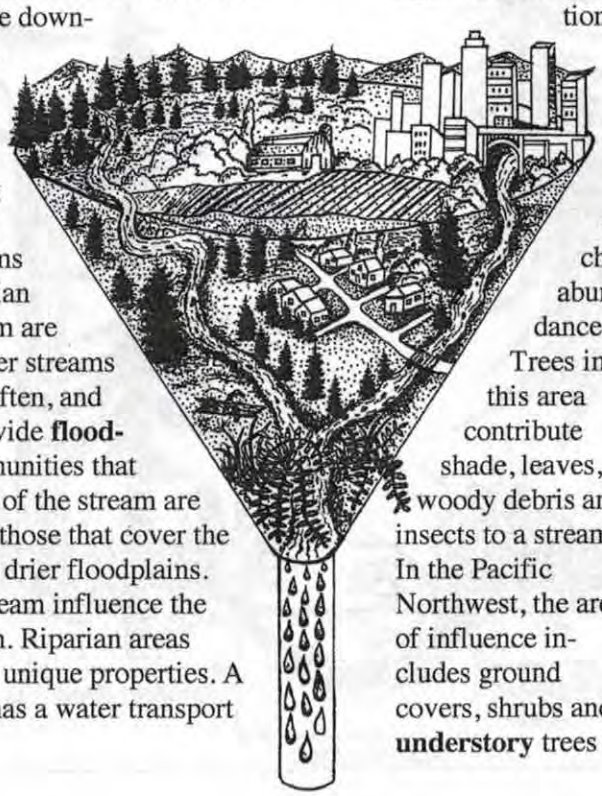
Riparian areas

6

"Most people camp too close to the creek to make good coffee."
— Rube Long

The physical, chemical, and biological makeup of a stream relates to the surrounding physical features of the watershed and its geologic origin. Looking at these features helps us understand stream-watershed relationships and allows managers to predict the effects of human influences on different streams.

Think of the uplands of a watershed as the sides of a funnel, and the stream flowing from the mouth of the funnel. The **riparian area** is the sides of the spout surrounding the stream. The riparian area is the green zone of plants along the stream. Water, nutrients, and sediments from across the uplands move downhill to support this lush and productive area.



Streams and riparian areas develop together, each affecting the development of the other. Headwater streams are small, and the riparian areas that surround them are relatively narrow. Larger streams and rivers flood more often, and floodwaters carve out wide **floodplains**. The plant communities that develop along the edge of the stream are generally distinct from those that cover the broader, and somewhat drier floodplains.

Plants along the stream influence the entire stream ecosystem. Riparian areas (Figure 6) have several unique properties. A riparian area is linear, has a water transport channel and floodplain, and is connected to upstream and downstream ecosystems.

Riparian habitat is a combination of three areas. Each is distinctive and contributes to the entire ecosystem.

Aquatic area: The aquatic area of streams, lakes and wetlands is generally wet. During dry periods, aquatic areas have little or no water flow. Any side channels or oxbows containing freshwater ponds are included in this area.

Riparian area: The riparian area is a terrestrial zone where annual and intermittent water, a high water table, and wet soils influence vegetation and microclimate.

Area of influence: This is a transition area between a riparian area and upland cover. An area of influence has soil moisture and is characterized by a noticeable change in plant composition and abundance. Trees in this area contribute shade, leaves, woody debris and insects to a stream. In the Pacific Northwest, the area of influence includes ground covers, shrubs and **understory** trees

Vocabulary

aquatic area
aquifer
area of influence
edge effect
floodplains
Oregon Forest Practices Act
riparian area
riparian management areas
understory

(usually deciduous) on the floodplains, and canopy trees (usually coniferous) on hillsides. This stair-stepping of vegetation provides a variety of wildlife habitat.

Role of riparian vegetation

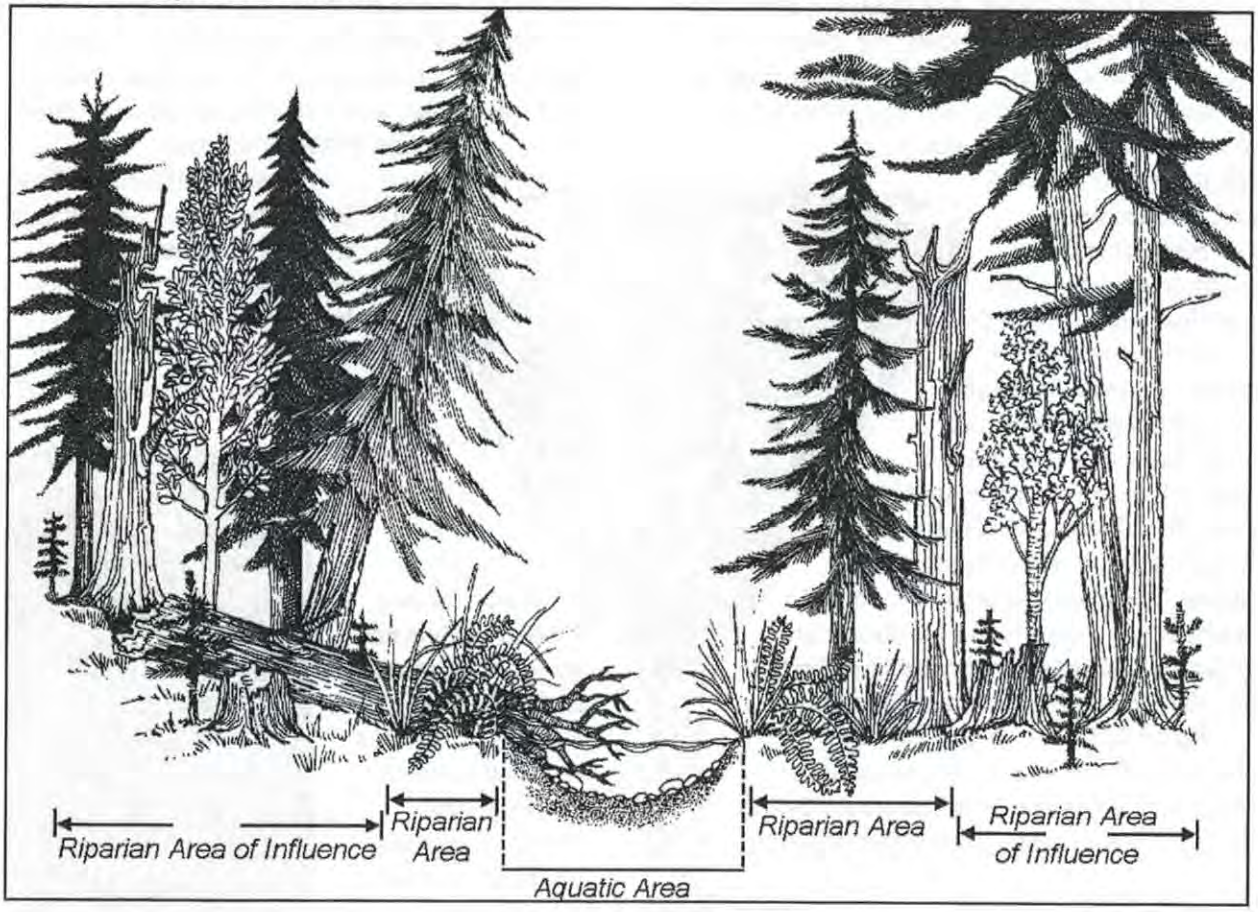
Riparian plant communities (Table 1) provide cover for aquatic and terrestrial animals. Shade created by the riparian vegetation moderates water and air temperatures. This vegetation limits water contamination, slows water velocities and filters and collects large amounts of sediment and debris. Uncontrolled sediments can kill fish and destroy spawning areas.

Stream food chains depend on organic debris for nutrients. In small headwater streams, 99% of the energy for organisms comes from the vegetation along the stream, and only 1% from photosynthesis. The leaves, needles, cones, twigs, wood, and bark dropped into a stream are a storehouse of readily available organic material that is processed by aquatic organisms and returned to the system as nutrients and energy.

A diverse population of insects depends on this varied food base. Between 60% and 70% of the debris is retained and processed in the headwaters by bacteria, fungi, insects, and abrasion, with very little leaving the system until it has been at least partially processed.

Riparian areas have a high number of edges (habitat transitions) within a very small area. The large number of plant and animal species found in these areas reflects habitat diversity. Since they follow streams, riparian areas are linear,

Figure 6. Riparian Habitat



increasing the amount and importance of **edge effect**. Extensive edge and resulting habitat diversity yield an abundance of food and support a greater diversity of wildlife than nearly any other terrestrial habitat.

Floodplains

Floodplains are an important part of a riparian area. Floodplain vegetation that shades or directly contributes material to a stream is considered part of the riparian area.

Flooding is critical to the exchange of nutrients and energy between stream and riparian area.

Stream channels rely on natural flooding patterns. Frequency of flooding and groundwater supply are the major factors controlling the growth of floodplain trees. Floodplains and backwaters act as reservoirs to hold surplus runoff until peak floods are past. This controls and reduces downstream flooding. Floodplains also spread the impact of a flood over a larger area as vegetation helps collect debris and sediment.

Composition of riparian plant communities depends on the water pattern (fast or slow moving or dry or wet periods). Both wet and dry phases are necessary in this area to complete the stream's nutrient cycle and food chain. Flooding is critical to the exchange of nutrients and energy between the stream and the riparian area.

When healthy, vegetated banks in the riparian area act as natural sponges. They help maintain soil structure, allow increased infiltration, and reduce bank erosion.

Vegetated streambanks also contribute to aquifer (groundwater) recharge. Precipitation is filtered through the riparian soils and enters underground reservoirs called **aquifers**. Good cover slows the flow and increases percolation into underground aquifers. Stored water is then available during drier periods to maintain and improve minimum flow levels. A major benefit of this aquifer recharge is maintenance of year-round streamflow.

Table 1. Functions of Riparian Vegetation As They Relate to Aquatic Ecosystems

Riparian Vegetation		
Site	**Component**	**Function**
Above ground-above channel	Canopy and stems	• Shade—controls temperature and instream photosynthetic productivity • Source of large and fine plant detritus • Source of terrestrial insects
In channel	Large debris derived from riparian vegetation	• Control routing of water and sediment • Shape habitat—pools, riffles, cover • Substrate for biological activity
Streambanks	Roots	• Increase bank stability • Create overhanging banks—cover
Floodplain	Streams and low-lying canopy	• Retard movement of sediment, water and floated organic debris in flood flows.

Source: William Meehan et al., *Influences of Riparian Vegetation on Aquatic Ecosystems With Particular References to Salmonid Fishes and Their Food Supply*, 1977, p. 137.

Riparian vegetation uses large amounts of water in transpiration. Often, vegetation needs the most water during the period of lowest streamflow. At these times, vegetation may actually reduce streamflow.

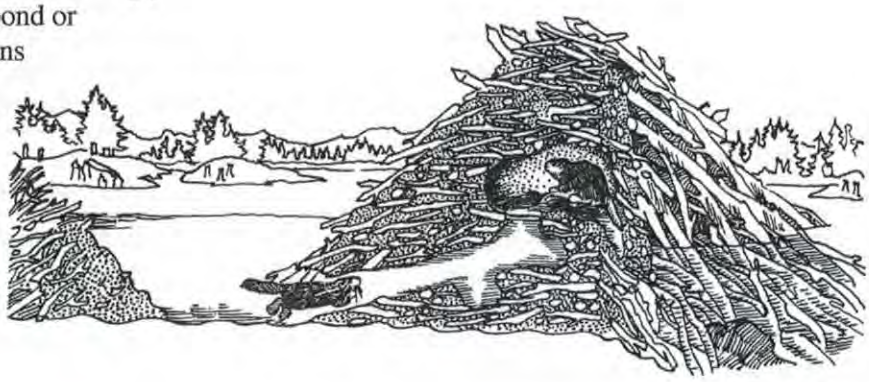
Wildlife in riparian areas

Riparian ecosystems provide the essentials of wildlife habitat: food, water and cover. In general, the area within 200 yards of a stream is used most heavily by wildlife. In western Oregon, of 414 known species of wildlife, 359 use riparian ecosystems extensively and 29 species are tied exclusively to this area. While riparian areas cover less than 1% of the land in eastern Oregon, 280 of 379 species use this area extensively.

Riparian areas provide migration routes and corridors between habitats for many animals. Woody plant communities in the riparian area provide cover, roosting, nesting and feeding areas for birds; shelter and food for mammals; and increased humidity and shade (thermal cover) for all animals.

Birds are the most common and conspicuous form of wildlife in a riparian ecosystem. In this important breeding habitat, as many as 550 breeding pairs have been found per 100 acres. Bird density is just one indicator of the productivity of a riparian area.

Mammals of all sizes are found in riparian areas. Many rodents are parts of various food chains. Some, such as beaver, may modify riparian communities. The effects of beavers on a watershed can be both positive and negative. Their actions change watershed hydrology as well as damage cover. A beaver dam changes energy flow in its immediate area by turning part of a stream environment into a pond or swamp. If high beaver populations coincide with heavy livestock use, the results can be devastating to streams. On the other hand, their dams can be beneficial as sediment traps and fish habitat. Water held behind a beaver dam is released more slowly over a longer period.



Amphibians and reptiles are another indicator of riparian quality. Nearly all amphibians depend on aquatic habitats for reproduction and overwintering. Certain turtles, snakes, and lizards also prefer riparian ecosystems.

Animal populations in riparian areas are affected by the size and diversity of available habitat. Adjacent land-use activities may have a direct effect on wildlife population size within a riparian area.

Amphibians and reptiles are another indicator of riparian quality.

Fish populations can be an indicator of watershed and riparian ecosystem health. Large woody materials, such as fallen trees and limbs, create pools and protective cover, which are necessary components of fish habitat. This woody debris also increases the diversity of invertebrates, which are a basic part of the food chain on which fish depend.

People in riparian areas

Since the land along streambanks and floodplains is often fairly flat, riparian areas are attractive locations for roads. Roadbuilding may increase sedimentation, which can adversely affect aquatic life, especially fish. Runoff from roads can carry oil, antifreeze, and other contaminants

into the stream. Road construction can also damage valuable wildlife habitat. Traffic, a hazard in itself, may disturb or displace many wildlife species.

Roads probably have a greater and longer-lasting impact on riparian areas than any other human activity. Routes should be selected and designed with careful consideration of potential long-term effects.

Riparian vegetation is often cleared for farming purposes. This often weakens bank structure, making it more susceptible to erosion and a contributor to sediment deposition downstream. Landowners who convert riparian areas to farmland for short-term gains in agricultural production may lose in the long run. The loss of vegetation on stabilized banks could cause the stream to wash away that same valuable land during periods of high flow.

Livestock, like wildlife, are attracted to shade, water and forage in riparian areas. If mismanaged—allowing the area to be grazed excessively or at the wrong time—livestock can severely affect the riparian area's value. Livestock can compact the soil near the water, reducing its infiltration capabilities. When riparian vegetation is damaged—either by trampling or overgrazing—shading is reduced, erosion potential is increased as streambanks slough away, water tables are lowered, and water quality is affected. Animal wastes may also threaten water quality.

Livestock can be managed. The impact of livestock can be reduced by controlling access and grazing levels along streambanks.

Residential and commercial development has occurred near riparian areas throughout history. Development in these sites has generally degraded the value of the resources. Degradation has included filling and altering of stream channels, removing vegetation for building construction, and paving large amounts of land for roadways.

Roads probably have a greater and longer-lasting impact on riparian areas than any other human activity.

Some problems associated with development can be avoided by good planning and site design. Residential communities can be planned with riparian area values in mind. Construction sites can avoid steep slopes, wetlands, and sensitive biological sites. Areas that offer the amenities of a relatively healthy riparian area often have an increased real estate value.

Construction of campgrounds and recreation sites in riparian areas encourages use by anglers, birdwatchers, hikers, boaters, and others. This use, especially irresponsible acts like littering or erosion caused by improper use of off-road vehicles, may conflict with the welfare of wildlife and reduce water quality.

Streams and their riparian areas are the source of domestic water for many cities. High water quality is important for these uses. To maintain it, riparian areas must be carefully managed.

Mining in and near streams has severe impacts on riparian ecosystems. Mining

often increases sedimentation and disrupts spawning areas by moving large amounts of gravel, rock and soil. In addition, mining may introduce poisonous heavy metals into streams.

Timber harvest in riparian areas

Timber harvest in riparian areas requires careful management and consideration for possible effects on fish and wildlife habitat. Prior to the Oregon Forest Practices Act in 1971, timber harvest was largely uncontrolled along streams, lakes, wetlands, or other waters. Clearcuts commonly extended to the edges of these waters, and most trees and understory brush were either removed or damaged. Removal of this vegetation eliminated future sources of large woody debris and reduced the shade that prevented increased water temperatures. Early logging practices also caused severe damage to stream habitat. For example, dragging and decking logs in stream channels and using splash dams to move logs down streams with man-made floods caused direct damage to spawning areas. Where and how early roads were built caused indirect damage by removing trees along the stream, increasing the amount of sediments in streams, and reducing the stream's ability to move across its floodplain.

Modern forest management requires the retention of vegetation within riparian areas along streams, lakes, wetlands, and other waters. **Riparian management areas** (RMAs) are required by the **Oregon Forest Practices Act** to protect resources such as fish habitat, water quality, and domestic water supplies. The Forest Practices Act is administered and enforced by the Oregon Department of Forestry. It applies to all commercial forest management activities on state and private lands. On federal lands the management of these zones is guided by other regulations and management plans, but the requirements of the Oregon Forest Practices Act must always be met or exceeded.

The width of riparian management areas under the Forest Practices Act varies from 50 feet to 100 feet along fish-bearing waters depending on the size of the stream. These areas are established along both sides of streams. The actual width of a riparian management area varies according to the amount of trees and other vegetation that must be maintained. The width of RMAs can be varied to adapt to features of the terrain or to address other concerns or sensitive sites encountered at the timber harvest operation.

Some problems with development can be avoided with good planning and site design.

Within riparian management areas, landowners are required to maintain vegetation (including trees) to achieve desired amounts of shade and cover. Activities are controlled to minimize negative effects on fish habitat and water quality. On fish-bearing streams, vegetation is managed to achieve a mature forest over time. Along some non-fish bearing streams, vegetation is maintained to protect water quality. There are also a number of streams without fish where no vegetation retention is required.

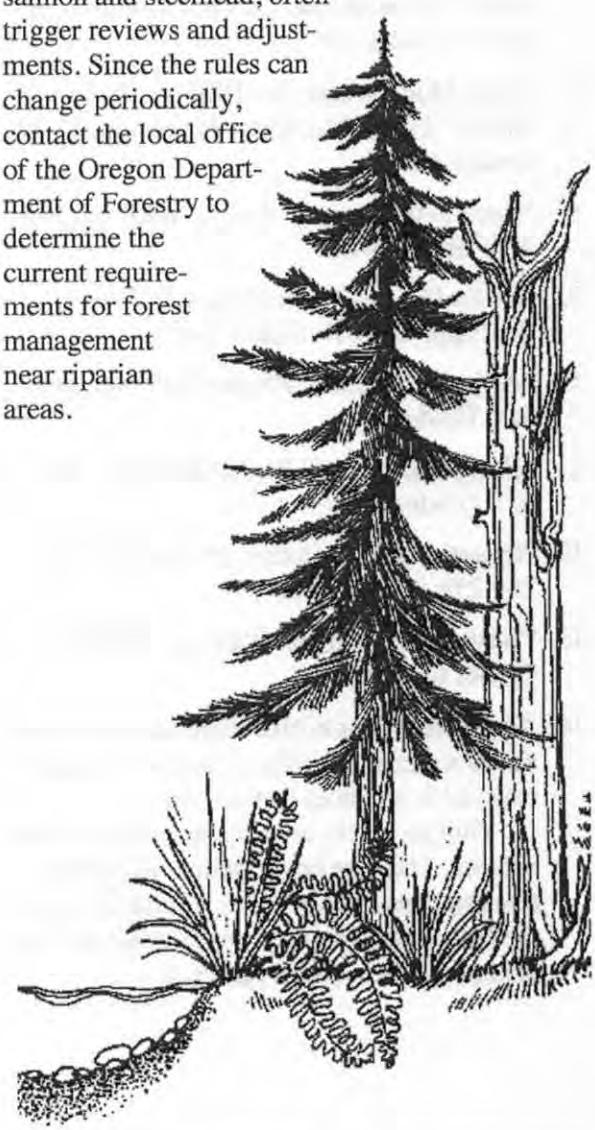
Besides maintaining vegetation, there are a number of other requirements for the management of riparian areas along fish-bearing streams. For example, all downed trees in aquatic habitats and within the riparian management area must remain. This assures that large woody debris in streams or on the ground is available as habitat for fish and wildlife. All snags not considered a safety hazard must be left in the riparian area. These dead trees serve as a source of future downed wood and, for as long as they are standing, provide foraging and nesting sites for birds and other wildlife.

The current "water protection rules" of the Forest Practices Act also include incentives for landowners to actively enhance stream habitat. One major factor that currently limits fish production in Oregon streams is a lack of large woody debris in streams. This is a result of historic logging practices that failed to keep trees as a source of large wood along streams. Cleaning stream channels by removing large wood to make transporting logs and fish migration easier also contributed to the current lack of woody debris. It could take centuries for enough streamside trees to fall into streams naturally to remedy this problem. To address the shortage of large woody debris in streams in a timely manner, the rules include an incentive for landowners to place large woody debris, or complete other needed restoration projects, in conjunction with nearby timber harvest operations. Landowners who complete enhancement projects to provide immediate benefits to fish habitat are allowed to remove a few additional trees from the riparian zone. The number of trees that can be removed is still limited, however, so a mature forest condition will eventually develop.

Modern forest management requires the retention of vegetation within riparian areas along streams.

Other forest management activities are also regulated to protect resources such as riparian areas. Those activities include road building and maintenance, chemical use, and prescribed burning, among others. These activities must be planned and implemented carefully to prevent damage to waters and other forest resources.

The Oregon Forest Practices Act, and its associated rules, are continually reviewed and adjusted. The current rules for protection of Oregon waterways include a commitment by the Oregon Department of Forestry to conduct monitoring to evaluate the rules and to report findings to the Board of Forestry for appropriate rule changes. In addition, other processes, such as the recent Endangered Species Act listings of coho salmon and steelhead, often trigger reviews and adjustments. Since the rules can change periodically, contact the local office of the Oregon Department of Forestry to determine the current requirements for forest management near riparian areas.



Extensions

1. "Riparian Retreat," *Aquatic Project WILD*, pp. 118. Grades 6-12.
2. "The Edge of Home," *Aquatic Project WILD*, pp. 75. Grades 4-12.
3. "Blue Ribbon Niche," *Aquatic Project WILD*, pp. 52. Grades 5-12.
4. "Porosity and Permeability," *Groundwater: A Vital Resource*, pp. 24-26. Grades 7-12.
5. "Farmers and Water Pollution," *Groundwater: A Vital Resource*, pp. 47-48. Grades 9-12.
6. "Municipal Waste Contamination of Groundwater," *Groundwater: A Vital Resource*, pp. 53-55. Grades 7-9.
7. "How Much Water Can Different Soils Hold?," *Earth: The Water Planet*, pp. 17-22. Grades 4-8.
8. "Back to the Future," *Project WET*, pp. 293-299. Grades 3-12.
9. "Get the Ground Water Picture," *Project WET*, pp. 136-141. Grades 6-12.
10. "A Grave Mistake," *Project WET*, pp. 311-314. Grades 6-12.
11. "Humpty Dumpty," *Project WET*, pp. 316-321. Grades 3-8.
12. "Irrigation Interpretation, *Project WET*, pp. 254-259. Grades K-8.
13. "Wish Book," *Project WET*, pp. 460-464. Grades 6-12.
14. A relatively simple procedure can be used to assess a stream's ability to hold the organic material it produces (retention).

    Ginkgo leaves are excellent to use in this activity. They are bright yellow in autumn (making them easy to spot), similar in size to the leaves of common riparian trees, and they are not native to North America.

    Collect ginkgo leaves (or any other bright yellow leaves, such as aspen, or readily available brightly colored autumn leaves). Dry them immediately after they fall in autumn and then store until needed. Soak the leaves for 12 hours before they are released. This creates neutral buoyancy to simulate natural distribution patterns.

    Release about 3,000 leaves at the upstream end of a 50-yard section. Map leaf distribution about three hours after release. About 30% to 90% will be retained. Students should be aware that retention is affected by channel structure, flow patterns, substrate types, and leaf characteristics.

    When the retained leaves are collected, make a record of what is causing the retention. To calculate the proportion of leaves retained by each type of feature, divide the number of leaves found at each structure type by the number of leaves released. Students can determine which structures are most effective in retention and the importance of leaves and other debris to aquatic food chains. Discussion can include collection of inorganic sediments, fine particulate organic matter, woody debris, or dissolved nutrients.

    Doing the same activity in different riparian areas (for example, a freshly logged site, second-growth forest, or old-growth forest) would provide an opportunity for comparison. A stream's ability to retain much of the energy base it produces is a primary function of riparian vegetation. (Speaker, Moore and Gregory, 1984.)
15. Riparian floodplain soils are a major reservoir of water depending on the degree of compaction. The following procedure can be used to determine how much void space (usually 30% to 50%)—space capable of being filled with water—exists in a soil.

    Locate a fairly uniform soil, relatively free of rocks. Using bottomless cans prepared as described in the following activity, "A dirty subject," tap a can down into the ground as far as possible. Leave the can in place while you dig around the sides. Con-

tinue to dig until you are able to slide a flat piece of metal under the bottom of the can. Do not disturb the plug of soil in the can. Seal the metal plate to the can with putty or a similar substance to make a watertight seal. Pour water into the can from a graduated cylinder, taking note of the amount of water used, until the soil is saturated.

Calculate the volume of the soil in the can ($\pi r^2 \times H$=volume of soil) and compare it with the amount of water added to its void spaces. Compare soils from various compacted and non-compacted areas. (Contributed by Bruce Anderson, 1988.)

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Passin' through

Activity Education Standards: *Note alignment with Oregon Academic Content Standards beginning on p. 483.*

Objectives

The student will (1) describe characteristics of substances considered as water pollutants, (2) describe how wetlands and riparian areas can filter water, and (3) discuss the negative effects of pollution on aquatic wildlife and habitats.

Method

Students conduct an experiment by putting a variety of pollutants into water and attempting to filter the pollutants out with a model soil filter.

For younger students

1. Use a sponge to demonstrate how a riparian area absorbs and filters substances before doing this activity.
2. Prepare the activity as a demonstration. Ask students to do the pH sampling.
3. Try "The Edge of Home," *Aquatic Project WILD*, pp. 75. Grades 4-12.
4. Try "How Much Water Can Different Soils Hold?" *Earth: The Water Planet*, pp. 17-22. Grades 4-8.
5. Try "Back to the Future," *Project WET*, pp. 293-299. Grades 3-12.
6. Try "Humpty Dumpty," *Project WET*, pp. 316-321. Grades 3-8.
7. Try "Irrigation Interpretation, *Project WET*, pp. 254-259. Grades K-8.

This activity is adapted from the draft "Invisible Travelers," an activity originally written for *Aquatic Project WILD*, pilot version, 1996, Western Regional Environmental Education Council.

Materials

- copies of student sheets (pp.187-190)

For each set of stations:

- 4 used plastic 2-liter drink bottles
- 4, 3-inch squares of screen or mesh
- 4 rubber bands
- 4 sturdy cardboard boxes to support filter
- catch container large enough to hold one quart of solution
- filter materials—rich topsoil, subsoil, sand, gravel, pebbles
- test solution #1—one quart of water mixed with one half cup of vinegar
- test solution #2—one quart of water mixed with one half cup of crushed charcoal
- test solution #3— one quart of water mixed with one half cup of cooking oil
- test solution #4—one quart of water mixed with one half cup of lawn clippings or bark mulch
- pH paper or other pH testing materials

Notes to the teacher

1. Use the diagram as a guide to set up the models. Make sure the hole cut in the bottom of the cardboard box is large enough to support the bottle. You may have to experiment to come up with the right diameter. Give students this information. It may prevent spills of dirt, water, and rocks.
2. If water is easily moving through the filters, it is not necessary to pour the entire quart of solution through the filters.
3. Students will explore pH in greater depth in Chapter 8, "Water Quality."

Vocabulary

riparian areas
sediments
wetlands

Background

Do you know . . .

... that water running over the land's surface can pick up many things, including pollutants, and carry them suspended in the water? Eventually these things are deposited somewhere. For example, in the spring—when high water erodes soil from river banks—clay, silt, and other soil particles are picked up and carried by rivers and streams. Normally these soil particles are carried for short distances, then settle out and are deposited when the current slows down. In small quantities this is not harmful. But large amounts of **sediment** from eroded agricultural or forest land, highway construction sites, and urban development are not a part of the normal cycle. Sediments can destroy fish spawning beds, suffocate filter feeding insects, and even damage fish gills.

The best solution for these problems is to prevent pollution. But eroded sediments or other pollutants carried by moving water can be filtered out by healthy **wetlands** or **riparian areas**. In a wetland or riparian area, the vegetation slows the speed of water moving over the land surface, letting some of the particles settle out. Wetland and riparian soils also filter water that infiltrates, or passes through the soil, removing even more pollutants.

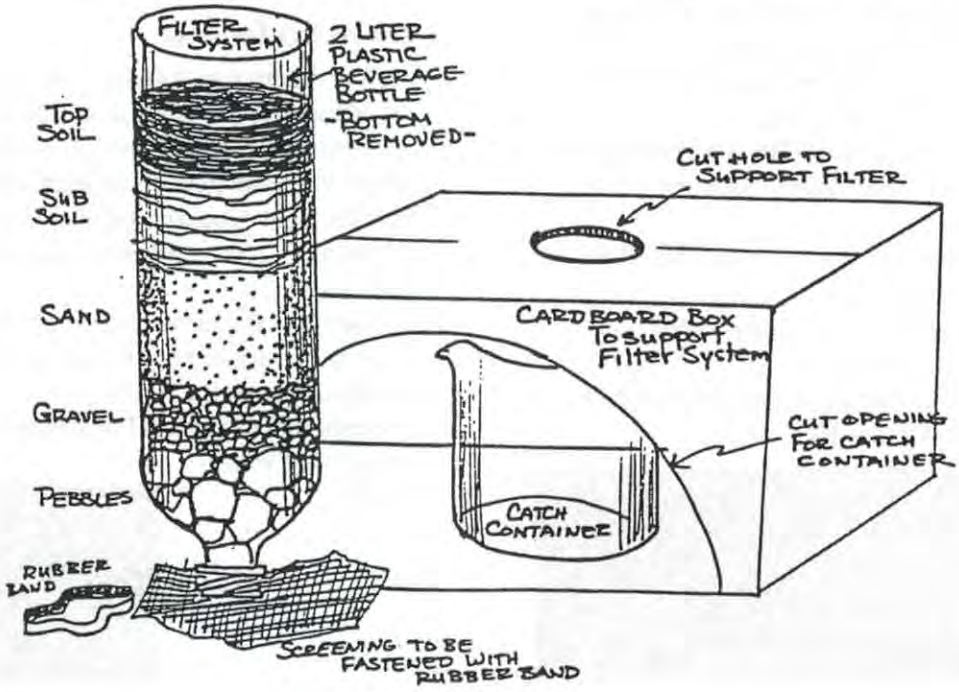
Procedure

Now it's your turn . . .

In this activity you will use a model to learn how riparian and wetland soils can filter pollutants from water. You will test the ability of soils to filter four different pollutants. At each test station follow the directions and write your observations on the data sheet. Then answer the questions that follow.

Note: Do not taste the test solutions.

Set up each of the four filter models as shown in the diagram. Label each filter, for example "Test Solution 1," "Test Solution 2," etc. Also label the test solution containers. Turn the cardboard box so the open end fits over the catch container. Cut a small hole in the bottom of the box to support the filter. To avoid spills, make sure the hole supports the filter before letting go of the bottle. Make sure the catch container is lined up below the hole in the bottom of the cardboard box and is large enough to catch the flow.



Station		Smell	Appearance (color, cloudy, or transparent)	pH
No. 1: Acid	Before filtering			
	After filtering			
No. 2: Charcoal	Before filtering			
	After filtering			
No. 3: Oil	Before filtering			
	After filtering			
No. 4: Organic debris	Before filtering			
	After filtering			

At each filter:

1. Observe and describe the test solution before filtering. Consider smell, transparency, cloudiness, and pH. Record your observations on the data sheet.
2. Place the catch container under the filter. Slowly pour the solution through the filter system.
3. Observe and describe the test solution after filtering. Record your observations on the data sheet.
4. Answer the following questions.

Questions

1. Which test solution's smell was most changed by passing through the filter?
   Answers may vary, but the odor of vinegar will likely persist through the filtering, even if it is less noticeable.
2. Which test solution's appearance was most changed by passing through the filter?
   The charcoal and organic debris solutions should be the most changed because they most likely will not make it through the filter.
3. Which test solution's pH was most changed by passing through the filter? How do you think the riparian filter changed the pH?
   Answers will vary depending on the soils used in creating the filters. The vinegar solution will probably be changed the most. pH factors will vary depending on the composition of the soil used in the filter.
4. For which solutions was the riparian filter most effective at removing pollutants? Why?
   Answers will vary based on how students evaluate effectiveness.

5. Riparian soils can only filter out a small amount of some pollutants before they lose their effectiveness. Which of the pollutants in the test solutions could riparian filters most likely filter indefinitely? Why?

   A riparian soil filter would have a nearly unlimited ability to filter charcoal and organic debris. Charcoal, organic debris, or other large materials are strained out and added to the top layers of riparian soils. But like a sponge, riparian soils can absorb only a limited amount of solutions they must "soak up."

6. Which test solution pollutants would riparian filters have a limited ability to filter? Why?

   Vinegar and oil. The soil's ability to buffer acid is limited. Oil will eventually coat so many soil particles that new additions will pass through unchanged.

7. List several pollutants that might move to streams or wetlands with runoff or overland flow. Which of these will riparian and wetland soils most likely filter out? Which of these will likely pass through riparian and wetland soils without much filtering?

   Answers will vary, but one good example is runoff from parking lots and other impervious surfaces.

Going further

1. Design an experiment to test the limits of your "riparian soils" for filtering out the test solution pollutants.

2. Riparian filter strips are commonly used to filter soils carried as sediments. Try the experiment with several solutions containing various soil types (sand, loam, clay). Is the filter as effective for each of these solutions of muddy water? Which types of sediment particles are riparian soils most effective in filtering out of solution?

Name

Passin' through

Do you know . . .

... that water running over the land's surface can pick up many things, including pollutants, and carry them suspended in the water? Eventually these things are deposited somewhere. For example, in the spring—when high water erodes soil from river banks—clay, silt, and other soil particles are picked up and carried by rivers and streams. Normally these soil particles are carried for short distances, then settle out and are deposited when the current slows down. In small quantities this is not harmful. But large amounts of **sediment** from eroded agricultural or forest land, highway construction sites, and urban development are not a part of the normal cycle. Sediments can destroy fish spawning beds, suffocate filter feeding insects, and even damage fish gills.

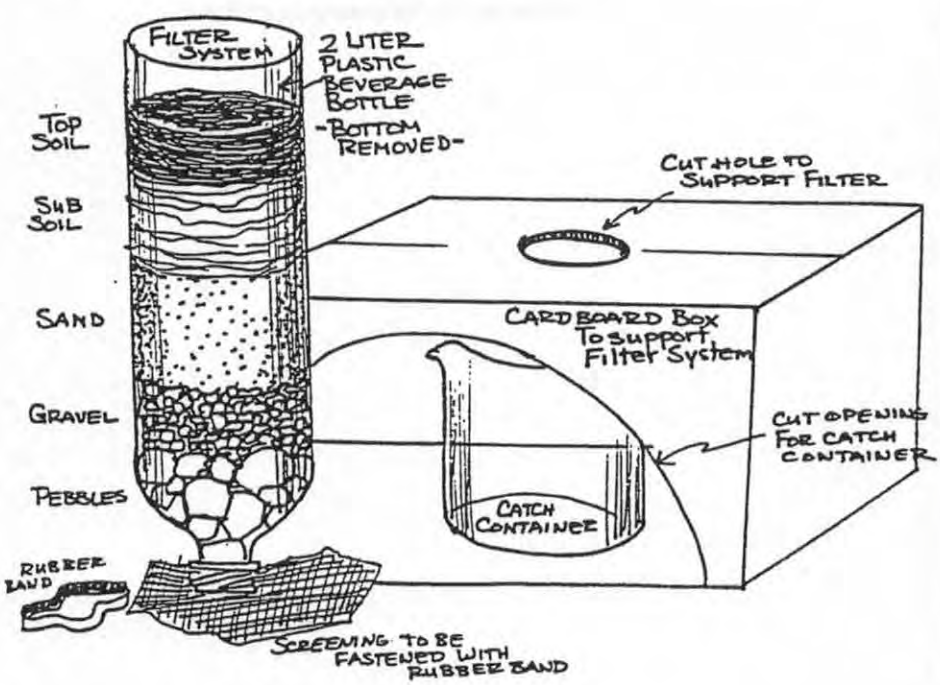
The best solution for these problems is to prevent pollution. But eroded sediments or other pollutants carried by moving water can be filtered out by healthy **wetlands** or **riparian areas**. In a wetland or riparian area, vegetation slows the speed of water moving over the land surface, letting some of the particles settle out. Wetland and riparian soils also filter water that infiltrates, or passes through the soil, removing even more pollutants.

Now it's your turn . . .

In this activity you will use a model to learn how riparian and wetland soils can filter pollutants from water. You will test the ability of soils to filter four different pollutants. At each test station follow the directions and write your observations on the data sheet. Then answer the questions that follow.

Note: Do not taste the test solutions.

Set up each of the four filter models as shown in the diagram. Label each filter, for example "Test Solution 1," "Test Solution 2," etc. Also label the



Vocabulary

riparian areas
sediments
wetlands

This activity is adapted from the draft "Invisible Travelers," an activity originally written for *Aquatic Project WILD*, pilot version, 1996, Western Regional Environmental Education Council.

Student sheet

Station		Smell	Appearance (color, cloudy, or transparent)	pH
No. 1: Acid	Before filtering			
	After filtering			
No. 2: Charcoal	Before filtering			
	After filtering			
No. 3: Oil	Before filtering			
	After filtering			
No. 4: Organic debris	Before filtering			
	After filtering			

test solution containers. Turn the cardboard box so the open end fits over the catch container. Cut a small hole in the bottom of the box to support the filter. To avoid spills, make sure the hole supports the filter before letting go of the bottle. Make sure the catch container is lined up below the hole in the bottom of the cardboard box and is large enough to catch the flow.

At each test station:

1. Observe and describe the test solution before filtering. Consider smell, transparency, cloudiness, and pH. Record your observations on the data sheet.
2. Place the catch container under the filter. Slowly pour the solution through the filter system.
3. Observe and describe the test solution after filtering. Record your observations on the data sheet.
4. Answer the following questions.

Student sheet

Questions

1. Which test solution's smell was most changed by passing through the filter?

2. Which test solution's appearance was most changed by passing through the filter?

3. Which test solution's pH was most changed by passing through the filter? How do you think the riparian filter changed the pH?

4. For which solutions was the riparian filter most effective at removing pollutants? Why?

5. Riparian soils can only filter out a small amount of some pollutants before they lose their effectiveness. Which of the pollutants in the test solutions could riparian filters most likely filter indefinitely? Why?

6. Which test solution pollutants would riparian filters have a limited ability to filter? Why?

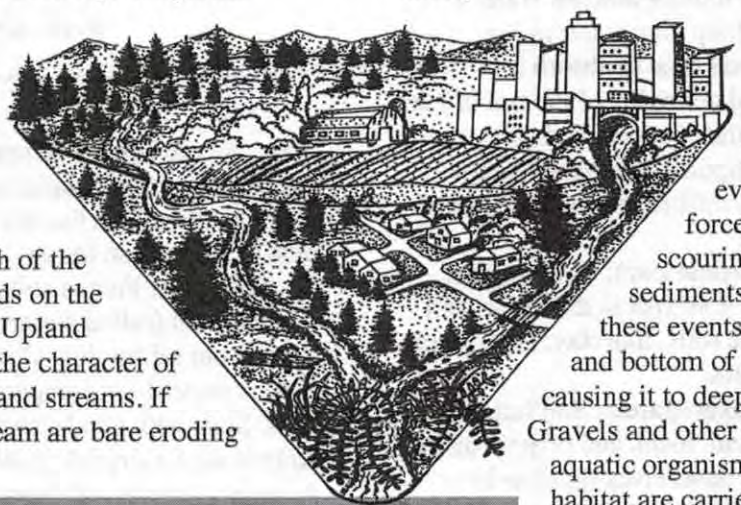
7. List several pollutants that might move to streams or wetlands with runoff or overland flow. Which of these will riparian and wetland soils most likely filter out? Which of thse will likely pass through riparian and wetland soils without much filtering?

Uplands

5

"To rule the mountain is to rule the river."
— Emperor Hu, Fifth Century China

Think of the stream as the mouth of a funnel. It accumulates and concentrates everything that flows into it. The uplands surrounding the stream are like the sides of the funnel. In total, a watershed is the network of rivers and streams that drain it, the riparian corridor along those channels, and the uplands that surround them. None of these areas is truly distinct or separated from the others.



Much of the health of the total watershed depends on the health of the uplands. Upland conditions determine the character of the riparian corridors and streams. If the slopes above a stream are bare eroding soil, then the riparian corridor and stream will receive a greater load of sediment washed from the uplands above.

Without a "sponge" of vegetation to help collect and slow water on its way to the stream, nearly all of the rainfall will quickly move into the streams, creating a "flashy" flow with a rapid rise in stream level—and perhaps even flash floods. The force of the water and the scouring power of the sediments it carries during these events can scrape the sides and bottom of the stream channel, causing it to deepen and widen. Gravels and other materials that many aquatic organisms depend on for habitat are carried away or buried. The uplands are the source of the materials carried by the stream. If a stream is, or is not, working as we think it should, the surrounding uplands may be responsible. They are all part of the same watershed. Whatever affects one ultimately affects the other.

Vocabulary

aquifers
arid
baseflow
best management practices
colloids
concrete frost
detachment
entrainment
forbs
forest practices act
groundwater
impoundments
infiltrate
non-point source pollution
organic matter
organisms
percolate
point source pollutants
Prior Appropriate Doctrine
riparian areas
Riparian Rights Doctrine
slope
soil frost
soil moisture
soil structure
soil texture
stalactite frost
subsurface flow
surface flow
surface runoff
total maximum daily loads
water quality limited
water rights

The keys to watershed management

The keys to a healthy watershed are *capture, store,* and *safe release of water*. Capture a raindrop where it

falls, store it in the soil, and safely release it to the stream over time. Managing a watershed for these goals minimizes erosion and flooding and provides cool water to streams over the longest time.

Capture

To capture a raindrop, it must be able to **infiltrate**, or soak, into the soil. Think of the difference between a raindrop falling on a pane of glass and a raindrop falling on a sponge. The porous structure of the sponge lets the water pass into it. Ideally the surface of the soil should be like that sponge—rough with plenty of open spaces for water to enter. A layer of organic material—such as plant litter and duff—on the soil surface can perform two functions. First, it acts like the sponge, absorbing and holding water. Second, since it takes time for water to enter the soil, it can help hold water in tiny puddles, giving the soil time to absorb it.

The structure and condition of the soil affects how well water infiltrates into it. Soils are composed of mineral components, organic components, air, and water. Infiltration can be affected by the following:

Soil texture (particle size): Coarse soils, like sand, have large pore spaces that allow fast infiltration rates. Fine soils, like clay, have much slower infiltration rates.

Soil structure (aggregates): Soil has many components: clay, sand, loam, and organic material. When they bind themselves together in larger particles they are called aggregates. The specific components that make up a soil and their relative amounts determine infiltration rates. Different types and combinations create aggregates of different size and shape. These aggregates affect infiltration through the size and shape of the spaces between them. Soil aggregates have structure, and soils with the most structure have the best infiltration rates.

Colloids: Colloids are very tiny particles such as clays. If colloids are present in large amounts they can produce "shrink-swell" effects that lead to soil cracking. They can also fill pore spaces between aggregate particles and reduce the rate and amount of infiltration. The chemical nature of colloids affects how strongly water molecules are attracted to them. Other substances, including various pollutants, may also be chemically attracted to colloids.

Soil moisture: Like a sponge, soils can only hold so much water before reaching capacity.

The keys to a healthy watershed are capture, store, *and* safe release of water. *Capture a raindrop where it falls, store it in the soil, and safely release it to the stream over time.*

Soils that are already saturated will not readily allow more water to infiltrate. The amount of moisture already in the soil determines the volume of infiltration for any particular soil.

Soil frost: Frozen soils or soils with a layer of ice on top (called **concrete frost**) may prevent water from infiltrating. Concrete frost occurs most commonly in compacted or unprotected soils. Soils with good structure may instead form large loose ice crystals (called **stalactite frost**). A loose structure with good pore spaces allows relatively greater and faster infiltration, even when frozen.

Slope: The slope of a hill affects how readily water can infiltrate into the soil that covers it. Gravity moves water off steep slopes more quickly, allowing little time for infiltration. A combination of steep slopes and heavily saturated soils can also create conditions that encourage "slumping," or landslides. The bonds that hold soil particles together are weakened when the soil is saturated. Saturated soils are also heavier. This means that heavily saturated soils on steep slopes without adequate plant cover can give way, dumping large volumes of soil onto the base of the slope. If the slope is above a stream channel,

this soil becomes sediments carried by the stream.

Organisms and organic matter: Organic material—plant litter and organic duff—on the soil surface promotes ponding. Ponding allows more time for infiltration to take place and increases the total volume of water that can enter

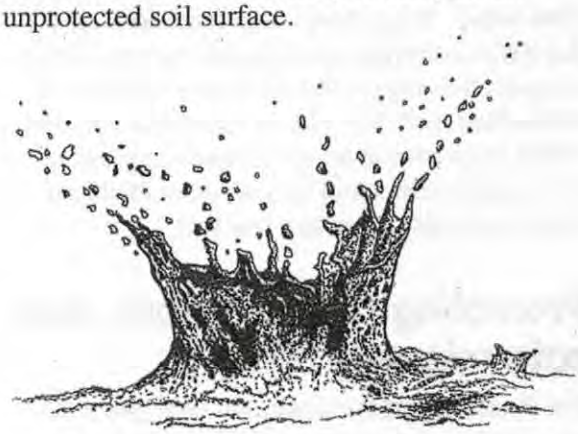
the soil. The activities of burrowing rodents, earthworms, and other organisms create holes, depressions, and increase surface roughness that promotes ponding.

Human activities can promote or limit infiltration. Activities that either compact or seal the soil surface—roadbuilding, residential development, or paving—reduce a watershed's ability to store water through infiltration and increases runoff. Agricultural and forest practices can also compact soils and remove vegetation that might otherwise slow the flow of water across the land. However, agriculture and forest activities that roughen the soil surface, such as leaving plow furrow, can have the opposite effect and help retain water through ponding.

When infiltration rates cannot keep up with rainfall rates, water begins to flow over the top of the soil. This is called **surface flow** or **surface runoff**. Surface runoff is rainfall that does not infiltrate into the soil, but flows over the surface until it reaches the stream. Less surface runoff generally means more infiltration. This increases storage and reduces erosion.

The force of water moving as surface runoff can cause soil erosion. The speed that water moves as runoff largely determines its erosive force. Rapidly moving water has more force and causes more erosion. The erosion process has two parts, **detachment** and **entrainment**. Detachment occurs when a particle of soil is broken loose from the soil surface. Entrainment is movement of that particle with the surface water flow. Soil particles carried with surface runoff may increase the rate of erosion by bumping into other particles and detaching them. Plants can reduce the amount of erosion by protecting the soil surface from the force of moving water and sediments.

When soil is unprotected by vegetation or surface litter, it is also in danger of detachment when raindrops splash on the soil. A falling raindrop carries a lot of force and can break soil aggregates into smaller particles. Some of these detached soil particles are carried away in the surface flow. Others are driven together, compacting them. Detached particles may be moved into soil pores, sealing the soil and reducing infiltration. Moist soils tend to compact more easily than dry soils. Raindrops provide the moisture and force necessary to compact the unprotected soil surface.



Store

Some of the infiltrating water is absorbed by the dry soil particles, and some fills the pore spaces between soil particles. This water is available for plants and other organisms. When the soil has taken in as much water as it can store, water begins to **percolate** through the soil on its way to

the stream. It can take a long time for water to move from the top of a watershed to the stream at its base, effectively increasing the time any particular storm contributes water to the stream. In addition, stored water is kept away from the sun's rays and provides cool water to the stream at a later time.

Safe release

The water that percolates through the soil to the stream is called **subsurface flow**. Subsurface flow is much slower than overland flow. Released slowly, it will sustain streamflow during dry seasons of the year. Subsurface flow is the **baseflow** of the stream. Delivered in a slow, measured fashion it does not contribute to flood peaks or the bad effects floods can have on stream channels and streamside vegetation.

If infiltration is stopped or reduced, there will be less **groundwater** recharge. Less groundwater recharge means less baseflow to recharge streams during dry times of the year. If baseflow is disrupted, streams that once flowed throughout the year may dry up in the summer.

Groundwater is also an important source of water for wells. Groundwater includes water found in **aquifers**—underground formations that store water. Wells draw water from aquifers for domestic, industrial, and agricultural use. Water in aquifers is held in the pores and openings of subsurface rock. The size of individual aquifers varies from several hundred square miles to a few square miles. And they range in thickness from hundreds of feet to a few feet.

Promoting capture, store, and safe release

For the most part the slope, soil type, precipitation pattern, and geology of a watershed are fixed. They cannot be easily altered. But human activities can change how well rainfall is captured, stored, and released in a watershed. Human activities can reduce infiltration, increase compaction, or in other ways disrupt a watershed's ability to capture, store, and safely release rainfall.

Another key to healthy watersheds is vegetation. Plants help reduce the force of falling rain, provide structure to promote ponding and puddling, slow overland flow, and anchor soils. Good watershed management promotes healthy plant cover across the soil surface. Managing watersheds as a total unit is largely a matter of managing vegetation.

Another key to healthy watersheds is vegetation.

Vegetative cover

Plant cover—whether trees, shrubs, grasses, or forbs—benefits a watershed. The canopy intercepts rain and reduces the force with which it strikes the ground. The canopy and stems also reduce wind velocity. Reduced wind velocity along with shade from the canopy reduce evaporation from the soil surface.

When leaves and twigs fall, they produce litter, which decomposes and is eventually incorporated into the soil. Litter protects the soil surface, allows infiltration, and slows down surface runoff.

Stems and roots lead water into the ground. Roots open up soil spaces for water retention and drainage as well as add organic materials to the soil. The movement of minerals from roots to canopy provides recycling.

Windbreaks of trees and shrubs protect crops and reduce moisture losses from evaporation. Grasses, trees, and shrub stems along riverbanks trap sediments and floating debris during high water or flooding. They also reduce a stream's erosive power by slowing the edge of the stream. Roots bind and stabilize streambanks and slopes, which helps reduce slides and slumps.

Grasses, **forbs**, shrubs and trees make up the major plant cover types. All four types build up organic litter and affect soil development. They usually develop under differing climatic conditions and all are important to watershed management.

A forest usually includes, in addition to trees in various stages of growth, an understory of shrubs and a low ground cover of forbs and grasses. While all plants in a forest have some effect on water, trees are the most important. Litter fall from trees protects the soil's surface. Tree roots go deep into the soil and help bind it, and tree crowns provide the most shade. The effects of shrubs and grasses are similar to those of trees including increased protection for soil against the beating action of rain and drying action of the wind.

Water quality is largely deteremined by the soils and vegetation in a surrounding watershed.

Plants also draw moisture from the soil, sometimes significantly reducing the amount of water available for other plants or as baseflow. An example is accelerated brush growth, particularly juniper, on central and eastern Oregon uplands. Increased juniper stands have, in some areas, decreased summer streamflows. Juniper competes more successfully than other vegetation for available moisture. This reduces ground cover and may cause increased runoff and less infiltration to groundwater storage. In addition, juniper roots can tap groundwater storage. Juniper's high transpiration rate leaves less water for stream runoff as summer progresses.

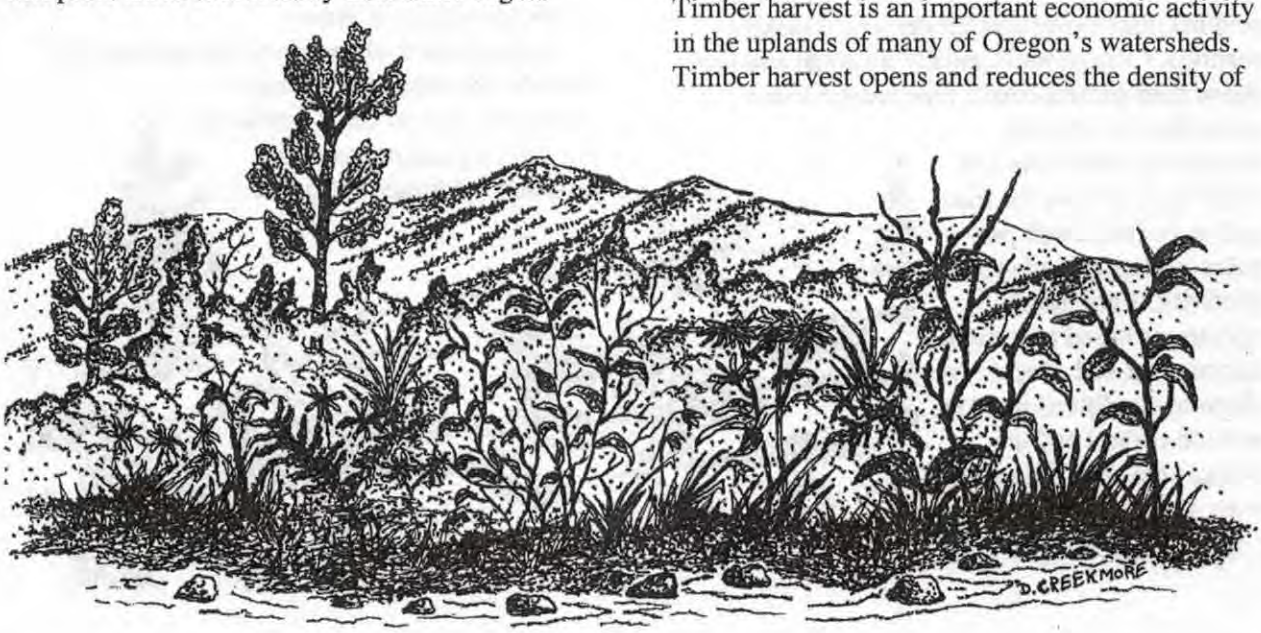
Areas too **arid** to support forests have a different community structure. On dry lands there is not enough rainfall to support an uninterrupted layer of plants to cover the soil. Between individual plants there are areas that may be bare or covered with plant litter. The organic material from shrubs, grasses, and forbs is especially important in these areas. Twigs, dead leaves, and other plant debris help protect the bare soil between plants from the erosive power of rainfall and overland flow.

Management considerations

Water quality in a stream or river is largely determined by the soils and vegetation in a surrounding watershed. Therefore human activities that effect soils and vegetation in the uplands have consequences for water quality. These activities include timber harvesting, farming, livestock grazing, mining, recreation, and urban or industrial development.

Timber harvest

Timber harvest is an important economic activity in the uplands of many of Oregon's watersheds. Timber harvest opens and reduces the density of



the canopy of plants that cover the forest floor. Timber harvest does not negatively affect a watershed if slope and soil are carefully considered and plant cover rapidly restored. In snow zones, timber harvest can change the amount and timing of water that flows from uplands to streams. Openings in the forest may catch more snow and the snow may melt at a different rate than in an unbroken canopy. Oregon and several other states have passed laws called **Forest Practices Acts** to make sure that soil and water resources are considered during timber harvest.

Farming

Agriculture is another important economic use of both floodplains and uplands. The effects of agriculture on watersheds are complex. On one hand, plowing and other soil preparation techniques can increase the amount of bare surface exposed to the elements. This could increase the amount of erosion and the amount of sediments carried from uplands to streams. On the other hand, these same activities can increase the roughness of the soil and the permeability of its surface. This will increase infiltration rates and slow surface flows. Conservation tillage practices, such as returning crop residue to the soil with no-till or minimum-till techniques, can also increase the organic matter in the surface layers of the soil.

To raise crops, farmers usually remove the original plant cover and till the soil to make a seedbed. Crop cover is usually seasonal and less dense than natural cover. This provides less protection for the soil. Erosion by both wind and water may remove the finer and more fertile soil particles, reducing land productivity. Agricultural operations based on careful appraisal of soil, slope, and climatic conditions include erosion control and are compatible with successful watershed management.

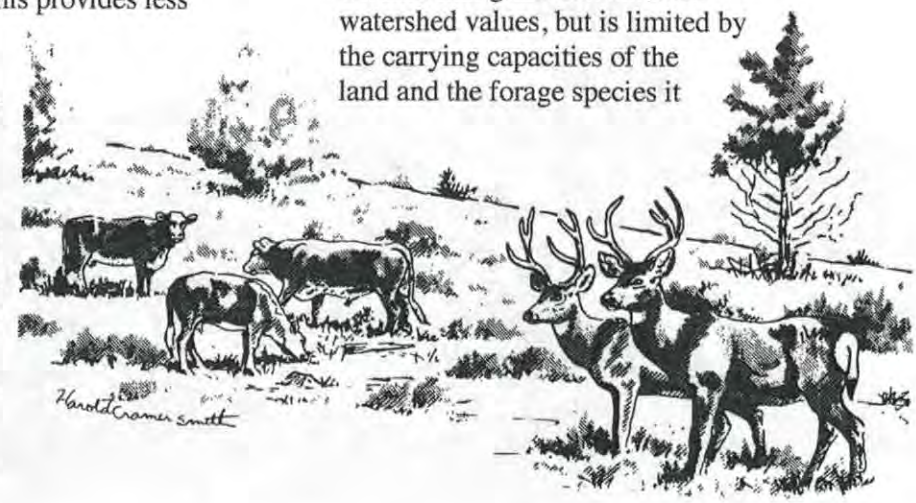
Livestock grazing

Many of the uplands in Oregon are used for livestock grazing. These rangelands are typically drier or less productive lands unsuitable for cultivated agriculture without irrigation. By their very nature rangelands support less plant cover and often have more exposed soil surface. Worldwide the greatest amount of erosion takes place in dry regions. Maintaining healthy rangeland watersheds requires good plant cover and good infiltration capacities. Overgrazing reduces plant cover and plant density, compacts soils, increases surface runoff, and increases erosion rates. Simply controlling livestock density and season of use is often enough to maintain vegetative cover.

Domestic livestock tend to concentrate in specific areas when grazing. Concentrated grazing impacts plant cover and soil. Grass cover can be improved by removing some of the annual growth, but forage productivity can be greatly reduced if overgrazing occurs. Improperly timed grazing, grazing too many animals, or grazing for too long can change vegetation over a period of years to species of lower value. Overuse of rangelands by native grazing animals can also seriously damage plant cover.

Excessive trampling by grazing animals can contribute to soil compaction, accelerated runoff, and erosion problems. Trampling can also help scatter seeds and mix them into the soil to create a new generation of plants.

Management of livestock and species of wildlife that graze can enhance watershed values, but is limited by the carrying capacities of the land and the forage species it



will support. Land managers must consider timing, density, and duration of animal use to capitalize on the positive aspects of grazing. Generally, recovery does not occur if vegetation is thinned to less than 70 percent of the natural cover. Without reseeding or other management practices to speed recovery, degradation will continue.

Fire

Fire is one of the most widespread and destructive agents affecting plant cover. Under certain conditions, fire can nearly remove cover and organic litter and, in extreme cases, sterilize and change the chemistry of the surface soil. Burning converts organic materials in plant cover, litter, and topsoil to gases and soluble, readily leached ashes that can make acid soils alkaline. Damage to soil varies, but it may take several seasons for soil conditions to return to normal.

Fire can be beneficial to a watershed when it is carefully managed.

Without a protective canopy and litter, force of falling raindrops may quickly seal the soil surface. Infiltration is greatly reduced, making runoff and erosion more rapid. Debris-laden floods often occur within fire-denuded watersheds during only slightly abnormal rainfall. Most of the water falling on a burned landscape is lost through rapid runoff.

Streams in burned watersheds at first carry heavy loads of salts dissolved from ashes, floating debris, and erosion sediments. Water quality may soon return to normal, except for sediment-laden high flows. Water levels fluctuate and become less dependable. These conditions may continue for several years until the plant cover becomes re-established on the watershed.

Fire can be beneficial to a watershed when it is carefully managed. It can reduce available fuel and prevent more destructive fires. Fire thins understory seedlings that compete with larger trees for available moisture. Open forest types—such as ponderosa pine—are maintained by fire.

Mining

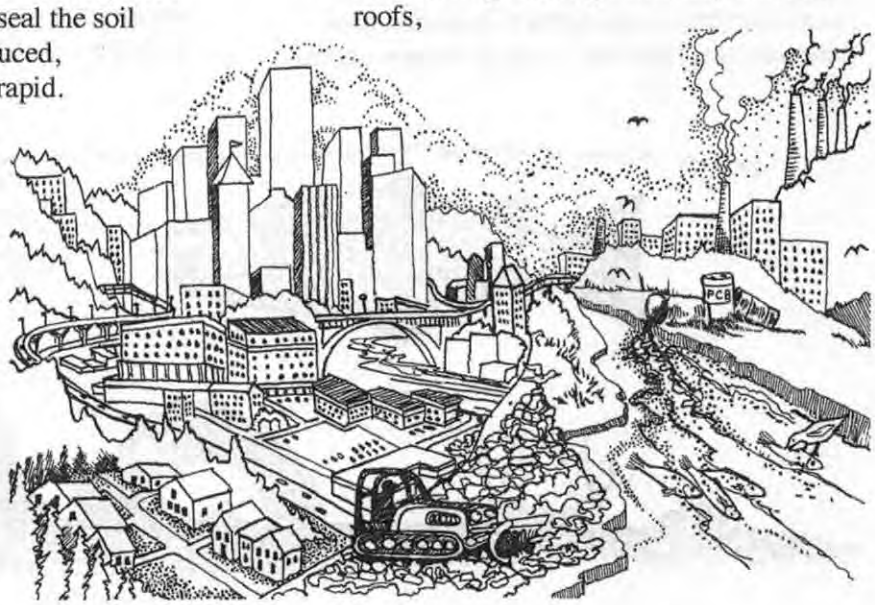
Mining requires opening the earth to remove mineral resources. It is done by stripping off the surface soil and rock layers or by drilling tunnels into the earth to reach minerals.

With either method, quantities of waste material are left on the surrounding land. This waste material is subject to erosion, adding to the sediment load of streams draining the mined area. Surface changes include altered topography and drainage. Drainage from mined areas may contain toxic mineral salts harmful to the aquatic habitat. To prevent degradation of the watershed, waste material disposal must be controlled.

Development

Urban development involves:

- clearing, leveling, and filling land surfaces,
- constructing buildings with impermeable roofs,



- paving roads and sidewalks with non-porous materials, and
- installing sewage disposal systems.

Such development greatly changes infiltration and runoff, reduces recharge to underground water, and increases runoff to produce rapidly fluctuating streamflows.

Communication and transportation developments include roads, railroads, airports, power lines, and pipelines. All of these may involve disturbance of plant cover, soil, and topography. Road and highway networks, with their impermeable paving and rapid drainage systems may radically change the runoff characteristics of their immediate area. They also require changing the natural topography and drainage, and moving huge amounts of soil and rock. Often these networks are responsible for extensive sediment production and may become the source of other water pollutants.

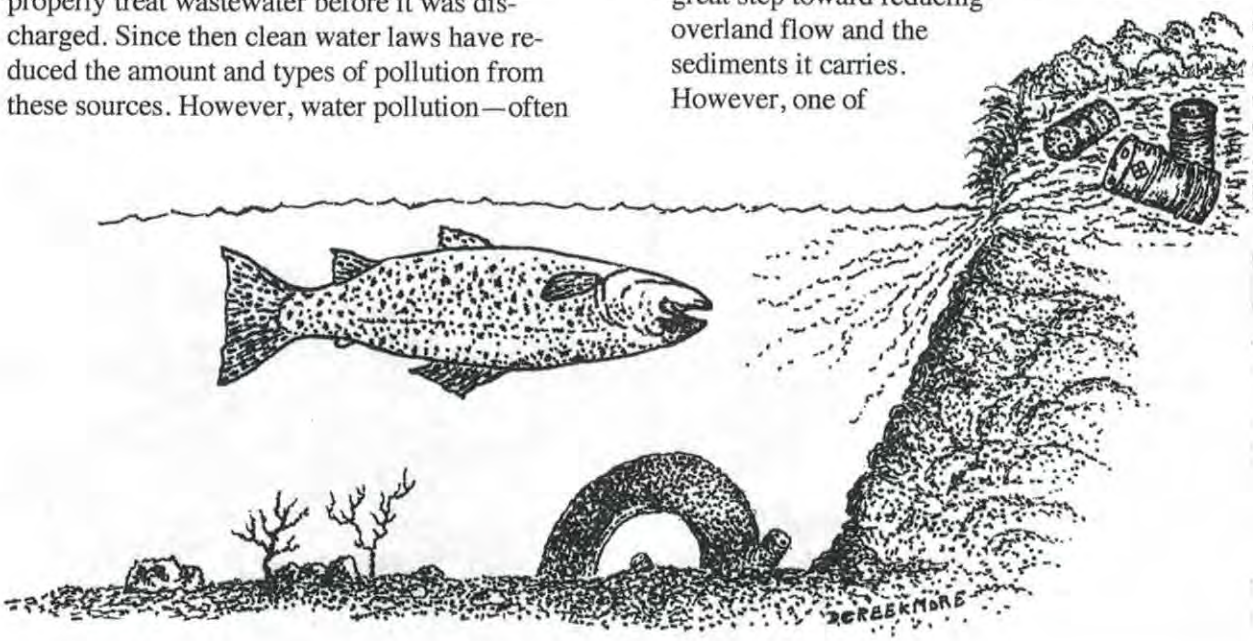
Railroads and airports have similar effects. Power lines and pipelines require open paths through the watershed and access roads for construction and maintenance.

Water pollution

Before the Clean Water Act of 1972 most of the nation's water pollution problems came from factories and sewage treatment plants that did not properly treat wastewater before it was discharged. Since then clean water laws have reduced the amount and types of pollution from these sources. However, water pollution—often caused by runoff carrying pollutants into surface waters—is still a problem. The federal Clean Water Act requires states to develop water quality standards and policies that are equal to or more stringent than federal standards. States are also required to identify those waters for which existing required pollution controls are not strong enough to achieve that state's water quality standards. These waters are considered **water quality limited.** For these waters, states are required to establish **total maximum daily loads** (TMDLs). TMDL standards are usually designed to protect the most sensitive beneficial use within a waterbody.

Point source pollutants are relatively easy to detect and treat.

One approach to dealing with pollutants from uplands is using **best management practices** (BMPs). BMPs describe practices that work for retaining soil and water on a particular piece of land under varying conditions. A number of BMPs have been identified for agriculture and forestry. Using these BMPs is a great step toward reducing overland flow and the sediments it carries. However, one of



the implications of the definition for "water quality limited" is that current BMPs are unable to provide the level of pollutant control needed to meet water quality goals. Meeting water quality goals on water quality limited streams requires efforts to control all sources of pollution in a basin.

Any specific body of water is classified by its desired uses. Water that is clean enough for irrigating crops may not be clean enough for fishing or swimming. Water that is clean enough for fishing or swimming may not be clean enough for household use.

High-quality water is described as cool, clear, clean, colorless, odorless, tasteless, oxygenated, free of floating and suspended materials, and carrying only limited amounts of dissolved materials. As quality is degraded, water is useful for fewer purposes.

Water quality problems are created when substances are added to water. Sometimes degraded water quality begins while rain is still in the clouds. This is the case with acid rain. Acid rain is formed when industrial and urban air pollutants mix with water vapor in the clouds.

Non-point source pollution is really a new name for an old problem—runoff and sedimentation.

This is especially true for photochemical smog caused by internal combustion gasoline engine emissions and industrial smokes. Rain from these clouds is acidic and damages plants, aquatic life, and manmade structures. Acid rain is a problem primarily in the eastern United States and Canada. The problem continues to grow, however, and the Pacific Northwest is not immune to the effects of acid rain.

Other pollutants might be added to water on the earth's surface. **Point source pollutants** enter waterways from a specific place or point. Common point source pollutants are discharges from factories, municipal sewage treatment plants, confined animal feeding operations (feedlots), and hot water discharges from power plants. This pollution is relatively easy to detect and treat.

Non-point source pollution, on the other hand, is really a new name for an old problem—runoff and sedimentation. Non-point source pollution runs off or seeps from large areas as a direct result of land use. It comes from a variety of sources such as agriculture, urban construction, residential developments, timber harvest, roadsides, and parking lots. Sediment, fertilizers, toxic materials, and animal wastes are major non-point source pollutants. The widespread source of these pollutants makes them more difficult to quantify and control than point source pollutants.

Non-point source pollution causes more than half the water pollution problems in Oregon. The effect of non-point source pollutants on water quality is variable. Some are potential health hazards for humans or harmful to fish and other aquatic organisms. Streams do have an absorption and disposal capacity for limited amounts of pollutants, but these limits are too often exceeded.

Non-point source pollution can also contaminate groundwater resources. When contaminated rain or runoff percolates through the soil it can carry pollutants into ground water. In this way non-point source pollution can affect both surface and sub-surface waters.

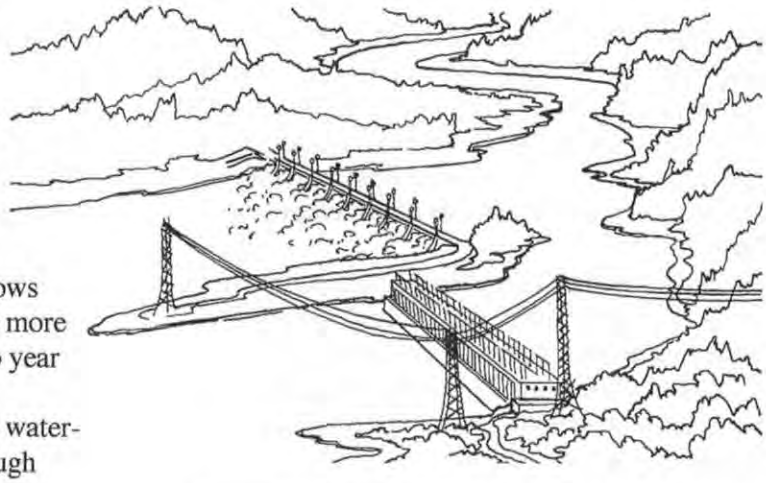
Dams and reservoirs

Flood control dams, lined stream channels, dikes and levees to restrict the spread of floodwaters, and channel bed stabilization techniques are all installations that modify channel capacity as well as the rate and volume of streamflow. All are the consequence of human efforts to modify water yields to better meet seasonal needs.

Dams are built and operated to do many things. They:

- control floods,
- store water for irrigation or other consumptive use,

- regulate flow for navigation, and
- provide power generation.



Effects of these structures on streamflow and aquatic habitat are similar no matter what they were built to do. **Impoundments**, if shallow, allow water to warm and, if deep, preserve cooler water. As streamflow peaks are reduced and low flows increased, streamflow generally becomes more regular from season to season and year to year regardless of climatic variations.

In many cases, reservoirs have added water-based recreation and new fisheries, although their construction may have destroyed stream habitat used by wild fish. A watershed under good management—where water storage occurs in the soils and **riparian areas**—lessens the need for reservoirs, particularly small headwater impoundments.

Water is often seasonally diverted from impoundments and streams for irrigation in agricultural areas. This reduces streamflows during the warm growing season. Some water is returned to the stream by drainage from the irrigated fields. These return flows are warmed and may contain soil salts, fertilizers, and pesticides leached from the fields.

A water right does not confer ownership of water but instead allocates who has the right to use it.

Water rights

The demand for water often exceeds the available supply. A legal system of **water rights** provides a system for allocating water. A water right does not confer ownership of water. Instead it allocates who has the right to use it. Water rights can be held by a person, group, business, or community. Instream rights provide for minimum flows to protect fish and wildlife.

The system of water rights differs across the country. In the eastern United States a water rights system called the **Riparian Rights Doctrine** is generally used. It gives people who own land adjacent to the stream the right to use water from it. In the more arid western United States a different legal system—**Prior Appropriation Doctrine**—developed. It gives the first person to put water to "beneficial use" the right to it, whether or not they own land adjacent to the stream. This "first in time, first in right," or "first-come, first-served" system of rights may also include rights to use groundwater.

Summary

The character and quality of a watershed is largely a product of the character and quality of its uplands. The keys to successfully managing a watershed to maintain the quality of its soil and water are "capture, store, and safe release"—capturing a raindrop where it falls, storing it safely in the ground, and releasing it to the stream slowly over time.

Covering the soil with a healthy layer of plants is vital in successful watershed management. Plants protect the soil from the force of falling rain and surface runoff. Plants also promote infiltration of rain into the soil. Water detained in the soil is available for plants and streams over a longer period.

Successful management of the soil and water resources of a watershed require careful management of human activities in the watershed. Human actions can potentially increase erosion, reduce infiltration, shorten the period that rainfall takes to drain from the basin, and can introduce pollutants into water resources. Careful management can reduce the effects of human actions.

Extensions

1. "Weather and Climate Investigation," *Watershed Uplands Scene*, pp. 89-108. Grades 9-12.
2. "Soils Investigation," *Watershed Uplands Scene*, pp. 109-124. Grades 9-12.
3. "Vegetation Investigation," *Watershed Uplands Scene*, pp. 125-144. Grades 9-12.
4. "Wildlife Investigation," *Watershed Uplands Scene*, pp. 145-162. Grades 9-12.
5. "Urban Investigation," *Watershed Uplands Scene*, pp. 167-182. Grades 9-12.
6. "Forestry Investigation," *Watershed Uplands Scene*, pp. 183-200. Grades 9-12.
7. "Recreation Investigation," *Watershed Uplands Scene*, pp. 201-222. Grades 9-12.
8. "Agriculture Investigation," *Watershed Uplands Scene*, pp. 223-244. Grades 9-12.
9. "Land Use Decision Making Investigation," *Watershed Uplands Scene*, pp. 249-259. Grades 9-12.
10. "A-Maze-ing Water," *Project WET*, pp. 219-222. Grades K-5.
11. "Capture, Store, and Release," *Project WET*, pp. 133-135. Grades 3-5.
12. "Just Passing Through," *Project WET*, pp. 166-170. Grades 3-8.
13. "Sum of the Parts," *Project WET*, pp. 267-270. Grades 3-8.
14. "Pass the Jug," "*Project WET*, pp. 392-396. Grades K-12.
15. "Perspectives," *Project WET*, pp. 397-399. Grades 6-12.
16. "Water Court," *Project WET*, pp. 413-420. Grades 6-12.
17. "Where Are the Frogs?" *Project WET*, pp. 279-286. Grades 6-8.
18. "Get the Ground Water Picture," *Project WET*, pp. 136-143. Grades 6-12.
19. "Irrigation Interpretation," *Project WET*, pp. 254-259. Grades K-8.
20. "A Grave Mistake," *Project WET*, pp. 311-315. Grades 6-12.
21. "The Pucker Effect," *Project WET*, pp. 338-343. Grades 6-12.
22. "Puddle Wonders," *Aquatic Project WILD*, pp. 114. Grades 2-12.
23. The patterns and effects of point and non-point source pollution can be easily demonstrated. To demonstrate point source pollution, place a wet paper towel on a slanted board. Put a small pile of brightly colored powdered drink mix near the lower edge of the towel. Slowly add water along the top of the towel. Observe the water that drains from the bottom of the towel.

    To demonstrate non-point source pollution place another wet paper towel on a slanted board. Lightly sprinkle brightly colored powdered drink mix across the entire surface of the towel. Once again, slowly add water along the top of the towel. Observe the water that drains from the bottom of the towel.

    A third demonstration can show the combined effects of point and non-point source pollution when they occur in the same watershed. Use two different colors of drink mix for this demonstration. The water draining from the bottom of the paper towel watershed will show both original colors and a third combined pollution stream.

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