A TCEQ GUIDE
FOR HANDS-ON
FIELD STUDY
OF TEXAS
WATERS

FIELD GUIDE TO WATER EDUCATION

TEXAS COMMISSION ON
ENVIRONMENTAL QUALITY

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contents

Introduction 3

Water Basics 4

Water Pollution 17

Pollution Management 23

Lesson Plans 24

Lesson 1 *The Water Cycle* 26

Lesson 2 *Area Watershed Survey* 28

Lesson 3 *The Aquatic Food Web* 29

Lesson 4 *Water Pollution* 30

Lesson 5 *Survey: On-Site Sketch* 32

Lesson 6 *Survey: Invasive Species—Aquatic Plants* 33

Lesson 7 *Survey: Physical Properties* 34

Lesson 8 *Survey: Chemical Properties* 36

Lesson 9 *Survey: Biological Properties* 37

Lesson 10 *Data Analysis* 39

Lesson 11 *Community Awareness Plan* 40

Supplementary Activities 42

Additional Resources 44

Glossary 46

References 49

Student Handouts 51

Illustrations, unless otherwise noted, were created by Christine M. Kolbe

Introduction

Why Water Education Is Important

Texas has some of the fastest growing cities in the nation and is home to millions of people along with a variety of businesses, industries, and diversified agriculture. Supporting the needs of its citizens puts great demands on the state's natural resources.

The resource that most affects growth is water. In addition to lakes, bays, and the Gulf of Mexico, there are 11,247 named streams in Texas. Their combined length is about 129,000 kilometers and they drain the water that comes from 682,496 square kilometers of land. Growth and development in Texas have increased the challenge of preserving the quality and quantity of the state's water supplies. In recent years, extended drought in the state has elevated the importance of maintaining the quality and quantity of water to support not only economic growth but also the natural environment.

Environmental education is essential to the future of Texas. Developing an appreciation for water and understanding how human activities affect its quantity and quality are the first steps in the protection and conservation of the state's water for a healthy, viable future.

Since the future of Texas depends on the wise management of water, the state's crucial supply must be protected. Through water education, we can work to conserve and protect water resources in our local environment. Although water quantity and quality are of equal importance, the activities in this guide focus on water quality.

Texas Water Quality

One of our most important natural resources is water, and Texas has an extensive monitoring network to evaluate the quality of its waters. The Texas Commission on Environmental Quality, local water authorities, other state agencies, and federal agencies work together to test water quality from thousands of monitoring stations across the state and analyze the results. This monitoring network informs Texans about our surface waters and allows the state to maintain water quality while planning for current and future water uses, and to promptly implement strategies to restore water quality should a problem arise.

Since 1998, the state improved the water quality in hundreds of kilometers of streams, thousands of acres of reservoirs, and over 25 square kilometers of estuaries. Texas waters are improving, and any emerging problems are being identified and treated more quickly than ever. Texans should go out and enjoy their rivers and lakes knowing that the state extensively monitors water quality while setting goals to improve and protect Texas waters.

Overview of This Guide

This guide introduces educators to the water (hydrologic) cycle, aquatic life, and water pollution. Following the introduction are lesson plans that educators may use to teach these subjects to their students. Each lesson plan is accompanied by a student handout, available in the back of the guide.

If you would like additional information about these subjects, please see *A Guide to Freshwater Ecology* (TCEQ publication no. GI-034), available online at <www.tceq.texas.gov/publications>. You can also use that link to download this *Field Guide to Water Education* (GI-026) and print the student handouts that are at the back.

Water Basics

What Is Water? What Is Water Quality?

The water molecule is …

- the most abundant, unique, and important substance on Earth;
- essential to life;
- an essential part of all living things;
- a universal solvent that makes all biological functions possible;
- the only substance that occurs naturally on Earth in all three physical states (solid, liquid, and gas);
- odorless, tasteless, colorless, and transparent; and
- composed of two hydrogen atoms and one oxygen atom (H_2O).

When you pour a glass of water, what is in that glass of water? It's not pure water because it is virtually impossible to remove all other substances from the water (including any dissolved gases like oxygen). Even if your water comes from a water treatment plant (or even if it's bottled), it probably contains small levels of organic matter, suspended particles, certain elements, or other molecules. If your water contains these substances, you shouldn't have to worry about them if they are at levels low enough to comply with the quality standards established for drinking water.

Water quality comprises the physical, chemical, and biological properties of the water at levels suitable for a particular use. Uses will vary, and so will the water quality standards. In the scenario above, the water treatment plant takes in water (groundwater, surface water, etc.) and prepares it for drinking; since it is being used for human consumption, the water must meet the drinking-water quality standards that are set at levels to protect the health of the general population. For another example, treated effluent (water) from a wastewater-treatment plant that will be used by aquatic life must meet the water quality standards set for that water body so the aquatic life is not affected by the incoming waters.

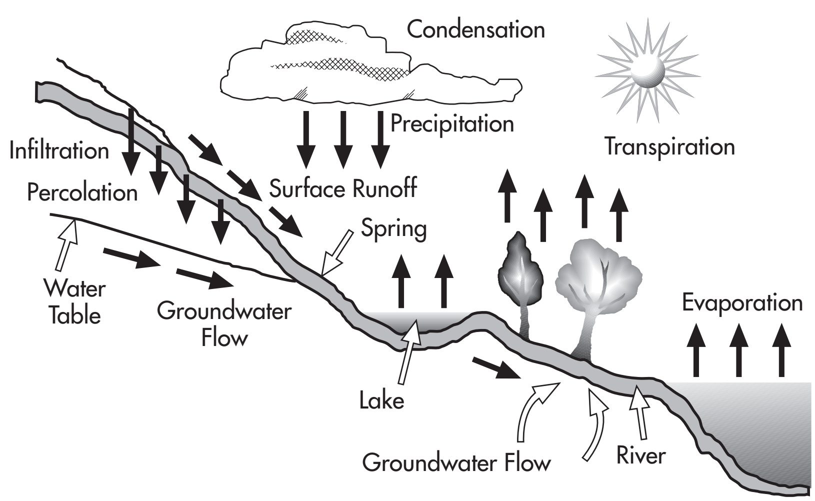
When you study water quality, you must know what the water is being used for to determine which tests you will need and what testing outcomes are appropriate for that water study. As an example, surface water quality might be tested for its:

- **Physical properties:** water temperature, flow, pH, amount of dissolved oxygen, and turbidity (water clarity)
- **Chemical properties:** amount of nutrients and heavy metals
- **Biological properties:** number and diversity of bacteria, plankton, benthic macroinvertebrates, and fish

The Water (Hydrologic) Cycle

The water cycle (also called the *hydrologic cycle*) is a model that describes continuous movement of water between the atmosphere, land, and water bodies. This section explains the water cycle and how some of the water's properties may change during the process. There is no beginning or end to the water cycle since it is a continuous loop; this guide will start with precipitation.

The Hydrologic Cycle



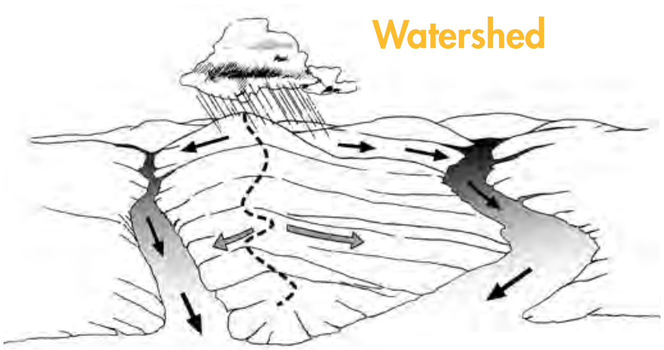
Precipitation

As water vapor moves through the atmosphere, it interacts with other molecules. Water vapor will react with some of the carbon dioxide in the atmosphere to form carbonic acid (a weak acid). If nitrogen oxides or sulfur dioxide are present, the water vapor will mostly likely react with these molecules to form stronger acids. Both nitrogen oxides and sulfur dioxide enter the atmosphere from natural sources (such as volcanoes) and human sources (such as fossil-fuel combustion).

When the water vapor cools, it condenses into clouds and eventually falls to the Earth as precipitation (rain, sleet, hail, or snow). Precipitation is naturally acidic, with a pH greater than 5.6, because it contains carbonic acid. Rainwater with a pH less than 5.6 contains stronger acids and is called ***acid rain***. Rainwater also contains items that are found in the atmosphere, such as pollen and dust.

Watershed

When precipitation hits the ground, it either enters the ground (called *infiltration*, or *percolation*) or drains across the land as surface runoff (called *stormwater*). The stormwater follows the drainage patterns of a *watershed*—a geographic area in which water, sediments, and dissolved materials drain into a common outlet. This outlet could be a stream, lake, reservoir, playa, estuary, aquifer, or ocean. The precipitation that enters the ground (*groundwater*) may eventually drain into a watershed or its outlet.



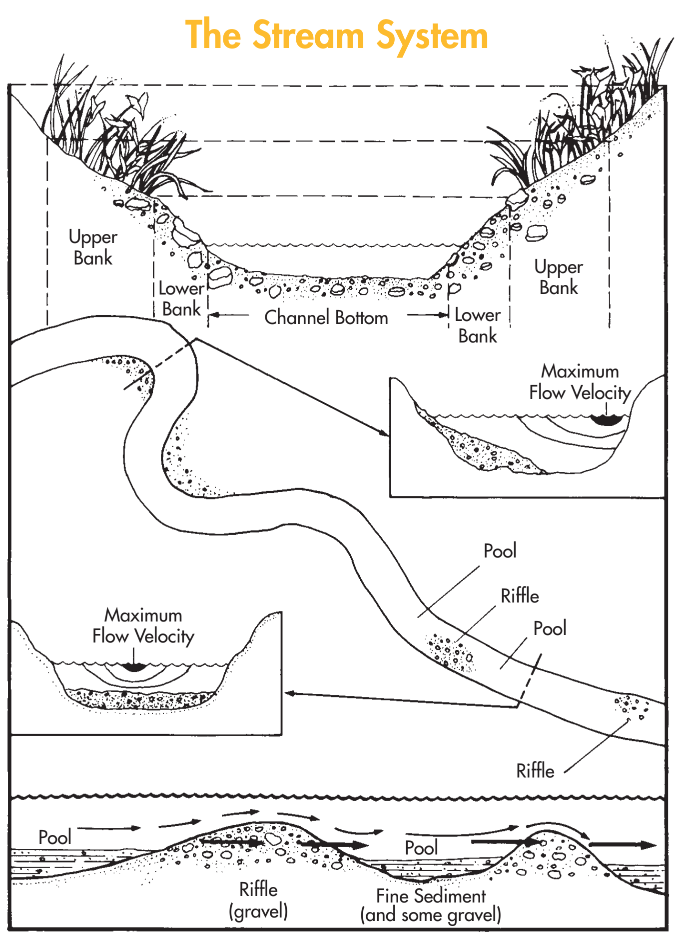
Watersheds are also commonly called *drainage basins* or *drainage areas*. The total area of land that contributes stormwater to the outlet is determined by topographic boundaries. A ridge or other area of elevated land (called a *divide*) separates one watershed from another. A stream on one side of the divide will flow to a different outlet than one that is on the other side of the divide.

In each watershed a variety of factors interact with the water in the system, including the climate, the amount of rainfall, the geology and geography of an area (soil, hills, lowlands, forests, etc.), and human activities (urban or industrial development, agriculture, etc.). Everything that happens in the watershed can contribute to what ends up in its outlet. Impurities such as oil and grease (from roads) or bacteria (from untreated wastewater, leaking septic systems, pet waste, or other sources) can be picked up in the stormwater and deposited into the watershed's outlet.

In natural areas (such as forests), vegetation slows the flow of water over the land, filters some impurities, and decreases erosion. As much as half of all rainfall that falls in these areas is absorbed into the ground. In urban areas, many vegetated surfaces are replaced with impervious cover (like concrete) which does not allow water to enter the ground. Instead, the amount of stormwater increases and it flows more swiftly downhill. This increased flow can lead to flooding, erosion, and additional impurities reaching a watershed's outlet. In many urban areas, less than one-third of all rainfall is absorbed into the ground.

Streams

Stream channels are created as stormwater from the watershed seeks a path of least resistance. If the watershed has a very steep terrain, the resulting swiftly moving water may



The above diagram shows the water flow and major structures of a stream. Notice how the pools and riffles alternate. A major feature of the riffle is that water flows through the gravel as well as over it. This enables small fish and small benthic invertebrates to obtain the oxygen they need while being protected from predation by larger organisms such as fish. *Source: Kentucky Division of Water* cut a deep stream channel and remove sediment from the stream bed. If the topography is flat, the stream may be shallow and meandering with suspended sediment in the water column.

Streams may contain one or more of the following instream habitats: pools, riffles, root mats, aquatic plants, undercut banks, overhanging vegetation, leaf litter, and submerged rocks and logs. These habitats, along with the depth and flow of the water, are key factors in determining the type of aquatic organisms found in a stream. Under natural conditions, a greater variety of combined habitats means a greater diversity of aquatic life. Poor quality instream habitats can often be the root cause of low diversity of aquatic life in streams.

A stream's bank and its associated riparian zone (a vegetated buffer between nearby lands and the stream) serve many functions other than keeping the water in the channel. They are home to many plants and animals. Under natural conditions, they help protect the stream from outside influences. When these areas are covered with trees, shrubs, and herbaceous (non-woody) plants, they provide erosion control, sediment collection, and nutrient absorption.

Rivers

Rivers are large natural streams that carry a considerable volume of water. Rivers serve as a collection point for all the smaller creeks and streams in a watershed and ultimately carry water to coastal areas. They are extremely important water-supply sources for domestic use, agriculture, industry, and generating electricity (hydroelectric power).

The amount of water a river transports is the result of many factors: the size of the watershed, climate, geography, geology, size of the stream channel(s), any stream alterations (channelization, dredging, reservoir construction), and the water table (level of groundwater). A river can receive water from groundwater subsurface flow; thus the water-storing capacity of rocks and soil surrounding a river can strongly influence flow.

Reservoirs

Texas has thousands of reservoirs—artificial lakes whose main function is to stabilize the flow of water from a watershed or to satisfy the varying demands from water consumers. Most reservoirs have a dam and a spillway that limits the maximum water level. Many reservoirs also have outlet structures that allow the controlled release of water. The outlet for a reservoir is an inlet for another water body, such as a river or another reservoir.

Evapotranspiration

Water on the surface of the Earth can change physical states, from liquid to gas (vapor). The amount of water changing into vapor depends greatly on temperature. Generally, the higher the temperature, the higher the amount of water that changes into vapor. This water vapor will rise into the atmosphere and eventually change its physical state back into a liquid (or even become a solid) and become precipitation.

Evapotranspiration refers to the two ways water moves from the land to the atmosphere as vapor. The word *evapotranspiration* is the combination of two words, *evaporation* and *transpiration*. Bodies of water (oceans, lakes, streams, etc.) releasing water vapor is called evaporation. Plants (that have absorbed groundwater) releasing water vapor is called transpiration.

Aquatic Food Web

Food chains are simplified models that describe the general flow of energy and food pathways that link different species in an ecosystem. Basically, food chains tell you what an organism eats. A food chain links an organism to one source of food whereas a food web (a more realistic model) may link an organism to many sources of food.

Aquatic food webs for surface water ecosystems begin with the sun, the source of light. Certain wavelengths of light are absorbed by primary producers (also called *autotrophs*). Through a process called *photosynthesis*, primary producers use this light to convert carbon dioxide and water into carbohydrates and oxygen (Figure 1 illustrates this chemical reaction). The primary producers will use a portion of the carbohydrates and oxygen during respiration—the process in which carbohydrates and oxygen are converted into carbon dioxide, water, and energy (see Figure 2). Primary producers can grow and reproduce if energy and certain nutrients are available.

Figure 1.
Photosynthesis

$6CO_2$ +	$6H_2O$ +	light energy =	$C_6H_{12}O_6$ +	$6O_2$
carbon dioxide	water		carbohydrate	oxygen

Figure 2.
Plant Respiration

$C_6H_{12}O_6$ +	$6O_2$ =	$6CO_2$ +	$6H_2O$ +	released energy
carbohydrate	oxygen	carbon dioxide	water	

Animals must also respire so they can create energy to move, grow, etc. Since animals cannot produce their own food like the primary producers, they must consume (eat) their food. Animals that eat primary producers are called primary consumers (*herbivores*, or plant eaters). Animals that eat primary consumers are called secondary consumers (*carnivores*, or meat eaters). The secondary consumer group may contain more than one level of carnivore; therefore, a food web may have tertiary consumers—animals that eat secondary consumers. In addition, a food web may also contain *omnivores*—animals that eat plants and meat.

Animals that eat dead organic materials are called *detritivores* (scavengers). They are an important part of the food web because they help in decomposition by shredding and eating dead organic materials. Decomposers (bacteria and fungi) are the final link in the food web; they break down dead material and release nutrients that can be used by primary producers.

Common Aquatic Plants and Benthic Macroinvertebrates Found in Texas

Aquatic Plants

The following list describes some of the aquatic plants commonly found in Texas. Based on information from <texasinvasives.org>, each plant description indicates if it is an invasive species—a nonnative species whose introduction harms (or is likely to harm) the economy, environment, or human health. For more information about invasive species, visit <texasinvasives.org>.

Aquatic Plants

Submerged

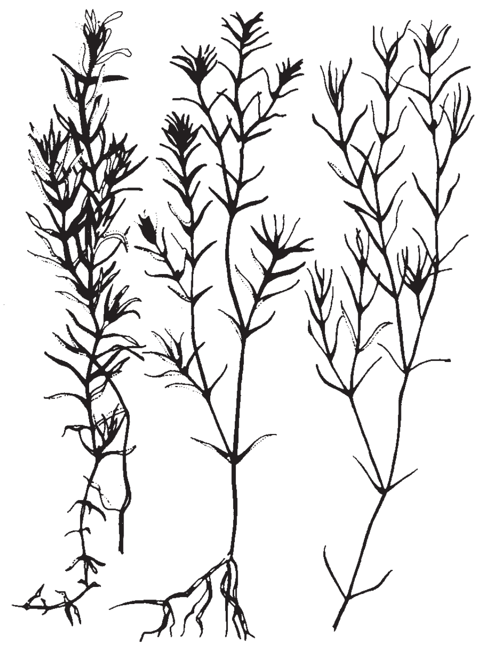
Plants generally rooted to the substrate and completely underwater

BUSHY PONDWEED (SOUTHERN NAIAD)

Scientific Name: *Najas guadalupensis*

Description: Slender plant possessing linear, deep-green or greenish-purple leaves (13 to 19 millimeters long). Bushy pondweed inhabits a variety of water habitats.

Invasive: No



COONTAIL

Scientific Name: *Ceratophyllum demersum*

Description: Olive to dark-green plant with many branched stems and no roots. When submerged, the leaves look much like the tail of a raccoon. Coontail inhabits standing water and often forms dense colonies.

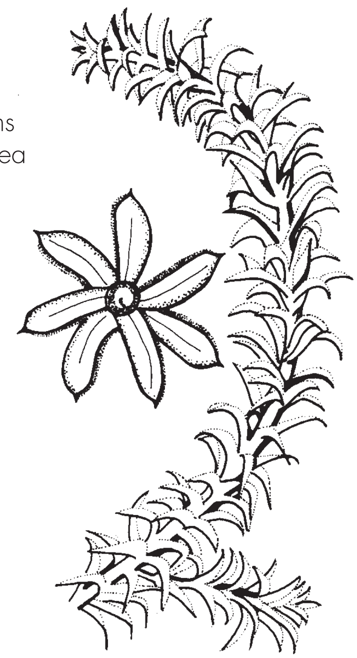
Invasive: No

ELODEA

Scientific Name: *Elodea canadensis*

Description: Heavily rooted plant with densely packed green leaves (each whorl contains three leaves). The leaf surface and its margin are smooth with no prominent midrib. Elodea is found in many habitats—from fast-moving streams to still waters up to 3 meters deep.

Invasive: No



HYDRILLA

Scientific Name: *Hydrilla verticillata*

Description: Dark-green plant with long branching stems. Unlike elodea, hydrilla leaves have toothed margins and midrib spines. Flowers are inconspicuous and white on long stalks. Hydrilla is found in most water habitats.

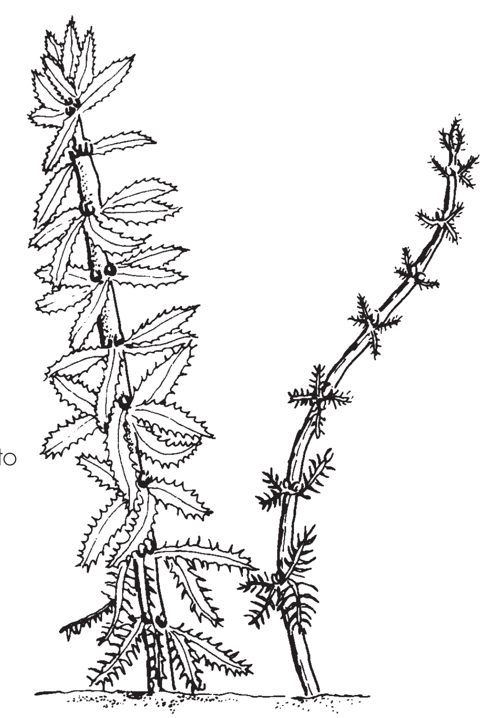
Invasive: Yes

PARROTFEATHER MILFOIL

Scientific Name: *Myriophyllum aquaticum*

Description: Plant with reddish-brown stems and olive-green leaves divided into feather-like segments. It often extends above the water surface approximately 10 centimeters. Parrotfeather milfoil is found in a variety of water habitats.

Invasive: Yes



Emergent

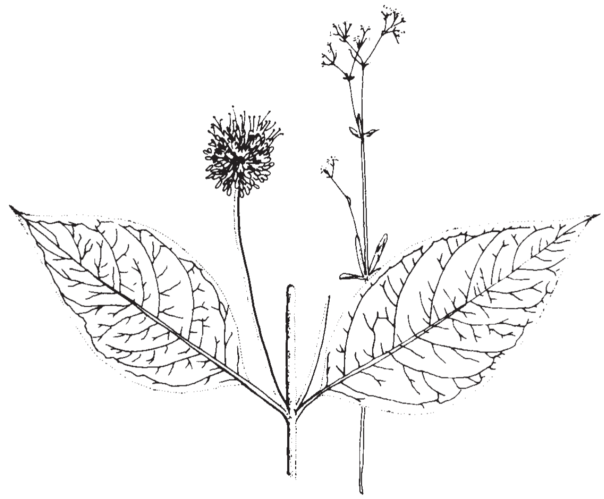
Plants (along shorelines and shallow areas) rooted to the substrate and growing above the water

ALLIGATOR WEED

Scientific Name: *Alternanthera philoxeroides*

Description: Perennial plant with leaves approximately 10 cm long. Leaves are long, narrow, and elliptical. White, clover-like flowers appear near the tip of the plant. Alligator weed can be found in any freshwater habitat.

Invasive: Yes



BUTTON BUSH

Scientific Name: *Cephalanthus occidentalis*

Description: Low-growing shrub bush often approaching the size of a small tree. Leaves are long and round or elliptical. It is best identified by the white flowers that resemble buttons. Button bush inhabits the shorelines of lakes and ponds or in water up to 1.2 meters deep.

Invasive: No

CATTAIL

Scientific Name: *Typha* spp.

Description: Tall, erect, and jointless plant. At the end of each is a spike followed by a long and dense seed cylinder. Cattails inhabit shallow banks, shorelines, ditches, and canals.

Invasive: No

SMARTWEED

Scientific Name: *Polygonum* spp.

Description: Plant with hairy stems and often swollen at the nodes. It produces small pinkish-white flowers commonly over 5 cm long. The plant inhabits irrigation ditches and marshes, and lives along the banks of streams and lakes.

Invasive: No

WATER PRIMROSE

Scientific Name: *Ludwigia* spp.

Description: Medium-size tree-bush. It has many side branches with leaves approximately 5 cm long and lance-shaped. Each leaf has tiny soft hairs on both sides. Flowers are yellow with four petals. Water primrose inhabits the banks of ditches, canals, and streams.

Invasive: No

Floating

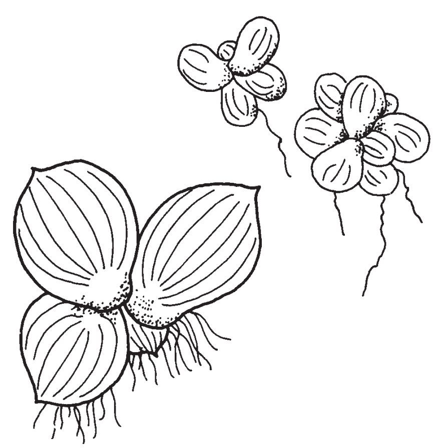
Plants floating freely on the surface or rooted to the substrate with leaves floating on the surface

DUCKWEED

Scientific Name: *Lemna minor*

Description: Small free-floating green frond (leaf) with one root per frond. Fronds may occur singly or in groups. The fronds are usually ridged and range from two to four millimeters in diameter. Duckweed inhabits fertile waters with little current.

Invasive: No

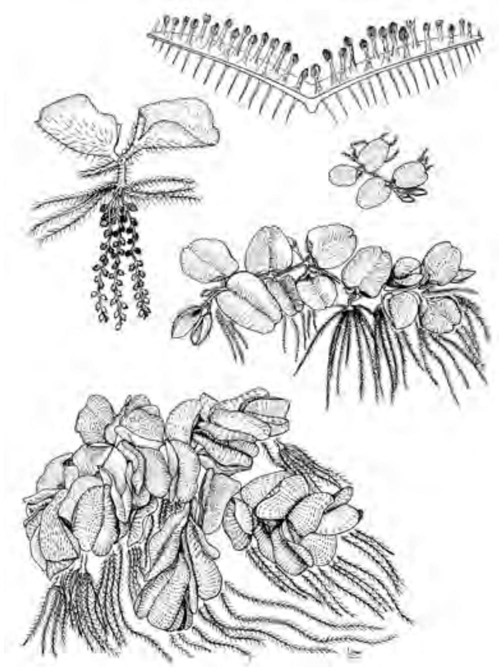


GIANT SALVINIA

Scientific Name: *Salvinia molesta*

Description: Green aquatic fern with a chain-like appearance that can form dense floating mats. Each leaf (frond) is approximately 13 millimeters wide and 25 mm long. The upper surface of the leaf contains coarse, white hairs. Underwater are brown, thread-like leaves that resemble roots. Giant salvinia inhabits warm, slow-moving waters.

Invasive: Yes



Source: University of Florida Center for Aquatic and Invasive Plants

SPATTERDOCK (COW LILY)

Scientific Name: *Nuphar luteum*

Description: Plant with heart-shaped leaves that float on the surface or stand above the water. A yellow flower (about 5 cm in diameter) may also appear above the surface. Each of the leathery, dark green leaves is approximately 20 to 25 cm wide. The stem is stout, tough, and fibrous, and is connected to a large, spongy rootstock that sends roots down into the substrate. Spatterdock inhabits calm, shallow waters with a muddy substrate.

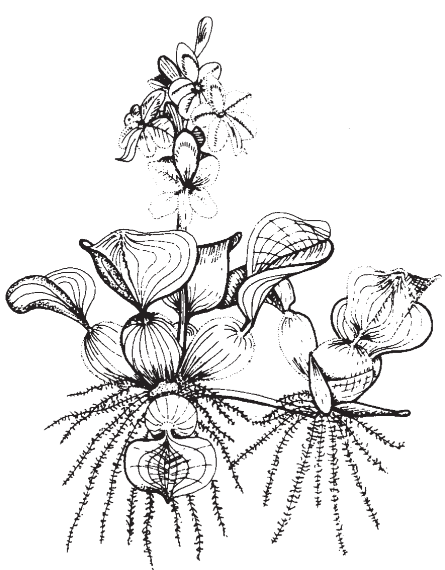
Invasive: No

WATER HYACINTH

Scientific Name: *Eichhoria crassipes*

Description: Free-floating plant with spongy stems and light-blue (or even violet) flowers. Beneath the plant are numerous dark fibrous roots. The plant is dark green and ranges from seed plants (10 to 15 cm across and 10 cm high) to large plants (measuring 61 cm across and almost 1 meter high). Water hyacinth can inhabit almost any moist environment.

Invasive: Yes

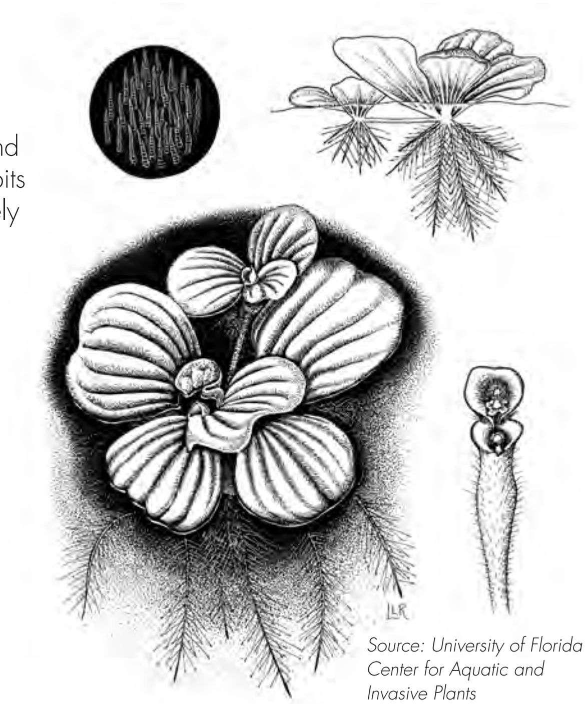


WATER LETTUCE

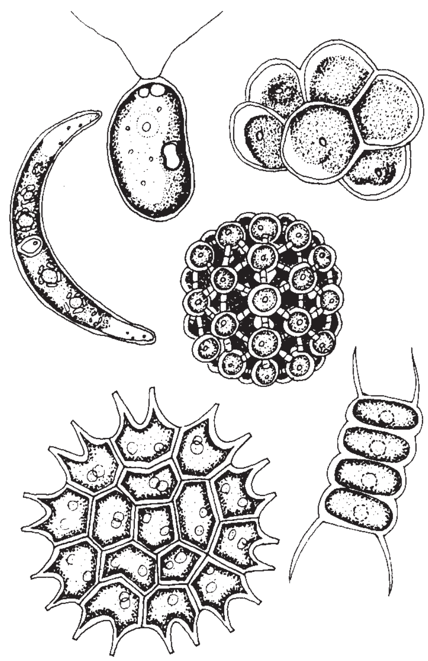
Scientific Name: *Pistia stratiotes*

Description: Plant with floating leaves that are thick, hairy, ridged, and light green. It resembles an open head of lettuce. Water lettuce inhabits lakes, ponds, and slow-moving streams in regions that remain relatively warm throughout the year.

Invasive: Yes



Source: University of Florida Center for Aquatic and Invasive Plants



Algae

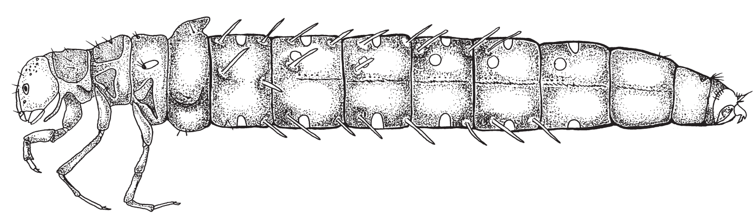
Algae are small plants or plant-like organisms that live primarily in water. Algae falls into four basic physical structures: single-celled; colonial (groups of single algae cells); filamentous (algae made up of single cells arranged end to end, either in a straight line or branched); and plant-like (large algae that resemble vascular plants). Free-floating algae that are single-cell or colonial are commonly referred to as phytoplankton.

Benthic Macroinvertebrates

The following list includes some of the benthic macroinvertebrates commonly found in Texas.

Intolerant Species

Sensitive to poor stream conditions



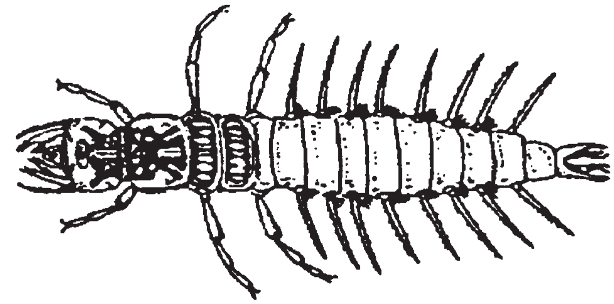
CADDIS-FLY LARVAE

Order: Trichoptera

Size: 3 to 13 mm

Description: Most are found in streams and rivers, with a few inhabiting ponds and lakes. Caddis-fly larvae have three pairs of thoracic legs (near head) and short anal prolegs (no joint) at the end of the abdomen with pointed anal claws. Some species will build snail-like cases made from sticks and small particles of rock. They can usually be seen moving about on the substrate.

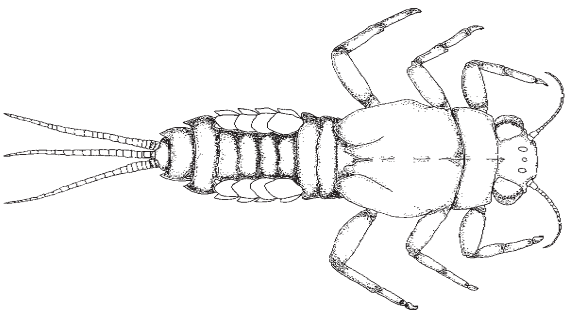
DOBSONFLY AND ALDERFLY LARVAE



Order: Megaloptera

Size: 13 to 76 mm

Description: Dobsonfly larvae are found under rocks in riffles (and other stream habitats with fast-moving water) while alderfly larvae are found mostly in deposited sediments of streams, ponds, and lakes. The dobsonfly and alderfly larvae look similar, except alderfly larvae are smaller. Both have mandibles (unsegmented jaws) and lateral filaments (thread-like extrusions on both sides of its body); dobsonfly larvae have eight pairs of lateral filaments, while alderfly larvae have seven.



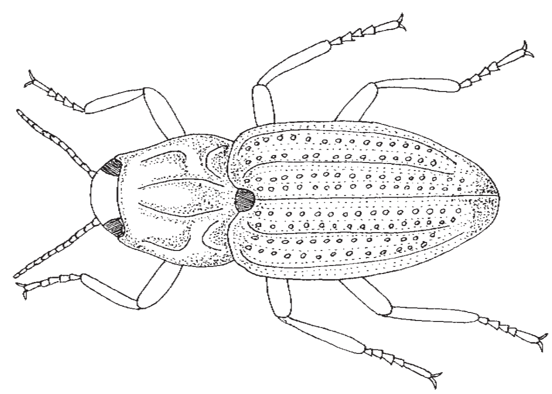
MAYFLY NYMPHS

Order: Ephemeroptera

Size: 3 to 19 mm

Description: Found in a variety of stream habitats. Mayfly nymphs have antennae, wing pads, and three caudal filaments (tails).

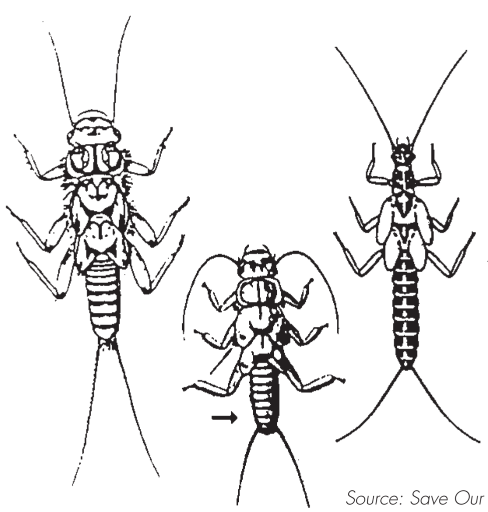
RIFFLE BEETLES



Order: Coleoptera

Size: Less than 6 mm

Description: Found on stones, logs, and other debris in the swiftest-moving water of a stream or on a wave-swept shore. Riffle beetles are oval to cylindrical, brown or black; they have long legs, and two long claws at the end of each leg.



Source: Save Our Streams

STONEFLY NYMPHS

Order: Plecoptera

Size: 6 to 13 mm

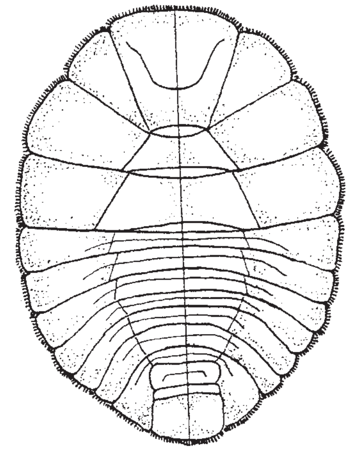
Description: Found under rocks, in debris, and in thick mats of algae. Stonefly nymphs need an oxygen-rich environment due to the lack of extensive gills. The nymph has long antennae, wing pads, two long caudal filaments (tails), and two long claws at the end of each leg.

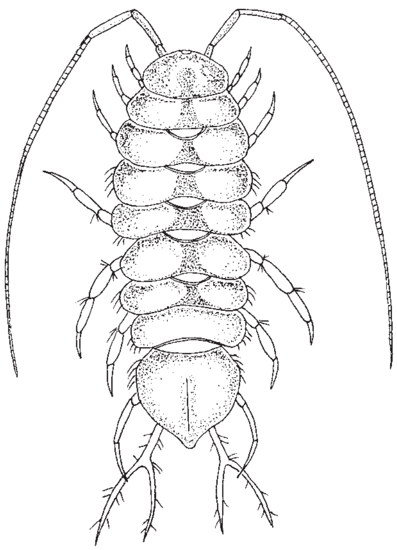
WATER-PENNY LARVAE

Order: Coleoptera

Size: About 6 mm

Description: Found on the underside of rocks in fast-moving water and on wave-swept shores. Each water-penny larva has a flat and round body, is brownish, and has legs underneath.





Intermediate Species

Moderately tolerant of degraded habitat and water quality

AQUATIC SOWBUGS

Order: Isopoda

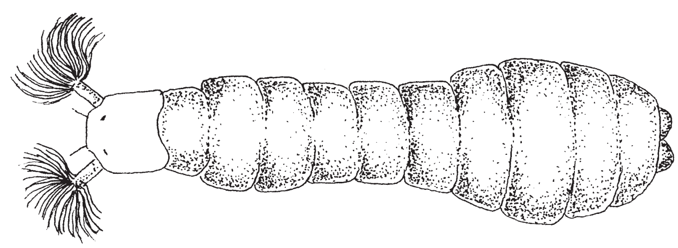
Size: 6 to 13 mm

Description: Found on vegetation and also in shallow water under logs and rocks. Aquatic sowbugs are dorsoventrally flattened and have seven pairs of leg-like appendages.

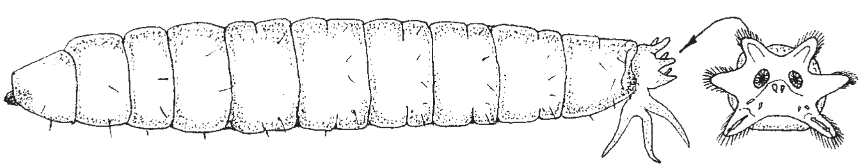
BLACK-FLY LARVAE

Order: Diptera

Size: 3 to 6 mm



Description: Found in flowing water on stones, vegetation, or other objects (usually in the swiftest part of the stream). In many cases, the larvae are so numerous that they appear moss-like over the surface of the attached object. Black-fly larvae have swollen abdomens that are attached to rocks and other debris by a caudal (posterior-end) sucker.



CRANE-FLY LARVAE

Order: Diptera

Size: 10 to 25 mm

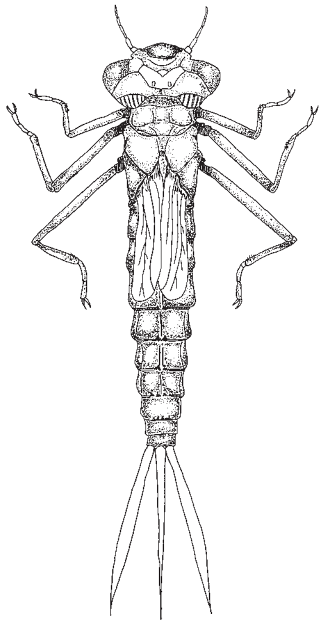
Description: Found in both running-water and standing-water habitats. Crane-fly larvae have worm-like, thick-skinned bodies that range in color from brownish-green to somewhat transparent white. Larvae also have spiracles (external openings for the respiratory system) that extend from the end of the body.

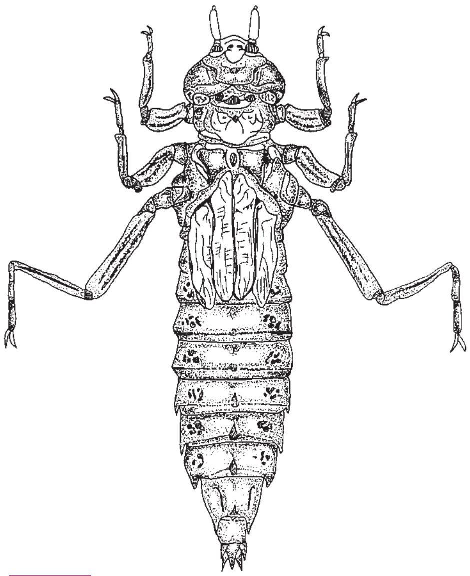
DAMSELFLY NYMPHS

Order: Odonata

Size: 6 to 25 mm

Description: Found underneath rocks and logs in streams, lakes, and ponds. Damselfly nymphs appear to have three tails, but those are actually gills that help them breathe in oxygen from the water.





DRAGONFLY NYMPHS

Order: Odonata

Size: 6 to 51 mm

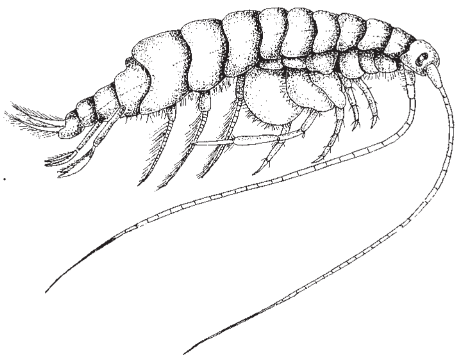
Description: Found in all types of freshwater areas, such as ponds, lakes, streams, and swampy areas. Dragonfly nymphs are dark brown to greenish and have wing pads and three triangular cerci (dorsal appendages at the end of the abdomen).

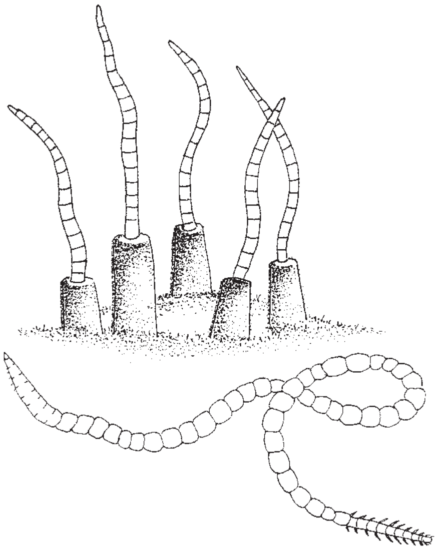
SCUDS

Order: Amphipoda

Size: 3 to 6 mm

Description: Found in lakes, streams, ponds, springs, and subterranean waters. Scuds live close to the bottom or among submerged objects to avoid light. Scuds have a laterally flattened body (like a flea's) and have seven pairs of leg-like appendages.





Tolerant Species

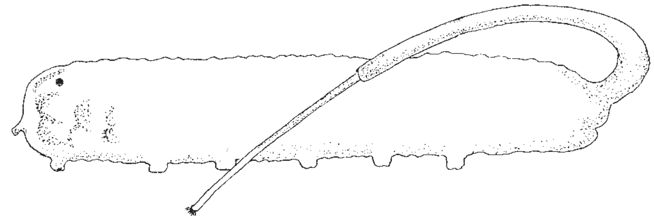
Most tolerant of degraded habitat and water quality

AQUATIC WORMS

Class: Oligochaeta

Size: 3 to 13 mm

Description: Found on the substrate of all types of water bodies; commonly found in soft mud. They sometimes become very abundant where water is polluted. Aquatic worms have segmented bodies and have many bristles.

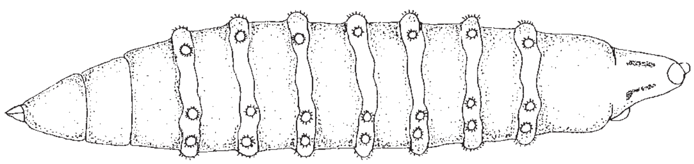


DRONE-FLY LARVAE (RAT-TAIL MAGGOTS)

Order: Diptera

Size: Body about 19 mm

Description: Found in standing-water habitats, along the edges of running-water habitats, and sewage lagoons; commonly found in areas with large amounts of decomposing organic matter and sludge. Drone-fly larvae are very tolerant of poor water quality, including low dissolved-oxygen levels. Each larva has a breathing tube to get oxygen from the air; it can be extended three to four times its body length.



HORSEFLY LARVAE

Order: Diptera

Size: 10 to 25 mm

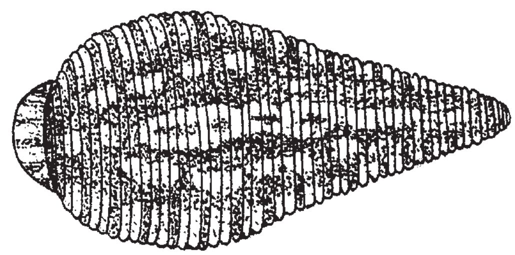
Description: Found in stream riffles, shallow stream margins, and shallow vegetated habitats. Horsefly larvae have no pro-legs (fleshy legs on the abdomen); instead, they have six or more pseudopods (false feet) on most abdominal segments.

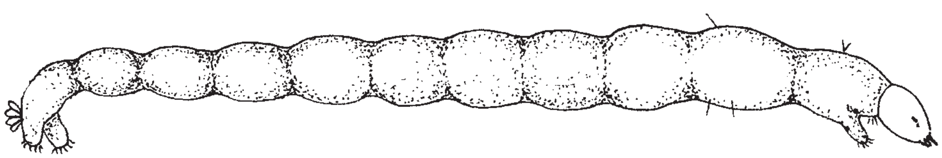
LEECHES

Class: Hirudinea

Size: 6 to 25 mm

Description: Found often in calm, shallow, warm waters that have bottoms cluttered with debris. Leeches are dorsoventrally flattened and segmented, with anterior and posterior suckers, and are usually dark brown to black.





MIDGE-FLY LARVAE

Class: Diptera

Size: 3 to 6 mm

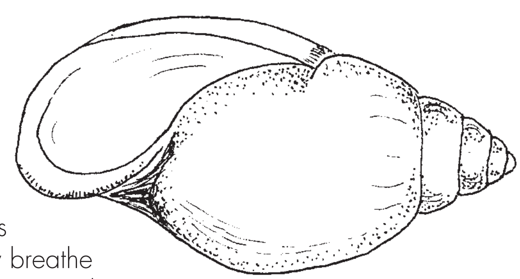
Description: Found in the shallow water areas of lakes, ponds, and streams. Midge-fly larvae prefer soft, mucky sub-strate because they use this type of material to construct their tube-like homes. The larvae are extremely tolerant of low levels of dissolved oxygen. Midge-fly larvae have narrow bodies and antennae that resemble two feathers on the front of their heads.

POUCH SNAILS

Class: Gastropoda

Size: 3 to 25 mm

Description: Snails are found in every freshwater environment, from the smallest ponds and ditches to the largest lakes and rivers. While most snails need high dissolved-oxygen concentrations, pouch snails do not, since they breathe air from the atmosphere. Therefore, pouch snails are very tolerant of pollution. Pouch snails creep along any type of substrate, generally in waters up to 2 meters deep.



Water Pollution

This section discusses water pollution, the types of pollution, and the indicators used to identify possible pollution problems. Even though water quality is improving, we must continue to monitor and evaluate its quality to protect and keep improving our Texas waters.

What is Water Pollution?

Water pollution is defined as the alteration of the chemical, physical, or biological integrity of water. Pollution is caused by activities that affect overall water quality. A *pollutant* is a substance that can cause pollution.

Pollutant Types

There are several main groups of pollutants that can affect water quality. This guide will focus on nutrients, oxygen-demanding substances, suspended solids, and sedimentation since the effects of these pollutants are easily observable or measurable with simple test kits. A fifth pollutant category, toxic substances, is also important; this pollutant is discussed below but requires advanced methods to determine its presence.

Nutrients

Nutrients, such as nitrogen and phosphorus, are essential for plant growth. The rate of plant growth is controlled by a limiting nutrient—a nutrient available in quantities smaller than necessary for plants to reach maximum abundance. When the limiting nutrient is used up, plant growth stops even if there is an adequate supply of other nutrients available. The limiting nutrient is typically nitrogen or phosphorus, although it can be any of the essential minerals needed for growth.

When excessive nutrients are available, an *algal bloom* may occur, in which algae multiply at an accelerated rate and may continue to grow until the limiting nutrient is exhausted. During these blooms, the levels of oxygen in the water (dissolved oxygen) during daylight hours can be very high from the abundance of algae producing oxygen during photosynthesis. However, oxygen production ceases at night and the DO levels may drop to lethal levels from algae and animals using the DO for respiration. In severe cases, algal blooms can kill fish and other aquatic organisms.

Sources of nutrients can include fertilizers and manure from agricultural activities, urban runoff containing fertilizer from lawns and golf courses, and domestic and industrial wastewater effluent.

Oxygen-Demanding Substances

In a body of water, the DO level will increase because of photosynthesis and natural aeration (rain, wind, waves, water currents, etc.) and will decrease from respiration. The DO level is also influenced by the water's temperature; the colder the water, the more oxygen it can hold.

Organic material (an oxygen-demanding substance because of its chemical nature) introduced into a water body can cause respiration levels to rise; that happens when organisms use DO and the organic materials for respiration. When respiration increases, DO decreases. Very low DO levels can kill fish.

The effects of organic materials are generally long lasting, with gradual deterioration of an aquatic ecosystem over time. The amount of oxygen required to decompose organic materials is called *biochemical oxygen demand* (BOD). When the BOD of the organic materials exceeds the available DO, the DO in the water body is reduced or depleted and is unavailable for aquatic life.

Sources of oxygen-demanding substances include raw sewage, household pet waste, waste from food-processing plants, and animal feedlot waste. With the exception of household pet waste, discharge from these sources requires permits with limits on the amount of oxygen-demanding substances released, so the water quality will not be reduced. For more information about permits, see the section "Pollution Management."

Suspended Solids

The term *suspended solids* is commonly used to describe the mineral and organic particles suspended in the water column. Most often, they are small clay and silt particles held in suspension by water currents. *Turbidity* refers to the amount of light blocked due to solids suspended in the water. When turbidity increases, light penetration decreases. Increases in turbidity affect aquatic life in several ways:

- When suspended solids block out light, primary producers (phytoplankton, algae, and other aquatic plants) are less able to produce oxygen. If light levels get too low, photosynthesis may stop altogether and plant life will die. Conditions that reduce photosynthesis also increase oxygen use and the amount of carbon dioxide produced.
- Turbid water reduces the visibility for fish and increases their difficulty in finding food. High turbidity also makes it easier for small fish to hide from larger predators.
- If the sediment load is too high, fish gills can become clogged.
- Suspended solids carry plant nutrients and also provide attachment places for other pollutants, such as metals and bacteria.
- Turbidity increases the temperature of the water when suspended particles absorb heat from the sun.

Sources of suspended solids can include runoff from construction sites or surface-mining operations without adequate erosion and sediment controls (silt fences, sediment traps, etc.), runoff from erodible agricultural lands, and upstream soil or substrate erosion naturally caused by fast-moving water during heavy rains.

Sedimentation

Sedimentation is a decrease in water flow and speed, allowing suspended materials to drop to the bottom. Sediment is mostly a mixture of loose inorganic particles (sand, silt, and clay) and organic substances (decomposing plants and animals).

In a natural river system, high flows scour the bottom carrying the sediment downstream; during floods, water leaves the river channel and sedimentation occurs on the floodplain. Since reservoirs can control the flow of water, a reservoir built on this river system may cause much of the sediment to deposit into the reservoir rather than downstream. Sedimentation may also increase downstream if the water flow is reduced so that sedimentation no longer occurs on the floodplain.

Increased sedimentation, especially in slow-moving areas, creates problems for aquatic organisms by covering up habitats. The reduction of aquatic habitats changes the types of aquatic plants and animals living in a water body. For example, a sandy or clay bottom may become a mucky bottom where different (and possibly fewer) organisms live.

Sources of sediment can include runoff from construction sites or surface-mining operations without adequate erosion and sediment controls (silt fences, sediment traps, etc.), runoff from erodible agricultural lands, and upstream soil or substrate erosion naturally caused by fast-moving water during heavy rains.

Toxic Substances

Substances that are considered toxic are distinct from the other pollutants because of the severe effect they can have on aquatic ecosystems. These are substances that can kill or harm organisms directly and in a relatively short time. Toxins generally disrupt an entire ecosystem, severely reducing the stream's natural ability to recover. *Acute toxicity* refers to high concentrations of a substance that cause immediate danger or death, whereas *chronic toxicity* refers to the long-term effect of sublethal levels of a substance that alters growth, reproduction, or development of aquatic organisms.

Common substances toxic to aquatic life are ammonia, chlorine, and heavy metals.

Ammonia is a valuable component of fertilizer and is also used in household cleaning supplies (like window cleaner), but it is highly toxic in nature. Ammonia enters water bodies in a variety of ways; the most common sources are raw (or partially treated) sewage and runoff from animal-feeding operations without adequate ammonia controls.

Chlorine is a very common disinfectant used in household cleaning supplies and wastewater-treatment plants, but is a chronic source of stress on the aquatic environment. Chlorine commonly enters the aquatic environment from treated domestic wastewater (discharged from wastewater-treatment plants).

Heavy metals are used in various industrial practices and in bridge pilings. Heavy metals can enter water bodies from industries that do not properly control (remove) the heavy metals in their wastewater or stormwater; they can also enter from the erosion of the bridge pilings.

Certain toxic substances enter bodies of water in very low concentrations that pose no apparent risk at that level; however, these toxins can *bioaccumulate* in an organism's body. If an animal eats many organisms that contain these toxins, the toxicity level in that animal increases; this is called *biomagnification*. The toxin level increases the higher you go up the food web.

Sources of Pollution

Water pollution can occur naturally or from human activities. If the water pollution originates from a human activity, it is classified as *point source* or *nonpoint source* pollution.

Point Source Pollution

"Point source pollution" refers to discharge of pollutants at a specific location, such as a pipe discharging wastewater or runoff into a stream. Regulations categorize point sources and then set pollution-control requirements for those categories. To ensure compliance with water quality standards, many point source owners or operators must monitor and document the chemical parameters of their discharge.

Nonpoint Source Pollution

"Nonpoint source" refers to pollutants that do not have a specific point of origin. These pollutants are generally carried by runoff. As the runoff flows over the land, it might pick up nutrients, oxygen-demanding substances, sediments, toxic substances, bacteria, and other pollutants. Nonpoint source pollution includes runoff that contains:

- excess fertilizers, herbicides, or insecticides from agricultural lands and residential areas
- motor oil, grease, or toxic chemicals from urban areas (roadways, parking lots, etc.)
- sediment from poorly managed construction sites, agricultural lands, or logging sites
- bacteria from a faulty septic system, livestock waste, or pet waste
- household chemicals that were improperly disposed of

Pollution Indicators

High Levels of *E. coli* Bacteria

Bacteria have long served as an indicator for determining if water is safe for drinking or recreational use. Indicator bacteria are not necessarily harmful, but may indicate the presence of harmful bacteria and viruses found in raw sewage. The higher level of indicator bacteria, the higher chance pathogens are in the water.

Historically, *fecal coliform* bacteria (commonly found in the small intestines of humans and other warm-blooded animals) were the most widely used indicator bacteria in surface waters. *Escherichia coli* (more commonly associated with human waste only) replaced *fecal coliform* as the indicator bacterium for freshwater bodies in Texas.

The presence of *fecal coliform* or *E. coli* is usually associated with inadequately treated sewage, improperly managed animal waste from livestock or pets, failing septic systems, and wildlife (birds and mammals) living near water (example: birds nesting under a bridge).

The Presence of Sewage Fungus

Sewage fungus is an indicator of organic material pollution (oxygen-demanding substances). Sewage fungus is:

- found in flowing waters
- white, gray, or brown
- slimy with cottony, wood-like plume
- generally found in massive amounts with long streamers clinging to twigs, leaves, or even the sides and bed of the stream

Changes in the Algae Concentration

The presence of little or no algae in a water body indicates a low nutrient content. Water bodies with low nutrient concentrations are known as *oligotrophic*. Besides low nutrient concentrations, oligotrophic water bodies are characterized by clear water capable of only supporting small populations of plants, invertebrates, fish, and wildlife. In contrast, water bodies with high nutrient levels capable of supporting an abundance of living organisms are called *eutrophic*. Eutrophic water bodies are also susceptible to algal blooms.

When algal blooms occur, the algae floating on the surface can decrease light penetration to the algae underneath and cause the algae to die off. Decay of the dead algae uses up oxygen, leading to very low dissolved-oxygen levels, potential fish kills, and strong odors. The effect is intensified at night when photosynthesis stops and oxygen consumption continues by aquatic plants including algae, as well as animals.

Algae attract attention because of their bright colors and overabundance in nutrient-enriched streams, ponds, and lakes. While the majority of freshwater algae are microscopic, the more obvious forms are often referred to as "pond moss" or "scum." Slick rocks in streams often result from algal growth.

Fish and Benthic Macroinvertebrates

Biological communities (fish and freshwater macroinvertebrates) can be used to determine past and present water quality. You can also tell if the water quality is improving, degrading, or remaining the same by analyzing any changes to this community over time.

Fish and benthic macroinvertebrates are placed into categories based on their tolerance to pollution and are used as indicator organisms in evaluating the health of streams. The three main categories of pollution tolerance are:

- **Intolerant:** sensitive to poor stream conditions.
- **Intermediate:** moderately tolerant of degraded habitat and water quality.
- **Tolerant:** most tolerant of degraded habitat and water quality.

As a general rule for healthy streams, intolerant organisms will be present along with intermediate and tolerant organisms.

Water quality is not always the limiting factor in the presence or absence of aquatic organisms. Physical habitat also plays a key role in the whether an organism inhabits a water body. The lack of physical habitat can be just as limiting as poor water quality.

The type and number of organisms present can tell a lot about a stream. If the aquatic community is made up of more intolerant species and a few intermediate and tolerant forms, the stream can be considered healthy. The presence of intolerant and intermediate species generally means that no significant pollution exists. Poor water quality is indicated when the number of tolerant species exceeds that of intermediate species, and intolerant species are absent. The number of individuals of any one species is also an indicator of quality. A good quality stream will have a larger number of species with fewer individuals per species, increased variety, and a balanced system. An unhealthy community includes a few species with numerous individuals, lacks variety, and is unbalanced.

Table 1.

Temperature Ranges Required for Growth of Certain Organisms

Temperature	Examples of Life
Over 68° F (warm water)	Most plant life; most bass, crappie, bluegill, carp, catfish, caddis-fly
Less than 68°F (cold water) • Upper Range (55-68°F)	Some plant life; stonefly; mayfly, caddis-fly, water beetle
• Lower Range (less than 55°F)	Trout, caddis-fly, stonefly, mayfly

Increased Turbidity

Material that becomes mixed and suspended in the water column increases water turbidity and decreases water clarity. Increased water turbidity can cause water temperatures to rise, thus decreasing the maximum amount of DO held in a body of water.

Factors contributing to turbidity are varied. In the summer, an important contributor is plankton. Planktonic organisms grow and multiply very rapidly in nutrient-rich waters that are warm and receive direct sunlight. During periods of heavy runoff, silt is also a factor.

Unexpected Changes to Water Temperature

Water temperature, one of the simplest water quality measurements, is one of the most important to the health of an aquatic ecosystem. Temperature characteristics of an aquatic environment affect the composition of its biological community (see Table 1). In general, aquatic organisms are cold-blooded and have body temperatures that fluctuate with the water temperature. Each aquatic species has an optimum temperature at which it functions the best. Most fish and other aquatic species in Texas are among those that can tolerate warmer water in summer and colder in winter.

The effects of temperature on a stream are normally chronic, with gradual changes in the aquatic community. However, extreme weather conditions can cause die-offs due to drastic temperature changes. Artificially heated water bodies (for example, bodies receiving discharges of warm water) can create a dependence on warm water. Fish kills can occur if warm water discharges stop during cold weather.

Removal of tree canopy and channelization of a stream reduce the thermal buffering capacity of that water body, resulting in bigger and more rapid shifts in temperature—higher than average temperatures in summer and colder than average in winter. Native aquatic fish and invertebrate species are adapted to the normal seasonal shifts in temperature, but can be affected by alterations to the normal stream conditions.

High water temperatures increase metabolism, respiration, and oxygen demand of fish and other aquatic organisms (in general, metabolic rates in aquatic organisms double with every rise of 10°C in temperature). Increased temperatures also enhance the effect of nutrients on plankton blooms. The effects of oxygen-demanding substances are intensified by temperature increases. Unnaturally warm temperatures can have impacts on aquatic organisms and favor tolerant over intolerant species. This can lead to an aquatic community dominated by tolerant species (such as carp and gar) with reduced number of intolerant species (such as darters and Guadalupe bass—the state fish of Texas).

Low Levels of Dissolved Oxygen

DO is one of the most important indicators of water quality for aquatic life because it is essential for all aquatic plants and animals. DO is a particularly sensitive factor because chemicals, biological processes, and temperature often determine its availability at different times during the year. DO levels often vary during the day; levels are usually lowest in the early morning, slightly after dawn and before photosynthesis begins.

The DO saturation level tells you how much DO the water can hold at a given temperature, pressure, and salinity. Elevated temperatures, increased salinity (salts), and pressure decreases reduce the amount of DO that the water can hold. For example, water at sea level (where pressure equals 1 atmosphere), with no salts, and at 0°C can hold up to 14.6 parts per million of DO. When this same water is at 30°C, it can hold up to 7.6 ppm of DO. Table 2 shows this relationship at various temperatures.

As shown in Table 2, DO levels can vary greatly. In addition to temperature, pressure, and salinity, there are other things that influence DO levels—including photosynthesis, natural aeration, and respiration. For example: during algal blooms, DO levels in the daylight hours can be extremely high (often greater than 10 ppm) because of photosynthesis; at night, DO can drop to lethal levels when photosynthesis stops producing oxygen and organisms respire only using the DO stored in the water. As another example, decreased sunlight causes a reduction in photosynthesis, which results in a net loss of DO.

Water can sometimes have DO levels above its saturation level, called supersaturation. Water bodies with elevated nutrient concentrations (eutrophic), high temperatures, and large amounts of filamentous and planktonic algae can create supersaturated conditions during daylight hours.

Texas changes greatly in climate, geology, and topography from east to west. For example, streams in the Hill Country of central Texas are generally higher in gradient (slope), are swift-moving, and have rocky bottoms. Aquatic organisms living in these streams are generally adapted for cooler water and high DO levels. In contrast, streams in east Texas are lower in gradient, warmer, are slower-moving, and have muddier bottoms. Aquatic organisms inhabiting these streams are generally more tolerant of warmer temperatures and lower DO levels. A DO level of 5.0 ppm or greater is generally considered the optimum to sustain the growth and health of aquatic organisms.

When DO levels fall below 2 to 3 ppm, fish and many other aquatic organisms may become stressed and some may not survive. Many fish kills in ponds and streams during the summer months are caused by low DO levels from a combination of elevated nutrients and warm water.

Table 2.

Variation in Levels of Dissolved Oxygen as Temperature Increases

Temperature		Saturation*
°F	°C	mg/L (ppm)
32	0	14.6
33.8	1	14.2
35.6	2	13.8
37.4	3	13.5
39.2	4	13.1
41	5	12.8
42.8	6	12.5
44.6	7	12.1
46.4	8	11.8
48.2	9	11.6
50	10	11.3
51.8	11	11.0
53.6	12	10.8
55.4	13	10.5
57.2	14	10.3
59	15	10.1
60.8	16	9.9
62.6	17	9.7
64.4	18	9.5
66.2	19	9.3
68	20	9.1
69.8	21	8.9
71.6	22	8.7
73.4	23	8.6
75.2	24	8.4
77	25	8.3
78.8	26	8.1
80.6	27	8.0
82.4	28	7.8
84.2	29	7.7
86	30	7.6

**Maximum amount of oxygen water will hold at a given temperature, under 1 atmosphere of pressure and 0% salinity.*

High or Low pH

The pH scale, numbered from 0 to 14, is used to measure the acidity of a water body. Pure water has a pH value of 7.0, which is considered neutral and is neither acidic nor basic. When the pH is less than 7.0, water is considered acidic; a pH greater than 7.0 is considered basic (alkaline). Generally, the ability of aquatic organisms to complete a life cycle greatly diminishes as pH becomes greater than 9.0 or less than 5.0. Figure 3 shows the habitable pH ranges for certain aquatic organisms.

The pH scale is logarithmic, with a base of 10. This means each whole number on the pH scale is ten times the whole number that precedes it. For example, a pH of 4 is 10 times more acidic than a pH of 5; a pH of 4 is 100 times more acidic than a pH of 6. A pH change of one whole number is therefore quite a large change.

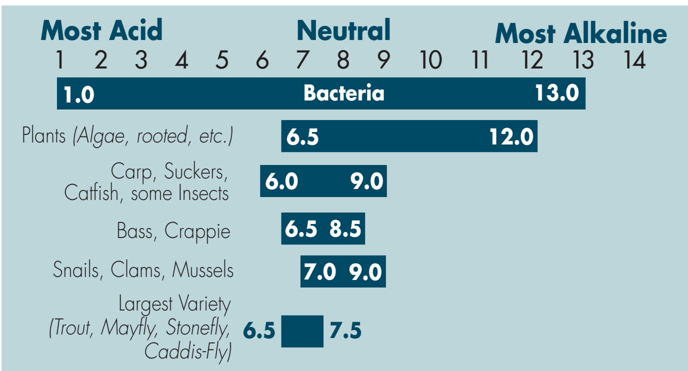
The pH of an aquatic system is influenced by a number of factors. Water dissolves mineral substances it comes in contact with, picks up aerosols and dust from the air, receives human-originated wastes, and supports photosynthetic organisms—all of which affect pH.

As explained in the discussion of the water cycle, carbon dioxide reacts with water to form a weak acid called carbonic acid. This weak acid serves as a buffer (conferring the ability to resist pH change) which diminishes extreme fluctuations in the water's pH. When photosynthesis occurs, carbon dioxide (CO_2) levels in the water reduce, along with carbonic acid levels. When carbonic acid decreases, pH increases. Therefore, you should expect the pH to increase in waters with abundant plant life (including planktonic algae) during a sunny afternoon, especially in slow or still waters.

Other events in the watershed that may also affect pH include increased leaching of soils or minerals during heavy rainfall runoff, accidental spills, agricultural runoff (pesticides, fertilizers, soil leachates), and sewage overflows.

Figure 3.

pH Ranges That Support Aquatic Life



Increased Nutrient Content

The addition of excessive nutrients to water bodies can cause an algal bloom (normally composed of phytoplankton or filamentous algae). An algal bloom is often followed by a zooplankton bloom, and later decomposition, which reduces the water's DO level.

Nonpoint source runoff may contain phosphorus or nitrogen compounds; for example, rainwater could carry excess fertilizer (containing phosphates and nitrate) into a stream. Point source pollution may also contain these compounds; for example, household chemicals flushed down the drain could enter a water body if they are not removed by the wastewater-treatment plant.

Upstream Channelization

Channelization is one of the major causes of the decreasing health of the biological community. It is the straightening of a stream's channel by removing its natural meanders. Channelization is used to control flooding; however, this change can cause a stream to become nearly lifeless. Channelization typically involves removal of large trees and natural bank vegetation, resulting in banks that are high, steep, and exposed. While most channelized streams have grass-covered banks, some in urban areas are lined with concrete. Bottom sediments are disturbed and important habitats (such as logs, rocks, tree stumps, and root mats) are removed.

Effects of Channelization

WATER-TEMPERATURE INCREASES

The removal of stream-bank vegetation reduces shading (to almost zero) and increases exposure to sunlight, increasing water temperature.

INCREASED TURBIDITY

Erosion of exposed banks during storms and high flows increases turbidity. Turbidity can also increase water temperature by absorbing the sun's rays.

CHANGES IN FLOW

The removal of natural stream-channel characteristics, and straightening the channels to accommodate flood waters, increase the velocity of the water and the potential for downstream flooding. Under normal conditions, the flow in a stream will leave the stream channel and move onto the floodplain, thereby displacing the water over a larger area. With flows confined to a straight and narrow channel, the stream loses the ability to reduce the force of the water. Restricting flow within a channel also eliminates the ability of a stream to deposit part of its sediment load onto the floodplain.

BOTTOM SUBSTRATE

Channelized stream bottoms tend to be unstable, muddy, and unsuitable for many benthic organisms. Channelization can also result in increased sediment buildup in streams.

Pollution Management

The quality of life-sustaining water affects us both physically and aesthetically. We depend on surface waters for drinking as well as for recreation, transportation, and agriculture. In addition to our own needs, it is important to protect surface waters for aquatic and terrestrial wildlife.

Congress passed the Clean Water Act in 1972 to "restore and maintain the chemical, physical, and biological integrity of the nation's waters." As a result of the Clean Water Act, many of the most severe pollution problems that plagued our waterways in the 1960s and 1970s have ended. There are, however, some instances that require the cleanup of toxic substances in sediments and water. Further, we want to continue to ensure the protection of groundwater and the responsible management of nonpoint sources of pollution.

Under the Clean Water Act, the EPA has legal authority and funding provisions to control water pollution at the national level. The Texas Commission on Environmental Quality is the lead state agency in Texas responsible for the regulation of water quality. Part of the TCEQ's responsibility is to set and implement standards for surface water quality. These standards establish explicit goals for the quality of streams, rivers, lakes, and bays throughout the state. The TCEQ designed the standards to maintain the quality of surface waters in Texas so that it supports public health, public enjoyment, and protects aquatic life (consistent with the sustainable economic development of the state). The standards can be found in Title 30, Texas Administrative Code, Chapter 307.

The TCEQ monitors water quality data from all over the state to determine if water bodies are meeting their quality standards or need improvements. Standards are also used for "permitting"—the authorization to release certain pollutants at levels that comply with the standards. To ensure water quality is not harmed by a new source wanting to release wastewater or stormwater (such as a new industrial source), the TCEQ evaluates the receiving water body, applies the water quality standards, analyzes the data, and then assigns permit limits to this new source. This source is called a point source because it comes from a known point that can easily be monitored.

Nonpoint sources can also affect water quality and are therefore studied and controlled when possible. Nonpoint sources include runoff of sediment, fertilizers, pesticides, pet waste, livestock waste, septic systems, and others. When data indicate that water quality standards are not being met in a water body, a group of individuals (stakeholders) come together to determine the cause of pollution and the best plan of action to reduce the amount of pollutants entering the body. Once developed, they implement the plan. This plan could include vegetated filter strips next to waterways to reduce sediment and nutrients from agriculture or ranching. The plan could also include educating homeowners about the proper disposal of pet waste, effects of putting excessive amounts of fertilizer or other chemicals on lawns, or any other practical method (or combination of methods).

The state of Texas prevents water pollution by issuing permits and reduces it by helping stakeholders implement their plans. It actively monitors water quality to verify the success of its permits and plans and to identify any new issues.

For the educators reading this guide, you can help reduce water pollution by teaching Texans the importance of water quality, how to identify water pollution, and promote new habits that reduce water pollution. We encourage educators to present the following lessons to help protect one of Texas' most important natural resources.

Lesson Plans

Introduction

The lesson plans in this guide help students navigate the process of selecting and surveying a local creek, stream, or river. By surveying a local body of water, students will learn to identify invasive aquatic plants, possible pollution issues, and possible pollution sources. The final lesson plan allows students the opportunity to brainstorm methods for resolving any problems they have discovered, such as developing posters to inform the community about nonpoint source pollution and how to reduce it.

After the lesson plans, you will see a list of supplementary activities. These activities provide hands-on experiments for students in areas where surface water is not readily available. You can also use these activities to help your students further understand certain water quality concepts. Following the supplementary activities is a list of additional online resources (such as free apps, etc.). At the very end of this guide are the student handouts; to make copies of these handouts, you can download this *Field Guide to Water Education* (GI-026) at <www.tceq.texas.gov/publications> and print those pages.

These lessons are appropriate in the regular classroom, as an extension, or an extracurricular activity. The suggested grade levels are 4th through 6th; with some modifications, you can teach these lessons to anyone. To conserve paper and develop teamwork skills, we recommend that teachers create student teams that work together to complete the lessons.

Format

Each lesson plan begins with the applicable Texas Essential Knowledge and Skills for that plan, to benefit teachers who use the *Field Guide* in their classrooms. For example, Science TEKS 4.1 B (for 4th grade) requires students to "make informed choices in the use and conservation of natural resources and reusing and recycling of materials such as paper, aluminum, glass, cans, and plastic." For information about these important standards, visit the Texas Education Agency's Web page <www.tea.texas.gov/curriculum/teks/>.

Following the TEKS are duration estimates, but lessons could take more or less time; we encourage teachers to read this entire guide and determine how long each lesson might take. Also included in each plan are prerequisites; these are general skills that the students should know so they can understand the lesson and complete the associated handout. The prerequisites also contain preparatory information for teachers.

Besides the general materials described below, each lesson lists the additional materials you will need. Each lesson plan also has a general-procedures plan; you might want to read the procedures and determine if you need to develop any additional procedures for your class. Please see the *Additional Resources* section if you need assistance developing additional procedures.

You can find the answers to handouts 1 through 4 in the corresponding lesson plan (after the procedures).

Objectives

The lessons in this guide will allow students to practice:

- completing laboratory experiments
- collecting information from the field using their senses, such as sight and smell
- ordering and sequencing data
- drawing logical conclusions
- forming generalized statements
- communicating data orally and in writing
- understanding concepts and skills of measurement
- applying defined terms based on observations

Materials Needed

Each lesson plan lists specific materials needed to complete that lesson. Many of the lessons require science supplies that are available for purchase online. Alternatively, you could contact local organizations (universities, aquatic-science labs, environmental-engineering firms, etc.) that would have these supplies and see if they can help you perform these tests.

The following list contains the general materials you will need:

- three-ring binder containing the handouts from this guide
- topographic map of the survey area
- composition paper
- pens and pencils
- goggles or safety glasses
- safety gloves (latex or nitrile)
- magnification lenses

Safety Precautions

Science TEKS for grades 4 through 6 require students to "demonstrate safe practices and the use of safety equipment as described in the Texas Safety Standards during classroom and outdoor investigations." The following list contains some of the safety precautions your students should understand before starting these lessons.

- Wear safety eyewear and gloves when performing tests that use harmful chemicals.
- Wear work or garden gloves when picking up trash.
- Wash hands with soap and water after contact with a natural water source.
- Do not carry around glass containers during outdoor lessons.
- Work in teams of two or more.
- Wear sunscreen.

Teachers should also follow these precautions before conducting outdoor lessons:

- Select safe routes to the survey area.
- The survey area should be easily accessible in case of emergencies.
- Obtain permission before entering any private property.
- Bring a simple first-aid kit to handle minor injuries.
- Bring poison-ivy washes or prophylactic lotions (or both).
- Bring life jackets if any students will be in water above their ankles.
- Teachers and their assistants should position themselves so all students are observed during the outdoor lessons.
- Always let someone know exactly where your class is working each day.
- Cancel on-site visits during periods of heavy rain when flash flooding is possible.

LESSON 1

The Water Cycle

Applicable TEKS

Science Grade 4	Science Grade 5	Science Grade 6
4.1 B 4.7 A, B, C 4.8 B	5.1 B 5.5 D 5.7 B 5.8 B 5.9 A, B, D	6.1 B

Duration

Three 40-minute lessons

Objectives

Students will grasp the relatively small amount of water that is available for human consumption. Students will understand the water cycle and its nomenclature. Students will also understand a water cycle that includes human activities (watering the lawn, washing your hands, flushing the toilet, etc.).

Prerequisites

None.

Materials

- Glass of water
- Apple and a knife
- *Handout 1—Water Recycles: The Complete Story* (GI-403)
    - You can request free color copies online at <takecareoftexas.org/publications>

Procedure

Introduction

1. Show your students a glass of water. Ask them what they know about water.
2. Review with your students the information in the guide under the section "What Is Water? What Is Water Quality?"—specifically, about water's basic properties and how the water they drink contains dissolved gases, maybe some organic matter, or even suspended particles.
3. Next, ask them where did this water come from. After the class understands that the water came from groundwater or surface water (rivers and lakes), continue to the lesson Earth's Water.

Earth's Water

1. Tell your students that you will show them how much water is on the Earth that is available for human use.
2. Show the apple and tell them that this apple represents all of the water that is on the Earth. Ask them: how much of this water is ocean salt water?
3. Cut a very small slice out of the apple, about 3 percent of the entire apple.
4. Say that this small slice represents freshwater (3 percent) and the rest represents ocean saltwater (97 percent). Let them know that this "freshwater" piece includes water trapped in glaciers and ice caps, but we don't get our water from these sources.
5. Next, cut a third off this small slice.
6. Tell them that the bigger piece is the freshwater trapped in glaciers and ice caps (about 2 percent of the total water on the Earth); the tiny little piece (only 1 percent of the total water on the Earth) represents all of the groundwater and water held in lakes and rivers. Let them know that this is where all of our water comes from, this one tiny, little piece.
7. With the little piece in your hand, point to the peel and say that this represents the water that is in rivers and lakes (only 0.02 percent of the total water on the Earth).
8. Let your students know that the upcoming lessons are about water and protecting our surface drinking water sources, the peel of the tiny little piece.

Handout 1—Water Recycles, the Complete Story

1. Review with your students the information in the guide under "The Water (Hydrologic) Cycle."
2. When ready, have them open up their binder to Handout 1. Discuss the water cycle that includes human consumption, including these points:

a. We get our water from the ground (groundwater) and from the surface (surface water).

b. More than likely, the water that enters your house came from a water-treatment plant. Water-treatment plants prepare the water for human consumption; they might do that by disinfecting and filtering the water.

c. Water that goes down your drains either goes to a wastewater-treatment plant or a septic system; both systems are designed to remove certain pollutants before releasing the water back into the environment as surface water or groundwater.

3. You and your students should work together to complete the water-trivia handout. You might want to give students a word bank for the crossword puzzle, since some of the words in the puzzle are not discussed in this guide.

Crossword Puzzle

DOWN		ACROSS	
1	ESTUARY	4	GROUNDWATER
2	OZONE	6	EFFLUENT
3	POLYMER	9	TURBID
5	RESIDENTIAL	10	CHANNELIZATION
7	HARVESTING	16	RESERVOIR
8	SILVICULTURE	17	AQUIFER
11	AGRICULTURAL	19	AERATION
12	INDUSTRY	20	BIOSOLIDS
13	CHLORINE	21	WETLAND
14	REUSE		
15	EUTROPHIC		
18	POTABLE		

Handout Answers

Fill in the Blanks

1	Rain barrel	4	Precipitation	7	Reuse	10	Condensation
2	Sludge	5	Power plant	8	Surface water	11	Drinking water
3	Infiltration	6	Groundwater	9	Sewage	12	Evaporation

Bonus: The dinosaurs are a reminder that the water on Earth today is the same water that was on Earth a long time ago when the dinosaurs were alive. That means there is a chance that the water you used to wash up this morning may be the same water that a dinosaur once drank. It also means that, a hundred years from now, your grandchildren may wash their hair with the same water that you drink today. That's why it's so important that we take care of the Earth's water; it's the only water we've ever had and the only water we will ever have.

Word Scramble

RAIN	LAKE	RESERVOIR	PLANTS	TAKE CARE OF TEXAS
SNOW	RIVER	FOG	BIOSOLIDS	
HAIL	HARVESTING	BARREL	POWER PLANT	
OCEAN	AQUIFER	SOIL	METHANE	

LESSON 2

Area Watershed Survey

Applicable TEKS

Science Grade 4	Science Grade 5	Science Grade 6
4.2 B	5.2 C	6.2 C
4.3 C	5.3 C	6.3 B
4.4 A	5.4 A	6.4 A
Math Grade 4	**Math Grade 5**	**Math Grade 6**
4.1 A	5.1 A, C	6.1 A, C
4.1 C	5.4 H	6.4 H
4.8 B, C	5.7 A	6.8 B, C

Duration

Two 40-minute lessons

Objectives

Students will outline a watershed and understand that stormwater in the watershed goes to its outlet.

Prerequisites

Students should understand the basics of topographic maps. Your students should also understand the water cycle and surface runoff.

Instructors should select a survey area and obtain topographic maps for that area before starting this lesson.

Materials

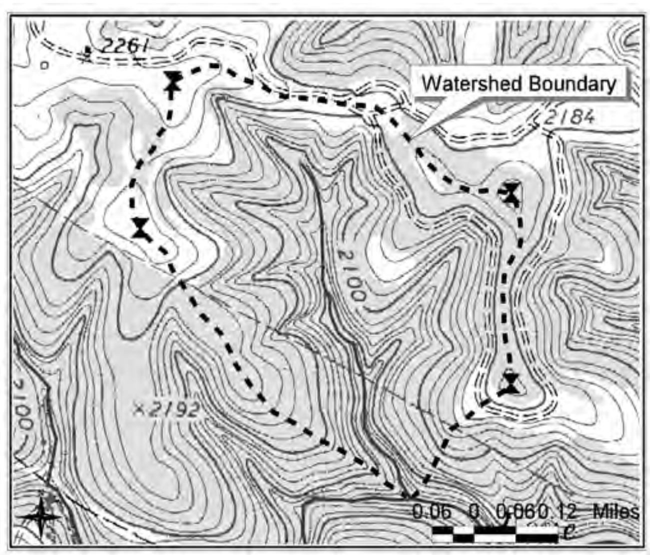
- *Handout 2—Area Watershed Survey*
- Topographic maps
  - Free topographic maps are available online at <nationalmap.gov/ustopo>. "Additional Resources" contains links to other sources.
- Rulers
- Optional: a computer and a projector

Procedure

1. Review with your students the information in the guide under "Watershed"—specifically, about surface runoff.
2. Have your students open their binders to Handout 2, which allows them to practice drawing a watershed. They should look at the map and visualize the topography of the stream and the watershed. Ask them to imagine which way the water would flow over the land. You might want your students to discuss together as a team.
3. Once they are familiar with the map, they should work together and:
   a. Find the stream and its low point.
   b. Mark the high points along the ridge of the stream.
   c. Start connecting the high points, following ridges, and crossing slopes at right angles to contour lines.
   d. Shade in or draw dots to fill in the estimated watershed area.
   e. Locate the scale on the map and estimate the dimensions of the watershed.
4. Discuss with your students that water at the low point could have come from anywhere within this watershed.
5. Next, show your students the survey area on their topographic maps.
6. Have your students outline the watershed for this area. Have them use the survey area as the low point. Explain that watersheds are very complex so everyone's watershed boundaries might look different.
7. Once completed, explain to them that stormwater within that watershed will go through their survey area.

Handout Answers

Watershed Boundaries



LESSON 3

The Aquatic Food Web

Applicable TEKS

Science Grade 4	Science Grade 5	Science Grade 6
4.3 A 4.9 A, B	5.3 A 5.9 A, B	6.3 B 6.12 A, F

Duration

One 40-minute lesson

Objectives

The students will learn about the aquatic food web. They will also learn why dissolved oxygen increases and decreases.

Prerequisites

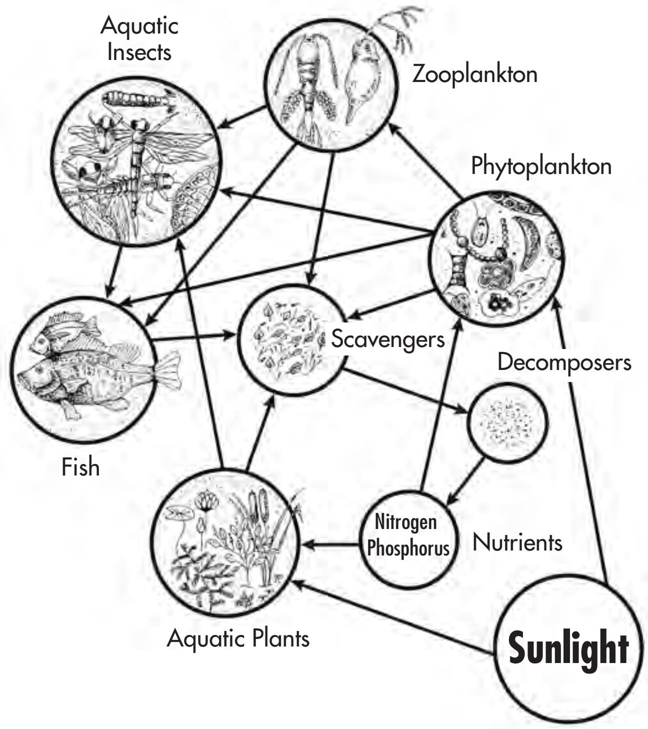
None.

Materials

- *Handout 3—The Aquatic Food Web*

Handout Answers

Food Web



Procedure

1. Review with your students the information in the guide under "Aquatic Food Web." Your students should realize that all living things respire and know the reactants and products of photosynthesis and respiration.
2. When ready, have your students open their binder to *Handout 3—The Aquatic Food Web*. They should work together to draw arrows between the different plants and animals.
3. Afterwards, the students should complete the fill-in-the-blank section of the handout, using the words in the word bank.

Fill in the-Blanks

Aquatic food webs for surface water ecosystems begin with the **sun**, the source of light. Certain wavelengths of light are absorbed by **primary producers** (also called autotrophs). Through a process called **photosynthesis**, primary producers use this light to convert **carbon dioxide** and **water** into carbohydrates and oxygen. The primary producers will use a portion of the carbohydrates and oxygen during **respiration**—the process in which carbohydrates and oxygen are converted into carbon dioxide, water, and energy. Primary producers can grow and reproduce if energy and certain nutrients are available.

Animals must also respire so they can create energy to move, grow, etc. Since animals cannot produce their own **food** like the primary producers, they must consume (eat) their food. Animals that eat primary producers are called **primary consumers** (herbivores, or plant eaters). Animals that eat primary consumers are called **secondary consumers** (carnivores, or meat eaters). The secondary consumer group may contain more than one level of carnivore; therefore, a food web may have **tertiary consumers**—animals that eat secondary consumers. In addition, a food web may also contain **omnivores**—animals that eat plants and meat.

Animals that eat dead organic materials are called **detritivores** (scavengers). They are an important part of the food web because they help in decomposition by shredding and eating dead organic materials. **Decomposers** (bacteria and fungi) are the final link in the **food web**; they break down dead material and release **nutrients** that can be used by primary producers.

LESSON 4

Water Pollution

Applicable TEKS

Science Grade 4	Science Grade 5	Science Grade 6
4.2 D, F 4.3 A	5.2 D, F 5.3 A 5.5 D 5.9 C, D	6.2 E 6.3 A

Duration

Two to three 40-minute lessons

Objectives

Students will learn about water pollution and pollution indicators. Students will identify potential water pollution sources within a watershed using sight and smell.

Prerequisites

Students should complete *Handout 2—Area Watershed Survey* before starting this lesson.

Materials

- *Student Reference Tables*
- *Handout 4—Water Pollution*

Procedure

1. Review with your students the information in the guide under the sections "What Is Water Pollution?," "Pollutant Types," and "Sources of Pollution." Your students should understand the pollutant types and how they change the water's quality. They should also understand the difference between point source and nonpoint source pollution.
2. Have your students turn to the topographic map of the survey area. Ask students to name all of the possible human and natural activities that might be taking place within the watershed.
3. Ask students to name possible pollution sources that might be found in the survey area. Let them know that it might be difficult to identify pollution sources because watersheds can be complex and there could be many human and natural activities occurring within the watershed.
4. Using the information in the guide under "Pollution Indicators," briefly introduce your students to the following pollution indicators they will use in their survey:
   a. temperature
   b. pH
   c. dissolved oxygen
   d. *E. coli* bacteria
   e. nutrients
   f. benthic macroinvertebrates
5. Tell them: besides using these pollution indicators to tell if there is a pollution issue, you can tell if there are any pollution problems by just using your sight and smell; from that, you can then guess what the pollution source might be.
6. Have all students open their binders to *Handout 4—Water Pollution* and pull out the *Student Reference Tables*.
7. Let them know that the handout lists different things they might see or smell along a stream. They will then use the *Student Reference Tables* to determine the possible pollutant and its source.

Handout Answers

	Scenario	Possible Pollutant(s)	Possible Pollutant Source(s)
1	A rainbow film is on the surface and a nearby ditch carries stormwater from the highway into the stream.	Toxic substance (motor oil)	Motor oil leaking from highway vehicles (nonpoint source)
2	There is a musty odor; animal feedlots and construction sites are nearby.	Oxygen-demanding substance (organic materials)	Manure from the animals (nonpoint source)
3	A storm caused trees to fall into the stream over a month ago; the water now resembles coffee.	Oxygen-demanding substance (organic materials)	Decaying leaves from the trees (nonpoint source)
4	There is a faint odor of bleach; aquatic plants near an outfall are very light colored.	Toxic substance (chlorine)	Chlorine from the wastewater-treatment plant; using too much disinfectant (point source)
5	Water is bright green; next to the stream are very lush residential yards and a construction site.	Nutrients (nitrogen and/ or phosphorus com-pounds)	Overfertilized residential yards (nonpoint source)
6	A stream near a construction site is very turbid and light brown. Also nearby is a residential area.	Suspended solids (particles like clay and silt)	Soil erosion from the construction site with inadequate erosion and sediment controls (nonpoint source)
7	There is a smell of rotten eggs; a road and an old residential area (that uses septic systems) are next to the stream.	Oxygen-demanding substance (raw sewage or organic materials)	Raw sewage coming from leaking septic systems in the residential area (nonpoint source)
8	An unusual smell is coming from the stream, very sharp and pungent. Nearby are a city and outfalls for both an industrial source and a wastewater-treatment plant.	Toxic substance (chemicals or pesticides)	Chemicals from an industrial source (point source) or from the city (nonpoint source)
9	The stream contains fungus that feels slimy and resembles the texture of cotton. It is found near an outfall.	Oxygen-demanding substance (organic materials)	An outfall from a wastewater-treatment plant or an industrial source; did not remove enough organic materials (point source)
10	The bottom of a stream became very muddy and the water is turning green. Nearby are forests and also crop-lands.	Sedimentation (organic and inorganic particles) and nutrients (nitrogen and/or phosphorus compounds)	Soil erosion and fertilizer from the croplands (nonpoint source)

LESSON 5

Survey: On-Site Sketch

Applicable TEKS

Science Grade 4	Science Grade 5	Science Grade 6
4.2 B, D 4.3 A 4.4 A 4.7 A	5.2 C 5.3 A 5.4 A	6.2 C 6.4 A

Duration

Two 40-minute lessons

Objectives

Students will sketch the survey area and surrounding lands. Students will identify different aquatic habitats.

Prerequisites

Students should complete *Lesson 4—Water Pollution* before starting this lesson.

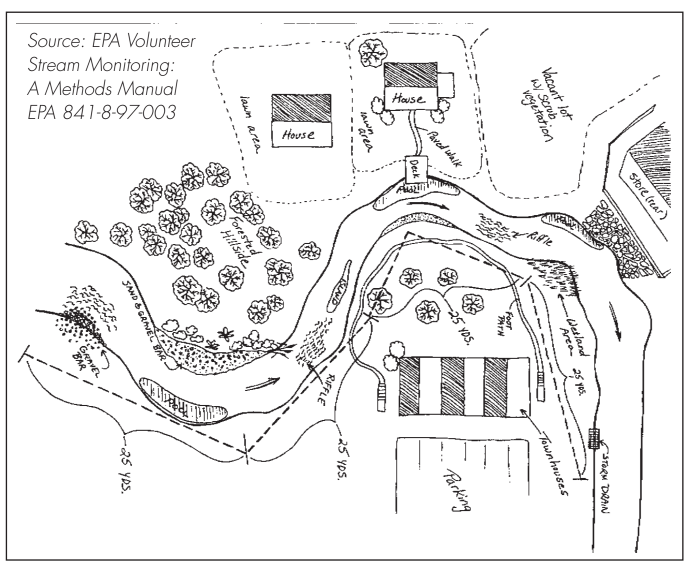
Materials

- *Handout 5—Survey: On-Site Sketch*
- Ruler

Procedure

1. Discuss the safety procedures. Inform them that there is to be no water contact during this lesson.
2. At the survey area, show your students the different aquatic habitats, such as—
   a. Pool: an area relatively deep and wide with slow-moving water compared to a riffle. Pool areas support fish, aquatic invertebrates, and aquatic plants.
   b. Riffle: the shallow portion characterized by relatively fast-moving, turbulent water with bottom materials composed of cobble, gravel, or bedrock. Riffle areas of streams are important habitats for many aquatic insects and small fish that require flowing water (for feeding) and high oxygen levels.
   c. Aquatic plants: generally found in sheltered areas and provide habitat for a variety of invertebrates and small fish.
3. Let your students know that these habitats (along with the depth and flow of the water) are key factors in determining the type of aquatic organisms you will find in the survey area.
4. Tell the students they are conducting a visual survey and have them all open their binders to *Handout 5—Survey: On-Site Sketch*.
5. The first part of the handout requires the students to walk around the survey area and take notes of what they see and smell. The last part is a blank page where the students will sketch the survey area and surrounding lands. Remind your students that the information they collect now will help later in future lessons when finding potential pollution sources.
6. On the blank page, students should map and describe the site, including:
   a. any noticeable pollution (use the *Student Reference Tables* for assistance)
   b. the direction the water is moving
   c. substrate characteristics (example: rocks, clay, sand, mud, etc.)
   d. bridges and other structures in the area (example: homes, fences, roads, sidewalks, etc.)
   e. surrounding land use (example: lawn areas, parking lots, exposed soil, forest, park, etc.)
   f. gravel, sand, dirt, or vegetated banks
   g. outlets for pipes, storm sewers, etc.
   h. any channelization and its substrate (example: ditches)
7. The sketch does not have to be a perfect likeness of the stream, but it should include the major habitat types, dams, bridges, location of discharge pipes, and dumps. Students should make notes on any unusual stream odors or colors.

Stream Sketch



Source: EPA Volunteer Stream Monitoring: A Methods Manual EPA 841-8-97-003

LESSON 6

Survey: Invasive Species—Aquatic Plants

Applicable TEKS

Science Grade 4	Science Grade 5	Science Grade 6
4.1 A 4.2 B 4.4 A, B 4.10 A	5.1 A 5.2 C 5.4 A, B 5.10 A	6.1 A 6.4 A, B

Duration

One 40-minute lesson

Objectives

Students will learn about the types of aquatic plants, what invasive species are, and why invasive species can harm aquatic environments. They will examine aquatic plants and discover if certain invasive species (commonly found in Texas) are in their survey area.

Prerequisites

Teachers should determine the number of supervisors needed and ensure that those supervisors understand their responsibilities before starting this lesson.

Materials

- *Handout 6—Survey: Invasive Species—Aquatic Plants*
- rubber gloves
- soap and water
- paper towels
- waders (if treading into the water)
- trash bags

Procedure

1. Discuss the safety procedures. Since students might come in contact with the water, advise them to stay only in shallow waters and to wash their hands after the end of the lesson.
    a. You might want at least one student from each team to wear rubber gloves and waders to identify any submerged plants in the water.
2. Take your students near the water to start the discussion about aquatic plants.
3. Discuss with your students the different types of aquatic plants you might find in your stream.
    a. Submerged plants: generally rooted to the substrate and completely underwater.
    b. Emergent plants: rooted to the substrate and growing above the water. Found along shorelines and shallow areas.
    c. Floating plants: floating freely on the surface. You can also have plants that are rooted to the substrate with their leaves floating on the surface.
    d. Algae: small plants or plant-like organisms found floating in the water, attached to rocks or logs, on the substrate, or in large quantities floating on the surface (filamentous algae). Most algae are microscopic.
4. Explain that some of the aquatic plants you might find are considered invasive species—nonnative species whose introduction harms (or is likely to harm) the economy, the environment, or human health. Also explain that there are terrestrial plants (and even aquatic and terrestrial animals) that are considered invasive species.
    a. Give your students an example. The website <texasinvasives.org> contains information about invasive species and their ecological threat.
    b. Possible example—the floating aquatic plant called giant salvinia. Why is this nonnative plant an invasive species? It can harm the environment when it covers the water's surface and blocks the light entering the water; this leads to a reduction in photosynthesis, causing dissolved-oxygen levels to decrease (that could lead to changes in the aquatic life). In addition, giant salvinia can also harm the economy by clogging intake pipes (for irrigation, etc.) and reducing recreational activities (swimming, fishing, boating, etc.).
5. Have all students open their binders to *Handout 6—Survey: Invasive Species—Aquatic Plants*. For this handout, students will explore the survey area and see if any of the invasive species listed in the handout are in the survey area.
6. After the students complete the survey, clean off the waders and rubber gloves near the survey area so you don't transport invasive species to another area.

LESSON 7

Survey: Physical Properties

Applicable TEKS

Science Grade 4	Science Grade 5	Science Grade 6
4.1 A 4.2 A, B, D, E, F 4.3 A 4.4 A, B	5.1 A 5.2 A, C, D, E, F 5.3 A 5.4 A, B	6.1 A 6.2 A, E 6.3 A 6.4 A, B
Math Grade 4	**Math Grade 5**	**Math Grade 6**
4.1 A, C 4.8 C	5.1 A, C 5.7 A	6.1 A, C 6.3 B

Duration

Two 40-minute lessons

Objectives

Students will determine the water's physical properties by measuring temperature, pH, dissolved oxygen, and flow rate.

Prerequisites

Students should complete *Lesson 4—Water Pollution* before starting this lesson.

Teachers should determine the number of supervisors needed (example: one per station) and ensure those supervisors understand their responsibilities before starting this lesson.

Materials

- *Handout 7—Survey: Physical Properties*
- thermometer
- pH test kit
- dissolved-oxygen test kit
- meter stick (that can get wet)
- two measuring tapes (one should be 30 meters or greater, depending on the width of the survey area)
- cork or an orange
- stopwatch
- rubber boots or waders

Procedure

1. Discuss the safety procedures. Since students might come in contact with the water and harmful chemicals, remind your students to:
    a. stay only in shallow water,
    b. wear rubber boots or waders if entering the water,
    c. wash their hands at the completion of the lesson, and
    d. wear safety glasses and gloves when handling any harmful chemicals included with the test kits.
2. Have all students open their binders to *Handout 7—Survey: Physical Properties*. Remind them to enter test data on the handout.
3. Send student teams to each of the testing stations. If time permits and resources are available, have your student teams conduct more than one reading at each station to verify that their data is accurate.

Temperature Station

1. Discuss information in "Pollution Indicators" about temperature, including:
    a. When temperature increases, the amount of dissolved oxygen water can hold decreases.
    b. It is uncommon for high water temperatures to be the cause of death for aquatic organisms; instead, it's the effects of high water temperatures that kill them, such as low dissolved-oxygen levels.
2. To test water temperature:
    a. One student enters the water and places the thermometer bulb below the surface of the water, about a third of the way down.
    b. After a while, he or she pulls the thermometer out of the water and immediately reads the temperature to their team.
3. If needed, help students convert the water temperature from degrees Fahrenheit to degrees Celsius.
4. Discuss factors that influence water temperature—atmospheric temperature, the amount of cover, turbidity, the temperature of incoming waters (such as warm water from a shallow ditch), etc. Have students write down the factors they believe are affecting the water temperature in the survey area.

pH Station

1. Discuss information in "Pollution Indicators" about pH, including:

a. A pH less than 7.0 is acidic; greater than 7.0 is basic.
b. It can be difficult for aquatic organisms to complete their life cycle if the pH becomes less than 5.0 or greater than 9.0.

2. Follow the directions included with the pH test kit; this may require a student to enter the water to collect a water sample.
3. Discuss factors that influence pH—photosynthesis (photosynthesis decreases dissolved-CO_2 levels, causing the pH to increase), leaching of soils or minerals, the pH of incoming waters (such as stormwater containing sulfuric acid), etc. Have students write down the factors they believe are affecting the pH in the survey area.

Dissolved-Oxygen Station

1. Discuss information in "Pollution Indicators" about dissolved oxygen, including:
   a. Dissolved oxygen levels increase when photosynthesis and natural aeration are high and respiration is low.
   b. Dissolved oxygen levels decrease when photosynthesis and natural aeration are low and respiration is high.
   c. Generally, a dissolved-oxygen concentration of 5.0 ppm or higher is favorable for fish and other aquatic organisms.
2. Follow the directions included with the dissolved-oxygen test kit; this may require a student to enter the water to collect a sample.
3. Discuss factors that influence dissolved oxygen—photosynthesis (affected by the amount of sunlight, aquatic plants, etc.), temperature, natural aeration, the amount of oxygen-demanding substances, etc. Have students write down the factors they believe are affecting the dissolved-oxygen levels in the survey area.

Flow Station

1. Introduce the students to the following information regarding flow:
   a. Flow can be expressed as cubic feet per second, cubic meters per second, or even as gallons per second.
   b. To get the flow, you will need to measure three things: width, depth, and velocity (speed).
   c. Flow and depth influence the organisms you will find in the water.
2. To measure flow:
   a. Two team members measure the width and average depth.
      - Width: using the measuring tape, run the tape straight across the survey area, perpendicular to the direction the water is traveling. Do not include any dry land in the measurement. Record the width in meters (example: 20.0 meters).
      - Depth: along the measuring tape, use a meter stick to estimate the average depth along that line. Record the depth in meters (example: 0.25 meters).
   b. The other two team members measure the surface **velocity**.
      - Start upstream and roll out two meters of the measuring tape. Make sure the tape is parallel to the direction the water is traveling.
      - One team member will sit at 0 meters (the upstream point) while the other sits at 2 meters with the stopwatch.
      - The team member at 0 meters tosses the cork slightly upstream. Once the cork reaches 0 meters, he or she will say "start" so the other team member will start the stopwatch.
      - Once the cork reaches 2 meters, stop the stopwatch and collect the cork.
      - **Velocity:** take 2 and divide by the time (example: for a cork that traveled 2 meters in 5 seconds, the calculation is $2 \div 5 = 2/5 = 0.4$ meters per second).
   c. When ready, team members come together to calculate flow by multiplying together width, depth, and velocity (example: $20.0 \times 0.25 \times 0.4 = 2$ cubic meters per second).

LESSON 8

Survey: Chemical Properties

Applicable TEKS

Science Grade 4	Science Grade 5	Science Grade 6
4.1 A 4.2 A, B, D, F 4.3 A 4.4 A, B	5.1 A 5.2 A, C, D, F 5.3 A 5.4 A, B	6.1 A 6.2 A, E 6.3 A 6.4 A, B

Duration

One 40-minute lesson

Objectives

Students will determine the water's chemical properties by measuring *E. coli* concentrations and nutrient (nitrate or phosphorus) levels.

Prerequisites

Students should complete *Lesson 4—Water Pollution* before starting this lesson.

Teachers should determine the number of supervisors needed (example: one per station) and make sure those supervisors understand their responsibilities before starting this lesson.

Materials

- *Handout 8—Survey: Chemical Properties*
- *E. coli* (or coliform bacteria) test kit
- Phosphate or nitrate test kit (or both)

Procedure

1. Discuss the safety procedures. Since students might come in contact with the water and harmful chemicals, remind your students to:
   a. stay only in shallow water,
   b. wear rubber boots or waders if entering the water,
   c. wash their hands at the completion of the lesson, and
   d. wear safety glasses and gloves when handling any harmful chemicals included with the test kits.
2. Have all students open their binders to *Handout 8—Survey: Chemical Properties*. Remind the students to enter test data on the handout.
3. Send student teams to each of the testing stations.

E. coli Concentrations

1. Discuss information in "Pollution Indicators" about *E. coli*, including:
   a. You find *E. coli* in the intestines of humans and animals. They are also found in human and animal feces.
   b. They are not necessarily harmful, but may indicate the presence of pathogens (harmful bacteria and viruses). This is why *E. coli* are called "indicator bacteria."
   c. The higher level of indicator bacteria, the higher chance pathogens are in the water.
2. Follow the directions included with the *E. coli* test kit; this may require a student to enter the water to collect a sample.
3. Discuss factors that influence *E. coli* concentrations—inadequately treated sewage, improperly managed animal waste from livestock or pets, failing septic systems, wildlife living near water, etc. Have students write down the factors they believe are affecting the concentration of *E. coli* in the survey area.
   a. Example: if the *E. coli* concentration is low, then the factor affecting this low concentration could be minimal human and animal waste entering the stream.

Nutrient Levels

1. Discuss information in "Pollution Indicators" about nutrients, including:
   a. Excessive nutrients can cause an algal bloom.
   b. Algal blooms can eventually cause low dissolved oxygen levels, and this might cause problems to fish populations (stress and even death).
2. Follow the directions included with each test kits; this may require a student to enter the water to collect a sample.
3. Discuss factors that influence phosphorus and nitrogen concentrations—runoff containing fertilizer or manure, domestic and industrial wastewater effluent, etc. Have students write down the factors they believe are affecting the phosphorus and nitrogen concentrations in the survey area.
   a. Example: if concentrations are low, then the factors affecting nutrient levels could be minimal runoff containing fertilizers and possibly a release of water with low nutrient concentrations from a wastewater-treatment plant upstream.

LESSON 9

Survey: Biological Properties

Applicable TEKS

Science Grade 4	Science Grade 5	Science Grade 6
4.1 A 4.2 A, B, D, F 4.3 A 4.4 A, B 4.10 A	5.1 A 5.2 A, B, C, D, F 5.3 A 5.4 A, B 5.9 A 5.10 A, C	6.1 A 6.2 A, B, E 6.3 A 6.4 A, B 6.12 C, D

Duration

Two to three 40-minute lessons

Objectives

Students will learn what lives in a stream and how these organisms act as indicators of pollution. Rather than arriving at an accurate count, students will understand that it is more important to see how many different species of freshwater benthic macroinvertebrates are present in the body of water.

Prerequisites

Students should complete *Lesson 4—Water Pollution* before starting this lesson.

Teachers should determine the number of supervisors needed (example: one per team) and make sure those supervisors understand their responsibilities before starting this lesson. You do not need a permit for handling insects; if you would like to handle other animals, please visit the Texas Parks and Wildlife Department's Web page at <tpwd.texas.gov/business/permits/land/wildlife/research> for more information. In addition, you may want to build your own equipment; see the "Additional Resources" section for instructions on building your own dip nets and kicknets.

Materials

- *Handout 9—Survey: Biological Properties*
- Rubber boots or waders
- Magnification lenses
- Forceps
- Collection equipment (dip nets, and a hand screen or kicknet)
- White observation pans (enamel or plastic)

Procedure

1. Discuss the safety procedures. Remind your students to:
   a. stay only in shallow water;
   b. wear rubber gloves when they are using their hands to disturb the substrate, aquatic vegetation, roots, or stick piles;
   c. wear rubber boots or waders if entering the water; and
   d. wash their hands at the end of the lesson.
2. Discuss information in "Pollution Indicators" about benthic macroinvertebrates, including:
   a. Benthic macroinvertebrates are small animals without backbones that live on the bottom of water bodies.
   b. They are used to determine past and present water quality; in addition, continued sampling (over a period of time) can help you tell if the water quality is improving, degrading, or remaining the same.
   c. We categorize macroinvertebrates by their tolerance to pollution. For this lesson, the categories are intolerant (sensitive to poor stream conditions), intermediate (moderately tolerant to degraded habitat and water quality), and tolerant (most tolerant to degraded habitat and water quality).
   d. Water quality is not always the limiting factor in the presence or absence of aquatic organisms; physical habitat also plays a key role in the whether an organism inhabits a water body.
   e. As a general rule—a healthy stream contains intolerant species while polluted streams do not. Intermediate and tolerant species can be in both healthy and polluted streams.
3. Review with your students *Handout 9—Survey: Biological Properties* so they understand the handout. Based on the data previously collected, ask your students what results they might expect from this study (healthy or polluted stream).
4. Before your students start, discuss the collection protocols including:
   a. Do not collect fish, oysters, shrimp, clams, mussels, or crabs; instead, count how many you see and write that number on your handout.
   b. Return benthic macroinvertebrates slightly downstream of the collection area.
5. Assign student teams to their collection areas:

a. Teams using a hand screen or kicknet need to collect in habitats with running water, such as a riffle.

b. Teams using the dip nets can collect in almost any of the aquatic habitats.

6. Once your students complete the handout, discuss the results with your students. If students found:

   a. Intolerant species and a few intermediate and tolerant species, then the stream is considered healthy.

   b. No intolerant species, and more tolerant species than intermediate species, then the water quality is considered poor.

Hand-Screen (or Kicknet) Collection

1. One student will enter the water and stand in a location where he or she can disturb the substrate.
2. Two other students (each one holding an end of the screen) will enter the water and firmly place the bottom of the screen into the substrate approximately 0.5 meter downstream from the other student. The screen should be perpendicular to the substrate or slightly angled downstream so it can catch benthic macroinvertebrates and other dislodged material.
3. When ready, the student upstream will disturb the substrate with his or her hands or feet (or both) for at least 5 minutes. The area in front of the net should be thoroughly disturbed.
4. In a scooping action, lift the screen out of the water so that all captured material remains on the screen.
5. Bring the screen to the bank and lay it down on the ground.
6. As a team, use the forceps to collect the benthic macroinvertebrates and put them into the observation pan.
7. Using *Handout 7*, identify the collected organisms and enter the number for each species.

Dip-Net Collection

1. Use the following procedures when collecting benthic macroinvertebrates found on roots, stick piles, or aquatic vegetation:

   a. Place the dip net slightly downstream on the substrate. If there is little to no water movement, place the net in a manner that would catch the benthic macroinvertebrates.

   b. Vigorously move the vegetation, etc. for several seconds.

   c. In a scooping action, bring the dip net to the bank and pour its contents into an observation pan.

   d. Use the forceps to collect benthic macroinvertebrates and put them into another observation pan.

   e. Using *Handout 7*, identify the collected organisms and enter the number for each species.

2. To collect benthic macroinvertebrates from the substrate, follow the hand-screen procedures; however, only one student needs to hold the dip net to the substrate.

LESSON 10

Data Analysis

Applicable TEKS

Science Grade 4	Science Grade 5
4.2 E, F	5.2 E, F

Duration

One 40-minute lesson

Objectives

Students will share their data and enter any missing data into their handouts. Students will understand that there are one or more reasons for their results.

Prerequisites

Students should complete the survey handouts (5 through 9) before starting this lesson.

Materials

- Survey handouts (5 through 9)

Procedure

1. Have students share their data.
   a. Students that didn't perform every test should fill in any missing data using the results from other students.
   b. Discuss any differences and similarities between their data. Also discuss how repeating the same test or experiment increases the reliability of results.
   c. Point out that the stream appearance and water quality may change along its length (especially if students surveyed in different areas along the stream).
   d. If students report different water quality in the benthic-macroinvertebrate survey, you should combine everyone's results together and determine the water quality.
2. Use the following example to explain that one or more reasons caused the results of their data—if you recorded low dissolved oxygen levels, it could have been caused by:
   a. the decay of organic wastes (an oxygen-demanding substance);
   b. high water temperature (it holds less dissolved oxygen, respiration increases, etc.);
   c. tests conducted in the morning (before photosynthesis was fully active);
   d. few aquatic plants and algae in the water (low photosynthesis levels);
   e. poor natural aeration (less atmospheric oxygen entering the water);
   f. sampling error (inaccurate test results);
   g. etc.
3. Explain that it might be possible to find the main cause, but it can be very difficult. At best, you might be able to speculate about the main cause.
4. Tell your students that the next session will use problem-solving strategies to find any problems with your stream, discover possible causes, and then narrow this list down to the possible main cause.

LESSON 11

Community Awareness Plan

Applicable TEKS

Science Grade 4	Science Grade 5	Science Grade 6
4.2 C, D, F 4.3 A	5.2 D, F, G 5.3 A	6.2 E 6.3 A

Duration

Two to five 40-minute lessons

Objectives

Students will brainstorm and discover any problems with their stream and their main causes. The students will develop a community awareness plan to educate their community about water pollution and ways to reduce it.

Prerequisites

Students should complete *Lesson 10—Data Analysis*

Materials

- Team notebooks
- Optional: computer and projector (to show satellite imagery)

Procedure

1. Inform students that the class will work together to discover any problems with your stream and then brainstorm (a problem-solving process) to find the possible main cause.
2. Before starting the brainstorming process, students should review their handouts and see if they can identify any problems. (Examples: Were the dissolved oxygen levels low? Were there any unusual smells along the creek? Was the water temperature high? And so on.)
3. Before staring the brainstorming session, remind your students that there are no bad ideas and no wrong answers when brainstorming. Also let them know that you will be writing their ideas on the board.
4. Brainstorming session—
   a. Brainstorm: Ask your students to list all possible problems with their stream.
      - Example: high water temperatures.
   b. Select and Brainstorm: Select one or more of the problems and ask them to list all of the possible causes.
      - Example: high water temperatures possibly caused by sun exposure (no shade), high turbidity, tests conducted on a very hot day, nearby point sources releasing warm water into the stream, etc.
   c. Brainstorm and Select: Ask your students to remove items from this list that are not supported by their collected data. If only one item remains, then that is the possible main cause. If more than one remains, then you may need to select one as the possible main cause. If none remain, then you may need to restart the brainstorming session or select a different problem.
      - Example: from the data—the water was not turbid, it wasn't a hot day, and there were no point sources nearby; therefore, the only one remaining on the list was "sun exposure (no shade)," so that is possibly the main cause.
   d. Brainstorm: With the possible main cause known, ask your students to list ways that would minimize this cause (which should resolve or minimize the problem).
      - Example: increase shade by planting trees, installing artificial shade, planting native plants along the banks, etc.
   e. Select: Select the most reasonable item from this list and then proceed to developing a community awareness plan.
      - Example: plant trees to increase shade.
5. The development of the community awareness plan can be a classroom activity (via brainstorming sessions) or a predefined plan you created. To help develop this plan, you should think about the:
   a. Target group—who in the community can help minimize the cause?
      - Example: Landowners around the stream, environmental groups, or local garden clubs might help plant trees.
   b. Message—what simple message can you create to explain the problem and its main cause? In your message, you could also add information about water pollution, who conducted survey, etc.

- Example: Hot streams mean hot things! Caldwell Elementary students need your support to increase the amount of shade on our local stream to help reduce water temperatures and protect our aquatic life.

c. Message form—how should you deliver your message to your target group? It could be in the form of flyers, posters, banners, letters, Web pages, etc.

- Example: Create letters we can mail.

d. Mission—what is our mission?

- Example: Our mission is to create letters and mail them to landowners, garden clubs, and environmental groups to encourage them to plant trees along our stream.

6. Looking at the mission, discuss the implementation phase of your plan:

a. What needs to be done?

- Example: we need to develop additional language for the letter, develop a mailing list, print letters, etc.

b. How and where should we work on the plan?

- Example: Some students should develop the language for the letter while the others work in the computer lab to develop the mailing list, print the letters, place the letters in the envelope with a stamp, and then mail the letters.

c. Who should do what?

- Example: This spreadsheet shows all the students and their tasks …

7. Once you are ready, implement your community awareness plan.

Supplemental Activities

Use the following activities if you have limited access to surface water. You can also use these supplementary activities to reinforce certain aspects, such as surface runoff.

Indoor Watershed

Use a large tub, deep wagon, or wading pool to create a model watershed by placing two large mounds (hills) of dirt on either side of a gully (potential stream). Use the model to complete these three activities.

Create a Stream System

Pour water down one of the hills to show how a stream system is formed. Discuss where the water comes from and where it goes (some into the ground, some to the stream, and some into the air).

Illustrate How Sediment Can Be a Nonpoint Source Pollutant

Place a sheet of white paper in the bottom of the gully. Pour water down one of the hills and observe the runoff as it makes its way to the stream (easily seen on the white paper). Discuss how the sediment (soil) can become a pollutant—how it can harm aquatic life, and eventually fill the stream with soil. This can happen naturally over a long period of time, but how do human activities speed up the process?

Illustrate How Nonpoint Source Activities on the Land Affect the Stream

Place large rocks up to the brim of a cup and then fill it up with dyed water (use lots of drops, preferably a dark color). Dig a small hole in a hill, gently place the cup inside, and then cover the cup with soil. This simulates an underground storage tank or a septic system that leaks into the groundwater. Use a watering can to simulate rain and saturate the area on top of the cup. Observe if the water in the stream has changed colors. Discuss how nonpoint source pollution can occur through both groundwater and surface water.

Pollution Cleanup Difficulties

Illustrate how difficult it is to clean up pollution once it occurs. Put one drop of motor oil into a bowl of water and observe. Try to remove it with various tools such as a spoon, pencil, leaf, paper, or eyedropper. Also, mention that used motor oil can be recycled and you should never pour it down the drain or on the ground.

Oxygen from Aquatic Plants

Demonstrate how aquatic plants produce oxygen. Place a test tube over a submerged aquatic plant, such as Elodea. Observe oxygen bubbles being produced when the tube is in strong light.

Sunlight and Aquatic Life

Show how sunlight is important for aquatic life. Pour stream water into two airtight bags or jars. Hang or place one in a window and the other in a dark closet or box where no light can reach the water. After a few days, discuss with the students any differences between the two bags (smell, color, etc.) and what might have caused those differences.

Phosphate Levels in Water

Show how phosphate can be the limiting nutrient in water and how adding phosphate may cause an algal bloom. Pour stream water into five 1-gallon bags or jars. Pour powdered detergent (containing phosphates) into the bags: bag one—0 teaspoons; bag two—⅛ tsp; bag three—¼ tsp; bag four—⅜ tsp; bag five—one tsp. Allow the bags to sit in sunlight for a few days. After a few days, at least one of the bags should be very cloudy from algal growth. If nothing happens in those few days, you might want to allow the bags to sit a few more days. If still nothing happens, the stream water might have a different limiting nutrient, or the detergent could be too strong.

Oxygen and Decay

Demonstrate how the decay of organic matter uses dissolved oxygen. In this activity, a steel-wool pad represents detritivores (organisms that feed on decaying organic matter), and methylene blue indicates the amount of dissolved oxygen in the water (the darker it is, the more dissolved oxygen is in the water). Obtain two small glass jars (with screw-cap tops) that have been thoroughly cleaned. Place a clean pad of steel wool into one of the jars. Fill both jars with tap water and add two drops of methylene blue solution to each jar. Fasten the caps and allow the jars to remain undisturbed. Periodically observe the jars and note the fading of the blue color in the jar containing the now-rusted steel wool pad. Observe the other jar that still has a blue color. Relate the steel-wool pad to detritivores who use dissolved oxygen and organic matter for respiration.

For another activity, pour tap water into a jar with leaves, plants, and grass. Seal the jar. Observe the contents of the jar over time. Discuss the decay of the vegetation. Mention that the process of decay uses dissolved oxygen.

Absorption Levels and Surface Runoff

Demonstrate the different infiltration levels (the amount of water absorbed into the ground) and also the characteristics of surface runoff. Vertically cut two 3-liter plastic bottles (upwards, through the mouth). Place the four identical pieces on a flat, slightly angled surface with the mouth at the lowest point. Pour different materials into each one (such as wood chips, bare dirt, sand, and sod). Each bottle should contain about the same volume of material, enough to roll a marble down its surface and out of the bottle's mouth. Place measuring cups at the bottom to catch the runoff. At the top of the bottle, pour two cups of water and compare the amount of water and materials collected in each cup. You can also increase the angle to show how gradient changes the characteristics of surface runoff. You might want to discuss how urbanization, agriculture, and other human activities can affect the water as it travels through a watershed.

For another activity, tour the playground or some other outdoor area and see if there is evidence of runoff. Discuss why it has or has not occurred. This activity will be especially meaningful after a heavy rain.

Microscopic Life in Water

Show your students microscopic life in stream water by using a light microscope. You should discuss their roles in the food web, such as phytoplankton (a primary producer) that produces oxygen during photosynthesis.

Acidity of Water and Other Substances

Help students understand the pH scale by testing the acidity of substances in water. Pour some bleach, egg whites, egg yolks, orange juice, lemon juice, and vinegar into different cups of water. Use litmus paper to test what's in each cup.

Natural Filtration

Show how the land can naturally filter the water when it travels through the land and soil. With a hot nail, punch a hole in the bottom of a clear plastic cup. Create a natural filter by filling the bottom of the cup with small rocks, pebbles, gravel, and sand. Pour dirty water into the cup and observe the difference in the water that comes out through the hole.

Additional Resources

Additional Data, Apps, Etc.

National Science Digital Library

Library containing videos, lesson plans, links to other resources, etc.: <nsdl.oercommons.org>

National Science Foundation

Science videos: <science360.gov>

Texas A&M University

Aquatic plant identification: <aquaplant.tamu.edu>

Aquatic plant identification app: <aquaplant.tamu.edu/plant-identification>

Texas Commission on Environmental Quality

A Guide to Freshwater Ecology (GI-034): <www.tceq.state.tx.us/goto/gi-034>

Surface Water Quality Monitoring Procedures, Volume 1: Physical and Chemical Monitoring Methods (RG-415): <www.tceq.texas.gov/goto/rg-415>

Surface Water Quality Monitoring Procedures, Volume 2: Methods for Collecting and Analyzing Biological Assemblage and Habitat Data (RG-416): <www.tceq.texas.gov/goto/rg-416>

Take Care of Texas resources regarding air, waste, and water: <takecareoftexas.org/publications>

Texas State University—Texas Stream Team

Water quality lesson plans, grades 3 through 12: <meadowscenter.txstate.edu/Service/TexasStreamTeam/educators/curriculum.html>

U.S. Environmental Protection Agency

Apps: <epa.gov/mygreenapps>

Benthic-macroinvertebrate protocols: <water.epa.gov/scitech/monitoring/rsl/bioassessment/upload/ch_07.pdf>

Water science information: <www2.epa.gov/science-and-technology/water-science>

US Geological Survey

Mobile water data: <m.waterdata.usgs.gov>

Questions answered by the USGS: <usgs.gov/faq>

Topographic and other maps: <nationalmap.gov/ustopo> or <usgs.gov/pubprod>

Topographic-map viewer: <ngmdb.usgs.gov/maps/TopoView>

Water quality information: <water.usgs.gov/owq>

Others

List of invasive species in Texas: <texasinvasives.org>

Building Sampling Equipment

Hand Screen

Materials:

- Nylon or wire door screen (1′ x 2′)
- Two wooden poles (1.5 to 1.8 meters long)
- Small nails or staples
- Tin shears or tin snips

Attach the nylon or wire door screen to the two wooden poles. If you use wire door screen, put the woven (finished) edge on the end that will be in contact with the stream bottom. The opposite edge should be folded, leaving no projecting wire ends. Wrap the folded ends of the screen around the poles and either nail or staple them.

Dip Net

Materials:

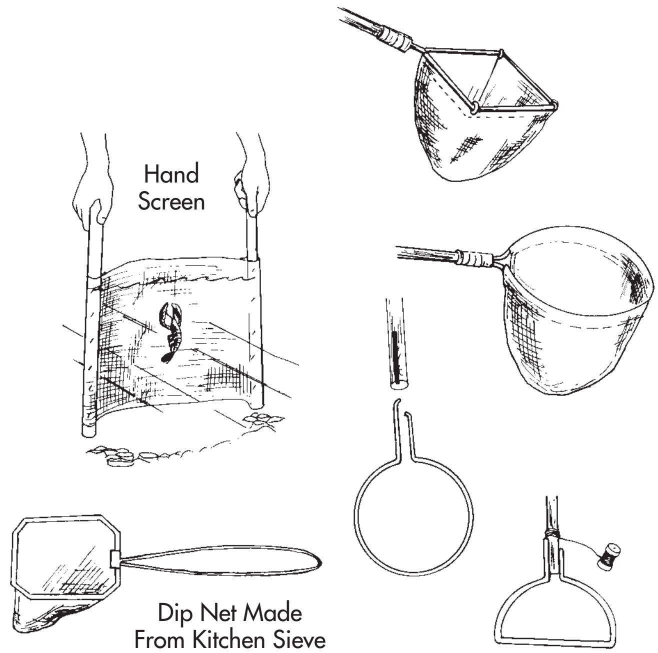
- 80 centimeters of heavy-gauge steel wire
- Wooden pole (1.5 to 1.8 meters long)
- Thin wire
- Meshed netting (curtain fabric, mosquito netting, etc.) cut into a circle with a diameter of about 36 cm
- Heavy twine
- 64 cm strip of heavy fabric (10 cm wide) or duct tape
- Durable thread and a needle

Using the heavy-gauge steel wire, create a circular frame with a diameter of about 20 cm. When the two ends overlap, bend outwards so that each end extends beyond the circular frame about 8 cm.

Next, take the wood pole and cut two 8 cm groves into one of the pole ends (so the wire can fit within the groves). Create a hole within each grove and then bend the wire so it goes into the groove. After you insert the circular frame ends into the grooves, use the thin wire to secure the frame to the pole.

Feed the meshed netting through the mouth of the frame and allow 5 centimeters to fall over the outside of the frame. Fold the fabric strip lengthwise and then place it on top of the frame and net to create a more durable dip net that can tolerate rocky substrate. When ready, use the durable thread to secure the net and fabric to the frame.

Sampling Equipment



Glossary

acid rain. Rainfall that has reacted with airborne pollutants such as sulfur dioxide and nitrogen oxides, thereby reducing the pH (or increasing the acidity) of the rain.

acute toxicity. The ability of a substance to cause poisonous effects resulting in severe biological harm or death soon after a single exposure or dose.

algal bloom. Prolific growth of algae and phytoplankton caused by excessive nutrients. It results in the depletion of dissolved oxygen.

aquifer. Stratum of the earth composed of water and layered between permeable rock, sand, or gravel.

backwater. Part of a stream or river where the water moves slowly because it is away from the main part of the stream or river.

bed rock. Soil mainly composed of rocks greater than 4 meters in diameter.

benthic. Living on the bottom of a lake or sea; pertaining to the ocean bottom.

bioaccumulation. Accumulation of a toxin in an organism's body.

biochemical oxygen demand. A measure of the amount of oxygen consumed in the biological processes that break down organic matter in water. The greater the BOD, the greater the degree of pollution.

biomagnification. Increasing toxicity concentrations in organisms that are higher on the food web, caused by predators accumulating all of their prey's accumulated toxins.

buffer zone. An area along the streamside whose vegetative integrity is maintained in order to prevent erosion and trampling by livestock, and to reduce the amount of chemicals entering the creek.

clay. Soil mainly composed of particles smaller than 0.002 millimeters; feels slick and sticks together.

channelization. Straightening and deepening streams so water will move faster. It is a method of flood control that disturbs fish and wildlife habitats and can also interfere with a water body's ability to assimilate waste.

chronic toxicity. The capacity of a substance to cause long-term health effects.

Clean Water Act. A law controlling water pollution passed to restore and maintain the nation's waters. The nation's primary legislation that specifies the methods to be used in determining how much treatment is required for discharges from publicly owned treatment works.

cobble. Rocks between 6 and 25 centimeters in diameter.

dissolved oxygen. The oxygen freely available in water. Dissolved oxygen is vital to fish and other aquatic life and for the prevention of odors. Traditionally, the dissolved-oxygen level has been accepted as the single most important indicator of a water body's ability to support desirable aquatic life.

drainage basin. A synonym for *watershed*.

dredging. The use of machinery to widen or deepen a channel, or to remove debris.

effluent. Wastewater (treated or untreated) that flows out of a wastewater-treatment plant or industrial outfall (point source) and into a water body.

Escherichia coli. A species of fecal coliform bacteria that is present in the intestinal tracts and feces of humans and warm-blooded animals. It is not necessarily harmful and is used as an indicator bacterium for the potential presence of pathogens.

ecosystem. The interaction of a biological community with its nonliving environment.

estuary. A region of interaction between a river and near-shore ocean water where tidal action and river flow cause freshwater and salt water to mix.

eutrophic. Having high levels of nutrients capable of supporting abundant growth of algae or aquatic plants. Eutrophic water bodies are able to support an overabundance of living organisms and may experience algal blooms and resulting fish kills.

fecal coliform bacteria. A portion of the coliform bacteria group that is present in the intestinal tracts and feces of humans and warm-blooded animals. They are used as an "indicator bacteria" for the potential presence of pathogens.

filamentous algae. Algal cells arranged end-to-end, either in a straight line or branched. They are found attached to rocks, submerged logs, vegetation, or floating mats.

floodplain. The area adjacent to a channel that is occasionally submerged under water. Usually the floodplain is a low-gradient area well-covered by various types of riparian vegetation.

food chain. A simplified model showing a series of organisms contributing to a consumer's diet. The chain begins with producers (plants) and ends with the largest of the consumers (carnivores).

food web. An interlocking pattern of several or many food chains.

gravel. rocks between 2 and 60 millimeters (6 centimeters) in diameter.

groundwater. Water that remains below the land's surface and travels below ground, such as in an aquifer.

habitat. A place where the physical and biological elements of ecosystems provide a suitable environment for plant and animal livelihood, including the food, cover, and space resources needed.

herbaceous. Having no woody tissue.

herbicide. An agent used to destroy or inhibit plant growth.

impervious cover. Cover (typically in urban areas) that limits the amount of water soaking into the ground, such as parking lots, roads, and sidewalks.

invasive species. A nonnative species whose introduction harms (or is likely to harm) the economy, environment, or human health.

invertebrate. An animal lacking a backbone.

infiltration. The penetration of water through the ground's surface into subsurface soil.

insecticide. An agent that destroys insects.

macroinvertebrate. A multicellular organism without a spinal column, living in, on, or under the water and large enough to be seen without a microscope. Examples. snails, clams, leeches, crayfish, and larval or other immature forms of insects.

nonpoint source pollution. Pollution from sources that are diffuse and lacking a single point of origin, or not introduced into a receiving stream from a specific outfall. The pollutants are generally carried off the land by stormwater runoff.

nymph. A young insect that has almost the same form as the adult.

oligotrophic. A water body characterized by clear water, few nutrients entering the water body, and capable of only supporting small populations or plants, invertebrates, fish, and wildlife.

outfall. A designated point of effluent discharge.

phosphate. An ion composed of a phosphorus atom with 4 oxygen atoms attached (PO_4^{-3}). It is an important plant nutrient.

pH. The measure of the hydrogen-ion activity of water and the presence of dissolved acids and bases.

phosphorus. A nutrient that is essential to the growth of organisms. It can be the nutrient that limits the primary productivity of water.

photosynthesis. The manufacture of carbohydrates and oxygen from carbon dioxide and water using sunlight as an energy source.

phytoplankton. Microscopic algae (single celled or colonial) that float suspended in the water column.

plankton. Organisms (plants and animals) that live in open water, either suspended or floating.

playa. A kind of lake found in the southern High Plains of Texas that is small, shallow, and circular.

point source pollution. Pollutants discharged from a specific location. It can also be defined as a single identifiable source of pollution (for example, the outlet of a pipe).

pool. In a stream, an area that is relatively deep and wide with slow-moving water compared to a riffle. The substrate is usually composed of silt and sand. Pools and riffles usually follow in sequence along the water course. Pools often contain large eddies with widely varying directions of flow, compared to riffles where flow is nearly exclusively downstream.

reservoir. Any natural or artificial holding area used to store, regulate, or control water.

riffle. A shallow portion of a stream extending across its bed, characterized by relatively fast-moving, turbulent water. The water column in a riffle is usually constricted, and water velocity is high due to a change in surface gradient. The channel profile in a riffle is usually straight to convex. The substrate is usually cobble, gravel, or rock.

riparian zone. An area adjacent to and along a stream or river, often vegetated, that constitutes a buffer zone between nearby lands and the river or stream. The area is considered to be important in controlling sediment and nutrient delivery into the channel. It generally includes the area of the stream bank and out onto the floodplain that is periodically inundated by waters from the stream. The limit of the zone depends on many factors, including the makeup of the native plant community, soil moisture levels, and distance from the stream (or the limit of interaction between land and stream processes). Interaction between this terrestrial zone and the stream is vital for the health of the stream.

river system. The network of streams in a single watershed.

runoff. The part of precipitation or irrigation water that runs off land into streams and other surface water.

sand. Soil mainly composed of particles between 0.06 and 2 millimeters; feels gritty.

scum. A thin, filmy layer floating on the surface of a body of water made up of biological material (dead plankton, bacteria, and other microscopic organisms) or substances of human origin (examples: oil or gasoline).

sediment. Bottom layers composed of particles of sand, clay, silt, and plant or animal matter carried in water that are deposited in reservoirs and slow-moving areas of streams and rivers.

silt. Soil mainly composed of particles between 0.002 and 0.06 millimeters; feels smooth.

substrate. The bottom of an aquatic system. Substrates can be composed of clay, silt, sand, gravel, bed rock, or a mixture of materials.

stormwater. Runoff from rain or melting snow. Pollutants might enter the water as it passes over the land, such as sediment from a construction site with inadequate erosion and sediment controls.

surface water. Water that remains on the land's surface and contributes to streams, rivers, lakes, and reservoirs.

turbidity. Optical property of a water sample that causes light to be scattered and absorbed, rather than transmitted in straight lines through the sample.

wastewater. Runoff from industrial, recreational, or domestic activities. Pollutants might enter the water during an activity, such as washing clothes with a detergent containing phosphates.

Wastewater-treatment plant. A facility designed to reduce pollutants in wastewater below certain levels.

water (hydrologic) cycle. A model that describes the movement of all water on earth, in all of its phases (solid, liquid, and gas).

watershed. The area of land from which precipitation drains to a particular stream, river, or lake. It is a land feature that can be identified by tracing a line along the highest elevations between two areas on a map, often a ridge, which form the topographic dividing line from which surface streams flow in two different directions. Large watersheds, like the Mississippi River or the Chesapeake Bay, contain thousands of smaller watersheds.

wetland. An area that is regularly saturated by surface or groundwater and characterized by vegetation adapted for life in saturated soil conditions.

zooplankton. Microscopic animals that feed on phytoplankton, bacteria, and dead organic matter. Some zooplankton can be seen with the naked eye.

References

Borman, S., R. Korth, and J. Temte. 1997. *Through the Looking Glass … A Field Guide to Aquatic Plants.* Stevens Point, WI: U. of Wisconsin Press. Distributed by UWEX Lake Program, College of Natural Resources.

Buttonbush. Texas A&M Agrilife Extension. <aquaplant.tamu.edu/plant-identification/alphabetical-index/buttonbush>. Accessed on May 29, 2015.

Caduto, M.J. 1990. *Pond and Brook: A Guide to Nature in Freshwater Environments.* Hanover, NH: University Press of New England.

City of Bellevue, WA. 1988. *Stream Team Guidebook.* Bellevue, WA: Storm and Surface Water Utility.

Eilers, J.M., and R. Berg. 1981. *Sensitivity of Aquatic Organisms to Acidic Environment.* Duluth, MN: U.S. EPA Environmental Research Laboratory.

Florida LAKEWATCH. 2000a. *A Beginner's Guide to Water Management*—The ABCs. Information Circular #101. Gainesville: Department of Fisheries and Aquatic Sciences, Institute of Food and Agricultural Sciences, University of Florida.

———. 2000b. *A Beginner's Guide to Water Management—Nutrients.* Information Circular #102. Gainesville: Department of Fisheries and Aquatic Sciences, Institute of Food and Agricultural Sciences, University of Florida.

Hendrey, G.R., N. Yan, and K. Baumgartner. 1980. *Geological and Hydrochemical Sensitivity of the Eastern United States to Acid Precipitation.* Upton, NY: Brookhaven National Laboratory. EPA-600/3080-024.

Izaak Walton League of America. 1994. *Hands On Save Our Streams: The Save Our Streams Teacher's Manual.* Gaithersburg, MD: Save Our Streams Program, IWLA.

Kentucky Water Watch. 1986. *A Field Guide to Kentucky Rivers and Streams.* Frankfort: Kentucky Division of Water.

———. 1987. *Kentucky Water Watch Stream Monitoring Project.* Frankfort: Kentucky Division of Water.

McCafferty, W.P. 1983. *Aquatic Entomology.* Boston: Jones and Bartlett.

Merritt, R.W., and K.W. Cummins, eds. 1995. *An Introduction to the Aquatic Insects of North America. 3rd special ed.* Dubuque, IA: Kendall Hunt.

Murdoch, T.B., M. Cheo, and K. O'Laughlin. 1999. *Streamkeeper's Field Guide: Watershed Inventory and Stream Monitoring Methods.* Everett, WA: Adopt-A-Stream Foundation.

Pennak, R.W. 1953. *Fresh-Water Invertebrates of the United States.* 2nd ed. New York: Ronald Press Company.

———. 1989. *Fresh-water Invertebrates of the United States—Protozoa to Mollusca.* 3rd ed. New York: Wiley-Interscience.

Pistia stratiotes, *Water Lettuce.* Texas Invasive Plant and Pest Council. <texasinvasives.org/plant_database/detail.php?symbol=PIST2>. Accessed on June 5, 2015.

Prescott, G.W. 1969. *How to Know the Aquatic Plants.* Dubuque, IA: Wm. C. Brown.

———. 1978. *How to Know the Freshwater Algae.* Dubuque, IA: Wm. C. Brown.

Protected Wildlife Species in Texas. Texas Parks and Wildlife Department. <tpwd.texas.gov/huntwild/wild/rehab/protected/>. Accessed on May 19, 2015.

Rattailed Maggots. North Carolina State University. <ipm.ncsu.edu/AG369/notes/rattailed_maggots.html>. Accessed on June 5, 2015.

Salvinia molesta, *Giant Salvinia.* Texas Invasive Plant and Pest Council. <texasinvasives.org/plant_database/detail.php?symbol=SAMO5>. Accessed on June 5, 2015.

SK Engineering. 1980. *Teaching About Water: A Water Resource Education Guide for 4th, 5th, and 6th Grades.* San Angelo, TX: Developed for the U.S. Dept. of the Interior, Water and Power Resources Service.

Texas Administrative Code, Title 19, Sections 111.6, 111.7, 111.26, 112.15, 112.16, 112.18.

Texas Essential Knowledge and Skills. Texas Education Agency. <tea.texas.gov/curriculum/teks/>. Accessed on August 25, 2015.

Thorp, J.H., and A.P. Covich, eds. 1991. *Ecology and Classification of North American Freshwater Invertebrates*. New York: Academic Press.

U.S. Environmental Protection Agency. 1997. *Volunteer Stream Monitoring: A Methods Manual*. Washington: U.S. EPA. 841-B-97-003.

Water Cycle, The—USGS Water Science School. U.S. Geological Survey. <water.usgs.gov/edu/watercycleprecipitation.html>. Accessed on June 8, 2015.

Water Resources of the United States. U.S. Geological Survey. <water.usgs.gov/software/DOTABLES/>. Accessed on June 5, 2015.

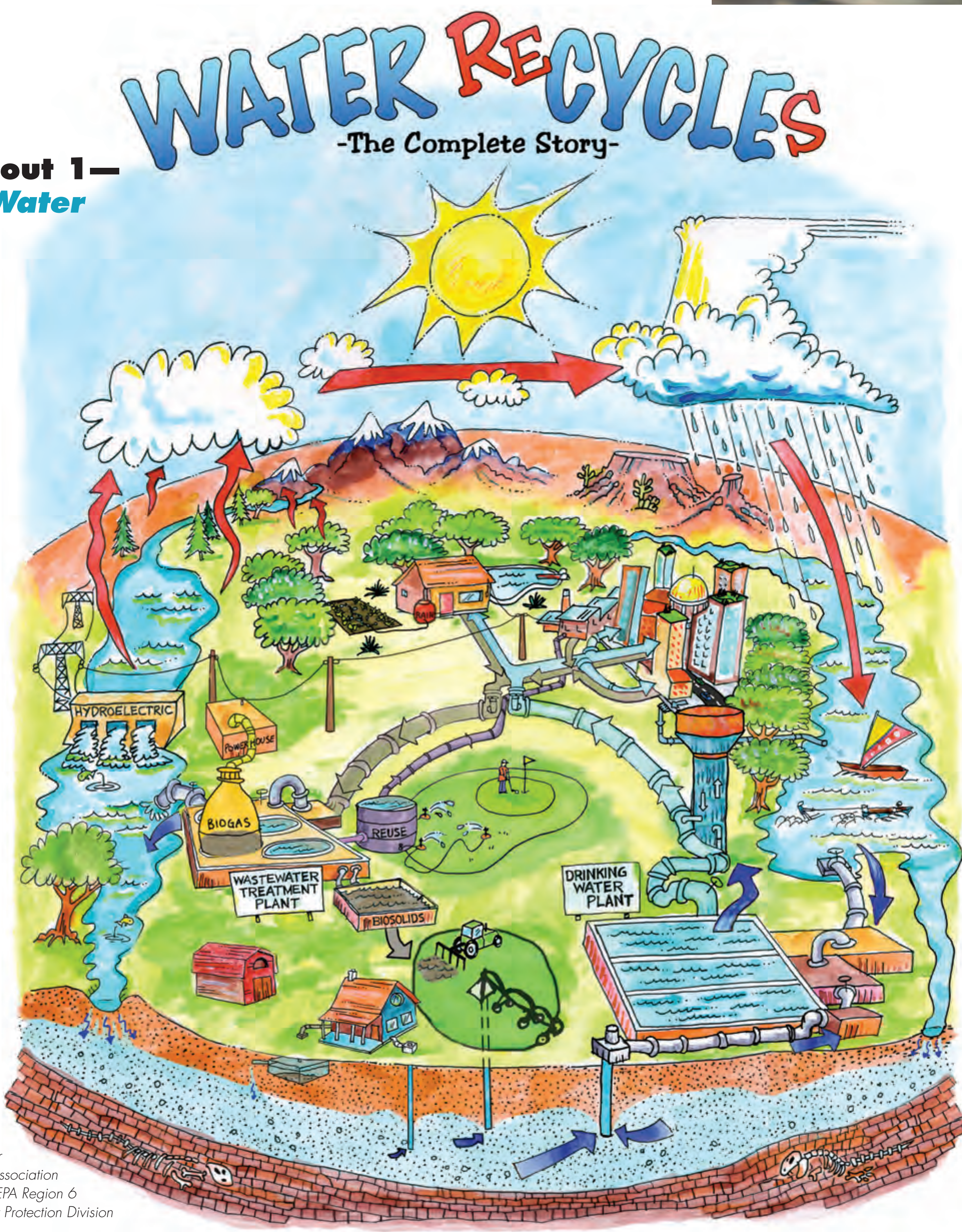
What Are Invasive Species? Texas Invasive Plant and Pest Council. <texasinvasives.org/i101/>. Accessed on May 15, 2015.

What Is Acid Rain? U.S. Geological Survey. <pubs.usgs.gov/gip/acidrain/2.html>. Accessed on June 8, 2015.

What's in My Soil? U.S. Geological Survey. <education.usgs.gov/lessons/soil.pdf>. Accessed on June 5, 2015.

Student Handouts

Handout 1— *The Water Cycle*



Source: Water Environment Association of Texas and EPA Region 6 Water Quality Protection Division

Water ^{Re}Cycle^{s}: The Complete Story

Water

Water (which has a chemical formula of Dihydrogen Monoxide or H_2O) covers 71 percent of Earth's surface. Almost all of that is saltwater in our oceans. Freshwater accounts for only 3 percent of total water and more than two-thirds of it is frozen in glaciers. Liquid freshwater (groundwater, lakes, streams, rivers), which is what people use to drink, farm, clean, and use for most tasks, makes up less than 1 percent of all the water on Earth! Most of the water we need to live is groundwater (about 99 percent) so understanding the water cycle and learning that water is a limited resource is important for teachers, students, and all Texans.

ReCycle

The word "recycle" calls to mind images of paper grocery bags filled with newspapers or a collection of crushed aluminum cans, plastic containers, and glass bottles. Most of us do not connect water with recycling. Yet, the water (or hydrologic) cycle is a good example of recycling. Water recycling means reusing treated wastewater for helpful purposes such as lawn and crop watering, industrial processes, toilet flushing, and replenishing a ground water basin (referred to as ground water recharge).

The Water Cycle

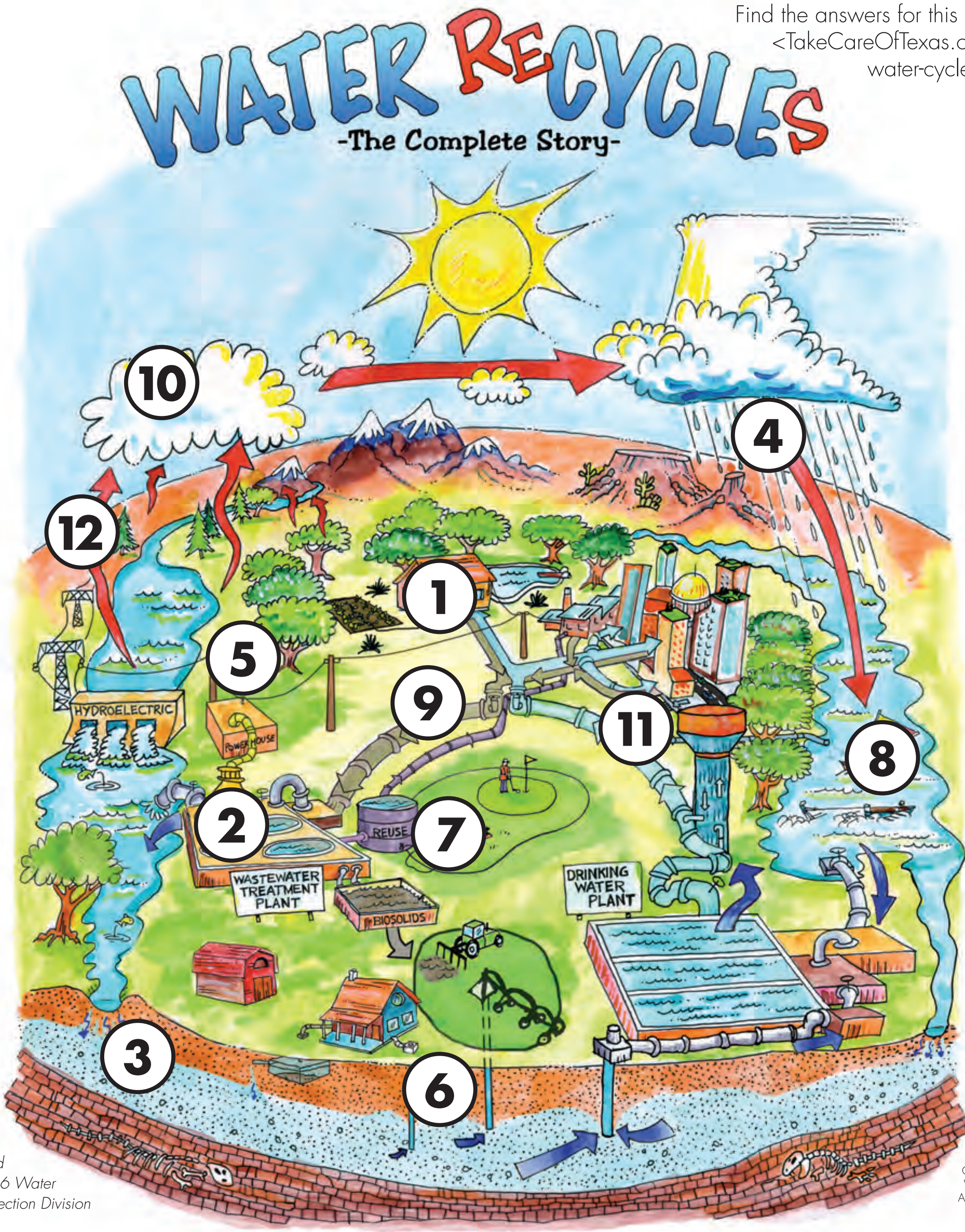
In its basic form, the cycle is simple. The sun's energy converts liquid to vapor (evaporation). The water vapor, being lighter than air, rises in the atmosphere until the cooler temperatures turn it into tiny droplets of water (condensation). These droplets come together to form clouds. In the clouds, the droplets combine to form larger drops. When these drops reach a larger size, gravity pulls them back to Earth's surface (precipitation). Though the water cycle can be much more complex, knowing the basics will help you understand where water comes from and where it goes.

Humans and The Water Cycle

This poster, Water ReCycles, is for "learners" of all ages, both in and out of a formal classroom. Most of us learn about water and the water cycle in grade school. However, even as adults, we often have trouble recognizing and understanding the ways humans affect the natural water cycle. By including the pumps, pipes, and treatment plants (infrastructure) in this poster, you can see these "two water cycles"—natural and human-affected—and how they relate to one another. Look at the poster for examples of water recycling that Texans can do at home, such as using a rain barrel to harvest rainwater.

The poster on the previous page also includes elements that show some of the complex water-related issues we face today, such as stormwater pollution and hydroelectric power generation, among others. We hope this poster encourages you to study and discuss these issues.

Find the answers for this activity at <TakeCareOfTexas.org/kids/water-cycle-poster>.



Source: Water Environment Association of Texas and EPA Region 6 Water Quality Protection Division

Fill in the blanks from these words:

sludge precipitation power plant ground water reuse surface water sewage rain barrel condensation drinking water evaporation infiltration

(1) ______	(4) ______	(7) ______	(10) ______
(2) ______	(5) ______	(8) ______	(11) ______
(3) ______	(6) ______	(9) ______	(12) ______

Bonus: **What do the dinosaur bones represent?**

How and Why Do We Recycle Water?

Unscramble the words to identify words related to water use and the environment.

Find the answers for this activity at <TakeCareOfTexas.org/kids/water-cycle-poster>.

nira ____ 2

wson ____ 9

ilah ____ 6

ecnao _____ 5

aelk ____ 3

vreir _____ 4

avsihretng __________ 1

fqruiea _______ 8

eirorvesr _________ 15

ogf ___ 10

erarbl ______ 14

isol ____

salptn ______ 11

silosiobd _________

ropwe nlatp _____ _____ 7

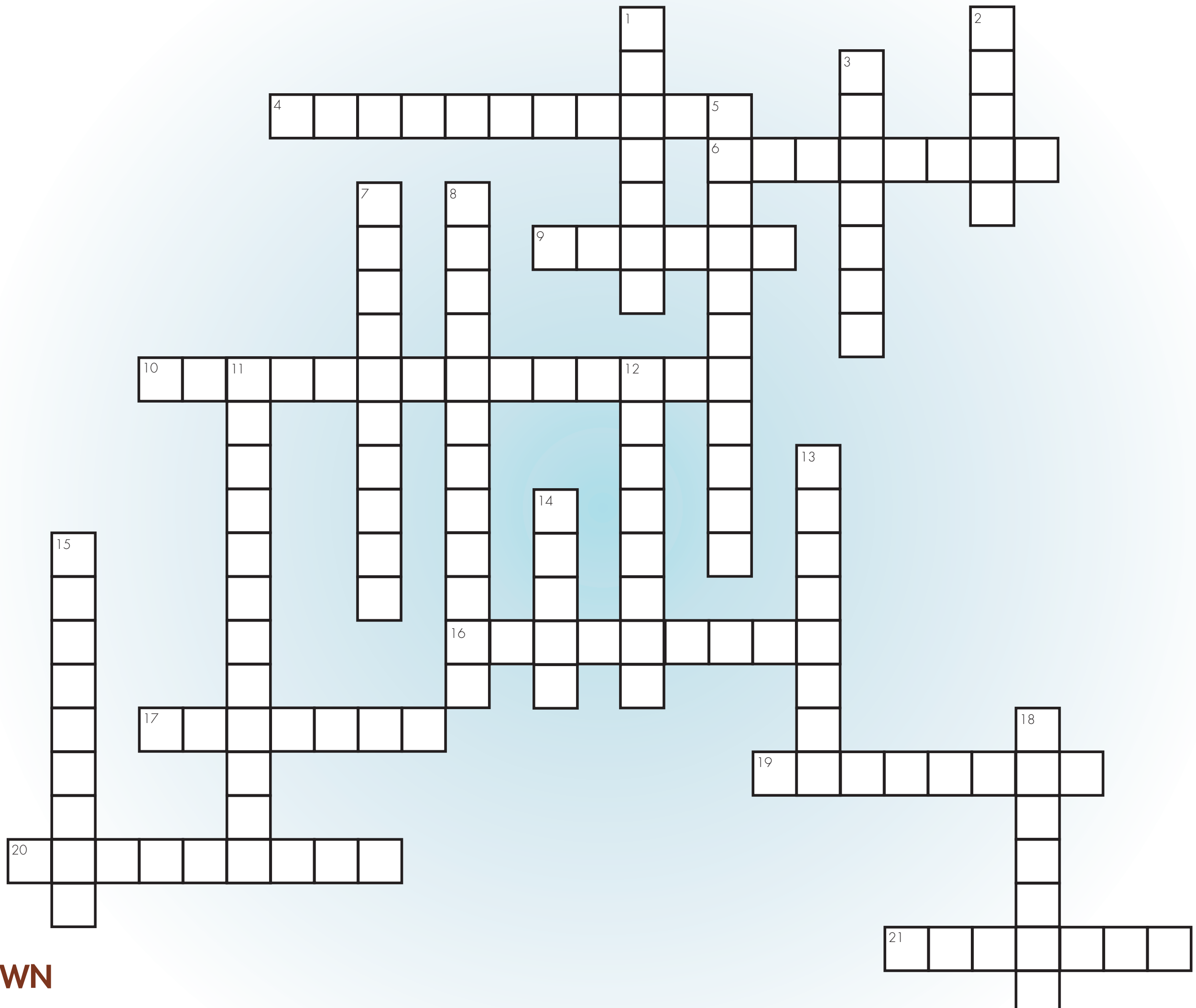
etneamh _______ 12

Use the numbered letters from above to find the answer!
What letter is missing?

___ ___ ___ ___   ___ ___ ___ ___   ___ ___   ___ ___ ___ ___ ___
1 2 3 4   5 6 7 8   9 10   11 12 13 14 15

Water, Land Use, and Wastewater Treatment

Find the answers for this activity at <TakeCareOfTexas.org/kids/water-cycle-poster>.



DOWN

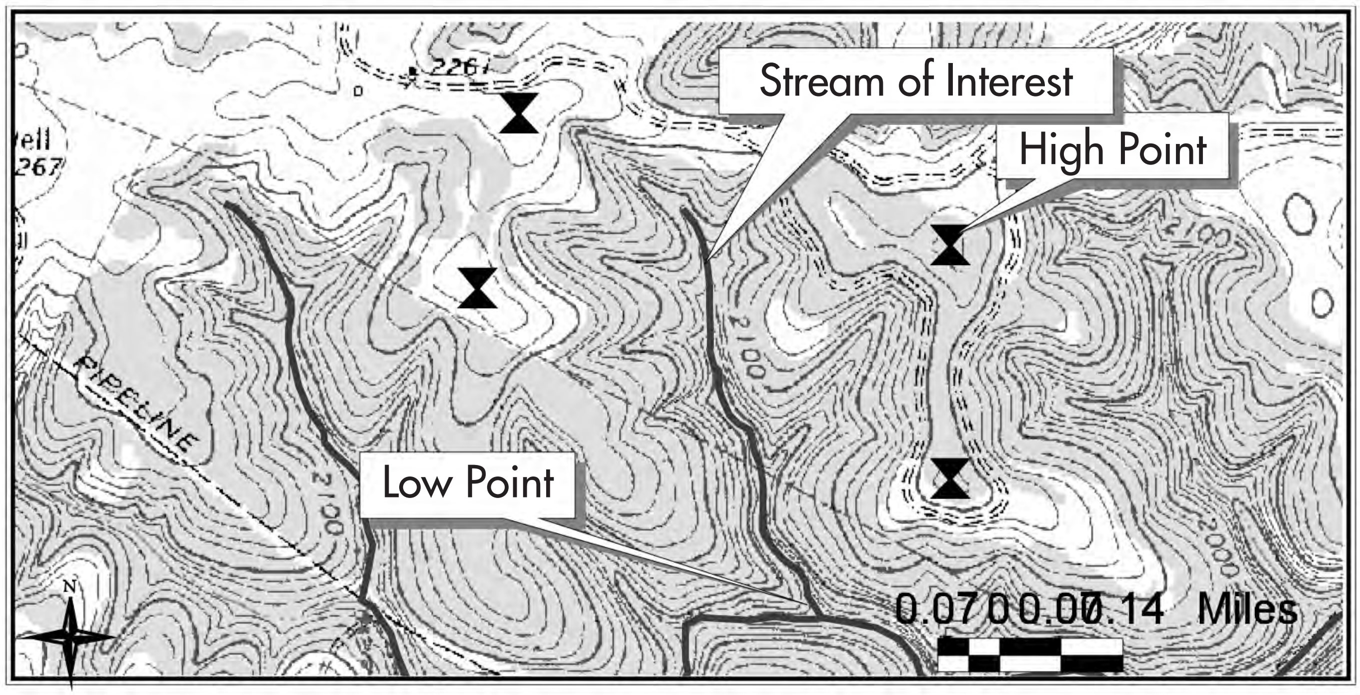
1 A mixing of fresh and salt water
2 Used in disinfection of water
3 Aids coagulation
5 Lawn fertilizer, oil drained from cars, septic tank overflows
7 What a rain barrel is used for
8 Erosion from logging, road construction
11 Fertilizers or manure draining into a stream
12 Numerous types of chemicals and products
13 Widely used disinfectant
14 Landscape irrigation with effluent
15 A lake containing a high concentration of dissolved nutrients
18 Water that is safe to drink

ACROSS

4 Water that remains below the land surface
6 Treated wastewater
9 Muddy water
10 Straightening and deepening of stream or river channels
16 Any natural or artificial holding area
17 Stratum of the earth composed of water layered between rock
19 The mixing or agitation of wastewater
20 Nutrient-rich, stabilized by-product used as fertilizer
21 An area that is regularly saturated by surface water

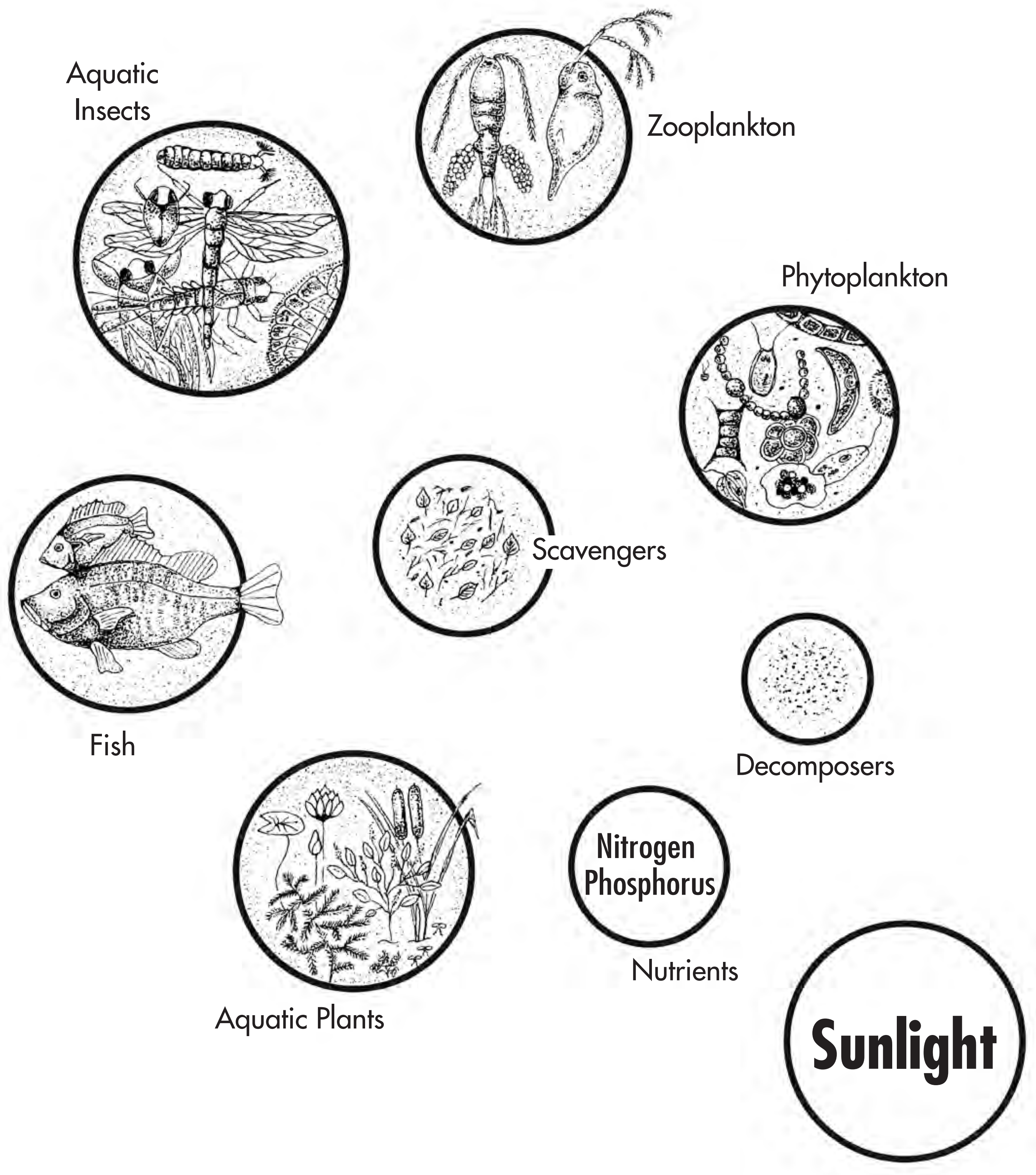
Handout 2—*Area Watershed Survey*

Environmental investigators surveyed the stream in this topographic map and discovered water pollution. Help the investigators find the pollution source by drawing the stream's watershed boundaries.



Handout 3—*The Aquatic Food Web*

A food chain links an organism to one source of food whereas a food web links organisms to many of its food sources. Draw arrows between the sun, plants, and animals to show the flow of food or energy and the different paths it can take through the food web.



Use the word bank to complete the following paragraphs.

WORD BANK				
Decomposers	Sun	Primary consumers	Nutrients	Food web
Photosynthesis	Food	Secondary consumers	Primary Producers	Water
Tertiary consumers	Omnivores	Carbon dioxide	Detritivores	Respiration

Aquatic food webs for surface water ecosystems begin with the ____________________, the source of light. Certain wavelengths of light are absorbed by ________________________________ (also called autotrophs). Through a process called ________________________________, primary producers use this light to convert __________________________ and _____________________ into carbohydrates and oxygen. The primary producers will use a portion of the carbohydrates and oxygen during ____________________________—the process in which carbohydrates and oxygen are converted into carbon dioxide, water, and energy. Primary producers can grow and reproduce if energy and certain nutrients are available.

Animals must also respire so they can create energy to move, grow, etc. Since animals cannot produce their own _____________________ like the primary producers, they must consume (eat) their food. Animals that eat primary producers are called ___________________________________ (herbivores, or plant eaters). Animals that eat primary consumers are called ___________________________________ (carnivores, or meat eaters). The secondary consumer group may contain more than one level of carnivore; therefore, a food web may have ____________________________________—animals that eat secondary consumers. In addition, a food web may also contain ___________________________—animals that eat plants and meat.

Animals that eat dead organic materials are called ____________________________ (scavengers). They are an important part of the food web because they help in decomposition by shredding and eating dead organic materials. _____________________________________ (bacteria and fungi) are the final link in the _________________________; they break down dead material and release _______________________ that can be used by primary producers.

Handout 4—*Water Pollution*

As an environmental investigator, you receive a phone call about possible pollution in a stream. Using your *Student Reference Tables*, enter the possible pollutant(s) and its source for each of the water pollution scenarios below. The pollutants can be nutrients, oxygen-demanding substances, suspended solids, sedimentation, or toxic substances.

	Scenario	Possible Pollutant(s)	Possible Pollutant Source(s)
1	A rainbow film is on the surface and a nearby ditch carries stormwater from the highway into the stream.		
2	There is a musty odor; animal feedlots and construction sites are nearby.		
3	A storm caused trees to fall into the stream over a month ago; the water now resembles coffee.		
4	There is a faint odor of bleach; aquatic plants near an outfall are very light colored.		
5	Water is bright green; next to the stream are very lush residential yards and a construction site.		
6	A stream near a construction site is very turbid and light brown. Also nearby is a residential area.		
7	There is a smell of rotten eggs; a road and an old residential area (that uses septic systems) are next to the stream.		
8	An unusual smell is coming from the stream, very sharp and pungent. Nearby are a city and outfalls for both an industrial source and a wastewater-treatment plant.		
9	The stream contains fungus that feels slimy and resembles the texture of cotton. It is found near an outfall.		
10	The bottom of a stream became very muddy and the water is turning green. Nearby are forests and also croplands.		

Handout 5—*Survey: On-Site Sketch* (page 1)

Date:	Time:	Air Temperature:

Team Member Names:

Stream Name:

Stream Location:

Weather Conditions: ❑ Clear ❑ Cloudy ❑ Raining ❑ Other: ____________

Stream Characteristics

Appearance:	Bed Coating:	Odor:
❑ Scum (color: _________)	❑ Orange to red	❑ Rotten eggs
❑ Foam (color: _________)	❑ Yellowish	❑ Musky
❑ Muddy (color: ________)	❑ Black	❑ Pungent
❑ Milky (color: _________)	❑ Dark brown	❑ Chlorine
❑ Clear	❑ Brownish tan	❑ Other: ______________
❑ Oily sheen	❑ No coating	❑ None
❑ Other: _______________		

Habitats:

❑ Pool	❑ Undercut banks	❑ Log piles
❑ Riffle	❑ Rock ledges	❑ Plant beds
❑ Wetlands	❑ Tree roots	❑ Large boulders
❑ Backwaters	❑ Logs or stumps	❑ Artificial objects

❑ Other: ____

Substrate composition is mostly:

❑ Clay/silt ❑ Sand ❑ Gravel ❑ Cobble ❑ Bed rock ❑ Other: _______________

Cover:

❑ Fully exposed (0% to 25% of the stream is shaded from the sun)

❑ Partially exposed (25% to 50%)

❑ Partially shaded (50% to 75%)

❑ Fully shaded (75% to 100%)

Bank Vegetation:

Trees: _________%	Plants: ________%	Exposed: ________%
Shrubs: _________%	Root mats: ________%	

Structures or Barriers:

❑ Upstream dam	❑ Downstream dam	❑ Bridge(s)
❑ Island(s)	❑ Waterfall(s)	❑ Other: _______________

Litter (estimated amount by size):

Paper, items smaller than a can:	❑ 0–5	❑ 5–10	❑ 10–50	❑ +50
Can-,bottle-sized items:	❑ 0–5	❑ 5–10	❑ 10–50	❑ +50
Items bigger than a can (tires, carts, etc.):	❑ 0–5	❑ 5–10	❑ 10–50	❑ +50

Handout 5—*Survey: On-Site Sketch (page 2)*

Biological Characteristics

Algae location: ❏ Everywhere ❏ In spots

The algae are: ❏ Attached ❏ Floating ❏ Other: ____________________

Animals:

❏ Fish ❏ Amphibians ❏ Reptiles
❏ Shore birds ❏ Waterfowl ❏ Mammals
❏ Mollusks (clams, etc.) ❏ Insects ❏ Crustaceans (crayfish, etc.)

Types of animals present: ____________________

____

____

Water Sources

Watershed (runoff from):

❏ Pasture, grazing lands ❏ Croplands ❏ Woodlands
❏ Homes, residential areas ❏ Factories ❏ Stores
❏ Surface mining ❏ Underground mining ❏ Logging
❏ Roads

❏ Construction activities (explain): ____________________

❏ Other: ____________________

❏ Channelized areas (explain): ____________________

Channelized substrate composition: ❏ Concrete ❏ Cobble ❏ Vegetation
❏ Mud ❏ Other: ____________________

Channelized bank composition: ❏ Concrete ❏ Cobble ❏ Vegetation
❏ Exposed soil ❏ Other: ____________________

Point sources (outfalls or discharge pipes from):

❏ Wastewater-treatment plant ❏ Industry (explain): ____________________

❏ Residential (explain): ____________________

❏ Unknown ❏ Farm lots ❏ Other: ____________________

Water Uses

Intake pipe takes water to:

❏ Water-treatment plant (drinking water)

❏ Industry (explain): ____________________

❏ Irrigation system ❏ Livestock ❏ Unknown

❏ Other: ____________________

Recreational Activities:

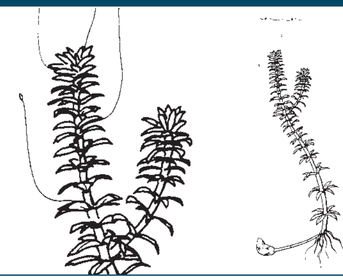
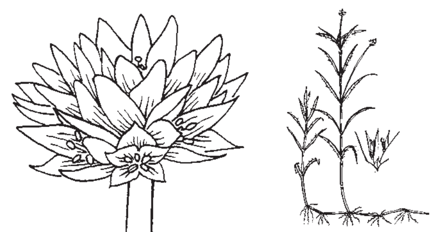
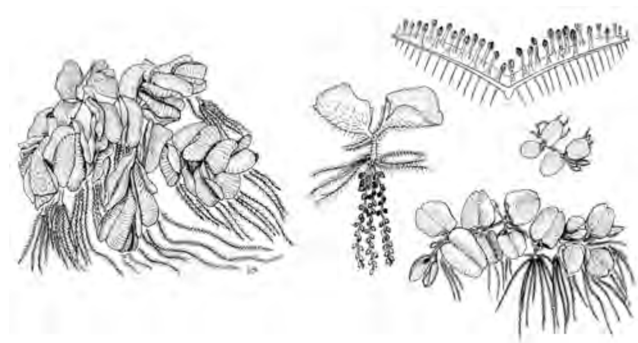
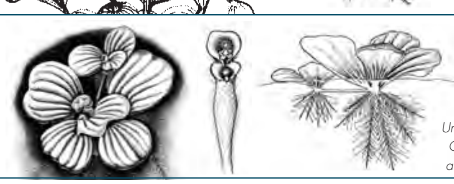
❏ Swimming ❏ Fishing ❏ Other: ____________________

Handout 5—*Survey: On-Site Sketch* *(page 3)*

Sketch the stream and surrounding area. Show in your sketch the different habitats in the stream (pool, riffles, etc.), structures that disrupt the flow of water (such as dams and bridges), human-built structures (buildings, roadways, etc.), any point sources (such as a discharge pipe), and the north arrow. Make sure to describe the characteristics of the stream bank, riparian zone, and adjacent land uses.

Handout 6—*Survey: Invasive Species—Aquatic Plants*

Check the survey area for the following invasive species. For more information about Texas invasive species, visit <texasinvasives.org>.

Submerged		
❏ Hydrilla	• Dark-green plant with long branching stems. • Leaves have toothed margins and midrib spines. • Flowers are inconspicuous and white on long stalks.	
❏ Parrotfeather milfoil	• Reddish-brown stems and olive-green leaves divided into feather-like segments. • Often extends above the water surface approximately 10 centimeters.	
Emergent		
❏ Alligator weed	• Perennial plant with leaves approximately 10 cm long. • Each leaf is long, narrow, and elliptical. • White, clover-like flowers appear near the tip of the plant.	
Floating		
❏ Giant salvinia	• Green aquatic fern with a chain-like appearance that can form dense floating mats. • Each leaf (frond) is approximately 13 millimeters wide and 25 mm long. • The upper surface of the leaf contains coarse, white hairs. • Underwater are brown, thread-like leaves that resemble roots.	 *Source: University of Florida Center for Aquatic and Invasive Plants*
❏ Water hyacinth	• Free-floating plant with spongy stems and light-blue (or even violet) flowers. • Beneath the plant are numerous dark, fibrous roots. • The plant is dark green and ranges from 10 cm to almost 1 meter high.	
❏ Water lettuce	• Plant with floating leaves that are thick, hairy, ridged, and light green. • Resembles an open head of lettuce.	 *Source: University of Florida Center for Aquatic and Invasive Plants*

Handout 7—*Survey: Physical Properties*

Date:	Time:	Air Temperature:
Team-Member Names:		
Stream Name:		
Stream Location:		
Weather Conditions: ❏ Clear ❏ Cloudy ❏ Raining ❏ Other: ______________		

Temperature

Water Temperature: ________°F

Convert to Celsius using the following equation: (________°F – 32) x $^5/_9$ = ________°C

Factors affecting water temperature: ____

____

pH

pH: ____________

The water is: ❏ Acidic ❏ Neutral ❏ Basic (Alkaline)

Factors affecting pH: ____

____

Dissolved Oxygen

Dissolved Oxygen: ____________ ppm (mg/L)

Factors affecting dissolved oxygen: ____

____

Flow

Width (W): ____________ meters (m)

Average depth (D): ____________ m

Time the cork traveled two meters: __________ seconds (s)

Calculate velocity (V) by entering the time above into following equation:

$$\frac{2\ \textit{meters}}{\_\_\_\_\_\ \textit{seconds}} = \_\_\_\_\_\_\_\_\_\ {}^{m}/_{s}$$

Calculate flow using the following equation:

$$W \times D \times V = \_\_\_\_\_\_\_\_ m \times \_\_\_\_\_\_\_\_ m \times \_\_\_\_\_\_\_\_\ {}^{m}/_{s} = \_\_\_\_\_\_\_\_\_\_\ {}^{m^3}/_{s}$$

Handout 8—*Survey: Chemical Properties*

Date:	Time:	Air Temperature:

Team-Member Names:

Stream Name:

Stream Location:

Weather Conditions: ❏ Clear ❏ Cloudy ❏ Raining ❏ Other: ____________________

E. coli

E. coli concentration: ________________

Factors affecting the *E. coli* concentration: ____

____

Nutrients

Phosphorus concentration: __________________

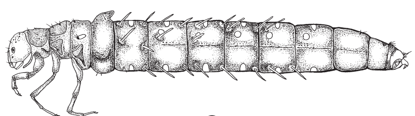
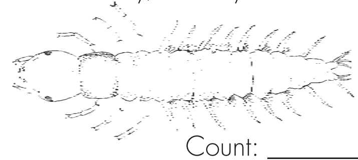
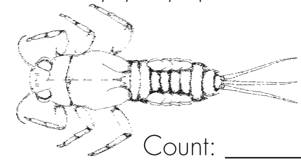
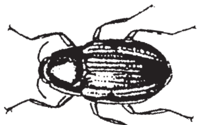
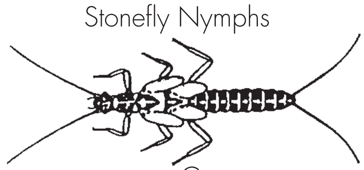
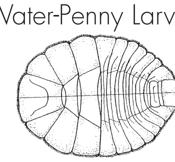
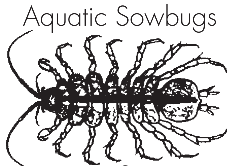
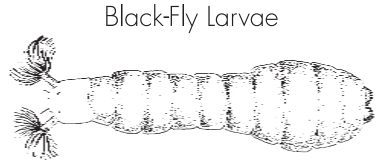
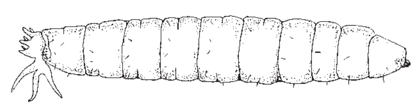
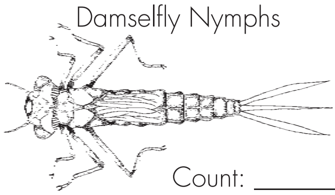
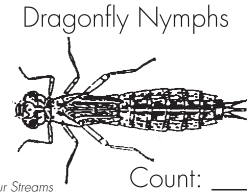
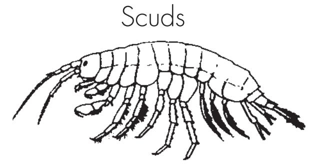
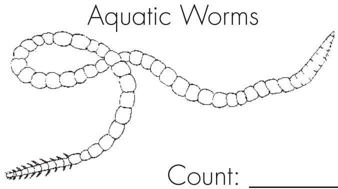
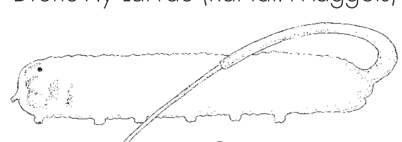
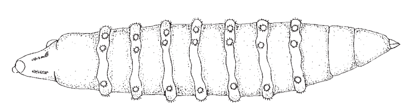
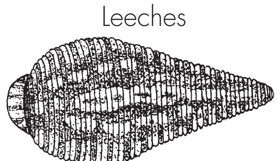
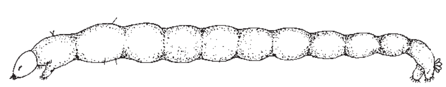
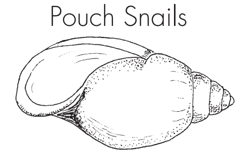
Nitrogen concentration:_____________________

Factors affecting phosphorus and nitrogen concentrations:____

____

____

Handout 9—*Survey: Biological Properties*

Date:	Time:	Air Temperature:
Team-Member Names:		
Stream Name:		
Stream Location:		
Weather Conditions: ❑ Clear ❑ Cloudy	❑ Raining	❑ Other: ______________________
Intolerant Species (sensitive to poor stream conditions)		
Caddisfly Larvae  Count: __________	Dobsonfly, Alderfly Larvae  Count: __________	Mayfly Nymphs  Count: __________
Riffle Beetles  Source: Save Our Streams Count: __________	Stonefly Nymphs  Source: Save Our Streams Count: __________	Water-Penny Larvae  Count: __________
Intermediate Species (moderately tolerant to degraded habitat and water quality)		
Aquatic Sowbugs  Source: Save Our Streams Count: __________	Black-Fly Larvae  Count: __________	Crane-Fly Larvae  Count: __________
Damselfly Nymphs  Count: __________	Dragonfly Nymphs  Source: Save Our Streams Count: __________	Scuds  Source: Save Our Streams Count: __________
Tolerant Species (most tolerant to degraded habitat and water quality)		
Aquatic Worms  Count: __________	Drone-Fly Larvae (Rat-Tail Maggots)  Count: __________	Horsefly Larvae  Count: __________
Leeches  Count: __________	Midge-Fly Larvae  Count: __________	Pouch Snails  Count: __________
Total Species Count		
Intolerant: ______________	Intermediate: ______________	Tolerant: ______________

Student Reference Tables

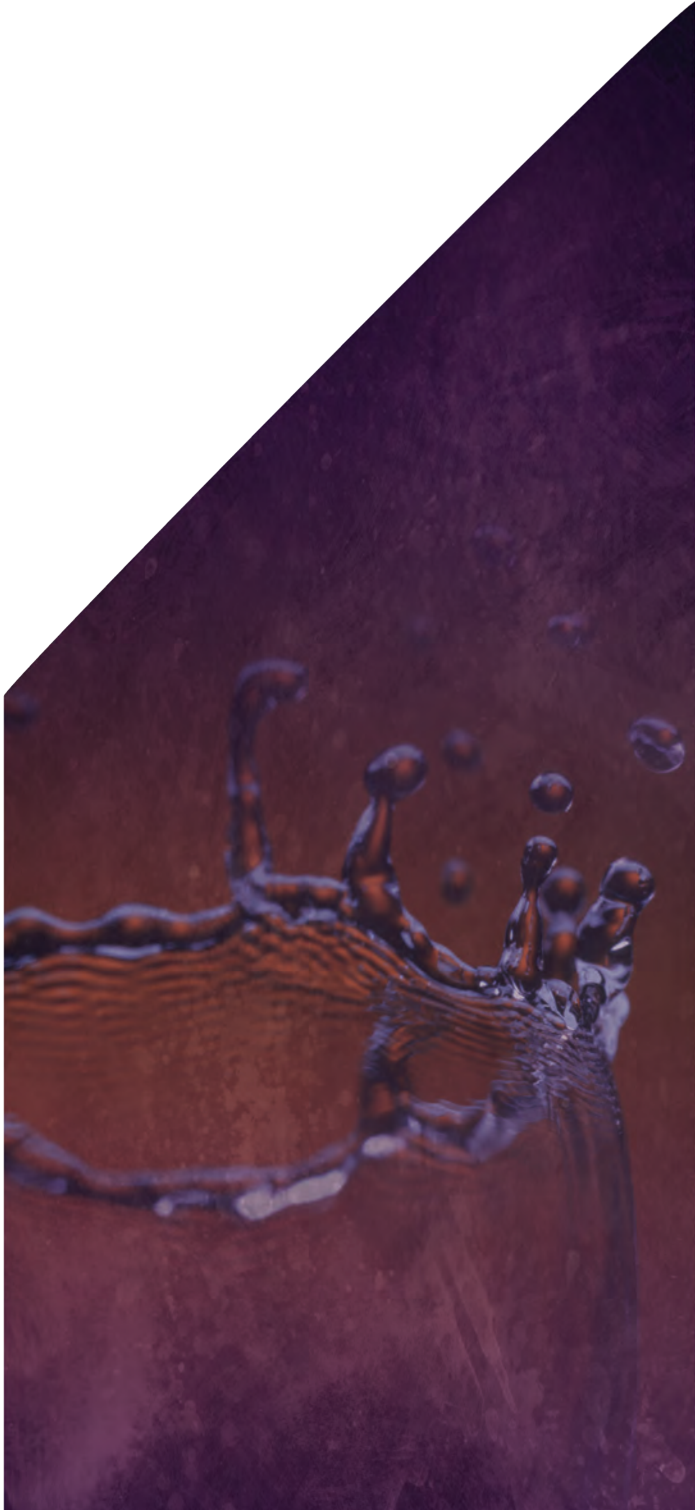
The following tables can help you determine if there is possible pollution in your stream by only using your senses. Use *Table 1—Physical Indicators of Water Pollution* to help determine the possible pollutant and then use *Table 2—General Land Uses That Might Affect Water Quality* to help determine the possible pollution source.

Table 1—Physical Indicators of Water Pollution

If you see the color(s) ...	The issue could be ...
Muddy tan to light brown	Suspended solids (silt and clay) due to: • upstream erosion of the banks and substrate due to channelization, • stormwater from logging or construction sites with inadequate erosion and sediment controls, or • Stormwater from one or more areas with soil erosion, such as poorly maintained croplands and rangelands, riparian zones with removed vegetation, exposed banks, etc.
Pea green, bright green, yellow, brown, brown-green, brown-yellow, blue-green	An algal bloom due to high nutrient content (phosphorus, nitrogen, or both). Water color is dependent on the dominant plankton type.
Tea or coffee	Dissolved decaying matter originating from the organic portion of the soil. This is usually seen in woodland or swampy areas.
Milky white	Paint (from a construction site) or milk (from a food processing site).
Dark red, purple, blue or black	Fabric dyes or inks from paper or cardboard manufacturers.
Milky gray or black	Oxygen depletion from raw sewage or other oxygen-demanding substance; a rotten-egg or hydrogen sulfide odor might be present.
Clear black	Turnover of oxygen-depleted bottom waters or sulfuric acid spill.
Orange-red	Deposits on stream beds often associated with oil-production areas, but not always (check for petroleum odor). The color could be due to iron in the water.
White, crusty deposits	Common in dry or arid areas where the evaporation of water leaves behind salt deposits. These deposits are also associated with brine water discharge (from oil production areas); check to see if the stream has a petroleum odor or an oily sheen along the banks.
If you smell ...	**The odor is from ...**
Rotten eggs or hydrogen sulfide	Raw sewage (oxygen-demanding substance) or oxygen-poor sediment.
Chlorine	Treated effluent, swimming pool overflow, or industrial discharges.
Sharp, pungent odor	Chemicals or pesticides.
Musty odor	Presence of raw or partially treated sewage or livestock waste (organic-demanding substances). Musty odor could also be caused by algae.
If you see on the surface ...	**Possibly caused by ...**
Tan foam	Water containing organic materials with high flow or wave action. This harmless foam can be in small patches to very large clumps.
White foam (thin or billowy)	Soap in treated effluent, possibly around a wastewater outfall.
Yellow, brown, black film	Pine, cedar, and oak pollens that form a film on the surface of ponds, backwater areas, or slow-moving water of streams.
Rainbow film	Oil or other fuel type. Sheens are common after rains when oil and gas residue wash off streets. Other sources include spills, pipelines, and oil and gas-production areas.

Table 2 — General Land Uses That Might Affect Water Quality

Land Use Type	Potential Effects
Woodland	Erosion from logging, road construction, or clear cutting may cause muddy waters.
Agricultural Land (croplands, pastures, feedlots, etc.)	Fertilizers or manure draining into a stream may increase the nutrient content and cause excessive algal and aquatic plant growth. Sedimentation may occur from soil erosion. Streams may also receive pesticides and herbicides in the runoff.
Cities and Towns	Depending on the activities occurring in the city or town, urban runoff might carry a variety of contaminants such as oil, pesticides, metals, and chemicals.
Industry	Industries have numerous types of chemicals and products that could cause color changes to the water, excessive algal growth, odors, absence of aquatic life, fish kills, elevated organic matter levels, and sewage fungus.
Wastewater-Treatment Plants	Effects may include excessive algal growth, white foam, sludge deposits (fluffy dark brown or gray solids), absence of fish and insects (or the abundance of tolerant forms), variable dissolved-oxygen levels, chlorine odor (and possible bleached vegetation near the outfall), sewage fungus, and elevated levels of *E. coli*.
Construction	Runoff from construction sites can cause water to become muddy and turbid.
Residential	Runoff from residential areas may contain fertilizers (nutrients), oil drained from cars (toxic substances), raw sewage from septic systems that overflow or leak (oxygen-demanding substances), detergents used to wash cars (toxic substances), and even litter (cans, bottles, paper, etc.).



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Published and distributed
by the
Texas Commission on Environmental Quality
P.O. Box 13087
Austin TX 78711-3087

GI-026 *(revised 10/15)*