accidents, spills, and other emergency releases of pollutants or contaminants should be handled. The Act creates a federal "Superfund" to clean up, contain, or remove pollutants and hazardous materials in these situations.

Under the Act, the EPA has the power to track down the parties responsible for the unsafe abandonment, spill, or release and require their participation in clean-up efforts. If the releaser cannot be found, or refuses to cooperate, the Act gives the EPA responsibility for cleaning up orphaned sites or situations. Once a "response action" to a situation is completed, CERCLA allows for the EPA to recover the costs of the action from financially solvent individuals and companies who were involved.

See also the "Superfund Amendments and Reauthorization Act (SARA)," below.

The Emergency Planning & Community Right-to-Know Act (EPCRA)

In 1986, Congress enacted the EPCRA, which is also known as Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA). The EPCRA is designed to provide assistance to local communities in protecting the public health, safety, and environment from chemical hazards.

Under the EPCRA, each state is required to create and maintain a State Emergency Response Commission (SERC), which is divided into Emergency Planning Districts. Each district must have a Local Emergency Planning Committee (LEPC). The SERCs and LEPCs are responsible for providing the community with information on chemical hazards that may affect the public and the dissemination of procedures to be followed in the event there is an emergency hazardous situation.

The Endangered Species Act

The Endangered Species Act is a unique piece of legislation that was passed in 1973. The purpose of the Act is to protect, and hopefully repopulate, threatened or endangered plants, animals, and animal habitats. Many species of plants and animals are in danger of extinction due to the impact of humans and pollutants, irritants, and toxins released into their environments.

The U.S. Fish and Wildlife Service of the Department of the Interior maintains a list of over 600 endangered plant and animal species, and almost 200 threatened species. Under the Endangered Species Act, anyone can petition to prohibit activities that may have an adverse effect on either endangered or threatened species.

Federal Insecticide, Fungicide & Rodenticide Act (FIFRA)

FIFRA was passed by Congress in 1972 and is enforced by the EPA, which has the power to prohibit the sale, distribution, or use of pesticides such as insecticides, fungicides, and rodenticides under the Act. If a threatened or endangered species will be adversely affected, the EPA can also issue an emergency suspension of certain pesticides.

FIFRA requires that farmers, utility companies, and other users of pesticides register when they purchase pesticides. These individuals are also required by the Act to take and pass a certification examination in order to apply pesticides. FIFRA also contains provisions which require that all pesticides used in the United States be approved and licensed by the EPA.

The National Environmental Policy Act (NEPA)

NEPA is one of the oldest federal environmental protection laws, having been passed in 1969. The overall purpose of NEPA is to ensure that the government researches and gives proper consideration to potential environmental effects before undertaking any major federal action, such as construction of a new highway. As part of this consideration, the government must complete Environmental Assessments (EAs) and Environmental Impact Statements (EISs) for any action they contemplate.

The Occupational Safety & Health Act (OSHA)

In 1970, concerned with the increasing lack of worker and workplace safety, Congress passed OSHA. The main thrust of OSHA is to require employers to provide their workers with a safe workplace. While some OSHA requirements do not directly affect the environment (such as the requirements concerning safety for workers on elevated sites), other provisions specifically address environmental issues (such as the use of toxic or hazardous substances in the workplace).

OSHA is one of the few federal laws that relate to the environment that is not controlled by the EPA. Instead, OSHA is enforced by the U.S. Department of Labor in concert with the National Institute for Occupational Safety and Health (NIOSH), which was specifically created to deal with OSHA issues. In addition, many states have their own workplace safety and health acts. The state acts must have provisions in place which meet, if not exceed, the federal OSHA requirements.

The Pollution Prevention Act

The Pollution Prevention Act, passed in 1990, includes provisions aimed at reducing the amount of pollution in the environment by making changes in production, operation, and use of raw materials by both private industry and the government. In other words, the Act is proactively focused on source reduction of pollution, rather than reactively focusing upon how to deal with pollution once it has entered the environment. An area of the Pollution Prevention Act which has had a dramatic and recognizable impact on the general public is the push towards recycling and reuse of materials.

The Resource Conservation and Recovery Act (RCRA)

This Act allows the EPA to control the generation, transportation, treatment, storage, and disposal of hazardous waste. RCRA also contains provisions for the management of nonhazardous solid wastes. In practice, RCRA complements CERCLA and the two, together, provide mechanisms for controlling all hazardous waste situations. While RCRA focuses upon active and future facilities, CERCLA deals with abandoned or historical sites and emergency situations.

In 1984, the federal Hazardous and Solid Waste Amendments (HSWA) were passed by Congress, amending RCRA to require the phasing out of land disposal of hazardous waste. To accomplish this goal, and to respond to other insufficiencies in RCRA, HSWA also created greater enforcement authority for the EPA and more stringent hazardous waste management standards.

With the phasing out of land disposal of hazardous waste, the EPA soon discovered that new storage issues were coming to the forefront. Therefore, in 1986 an amendment to RCRA was passed which allowed the EPA to focus upon and address specific issues and concerns related to the underground storage of petroleum and other products.

The Safe Drinking Water Act (SDWA)

This 1974 law, as the name implies, addresses issues relating to the quality and safety of drinking water in the United States. Under SDWA, the EPA is authorized to establish purity standards for both aboveground and underground sources of water that are either designated for, or potentially designated for, human consumption. SDWA contains both health-related standards and nuisance-related standards. Both are enforced with the cooperation of state governments.

The Superfund Amendments and Reauthorization Act (SARA)

This 1986 federal act reauthorized CERCLA to continue efforts to clean-up hazardous waste abandonments, spills, and releases. Some provisions of SARA specifically address problems or concerns that arose at specific CERCLA involved sites.
Title III of SARA also created the Emergency Planning and Community Right-to-Know Act (EPCRA), as described above.

The Toxic Substances Control Act (TSCA)

The purpose of TSCA, a 1976 Act of Congress, is to allow for the testing, regulation, and screening of all chemicals produced or imported into the U.S. before they reach the consumer market place.
TSCA also allows for the tracking of all existing chemicals that pose health or environmental hazards and for the implementation of cleanup procedures in the case of toxic material contamination. TSCA supplements other federal laws, such as the Clean Air Act and the Toxic Release Inventory under EPCRA.

Hypoxia 101

What is hypoxia and what causes it?

Hypoxia means low oxygen and is primarily a problem for estuaries and coastal waters. Hypoxic waters have dissolved oxygen concentrations of less than 2-3 mg/L. Hypoxia can be caused by a variety of factors, including excess nutrients, primarily nitrogen and phosphorus, and waterbody stratification (layering) due to saline or temperature gradients. These excess nutrients can promote algal overgrowth and lead to eutrophication. As dead algae decompose, oxygen is consumed in the process, resulting in low levels of oxygen in the water.

Nutrients can come from many sources, including any of the following:

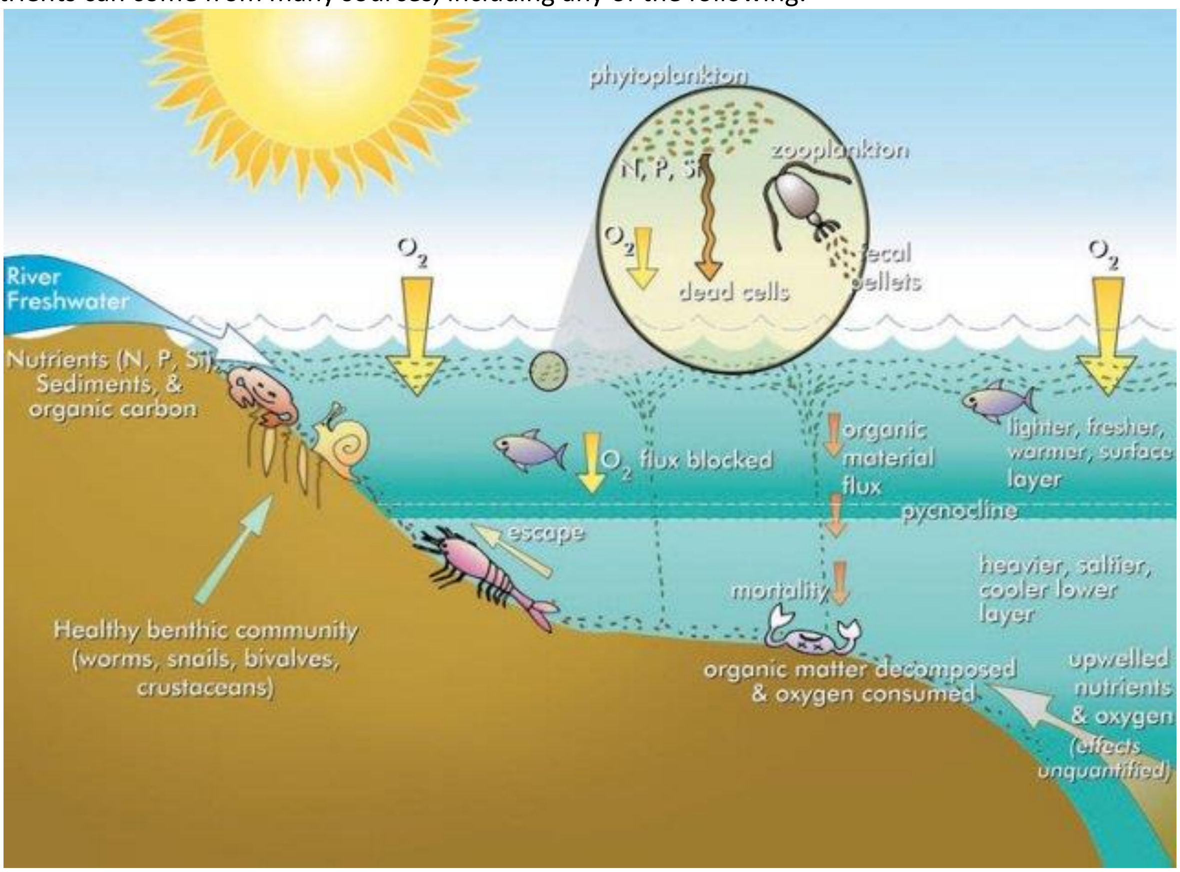


Diagram of Eutrophication

- Fertilizers from agriculture, golf courses, and suburban lawns
- Erosion of soil full of nutrients
- Discharges from sewage treatment plants
- Deposition of atmospheric nitrogen

  The hypoxic zone in the Gulf of Mexico forms every summer and is a result of excess nutrients from the Mississippi/Atchafalaya River and seasonal stratification (layering) of waters in the Gulf. As nutrient-laden water from the Mississippi flows into the Gulf, this freshwater is less dense and remains above the denser saline seawater. In addition to the saline gradient caused where the freshwater and saline water meet, the freshwater is warmer than the deeper ocean water, further contributing to the stratification. This stratification prevents the mixing of oxygen-rich surface water with oxygen-poor water on the bottom of the Gulf. Without mixing, oxygen in the bottom water is limited and the hypoxic condition remains.

Why is it important to reduce hypoxic zones?

Direct effects of hypoxia include fish kills, which deplete valuable fisheries and disrupt ecosystems. Mobile animals (e.g., adult fish) can typically survive a hypoxic event by moving to waters with more oxygen. Less mobile or immobile animals, such as mussels or crabs, cannot move to waters with more oxygen and are often killed during hypoxic events. Ultimately, hypoxia causes a severe decrease in the amount of life in hypoxia zones. Hypoxia also affects the ability of young fish or shellfish to find the food and habitat necessary to become adults. As a result, fish and shellfish stocks may be reduced or become less stable because less young reach adulthood. Hypoxia can also affect species that rely on fish for food. Such species might have to leave an area to find the necessary food to survive.

Where does hypoxia occur?

Hypoxia occurs naturally in many aquatic environments throughout the world, such as in deep basins in the ocean. Hypoxic waters have occurred throughout history, but they are occurring in shallow coastal and estuarine waters more frequently as anthropogenic (i.e., *human*) sources and inputs of nutrients increase.

The Gulf of Mexico hypoxic zone is located in the northern Gulf of Mexico off the coast of Louisiana and Texas. The zone was first documented in 1972.

Happening Now: Dead Zone in the Gulf 2021

The numbers are in. The 2021 Gulf of Mexico Hypoxic Zone, or Dead Zone, an area of low oxygen that can kill fish and marine life near the bottom of the sea, measures six thousand three hundred and thirty-four square miles.
This year's dead zone is larger than the average measured over the past five years.
This year's measurement is equivalent to more than four million acres of habitat potentially unavailable to fish and bottom species.

This “dead zone” begins innocently enough. Farmers use fertilizers and manure to increase the output of their crops so that we can have more food on our tables and more food to sell to the rest of the world. But it is this excess agricultural nutrient pollution combined with urban runoff and wastewater that brings excessive amounts of nutrients into waterways that feed the Mississippi River.

The Mississippi River is like a drainage system for your street, but it connects 31 U.S. states and even parts of Canada. These nutrients are ultimately funneled into the Gulf of Mexico, sometimes traveling more than 1,000 miles downstream to start a chain of events in the Gulf that turns deadly. The nutrients fuel large algal blooms that then sink, decompose, and deplete the water of oxygen. This is hypoxia, when oxygen in the water is so low it can no longer sustain marine life in bottom or near bottom waters—literally, a dead zone. And it happens every summer.

When the water reaches this hypoxic state, fish and shrimp leave the area and anything that can't escape like crabs, worms, and clams die. If the amount of pollution entering the Gulf isn't reduced, the dead zone will continue to wreak havoc on the ecosystem and threaten some of the most productive fisheries in the world.
What are States doing to help?

A variety of innovative technologies and practices are being implemented across the Mississippi River watershed to reduce nutrient pollution such as: technology that removes nutrients from wastewater, practices on the land to limit nutrients entering into waterways, and programs to support farmers in their efforts to implement conservation practices that protect water quality.

There are even steps you can take at home, such as reducing erosion and excess runoff from areas around the house, planting trees and other native plants in your yard, and applying slow-release fertilizers and only when needed.
Even though these efforts may take place far from the Gulf, they can still reduce the harmful impact of the dead zone!

Point Source and Nonpoint Sources of Pollution

For the purposes of regulation, the United States Environmental Protection Agency identifies two broad categories of pollution: point-source pollution and nonpoint-source pollution.

Almost everything humans do, from growing food to manufacturing products to generating electricity, has the potential to release pollution into the environment. Regulatory agencies charged with protecting the environment identify two main categories of pollution: point-source and nonpoint-source pollution.

Point-source pollution is easy to identify. As the name suggests, it comes from a single place. Nonpoint-source pollution is harder to identify and harder to address. It is pollution that comes from many places, all at once.

The United States Environmental Protection Agency (EPA) defines point source pollution as any contaminant that enters the environment from an easily identified and confined place.

Examples include smokestacks, discharge pipes, and drainage ditches.

Factories and power plants can be a source of point-source pollution, affecting both air and water. Smokestacks may spew carbon monoxide, heavy metal, sulfur dioxide, nitrogen dioxide, or “particulate matter” (small particles) into the air. Oil refineries, paper mills, and auto plants that use water as part of their manufacturing processes can discharge effluent—wastewater containing harmful chemical pollutants—into rivers, lakes, or the ocean.

Municipal wastewater treatment plants are another common source of point-source pollution. Effluent from a treatment plant can introduce nutrients and harmful microbes into waterways. Nutrients can cause a rampant growth of algae in water.

Nonpoint-source pollution is the opposite of point-source pollution, with pollutants released in a wide area. As an example, picture a city street during a thunderstorm. As rainwater flows over asphalt, it washes away drops of oil that leaked from car engines, particles of tire rubber, dog waste, and trash. The runoff goes into a storm sewer and ends up in a nearby river. Runoff is a major cause of nonpoint-source pollution. It is a big problem in cities because of all the hard surfaces, including streets and roofs. The amount of pollutants washed from a single city block might be small, but when you add up the miles and miles of pavement in a big city you get a big problem.

In rural areas, runoff can wash sediment from the roads in a logged-over forest tract. It can also carry acid from abandoned mines and flush pesticides and fertilizer from farm fields. All of this pollution is likely to wind up in streams, rivers, and lakes.

Airborne pollutants are major contributors to acid rain. It forms in the atmosphere when sulfur dioxide and nitrogen oxides combine with water. Because acid rain results from the long-range movement of those pollutants from many factories and power plants, it is considered nonpoint-source pollution.

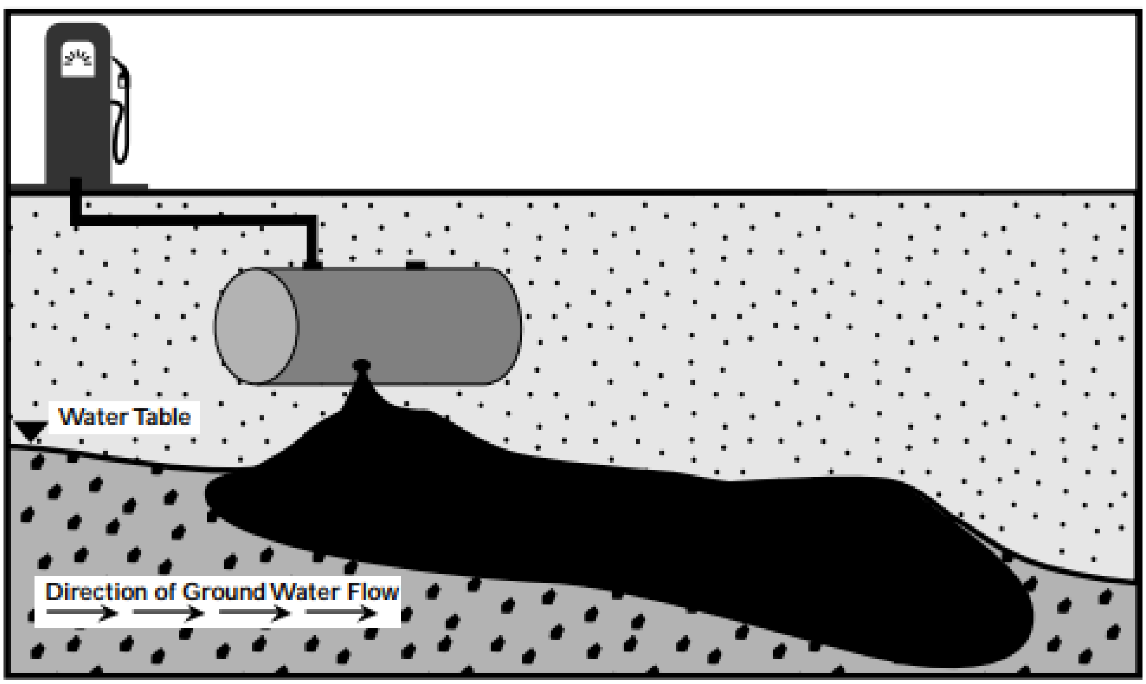
In the United States, the Clean Air Act and the Clean Water Act have helped to limit both point-source and nonpoint-source pollution. Thanks to these two legislative initiatives, in effect for some 50 years now, America’s air and water are cleaner today than they were for most of the 20th century.

GROUND WATER CONTAMINATION

Ground water contamination is nearly always the result of human activity. In areas where population density is high and human use of the land is intensive, ground water is especially vulnerable. Virtually any activity whereby chemicals or wastes may be released to the environment, either intentionally or accidentally, has the potential to pollute ground water. When ground water becomes contaminated, it is difficult and expensive to clean up. To begin to address pollution prevention or remediation, we must understand how surface waters and ground waters interrelate. Ground water and surface water are interconnected and can be fully understood and intelligently managed only when that fact is acknowledged. If there is a water supply well near a source of contamination, that well runs the risk of becoming contaminated. If there is a nearby river or stream, that water body may also become polluted by the ground water.

HOW DOES GROUND WATER BECOME CONTAMINATED? Depending on its physical, chemical, and biological properties, a contaminant that has been released into the environment may move within an aquifer in the same manner that ground water moves. (Some contaminants, because of their physical or chemical properties, do not always follow ground water flow.) It is possible to predict, to some degree, the transport within an aquifer of those substances that move along with ground water flow. For example, both water and certain contaminants flow in the direction of the topography from recharge areas to discharge areas. Soils that are porous and permeable tend to transmit water and certain types of contaminants with relative ease to an aquifer below. Just as ground water generally moves slowly, so do contaminants in ground water. Because of this slow movement, contaminants tend to remain concentrated in the form of a plume (see Figure 1) that flows along the same path as the ground water. The size and speed of the plume depend on the amount and type of contaminant, its solubility and density, and the velocity of the surrounding ground water.

Figure 1 CONTAMINANT PLUME



Ground water and contaminants can move rapidly through fractures in rocks. Fractured rock presents a unique problem in locating and controlling contaminants because the fractures are generally randomly spaced and do not follow the contours of the land surface or the hydraulic gradient. Contaminants can also move into the ground water system through macropores—root systems, animal burrows, abandoned wells, and other systems of holes and cracks that supply pathways for contaminants. In areas surrounding pumping wells, the potential for contamination increases because water from the zone of contribution, a land area larger than the original recharge area, is drawn into the well and the surrounding aquifer. Some drinking water wells actually draw water from nearby streams, lakes, or rivers. Contaminants present in these surface waters can contribute contamination to the ground water system. Some wells rely on artificial recharge to increase the amount of water infiltrating an aquifer, often using water from storm runoff, irrigation, industrial processes, or treated sewage. In several cases, this practice has resulted in increased concentrations of nitrates, metals, microbes, or synthetic chemicals in the water. Under certain conditions, pumping can also cause the ground water (and associated contaminants) from another aquifer to enter the one being pumped. This phenomenon is called interaquifer leakage. Thus, properly identifying and protecting the areas affected by well pumping is important to maintain ground water quality. Generally, the greater the distance between a source of contamination and a ground water source, the more likely that natural processes will reduce the impacts of contamination. Processes such as oxidation, biological degradation (which sometimes renders contaminants less toxic), and adsorption (binding of materials to soil particles) may take place in the soil layers of the unsaturated zone and reduce the concentration of a contaminant before it reaches ground water. Even contaminants that reach ground water directly, without passing through the unsaturated zone, can become less concentrated by dilution (mixing) with the ground water. However, because ground water usually moves slowly, contaminants generally undergo less dilution than when in surface water.

How to Read a Topographic Map and Delineate a Watershed

This fact sheet is an excerpt from Appendix E of the Method for the Comparative Evaluation of Nontidal Wetlands in New Hampshire, 1991. Alan Ammann, PhD and Amanda Lindley Stone. This document and method is commonly called "The New Hampshire Method."

Interpreting Topographic Maps

In order to successfully delineate a watershed boundary, the evaluator will need to visualize the landscape as represented by a topographic map. This is not difficult once the following basic concepts of the topographic maps are understood.

Each contour line on a topographic map represents a ground elevation or vertical distance above a reference point such as sea level. A contour line is level with respect to the earth's surface just like the top of a building foundation. All points along any one contour line are at the same elevation.

The difference in elevation between two adjacent contours is called the contour interval. This is typically given in the map legend. It represents the vertical distance you would need to climb or descend from one contour elevation to the next.

The horizontal distance between contours, on the other hand, is determined by the steepness of the landscape and can vary greatly on a given map. On relatively flat ground, two 20-foot contours can be far apart horizontally.

On a steep cliff face two 20-foot contours might be directly above and below each other. In each case the vertical distance between the contour lines would still be twenty feet.

One of the easiest landscapes to visualize on a topographic map is an isolated hill. If this hill is more or less circular the map will show it as a series of more or less concentric circles (Figure E-1). Imagine that a surveyor actually marks these contour lines onto the ground. If two people start walking in opposite directions on the same contour line, beginning at point A, they will eventually meet face to face.

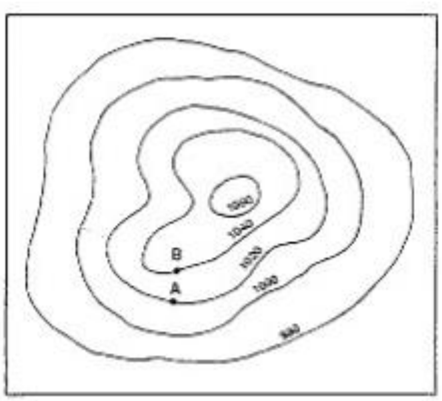


Figure E-1: Isolated Hill

If these same two people start out in opposite directions on different contours, beginning at points A and B respectively, they will pass each other somewhere on the hill and their vertical distance apart would remain 20 feet. Their horizontal distance apart could be great or small depending on the steepness of the hillside where they pass.

A rather more complicated situation is one where two hills are connected by a saddle (Figure E2). Here each hill is circled by contours but at some point, toward the base of the hills, contours begin to circle both hills.

How do contours relate to water flow? A general rule of thumb is that water flow is perpendicular to contour lines. In the case of the isolated hill, water flows down on all sides of the hill. Water flows from the top of the saddle or ridge, down each side in the same way water flows down each side of a garden wall (See arrow on Figure E-2).

As the water continues downhill it flows into progressively larger watercourses and ultimately into the ocean. Any point on a watercourse can be used to define a watershed. That is, the entire drainage area of a major river like the Merrimack can be considered a watershed, but the drainage areas of each of its tributaries are also watersheds.

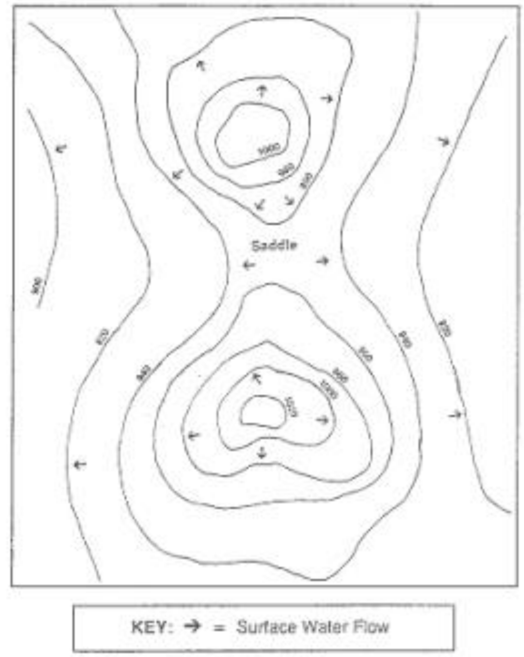


Figure E-2: Saddle

Each tributary in turn has tributaries, and each one of these tributaries has a watershed. This process of subdivision can continue until very small, local watersheds are defined which might only drain a few acres, and might not contain a defined watercourse.

Figure E-3 shows an idealized watershed of a small stream. Water always flows downhill perpendicular to the contour lines. As one proceeds upstream, successively higher and higher contour lines first parallel then cross the stream. This is because the floor of a river valley rises as you go upstream. Likewise, the valley slopes upward on each side of the stream. A general rule of thumb is that topographic lines always point upstream. With that in mind, it is not difficult to make out drainage patterns and the direction of flow on the landscape even when there is no stream depicted on the map. In Figure E-3, for example, the direction of streamflow is from point A to point B.

Ultimately, you must reach the highest point upstream. This is the head of the watershed, beyond which the land slopes away into another watershed. At each point on the stream the land slopes up on each side to some high point then down into another watershed. If you were to join all of these high points around the stream you would have the watershed boundary. (High points are generally hill tops, ridge lines, or saddles).

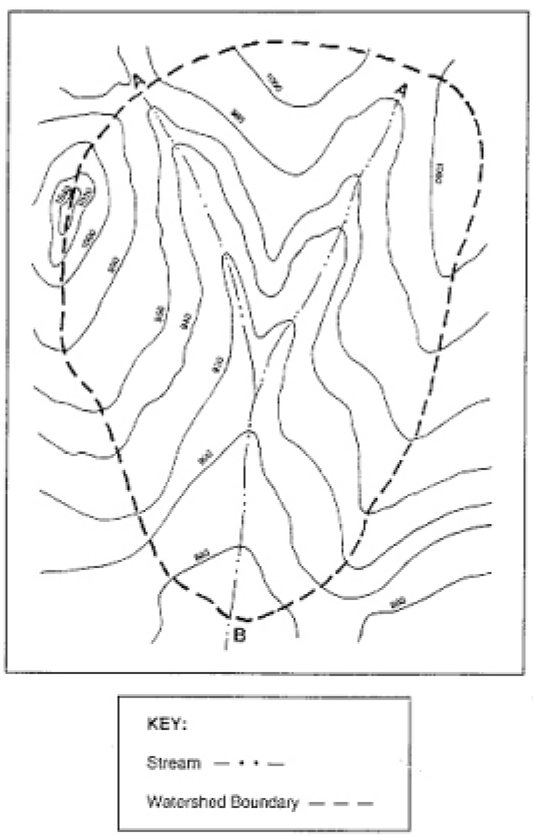


Figure E-3: Idealized Watershed Boundary

2022 NCF-Envirothon Ohio

Aquatic Ecology Study Resources

Key Topic #5 Aquifers and Hydrology

16. Determine the order of stream and describe what the order indicates.
17. Describe the basics of hydrology, including:
    a. stream/river geomorphology
    b. catchment area
    c. drainage basin
    d. bank
    e. channel
    f. meander
    g. riffle
    h. water table
    i. thalweg
    j. hyporheic zone
18. Define an aquifer and elaborate on how aquifers relate to local and global water supply.
19. Identify the role the water table in an ecosystem and how water tables affect human activity and use.
20. Describe the natural aging process of lakes and ponds.

Study Resources

Resource Title	Source	Located on
Stream Order: A Classification of the Rank of Streams and Rivers	*Amanda Briney, 2020*	Page 82-83
Diagram showing stream order of a watershed	*Derek Tripp, et al, 2018*	Page 84
Generalized depiction of the relationship between stream size (order), energy inputs and ecosystem function expected under the river continuum concept	*Vannote et al., 1980*	Page 84
How do Groundwater and Surface Water Interact?	*Vandas, S.J., Winter, T.C., and Battaglin, W.A., 2002*	Page 85
Aquifers	*National Geographic, 2022*	Page 86
Groundwater Quality	*US Geological Survey, 2022*	Pages 87-89
What are Riparian Areas?	*USDA Natural Resources Conservation Service, 2021*	Pages 90-93
The Stages of Lake and Pond Succession	*Paul Conti, 2021*	Pages 94-95

Study Resources begin on the next page! ➡

Stream Order: A Classification of the Rank of Streams and Rivers

By Amanda Briney, Updated on January 22, 2020

One of the most important aspects of physical geography is the study of the world's natural environment and resources—one of which is water. Because this area is so important, geographers, geologists, and hydrologists alike use stream order to study and measure the size of the world's waterways. A stream is classified as a body of water that flows across the Earth's surface via a current and is contained within a narrow channel and banks. Based on stream order and local languages, the smallest of these waterways are also sometimes called brooks and/or creeks. Large waterways (at the highest level the stream order) are called rivers and exist as a combination of many tributary streams. Streams can also have local names such as bayou or burn.

How It Works

When using stream order to classify a stream, the sizes range from a first-order stream to the largest, and 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. Also, 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. Over 80% of the world’s waterways are estimated to be 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 10th-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 more slowly. 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

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.

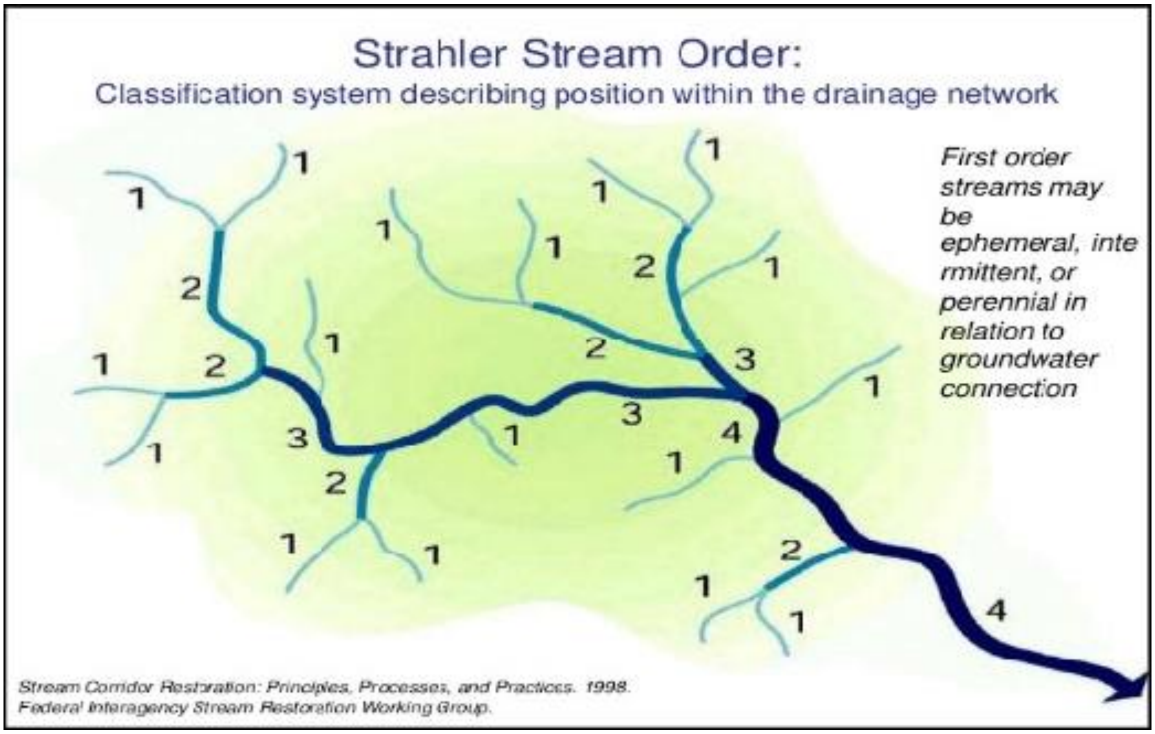
Importance

Stream order also helps people like biogeographers and biologists in determining what types of life might be present in the waterway.

This is the idea behind the River Continuum Concept, a model used to determine the number and types of organisms present in a stream of a given size. More types of plants, for example, can live in sediment-filled, slower flowing rivers like the lower Mississippi than can live in a fast-flowing tributary of the same river.

More recently, stream order has also been used in geographic information systems (GIS) to map river networks. The algorithm, developed in 2004, uses vectors (lines) to represent the various streams and connects them using nodes (the place on the map where the two vectors meet.)
By using the different options available in ArcGIS, users can then change the line width or color to show the different stream orders. The result is a topologically correct depiction of the stream network that has a wide variety of applications.

Whether it is used by a GIS, a biogeographer, or a hydrologist, 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.



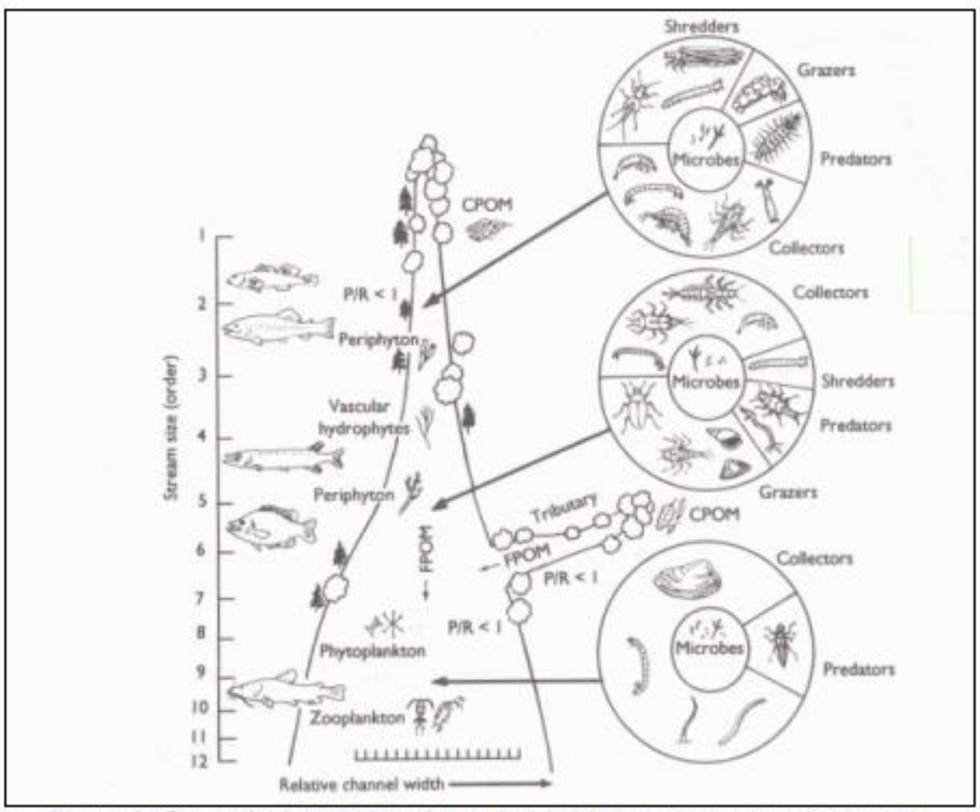


Figure 4. Generalized depiction of the relationship between stream size (order), Energy inputs and ecosystem function expected under the river continuum concept. (From Vannote et al., 1980).

Source: Allan, J. David. Stream Ecology. New York: Chapman & Hall, 1995.

How do groundwater and surface water interact?

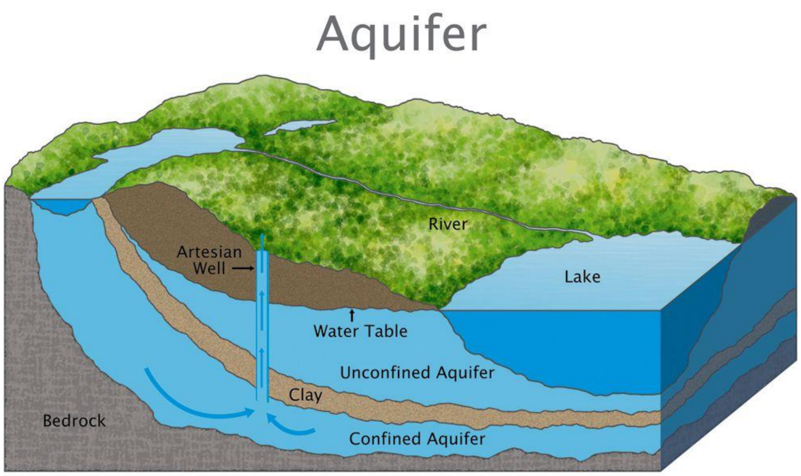
Material adapted from: Vandas, S.J., Winter, T.C., and Battaglin, W.A. 2002. Water and the Environment, p. 28-29. Published by the American Geosciences Institute Environmental Awareness Series.

Surface water and groundwater systems are connected in most landscapes. Streams interact with groundwater in three basic ways: streams gain water from inflow of groundwater through the streambed, streams lose water by outflow through the streambed, or they do both depending upon the location along the stream. It is the groundwater contribution that keeps streams flowing between precipitation events or after snowmelt. For a stream to gain water, the elevation of the water table in the vicinity of the stream must be higher than the stream water surface. For a stream to lose water to groundwater, the water table must be below the elevation of the stream-water surface in the vicinity of the stream. If the water table has large variations during the year, a stream segment could receive water from groundwater for a portion of the year and lose water to groundwater at other times.

Surface-water bodies such as lakes and wetlands can receive groundwater inflow, recharge groundwater, or do both. The movement of water between groundwater and surface-water systems leads to the mixing of their water qualities. High quantities of nutrients or other dissolved chemicals in surface water can be transferred to the connected groundwater system.

Aquifers

An aquifer is a body of rock and/or sediment that holds groundwater. Groundwater is the word used to describe precipitation that has infiltrated the soil beyond the surface and collected in empty spaces underground. Groundwater enters an aquifer as precipitation seeps through the soil. It can move through the aquifer and resurface through springs and wells.



There are two general types of aquifers: confined and unconfined. Confined aquifers have a layer of impenetrable rock or clay above them, while unconfined aquifers lie below a permeable layer of soil. Many different types of sediments and rocks can form aquifers, including gravel, sandstone, conglomerates, and fractured limestone. Aquifers are sometimes categorized according to the type of rock or sediments of which they are composed.

A common misconception about aquifers is that they are underground rivers or lakes. While groundwater can seep into or out of aquifers due to their porous nature, it cannot move fast enough to flow like a river. The rate which groundwater moves through an aquifer varies depending on the rock's permeability.

Much of the water we use for domestic, industrial, or agricultural purposes is groundwater. Most groundwater, including a significant amount of our drinking water, comes from aquifers. In order to access this water, a well must be created by drilling a hole that reaches the aquifer. While wells are manmade points of discharge for aquifers, they also discharge naturally at springs and in wetlands.

Groundwater can become depleted if we use it at a faster rate than it can replenish itself. The replenishment of aquifers by precipitation is called recharging. Depletion of aquifers has increased primarily due to expanding agricultural irrigation. Groundwater can become contaminated when an excessive amount of pesticides and herbicides are sprayed on agricultural fields, septic tanks leak, or landfills are improperly lined or managed and toxic materials seep through the soil into the aquifer.

Aquifers naturally filter groundwater by forcing it to pass through small pores and between sediments, which helps remove substances from the water. This natural filtration process, however, may not be enough to remove all of the contaminants.

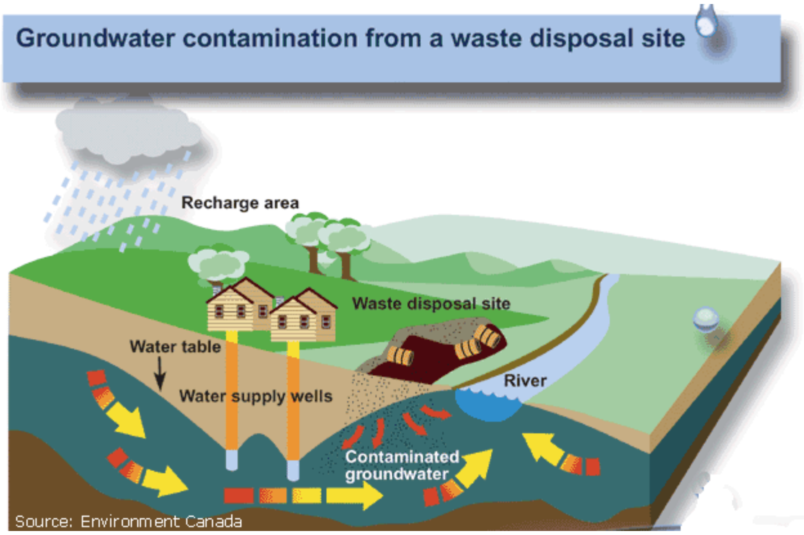
Groundwater Quality

Even though the ground is an excellent mechanism for filtering out particulate matter, such as leaves, soil, and bugs, dissolved chemicals and gases can still occur in large enough concentrations in groundwater to cause problems.

Groundwater usually looks crystal clear, but before drinking it, care must be taken to make sure it doesn't contain dissolved chemicals that could be harmful.

Just because you have a well that yields plenty of water doesn't mean you can go ahead and just take a drink. Because water is such an excellent solvent it can contain lots of dissolved chemicals. And since groundwater moves through rocks and subsurface soil, it has a lot of opportunity to dissolve substances as it moves. For that reason, groundwater will often have more dissolved substances than surface water will. (photo credit: Howard Perlman, USGS**)**.

Underground water can get contaminated from industrial, domestic, and agricultural chemicals from the surface. This includes chemicals such as pesticides and herbicides that many homeowners apply to their lawns.



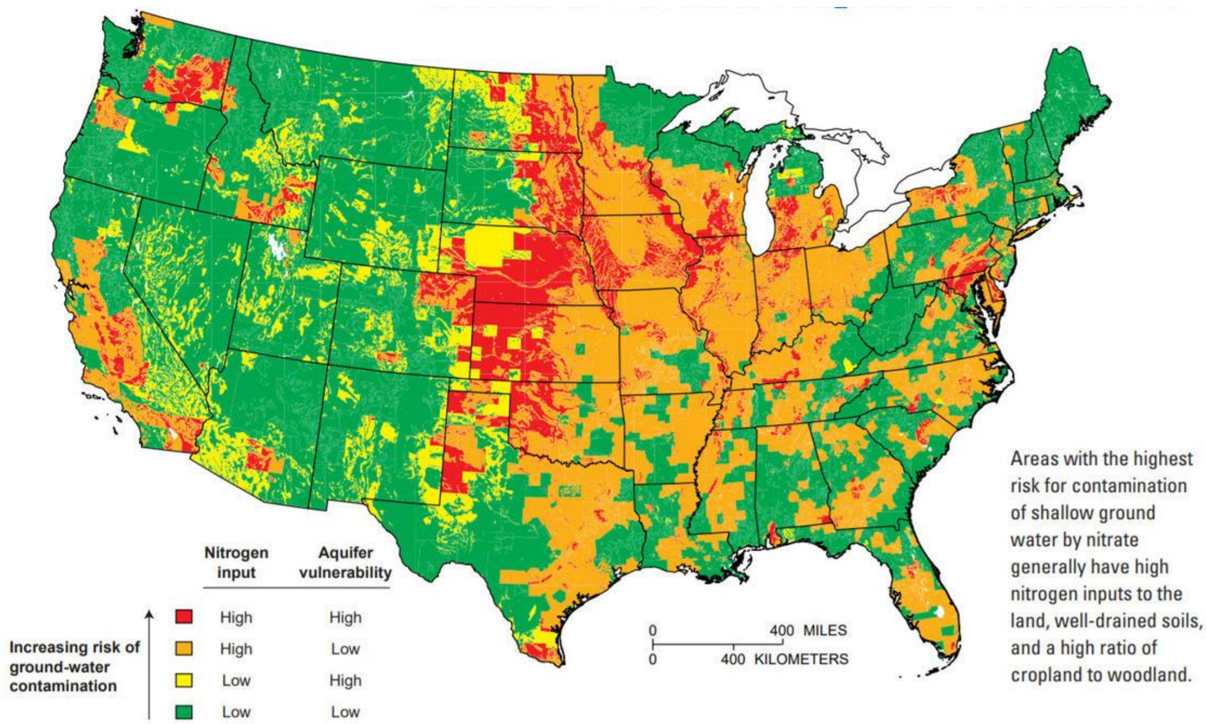
Contamination of groundwater by road salt is of major concern in northern areas of the United States. Salt is spread on roads to melt ice, and, with salt being so soluble in water, excess sodium and chloride is easily transported into the subsurface groundwater. The most common water-quality problem in rural water supplies is bacterial contamination from septic tanks, which are often used in rural areas that don't have a sewage-treatment system. Effluent (overflow and leakage) from a septic tank can percolate (seep) down to the water table and maybe into a homeowner's own well. Just as with urban water supplies, chlorination may be necessary to kill the dangerous bacteria. *Sources/Usage: Public Domain.*

The U.S. Geological Survey (USGS) is involved in monitoring the Nation's groundwater supplies. A national network of observation wells exists to measure regularly the water levels in wells and to investigate water quality.

Contaminants can be natural or human-induced

View a long list of chemicals and contaminants that can be found in groundwater.

Naturally occurring contaminants are present in the rocks and sediments. As groundwater flows through sediments, metals such as iron and manganese are dissolved and may later be found in high concentrations in the water. Industrial discharges, urban activities, agriculture, groundwater pumpage, and disposal of waste all can affect groundwater quality. Contaminants from leaking fuel tanks or fuel or toxic chemical spills may enter the groundwater and contaminate the aquifer. Pesticides and fertilizers applied to lawns and crops can accumulate and migrate to the water table.



Sources/Usage: Public Domain.

One USGS model, based on nationwide data, was developed to estimate the risk of nitrate contamination to shallow ground water across the United States. The model integrates nitrogen inputs and aquifer vulnerability by use of Geographic Information System (GIS) technology. Nitrogen inputs include commercial fertilizer and manure application rates, atmospheric contributions, and population densities (the latter representing residential and urban nitrogen sources, such as septic systems, fertilizers, and domestic animal waste). Aquifer vulnerability is represented by soil-drainage characteristics—the ease with which water and chemicals can seep to ground water—and the extent to which woodlands are interspersed with cropland.

Groundwater can contain hydrogen sulfide or other naturally occurring chemicals. Groundwater also may contain petroleum, organic compounds, or other chemicals introduced by humans' activities. Contaminated groundwater can occur if the well is located near land that is used for farming where certain kinds of chemicals are applied to crops, or near a gas station that has a leaking storage tank. Leakage from septic tanks and/or waste-disposal sites also can contaminate groundwater. A septic tank can introduce bacteria to the water, and pesticides and fertilizers that seep into farmed soil can eventually end up in water drawn from a well. Or, a well might have been placed in land that was once used for something like a garbage or chemical dump site. In any case, it is wise to have your well water tested for contaminants.

The physical properties of an **aquifer**, such as thickness, rock or sediment type, and location, play a large part in determining whether contaminants from the land surface will reach the groundwater. The risk of contamination is greater for unconfined (water-table) aquifers than for confined aquifers because they usually are nearer to land surface and lack an overlying confining layer to impede the movement of contaminants. Because groundwater moves slowly in the subsurface and many contaminants sorb to the sediments, restoration of a contaminated aquifer is difficult and may require years, decades, centuries, or even millennia.

Many Americans drink groundwater from their own wells
If you drive on a rural highway almost anywhere in the Nation you might see some small "doghouse-looking" enclosures or some metal pipes and tubing in the side yard of many homes and trailer parks. These are small **wells that supply domestic water** to individual and small groups of families.

If you ask them if the possible contamination of groundwater is of interest to them, they would have to say "yes". This is the case with tens of millions of people across the country. The map below shows the percentage of each State's population that relies on their own well water for home use. Percentages range from 1 percent in Puerto Rico to 44 percent in Maine, with the National average being 14 percent. You can view this and other maps and the corresponding data from the USGS publication.

"Estimated Use of Water in the United States, 2015".

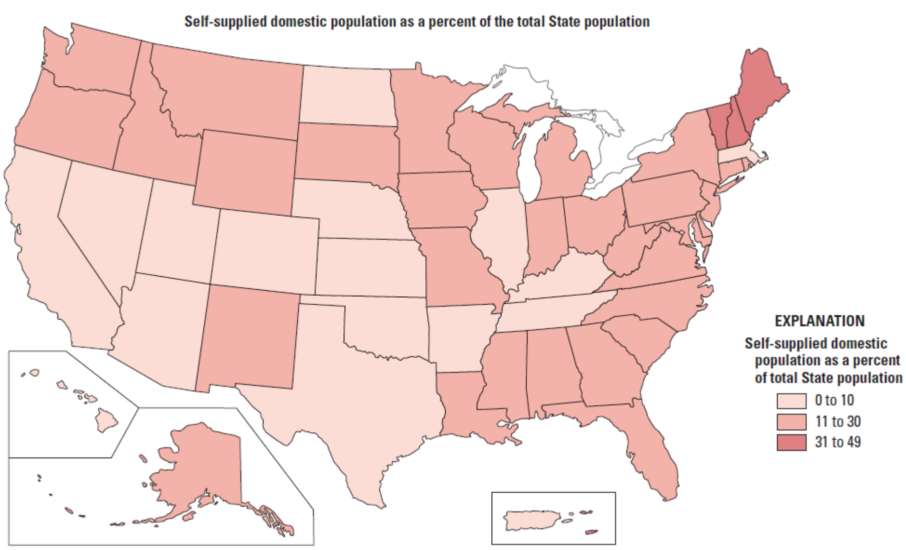
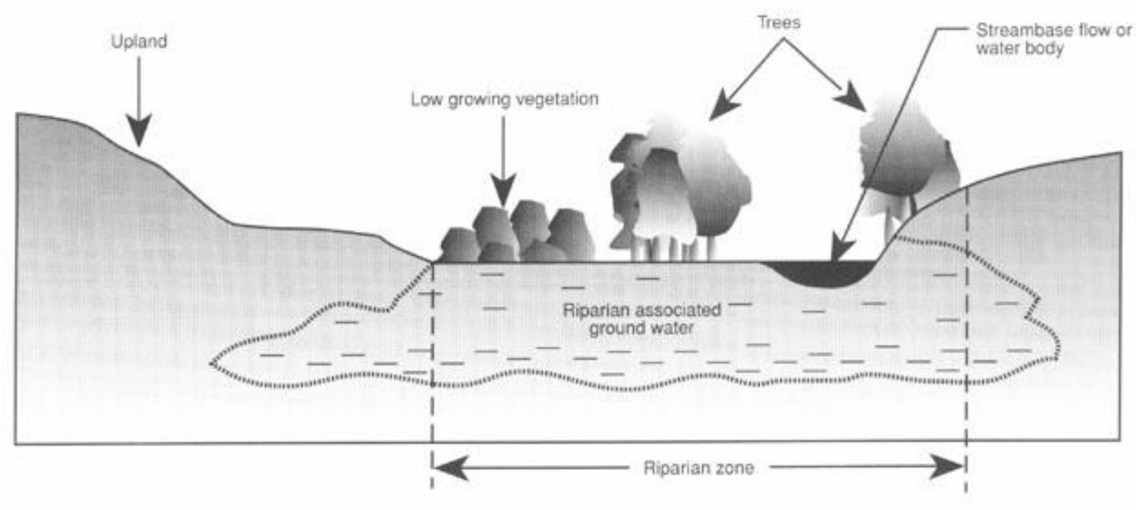


Figure 6*B*. Self-supplied domestic population and percentage of total population by State, 2015.

*Some information on this page is from **Ground Water and the Rural Homeowner**, Pamphlet, U.S. Geological Survey, 1982, by Roger M. Waller*

What are riparian areas? Riparian areas are lands that occur along watercourses and water bodies. Typical examples include flood plains and streambanks. They are distinctly different from surrounding lands because of unique soil and vegetation characteristics that are strongly influenced by the presence of water.

Major components of a stream or water body riparian area—Riparian areas can be symmetrical or asymmetrical in shape. The topography and hydrogeology determine the plant and animal communities associated with the width or meandering riparian area configurations.



General indicators of riparian areas include:

- **Vegetation**
  The kinds and amounts of vegetation differ from adjacent upland vegetation because more water is supplied to plants from the associated watercourse or water body.
- **Soil**
  Soil in natural riparian areas consists of stratified sediments of varying textures that are subject to intermittent flooding or fluctuating water tables that may reach the surface. The duration of soil wetness depends on the water levels of the adjacent water body.
- **Water**
  Riparian areas are directly influenced by water from a watercourse or water body. They occur along natural watercourses or next to natural lakes and constructed water bodies such as ditches, canals, ponds, and reservoirs.
  In the western United States, riparian areas comprise less than 1 percent of the land area, but they are among the most productive and valuable natural resources. There is a significant difference between the water-rich riparian areas and the arid uplands. Riparian areas are the major providers of habitat for endangered and threatened species in the western desert areas. In the humid east, the riparian areas are more similar to the uplands. In many areas, the separation of the riparian zone from the upland is not distinct.

Values and functions of riparian areas

Because of their variation across the country, riparian areas function in different ways. In spite of their differences, all riparian areas possess some similar ecological characteristics such as energy flow, nutrient cycling, water cycling, hydrologic function, and plant and animal population. These functions give riparian areas unique values relative to the surrounding landscape. Some of the more recognizable functions and values of riparian areas are:

Hydrology

Water flow that shaped the riparian zone affects soil development and growth of vegetation.

- Because riparian zones occupy low areas in the landscape, ground water is generally nearer to the surface and available for plants. The fine-textured sediments in flood plains are also able to hold large amounts of water. These two conditions promote productive and diverse plant communities.
- Nutrients for plant growth in riparian ecosystems depend on sedimentation of nutrient-rich organic matter and on the dissolved nutrients in the water. Riparian zones are often nutrient-rich ecosystems.
- Because flooding occurs periodically, and ground water moves through flood plain soils, the surface layers of soils are wetted and dried seasonally. The presence and movement of the surface and ground water enhance the recycling of nutrients and other chemical reactions beneficial to plant growth within the riparian zone.

  The timing of flooding is important to the life cycle of many aquatic species and some terrestrial species. A naturally occurring flood pulse enhances survivability of organisms within the riparian zone and promotes species diversity and biological productivity.

Base flow

Alluvial soil, which is sedimentary material deposited by flowing water, is usually deep and stores large amounts of water from rainfall and runoff. Many alluvial aquifers in the western United States are maintained by infiltration of upland runoff in the stream channel or riparian alluvial deposits. Base flow--that portion of water flowing in a stream that is due to ground water seepage into the channel--is further maintained by riparian vegetation that shades the water, keeping it cooler and slowing evaporation.

Nutrient cycling

Once nutrients enter a riparian area, they are exposed to mechanisms that may use or change them. Some nutrients, especially nitrogen, phosphorus, calcium, magnesium, and potassium, are taken up by shallow-rooted riparian vegetation. Dissolved nutrients moving with the ground water and those that are leached in the soil may be taken up by deeper-rooted riparian vegetation. Some nutrients pass through without being detained, and some that are taken up by riparian vegetation may be reintroduced into the water column when the vegetation dies and decomposes.

Energy transfer

The uniqueness of riparian areas derives from the fact that litter-fall produced within the riparian ecosystem may be transported laterally and made available to in-stream animal communities as well as those downstream from the source of organic matter production. As compared with purely aquatic or terrestrial ecosystems, riparian organic matter has the potential of supporting a diversity of food webs within both habitats.

Downstream flooding

Riparian area vegetation is a key factor in reducing downstream flooding. As floodwater flows through a vegetated area, the plants resist the flow and dissipate the energy, increasing the time available for water to infiltrate into the soil and stored for use by plants.

Water quality

As floodwater spreads over a flood plain, water velocities are reduced, making it less likely for sediment and nutrient-rich organic materials to reenter the stream. Sediment and nutrients carried by overland flow from adjacent uplands are also intercepted by the riparian area.

Aquatic life

Rooting herbaceous and woody vegetation helps shape aquatic habitat and stabilizes streambanks, retards erosion, and, in places, creates overhanging banks that serve as habitat for fish. Trapping sediment before it reaches the stream helps maintain a cleaner or more sediment-free stream bottom where aquatic organisms live. These organisms are important sources of food for fish and birds.

Terrestrial life

Riparian ecosystems are extremely productive and have diverse habitat values for wildlife. This is demonstrated most visibly in the western United States, where riparian habitat comprises less than 1 percent of the total land area at some time of the year but supports most of the terrestrial wildlife. The linear nature of riparian ecosystems provides distinct corridors that are important as migration and dispersal routes and as forested connectors between habitats for wildlife.

Some riparian areas meet the criteria established for wetlands. The functions of wetland and riparian areas generally depend on configuration, soils, vegetation, hydrology, and landscape context. Even nonwetland riparian areas share many characteristics, functions, and values with wetlands; such as surface or ground water, or both, and several varieties of plant and animal communities.

Disturbances to riparian areas

Flooding and the resulting erosion and deposition are common forces that shape the riparian area. During extreme flooding, these forces can sometimes appear devastating, but in most cases, the riparian area recovers rapidly. On the other hand, changes made by people often have long-term adverse effects on riparian areas. Building dams across channels, constructing levees, and the channelization of the streams may have the most adverse impact. These modifications significantly alter the movement and storage of water that is so important to the riparian system. Water withdrawals from streams also may reduce base flow, depriving riparian areas of moisture.

People's most common disturbance to riparian areas involves clearing vegetation and converting the area to other uses such as cropland and urban land. Excessive logging can strip the banks of vegetation. Overgrazing concentrates livestock in riparian areas for extended periods, reduces the vegetation, and tramples streambanks. Recreational development can destroy natural plant diversity and structure, lead to soil compaction and erosion, and disturb wildlife. Exotic plants that take advantage of the good growing conditions found in riparian zones often invade these areas. As these plants dominate native plants, the overall vegetative diversity decreases, resulting in less favorable habitat for most wildlife species.

The character of a riparian area is dependent upon the condition of its watershed. Most important is the relationship of watershed hydrology to the riparian area. In general, the amounts and type of vegetative ground cover, the area of the watershed, and the slope of the terrain are directly related to the percentage of water that will enter the drainage system as surface flow or as percolated water. Riparian plant composition, habitat structure, and productivity are determined by the timing, duration, and extent of flooding. Land use changes, paved-over areas, or the removal of vegetation cause water to flow quickly from a watershed and through a riparian zone. Soil moisture storage and productivity are reduced. This can lead to prolonged periods of no flow or low flow and increase frequency and duration of flooding, resulting in a drastic decline in productivity.

Multiple benefits

- Riparian areas help control nonpoint source pollution by holding and using nutrients and reducing sediment.
- Riparian areas are often important for the recreation and scenic values. However, because riparian areas are relatively small and occur in conjunction with watercourses, they are vulnerable to severe alteration and damages caused by people.
- Riparian areas supply food, cover, and water for a large diversity of animals and serve as migration routes and stopping points between habitats for a variety of wildlife.
- Trees and grasses in riparian areas stabilize streambanks and reduce floodwater velocity, resulting in reduced downstream flood peaks.
- Alluvial aquifers help maintain the base flow in many rivers in humid areas because of high water tables. In drier climates, streams lose water that can help build up the water table deep beneath the stream.

The Stages of Lake and Pond Succession

Written by Industry Expert Paul Conti, Environmental Scientist

Like any ecosystem, lakes and ponds naturally change over time through succession. As many outside inputs accumulate, changes in water chemistry, sediment makeup, and organism presence occurs. The aging of a lake or pond is a natural process but can be highly accelerated through human activity and industry, reducing a waterbody's life by decades. Through proactive and sustainable lake and pond management practices, we can slow the aging of a waterbody and, in turn, help keep it healthy and looking beautiful.

How is a lake or pond formed?

Initially, a lake or pond is created as a depression is formed; a depression can be formed in a number of ways, including the recession of the glaciers, a damming of a river, the impact of an asteroid, or a manmade digging event. Through rain and runoff events these depressions are eventually filled with water and become a lake or pond.

The Life of a Waterbody...

Throughout a waterbody's life there are many inputs contributing to its function. The input of water, nutrients, sediment, plants, and animals all accumulate over time and affect the way the lake or pond functions. At the beginning of a pond's life, it is first colonized with "pioneer species." At this point the pond contains very few dissolved nutrients in the waterbody which characterizes it as "oligotrophic." With so few nutrients in an oligotrophic environment, life is tough for most organisms. Only those well adapted to live in nutrient-poor environments survive. As organisms begin to colonize the waterbody, they reproduce, die, and decompose—causing sediment to settle at the bottom of the pond. The nutrients that make up these organisms are released into the aquatic ecosystem as they decompose, contributing to the total nutrient load of the waterbody.

As nutrient levels are increased in the pond over time, the pond will move to a "mesotrophic" state. Mesotrophic waterbodies have moderate nutrient levels. In most mesotrophic ponds, there is enough sediment and nutrients to support a diverse range of organisms. Typically, we begin seeing healthy populations of submersed vegetation and pondweeds, as well as diverse and balanced populations of both microscopic and filamentous algae. These organisms continue to reproduce, die and decompose, further contributing to the total nutrient load in the waterbody. As nutrient load in the pond increases, growth rates of organisms increase.

Increased growth rates of organisms in the pond lead to an increase in biomass, which further leads to an increase in nutrient loading and sediment accumulation. Once a pond contains excess dissolved nutrients, it is deemed "eutrophic." With so many available nutrients, plants and algae thrive and often grow to a nuisance level. It is quite common to experience potentially toxic algae blooms in a eutrophic system, as well as other problems such as fish kills.

With constant reproduction, and decomposition of the large amount of biomass in a eutrophic system, sediment rapidly accumulates and changes the ecosystem from a lake or pond to a wetland (marsh, swamp, bog, or fen). As the pond fills in, large populations of emergent plants, such as waterlilies and cattails, will begin to grow and encroach on the open water. The newly formed wetland will continue to succeed and eventually become an upland habitat.

How can the eutrophication process be slowed?

Excess plant and algae growth as a result of eutrophication can be managed through either treatment or mechanical removal. Through application, plant and algae growth is limited by treating it before it becomes too large of a problem.

With the mechanical removal of plants and algae, excess biomass is physically removed, which will have an even greater effect in slowing the eutrophication process by disposing of the biomass and nutrients outside of the waterbody, rather than allowing it to contribute to the filling in of your waterbody.

Aeration is another tool that can be beneficial in mitigating nutrients in your lake or pond. By having high amounts of dissolved oxygen in your pond, more favorable conditions exist for the bacteria necessary in the degradation of nutrients in the water and sediment that are contributing to the eutrophication process. The presence of oxygen can also create a better environment for phosphorus to bond with other nutrients, therefore converting it to a form that cannot be taken up by plants or algae.

In situations when large amounts of sediment have already accumulated, dredging, or hydro-raking, may be the only option. Dredging and hydro-raking will remove all excess sediment as well as the nutrients bound up in the sediment. This will result in a serious reduction of nutrients in the lake or pond, increase overall water depth, and help bring your waterbody back to a healthier state.