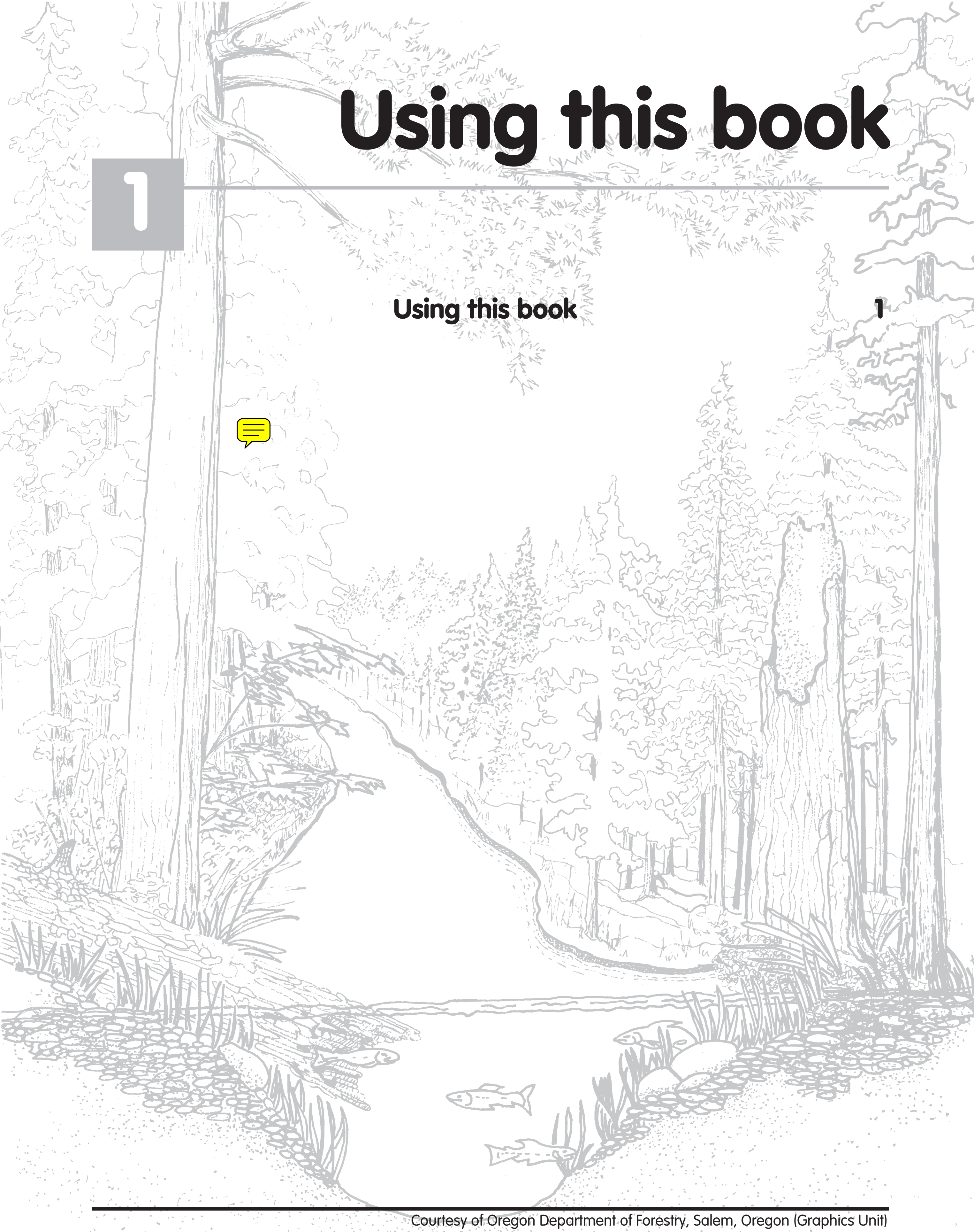
1 Using this book



Courtesy of Oregon Department of Forestry, Salem, Oregon (Graphics Unit)

Using this book

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"Life and water are inseparable . . ."
— David James Duncan

"Every river appears to consist of a main trunk, fed from a variety of branches, each running in a valley proportional to its size, and all of them together forming a system of valleys connecting with one another, and having such a nice adjustment of their descending slopes that none of them join the principal valley either on too high or too low a level; a circumstance which would be infinitely improbable if each of these valleys were not the work of the stream which flows in it."
Playfair's Law — John Playfair, 1802

A note from the authors

We thought we were on the cutting edge of watershed education when *The Stream Scene: Watersheds, Wildlife and People* began in 1985 at Corvallis (Oregon) High School. But John Playfair was far ahead of us, recognizing the basic features of a watershed and their implications in the early 1800s.

Human actions since Playfair's time have had huge impacts on this country's watersheds. We have dammed our rivers, logged our forests, farmed the bottomlands, grazed the hillsides, and developed nearly everything that's left—most without a clear understanding of the cumulative effects.

Today, Oregonians and others across the country are facing the problems created in our watersheds—problems with water supplies, problems with water quality, and problems with fish.

The Oregon Plan for Salmon and Watersheds, a grass-roots effort championed by Governor John Kitzhaber, is a call to all Oregonians, whether they live in a city, a suburb, or on a farm, to join the effort to save our salmon and protect our rivers. It represents commitments on behalf of government, organizations, and private citizens from all areas of the state—citizens who feel salmon, trout, rivers, streams, and watersheds are worth saving. The Oregon Plan began as a way to address declines in coastal salmon. It has now expanded into a comprehensive statewide approach to watershed protection that includes improvements in water quality and fish populations and an expansion of public consciousness.

Oregonians from all walks of life have focused their attention on watersheds.

As a result, Oregonians from all walks of life have focused their attention on watersheds—and the uplands, waterways, and fish in them. Restoration and recovery efforts are taking place in nearly every major watershed. Everyone is "getting their feet wet"—government agencies, businesses, private landowners, educators, students, and individuals. Everyone wants to help, but few know where to begin.

One place to begin a good watershed education is *The Stream Scene: Watersheds, Wildlife and People*. *Stream Scene* is a comprehensive look at watersheds from the top down. It starts with the water cycle, which drives the whole watershed system, and moves to uplands and riparian areas, hydrology, water quality, aquatic organisms, and lots in between.

Bruce Babbitt, U.S. Secretary of the Interior, in his address to Trout Unlimited on the event of their 40th birthday, confirmed the need for learning about watersheds:

> To protect wild salmon and trout, we must transcend traditional boundaries. After all, no stream—and no trout or salmon species—can be healthy if the land around it is sick. Moving water is a mirror of its surroundings. To save salmon and trout, we must heal the land itself. We must dream big dreams; we must think like a watershed.
>
> Thinking like a watershed means realizing everything counts, that all parts of a watershed are connected. It means seeing linkages—understanding the science of stream health. . . .
>
> Thinking like a watershed is about possibilities, too—about imagining the future by rediscovering the past. . . . Many say it can't be done. But I have a simple reply: It is happening already.

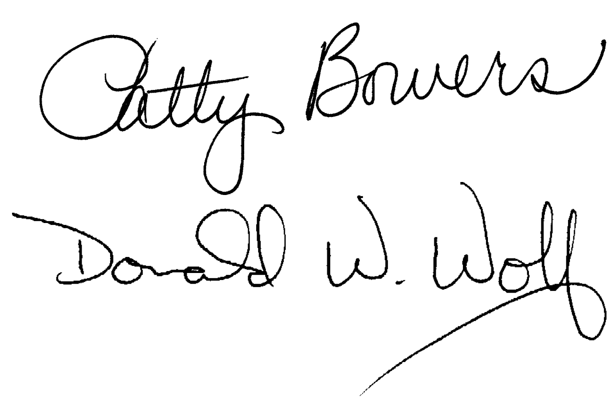
And the reason it's happening is because local individuals, organizations, educators, students, and others care enough to find a way to make a difference. Watershed education, whether community-based or school-based, is successful because each one of us has a deep-seated need for a "sense of place." A "sense of place" is an awareness of who we are. It is recognition of our role in a community, a role that may take the form of participation in a watershed council, watershed education, or watershed stewardship as a caretaker of the land on a ranch or farm.

Put a local map in front of someone and watch them point out where they live. That's a sense of place! Revisit your hometown and drop by your old school. That's a sense of place! Relive special wading, angling, or rafting experiences and recapture the connection you felt with those streams. That's a sense of place! A sense of place is also taking responsibility for shaping the future of a community, making personal choices to reduce our impacts on natural resources, and volunteering time and more just because it makes a difference.

Now, in Oregon and across the country, a sense of place is about watersheds. Watersheds have boundaries, but watershed education does not. Watershed education is for young and old, housewives and technical specialists, ranchers and developers. People, all kinds of people, are an integral part of watersheds. Michael Dombeck, chief of the U.S. Forest Service, described this human connection in a 1997 speech:

> Healthy watersheds retain historic flows and are resilient in the face of natural events such as floods, fire, and drought and are more capable of absorbing the effects of human-induced disturbances. They connect headwaters to downstream areas, wetlands and riparian areas to uplands, and subsurface to surface flows.… We simply cannot meet the needs of people if we do not first secure the health of our watersheds.

We hope *Stream Scene* is a meaningful guide as you develop a "sense of place" and watershed responsibility in your students, school, and community.



Active Learning

The Stream Scene: Watersheds, Wildlife, and People is a curriculum guide to basic knowledge about watersheds. It encourages responsibility, action and community involvement.

Activities in *Stream Scene* are largely designed for middle and high school students, but each activity suggests ways to adapt the concepts for younger students. Adult learners also benefit from the background material and activities in *Stream Scene*.

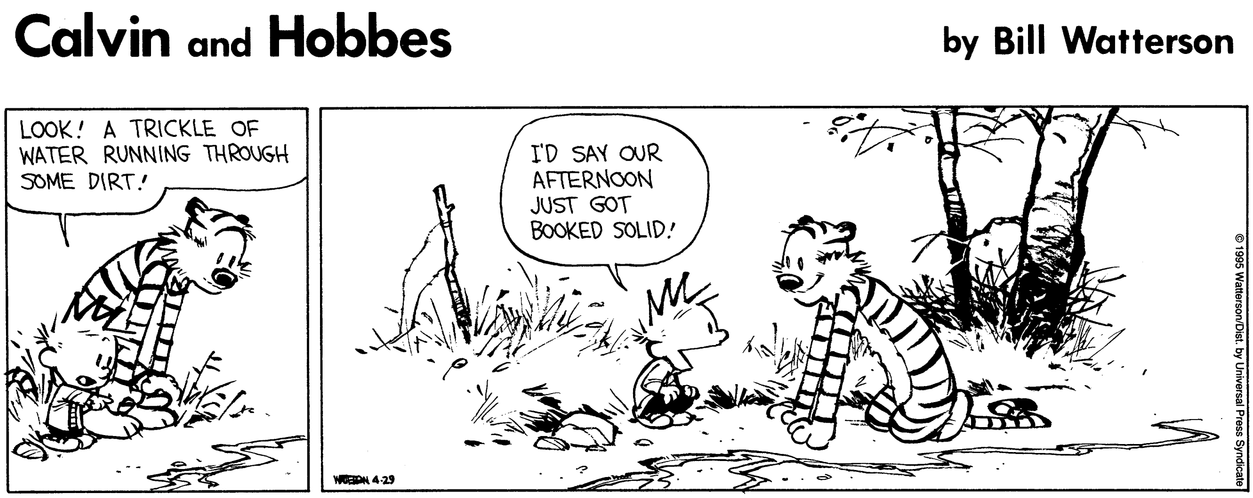
Each chapter provides teachers with clear, up-to-date background information. Chapter content is suitable for student reading or it can be outlined and used in a lecture or discussion format. Some sections are more technical than others. Evaluate the reading level before assigning student reading.

Other chapter features include a vocabulary list of key words, activity extensions, a bibliography, and student activities to develop and expand the concepts presented in the chapter.

Extensions, found at the end of each background section, include activities from other water and watershed education curriculum, including *Aquatic Project WILD*, *Project WET*, *Earth: The Water Planet*, *Groundwater: A Vital Resource*, *The Comprehensive Water Education Book*, *Watershed Uplands Scene*, and others. Educators can strengthen a student's watershed education experience by incorporating ideas from the extensions list. For copies of extension activity curricula, refer to the starred items in Chapter 14.4 of the resources section beginning on 519. You will also find sources of equipment, reference books, posters, and more in this section.

Activities are presented in both "teacher" and "student" versions. Teacher versions include objectives, methods, suggestions for younger students, materials lists, vocabulary, answer keys, notes to the teacher, and scientific inquiry ideas.

Ideally *Stream Scene* studies will lead to a series of field investigations. Classroom activities used without a field experience are generally effective, but to develop the connections hinted at by Babbitt, Dombeck, and others, students need to become "part" of their watershed. Only by studying its history, its future, its problems, its successes—totally immersing themselves in the reality of *their* watershed—can students develop the "sense of place" that translates into responsibility, action, and stewardship. Suggestions for field investigations begin on page 439. Begin with these procedures, but encourage students to ask questions and develop further investigations in their watershed. Brainstorm a list of individuals who can provide professional and technical resources. Invite them to visit your class or study site to share their knowledge. Once students are proficient and accurate with stream sampling methods, opportunities may exist to assist with local watershed monitoring efforts. Look into a



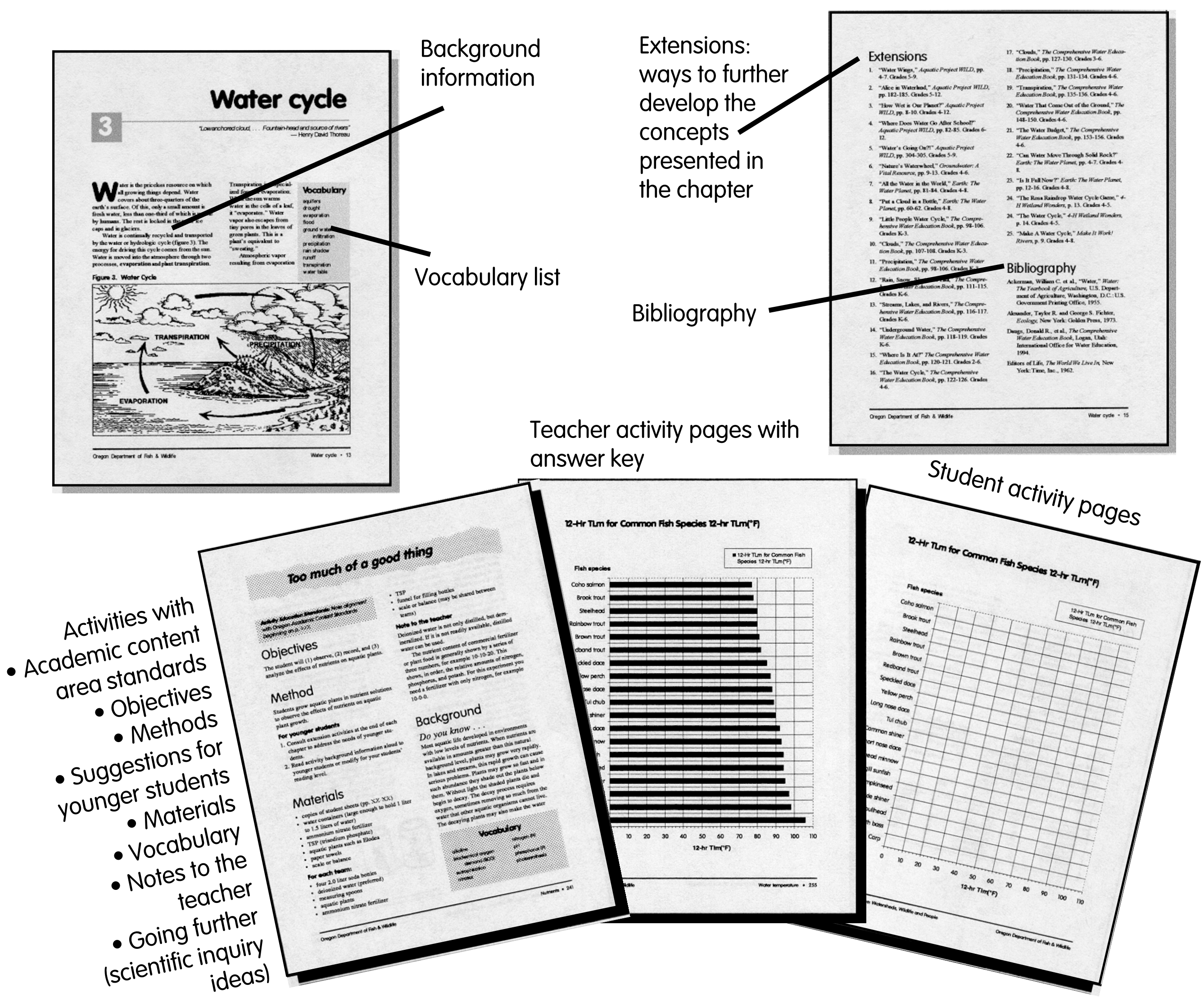
partnership with your local watershed council and encourage student participation in the watershed council process. Students can become an important part of what is happening in their watershed.

Assigned teams in a half-day field trip can complete all of the field investigations included in this book. Hopefully, you and your students are not limited to a single half-day field exercise. The more numerous and more varied the activities in the watershed system, the richer the experience for the students. Find ways to help them get their hands dirty and their feet wet. It's all part of effective watershed education.

In most cases the standard English system of measurement is used throughout *Stream Scene*. Refer to pages 511 for metric conversion tables.

Other helpful tools found in *Stream Scene* are hints for "make and take" field equipment, information about Oregon's Salmon-Trout Enhancement Program (STEP), field data collection sheets, other curriculum resources, websites, watershed council contacts, a glossary, and more.

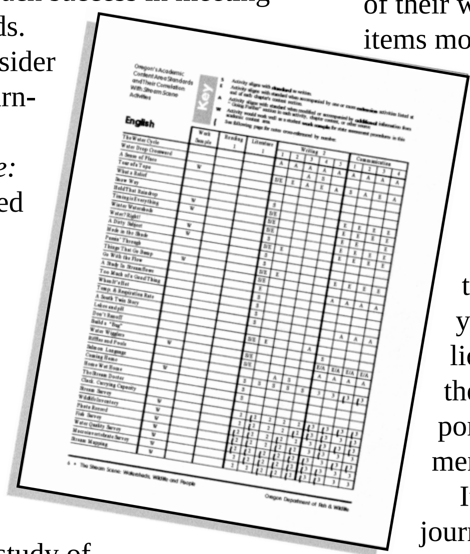
Because a number of Oregon's fish species are classified as threatened species under the Endangered Species Act (ESA), certain conditions and guidelines apply to fish sampling or habitat restoration work. When considering fish sampling or habitat restoration work as part of your watershed study, contact the nearest Oregon Department of Fish and Wildlife (ODFW) office to discuss your ideas with a STEP biologist or local fish biologist. Refer to the map and addresses in Chapter 11.



Meeting Oregon's education standards

An important part of each Stream Scene activity is its correlation with Oregon's academic content area standards. *Stream Scene* can help your students meet standards for English, science, social studies, math, and career related learning. Refer to the correlations in Chapter 13 beginning on page 483.

An important feature of each activity is the "Going Further" section. "Going Further" is a list of inquiry-based activities. Most of these suggestions will help students reach success in meeting scientific inquiry standards.



So, what's next? Consider using the self-directed learning approach outlined in *Watershed Uplands Scene: Catching The Rain*. Funded by the Governor's Watershed Enhancement Board and created by Kate Ferschweiler, Kermit Horn, and Al Hughes of the Environmental Education Association of Oregon, this program helps high school students dig deeper into the study of watersheds. Students work as part of independent study teams to explore the interdependencies among weather and climate, soils, vegetation, and wildlife in a watershed. The next level of study looks at human uses of a watershed—the social impacts and processes that affect land uses such as urban, forestry, recreation, and agriculture. Finally, students tie all they have learned together in a land-use decision-making investigation. Using activities from the *Watersheds Uplands Scene* is also a good way to help older students meet Oregon's education benchmarks. To get a copy of the *Watershed Uplands Scene*, consult the resources section on page 530.

For more information about ODFW's watershed education program and the annual Creeks and Kids workshops, contact the Aquatic Education Program Leader, Oregon Department of Fish and Wildlife, PO Box 59, Portland, OR 97207, (503) 872-5264 ext. 5366.

Suggestions for student assessment

One way students can monitor their progress toward achievement of the statewide education benchmarks is to create and maintain a portfolio of their work. A portfolio is a collection of work items most representative of a student's skills and accomplishments. It lets students and others track their progress, share what they have learned with others, and offers a way for students to value their own work.

Allow students to choose the items that go into the portfolio. Encourage your students to personalize their portfolio and update it regularly to represent their best work. Provide models of good portfolios and standards for their assessment.

Items in the portfolio might include journal entries, field data reports, artwork, creative writing, graded activities, related newspaper clippings or magazine articles, or any other evidence of participation in watershed education studies. Students should also include their own personal thoughts about the significance of any part of the portfolio or the community effects that may be realized as a result of student involvement in watershed issues.

Journal entries, as part of a portfolio, help students evaluate the benefits they have gained from their watershed education experiences. Journal entries might include:

- descriptions of new knowledge and skills they have gained;

- scenarios that assess their ability to clearly express ideas, think critically, revise previous thoughts, and expand understanding;
- activities or data reports that demonstrate their ability to develop a problem-solving process, analyze data, and draw conclusions;
- student explanations of how information they have learned is tied to other disciplines (i.e., English, math, social studies, science, career-related learning); and
- their feelings about the unit of study, how it might affect their future involvement as an adult in a community, and a self-evaluation of their effort and progress.

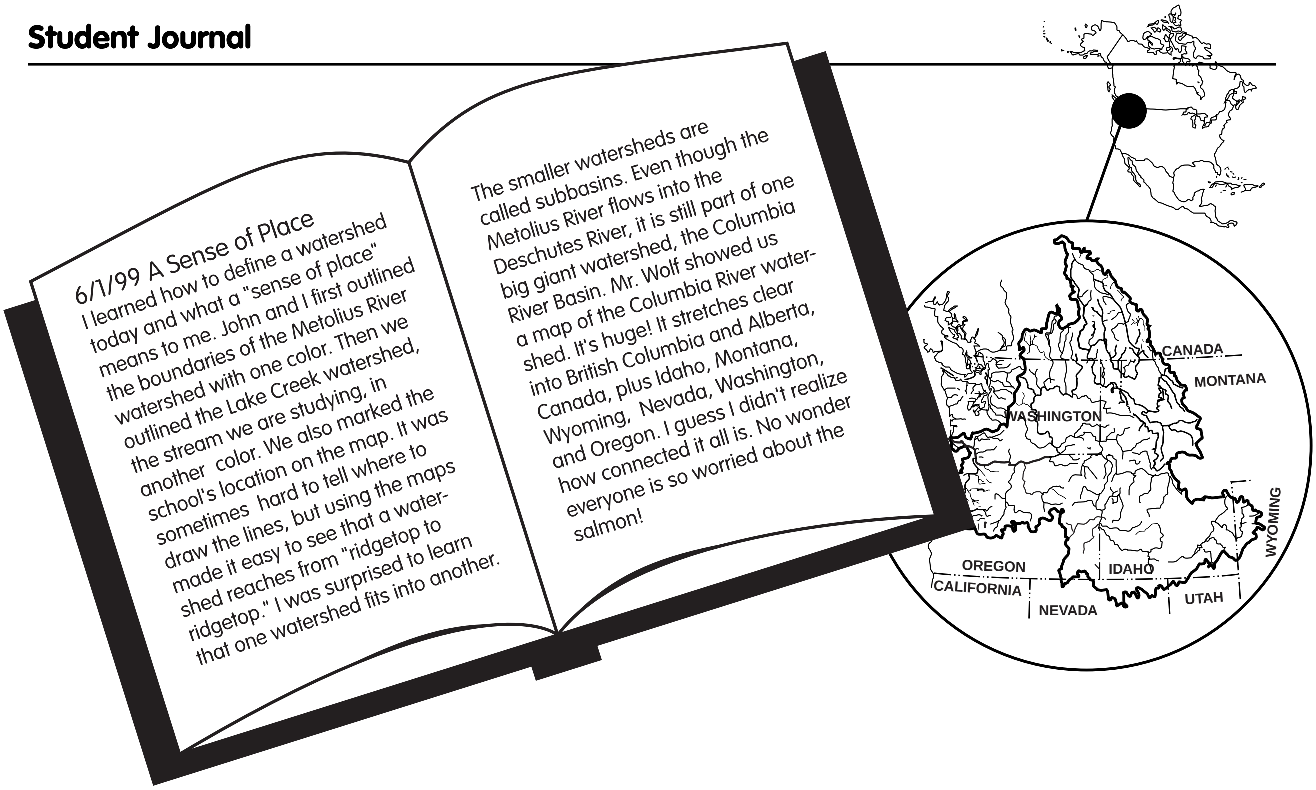
Evaluate a student's portfolio to the extent it demonstrates:

- a variety of writing skills
- comprehension of watershed concepts
- a progression of skill development (expressing ideas, critical thinking, revising thoughts, problem-solving, data analysis, drawing conclusions) from the beginning to the end of the watershed unit
- an appreciation for watersheds
- student understanding of issues affecting their watershed
- a sense of responsibility toward natural resources
- a self-evaluation of progress; and
- pride in one's work.

Collaborate with teachers in other disciplines to help students connect the study of watersheds across the curricula. Assessments provided by teachers in other subject areas will reinforce these connections for your students.

Portions of the "Suggestions for student assessment" section are adapted from the *Rivers Curriculum Project,* Southern Illinois University, Edwardsville, Illinois.

Student Journal



Example journal entry ideas

Activity Name ____

Describe what you did in this activity.

What did you expect to learn or discover during this activity? What new skills did you gain or improve?

What part of the activity was most important? Why?

What was the most enjoyable? What part was most useful?

What is the next logical question that could be answered by continuing this activity? What happened during the activity that caused you to ask this question?

Look at your question above. Design an investigation that would answer the question. Make sure the investigation is safe and can actually be accomplished.

Next, design a data or recording form to record the results of your investigation.

List the possible outcomes of your investigation. Answer your original questions for each of the outcomes.

How have your skills in other subject areas (English, math, social studies, etc.,) helped you with this activity?

How have you become more aware of watersheds during this activity? How has this affected your attitude about the environment in general and about watersheds specifically?

How would you rate your effort and personal progress in this activity? Explain.

Acknowledgements

The Oregon Department of Fish and Wildlife would like to thank the many people who contributed directly and indirectly to this work, including co-writers and editors Patty Bowers and Don Wolf; layout and design editor Anne Merydith-Wolf; graphic artists Sharon Torvik and Dave Creekmore; contributors Rosanna Mattingly, former district fish biologist Errol Claire, OSU aquatic entomologist Judy Li, OSU stream ecologist Stan Gregory, former STEP biologists Dennis Wise and Wayne Bowers, BLM riparian specialist Wayne Elmore, former U.S. Forest Service hydrologist Bruce Anderson, *Clearing* editor Larry Beutler, Oregon Department of Education natural resources specialist Don Sligar, Monument High School Stream Team leader Ron Gaither, Michael Goodrich of Geoquest Publications, Carolyn Hensley Johnson of Yamhill-Carlton High School, Patrick Griffiths of Pilot Butte Middle School, and current and former ODFW representatives Nancy MacHugh, Tony Faast, Bill Hastie, Shann Weston, Steve Andrews, and Rich Berry.

We would also like to thank the Oregon (formerly Governor's) Watershed Enhancement Board for their continued support and funding to complete both the original and current *Stream Scene* publications as well as base funding for the annual Creeks and Kids workshop program.

The following educational and technical reviewers provided key input throughout development of the Watershed Education project:

A: Bill Alexander, Betsy Anderson, Bruce Anderson, John Anderson, Tori Anderson, Steve Andrews, Kathy Aplin, Margaret Armstrong, **B:** Bill Bakke, Howard Barbour, Mary Barnhart, Hugh Barrett, Kim Bauer, Neil Bauer, Thomas Bedell, Jerry Belcher, John Benneth, Ken Bentz, Linda Bermbach, Rich Berry, Phill Bestor, Jerry Booth, Patty (Farthing) Bowers, Wayne Bowers, George Brown, Stephen Brownfield, Robert Buchanan, John Buckhouse, Bob Buscher, Cheryl Butler, **C:** Larry Callister, Suzanne Campbell, Jane Capizzi, Ruth Carpenter, Jeanne Carver, Dale Champion, Errol Claire, Mitch Coleman, Jo Cooper, Gail Cordell, David Cunningham, Lloyd Curtis-Cunningham, **D:** Lori Daniels, Susan Daugherty, Donna DeForest, Susan Derry, Rita Dick, **E:** Susanna Epler, **F:** Tony Faast, Jamie Fereday, Kathryn Ferge, Lynne Ferguson, Jim Fisher, Ruth Foster, Bob Fowler, Jerome Fulton, **G:** Kate Gillow-Wiles, Rebecca Goggans, Michael Goodrich, Fred Gonzales, Patrick Griffiths, David GrosJacques, Stephanie Gunckel, **H:** Mary Hanson, Linda Harrington, Elaine Harris, Leia Hart, Bill Hastie, Lydia Hayes, Marc Held, Scott Heller, Bob Heinith, Carolyn Hensley-Johnson, David Hill, Howard Hoffer, Karen Holland, John Houston, Lin Howell, Al Hughes, Georgine Hultz, Kirk Hutchinson, **I:** George Ice, **J:** David Johnson, Leslie Johnstone, **K:** Dale Kirk, Joe Koziol, **L:** Lori LaMarche, Andy Landforce, Jon Lea, Larry Lee, Judy Li, Jack Lowers, Dave Luman, **M:** Nancy MacHugh, Bruce Macke, Donn Maier, Neal Maine, Dierdre Malarkey, Grant Martinsen, Randi Maxfield, LaDona May, Bob Metzger, Judy Miller, Jeff Mitchell, John Monfore, Richard Myers, **N:** Bob Naidis, Dawn Kori Nearing, Jane Newton, Victor Noble, **O:** Jim O'Connell, Tom Ortman, Cara Osmin, **P:** Stephen Pauls, Bill Peal, Linda Pelroy, Ralph Perkins, Bob Phillips, Traci Pinkal, **R:** Mary Rellergert, Janell Renoud, Mary Roberts, Ralph Rogers, Fay Rust, **S:** Glen Schmidt, Marylou Schnoes, Ed Schwartz, Clark Seeley, Linda Segal, Linda Serbus, Don Sligar, Twyla Smith, Margaret Stabler, Steve Stanhope, Michael Stebbins, Carol Svoboda, Gail Sykes, **T:** Clair Thomas, Pat Thompson, Dan Tilson, Vivienne Torgeson, Van Tribble, **V:** Xavier Valdes, **W:** Shann Weston, Robert Wille, Steve Wille, Lynn Wilson-Dean, Ted Wise, Karen Withrow, Don Wolf, Fred Woods, Bill Wysham, and **Y:** Jon Yoder.

The Stream Scene

Watersheds, Wildlife and People

Second Edition

WATERSHED EDUCATION PROJECT

An Aquatic Education Program Publication
Distributed by Oregon Department of Fish & Wildlife
P.O. Box 59
Portland, OR 97207

This publication was partially funded through the Oregon Department of Fish and Wildlife Aquatic Education program. The program is funded by the 1984 Wallop-Breaux Amendment to the Federal Aid in Sport Fish Restoration Act of 1950. Funds are derived from a ten percent tax on fishing and boating equipment and supplies. The funds are distributed to state fish and wildlife agencies based on the number of fishing licenses sold in that state. Seventy-five percent of the Oregon Aquatic Education program is financed from this source, a sum of $293,975 in fiscal year 1999.

Funds for pilot testing the original curriculum and for completing the 1999 revisions were provided by the Governor's Watershed Enhancement Board through ORS 541.350 through ORS 541.395. Technical review and classroom field testing occurred from 1988 to 1990.

Additional funding and classroom and field support for trained teachers has been provided by the Salmon-Trout Enhancement Program (STEP) of the Oregon Department of Fish and Wildlife.

Authors

Patty (Farthing) Bowers
Don Wolf
Bill Hastie
Shann Weston

Contributors

Tori Anderson
Steve Andrews
Rich Berry
Wayne Bowers
William Bullard
Dave Courtney
Tony Faast
Michael Goodrich
Patrick Griffiths
Carolyn Hensley Johnson
Al Hughes
Eldon Korpela
Judy Li
Nancy MacHugh
Rosanna Mattingly
Judy Miller
Linda Pelroy
Marta Turksel
Dennis Wise

Layout & Design

Anne Merydith-Wolf

Illustration

David Creekmore
Sharon Torvik

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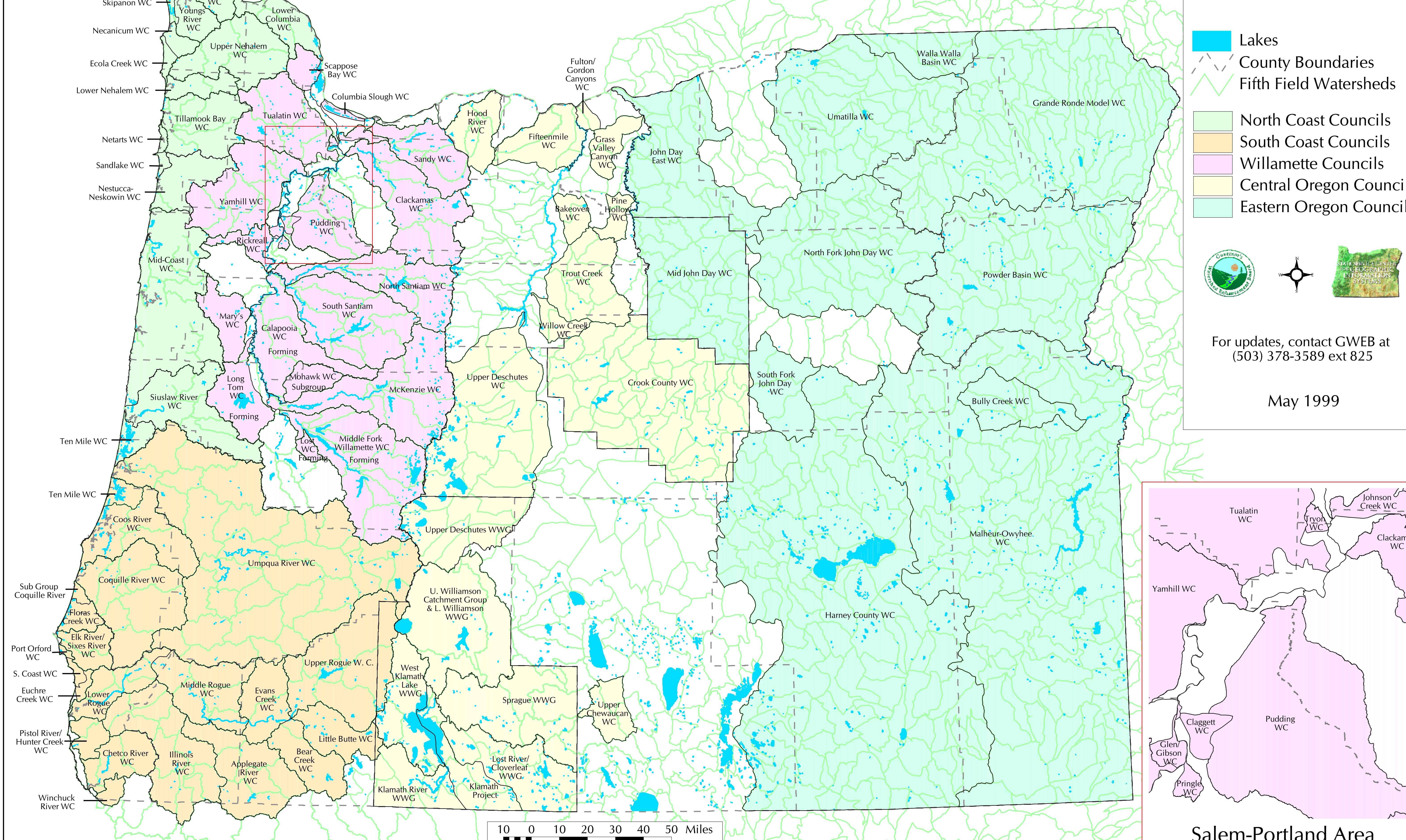
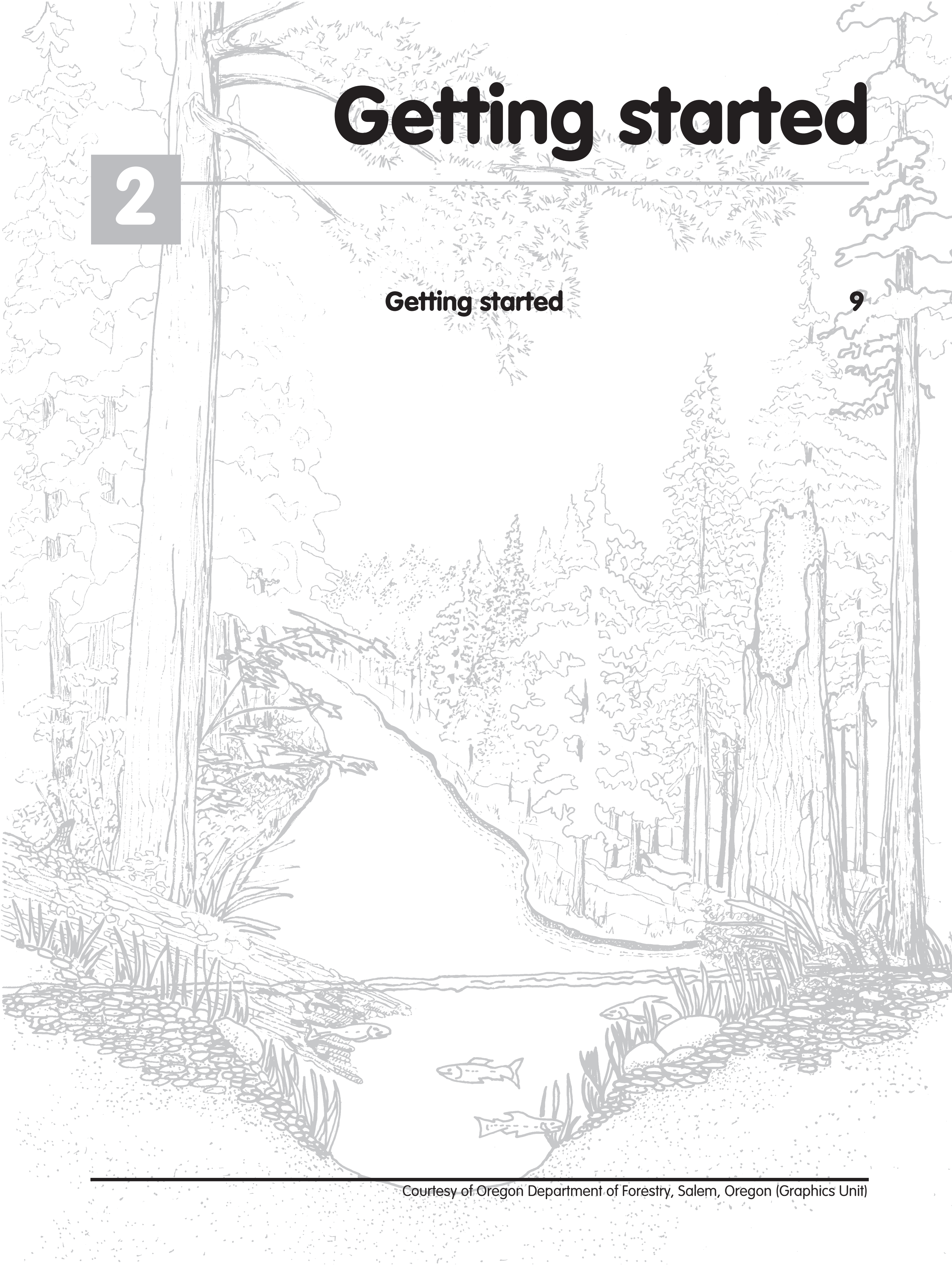
Oregon Watershed Council Boundaries



2 Getting started



Courtesy of Oregon Department of Forestry, Salem, Oregon (Graphics Unit)

Getting started

2

"Water is the great driver of nature"
— Leonardo Da Vinci

While the statement "all life depends on water" may seem obvious, it is the unique properties of water that allow life to exist on this planet. Most of the physical properties of water are unique to water.

Properties of water

Throughout the universe most matter exists as hot gases or frozen solids, but the earth is almost entirely covered with liquid. Within the huge range of possible temperatures, water exists as a liquid for only a relatively few degrees. It is this small temperature range that is most suited to life as we know it.

Water's density as a solid is less than it is as a liquid. This unique property allows ice to float.

The world's rivers act as pipelines for dissolved and suspended materials.

Water freezes first on the surface where heat is lost at the greatest rate by conduction, radiation and evaporation. Surface ice forms an insulating layer over water, and life can continue beneath it throughout the winter. In some instances, heavy ice along the edges of streams can be harmful to aquatic organisms, especially juvenile fish.

Water has the greatest ability to store heat (specific heat) of any liquid. This means it can absorb or release large amounts of heat without much change in its own temperature. For plants and animals living in water, temperatures change more slowly than on land. Water's moderating effects keep land near water warmer at night and during the winter, and cooler during the day and in summer.

Water is often called the "universal solvent" because of how easily most solids, liquids, and gases can dissolve in it. Not only do the world's rivers move water over long distances, they also act as pipelines for dissolved and suspended materials. Most aquatic organisms can survive in water only if it contains enough dissolved oxygen to satisfy their requirements. Nutrients transported by water make the rich variety of aquatic life possible.

Photosynthesis, the basis of most life, is a complex reaction involving carbon dioxide, water, chlorophyll, and light to form carbohydrates and oxygen. It can take place in water because of the dissolved carbon dioxide and water's unique transparency.

Demands on water

Weather and climate patterns replenish each watershed's water supply. Oregon's weather and climate patterns are largely controlled by the moderating influence of the Pacific Ocean and the effects of the Coast and Cascades mountain ranges on precipitation. Because of the endless movement of water through the water cycle, the amount of water in existence in Oregon and elsewhere is constant. But the amount of water available for use is limited. Demand for water continues to grow. Whatever amount is available to humans and wildlife depends on the quality that is maintained. Increasing numbers of users and uses place demands on our water resources. Competition and conflict will occur

In western Oregon, 200 communities currently obtain at least a portion of their water supply from municipal watersheds. Increasing population and per capita water use create greater demands.

Forestry

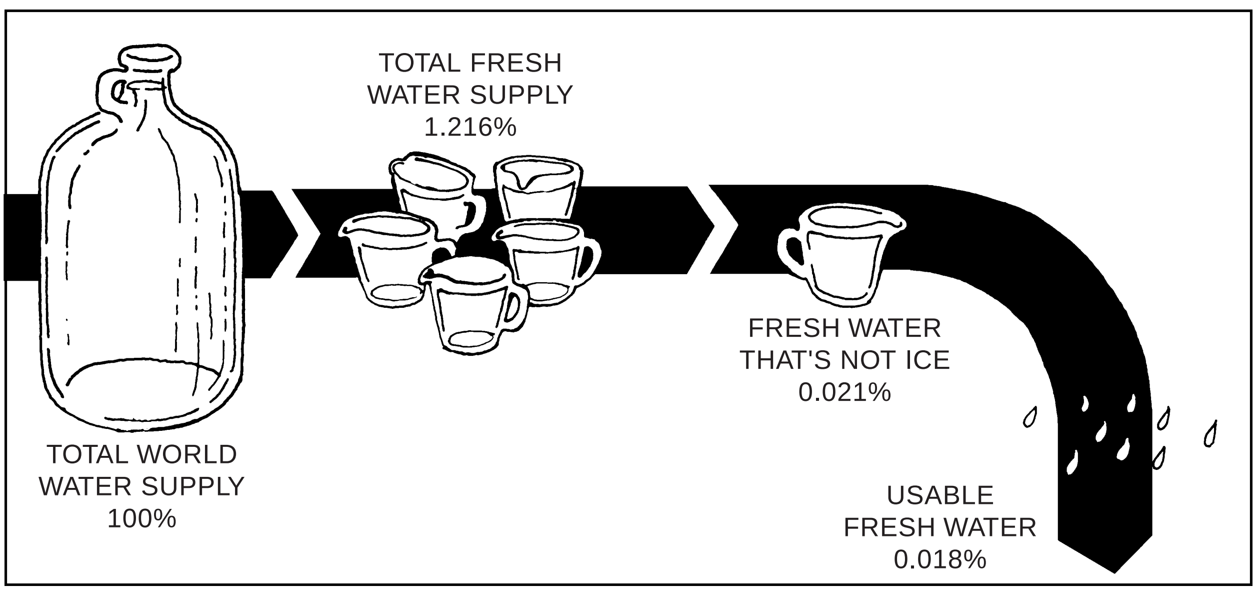
Forest practices and their impact on riparian (streamside) and upland environments are a frequent source of controversy. The size of riparian management areas left when logging near streams, the role of old-growth forests in water quality, and the impacts of timber harvest and road building on forested watersheds are public concerns. While not all issues have been resolved to everyone's satisfaction, improvements have been made. State Forest Practice rules regulate forest operations near streams and are designed to protect water quality as well as fish and wildlife habitat.

Agriculture

Riparian vegetation is often removed to the stream's edge to create more agriculturally productive land. Plant loss weakens streambank structure, lowers the water table, and could contribute to loss of valuable land during high flows. Additionally, sediment loads increase when unprotected banks are eroded by water. Soils and plants in healthy watershed capture and store precipitation and release it to a stream over time. Long term soil loss reduces the watersheds ability to hold and provide water for cropland and rangeland plant growth.

In many parts of the country, demand is growing more rapidly than aquifers can recharge.

Figure 1. World's Water Supply



Agricultural water use is not immune to controversy. Humans have irrigated crops for more than 6,000 years. Today, slightly less than one-half of all water used in the United States is for irrigation of various food and fiber crops, livestock, and livestock feed. In many parts of the country, demand is growing more rapidly than aquifers (underground reservoirs) can recharge. In some areas of Oregon, restrictions have been placed on new well drillings to reduce the rate at which local aquifers are being depleted.

Nationwide, the amount of water used by industry is about equal to that used for domestic purposes.

Grazing is another agricultural practice that may affect riparian areas. Grazing in riparian areas allows short-term economic return from rangeland. If livestock or wildlife concentrate near cool, green waterways and remove too much vegetation, the result can be increased erosion and decreased water retention.

Many central, eastern, and southwestern Oregon streams, once perennial, are now dry during the summer months. Without vegetation, unchecked spring runoff has eroded once stable streambanks to deep cutbanks, lowered the water table, and dried out formerly green lowland pastures.

Brush, particularly juniper, is rapidly spreading onto the uplands in central and eastern Oregon. It has drastically affected summer streamflows by intercepting surface water before it gets to the riparian areas.

Encroachment of brush on the uplands coincides with human management schemes. For example, fire suppression and overgrazing have allowed brush species to overtake areas where a mix of perennial bunchgrasses and brush species were co-dominant. The loss of grasses prevents fire from controlling the brush.

Some eastern Oregon streams are again perennial because of brush control and maintenance of mixed vegetation, including good grass cover on upland areas. This clearly shows the health of streams is interwoven with the health of upland and riparian areas.

Industry

Many industries use large amounts of water in processing and manufacturing. Nationwide, the amount of water used by industry is about equal to the amount used for domestic purposes. In the Pacific Northwest, large quantities are also put to use in production of electricity at hydroelectric plants. Power produced by these facilities is relatively pollution-free and inexpensive when compared with coal, diesel, or nuclear power sources.

Adequate facilities for upstream migration of adult fish and downstream passage for juvenile fish around dams are critical. Fish populations, as well as jobs and industries that rely on fisheries are at stake. Fish hatchery production replaces part of the fish lost to dam passage mortality and degraded spawning areas. Ultimately, the goal is to achieve and maintain naturally reproducing fish populations at levels similar to historic levels.

Urban areas

Urban development significantly impacts riparian and upland areas. Development includes filling and altering stream channels, removing vegetation for construction, and building roads. Pollutants from residential and commercial sites and roadways find their way into streams, adversely affecting water quality and aquatic organisms, especially fish and invertebrates. Increased loss of wetlands and groundwater recharge areas continue to significantly alter levels of urban streams.

Recreation

As population and leisure time increase, demand for water-based recreation also increases. While proper planning can provide some types of recreation and clean water for other uses, conflicts occur over how, and how much, water should be allotted to each use.

Fish and wildlife

Within each watershed are many species of wildlife. Beaver live in streams, elk move among many different watersheds, insects might never leave a watershed, birds may fly thousands of miles to live their lives in other watersheds during different parts of the year, and many more. Each of these animals requires food, water, shelter and space from the watershed.

Populations of different wildlife species within the watershed vary from season to season and from year to year. These variations may be natural, like migration and predation, or the result of human management, like hunting seasons.

Each species has an impact on the watershed. Some impacts are quite direct, as in the case of burrowing animals, beavers, or fish. Others are less direct.

Healthy populations of fish and wildlife depend on water. They provide recreation and aesthetic values and are an indicator of overall environmental health. Fish and wildlife habitat needs are frequently threatened by the needs and desires of other user groups.

Vegetation

Growth of vegetation in the watershed depends on many factors. Starting with soil from which plants draw nutrients and water required for photosynthesis to the slope on which they grow, each factor is some way affects the type and density of plant life. Soils within a watershed can vary greatly, resulting in differing amounts of plant nutrients and differing materials for root support. Climate determines temperature and rainfall and influences which plant species and plant associations can survive.

Interdependence

It is important to note the complexity of the entire watershed system. All components—weather, climate, soils, water, plants, aquatic and terrestrial organisms—are bound by a tight web of interdependence. A disturbance in one part may be reflected throughout the entire system. It is equally important for us, as managers of watersheds, to be aware of these relationships, and to take full responsibility for wise management of this valuable resource.

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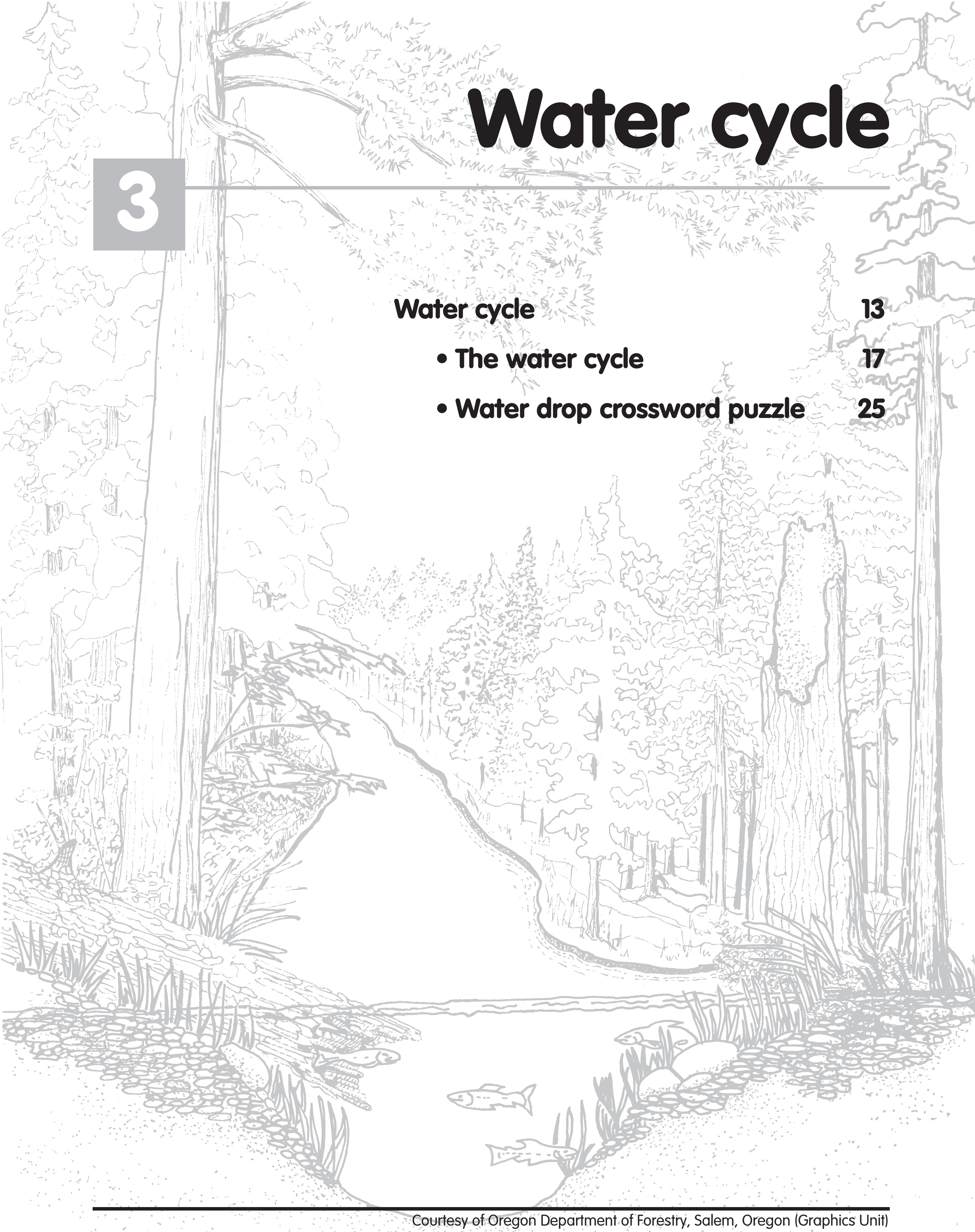
Water cycle

3



Courtesy of Oregon Department of Forestry, Salem, Oregon (Graphics Unit)

Water cycle

3

"Low anchored cloud,… Fountain-head and source of rivers"
— Henry David Thoreau

Water is the priceless resource on which all growing things depend. Water covers about three-quarters of the earth's surface. Of this, only a small amount is fresh water, less than one-third of which is usable by humans. The rest is locked in the polar ice caps and in glaciers.

Water is continually recycled and transported by the water or hydrologic cycle (Figure 2). The energy for driving this cycle comes from the sun. Water is moved into the atmosphere through two processes, **evaporation** and plant **transpiration**.

Transpiration is a specialized form of evaporation. When the sun warms water in the cells of a leaf, it "evaporates." Water vapor also escapes from tiny pores in the leaves of green plants. This is a plant's equivalent to "sweating."

Atmospheric vapor resulting from evaporation

Vocabulary

aquifers
drought
evaporation
flood
ground water
infiltration
precipitation
rain shadow
runoff
transpiration
water table

Figure 2. Water Cycle

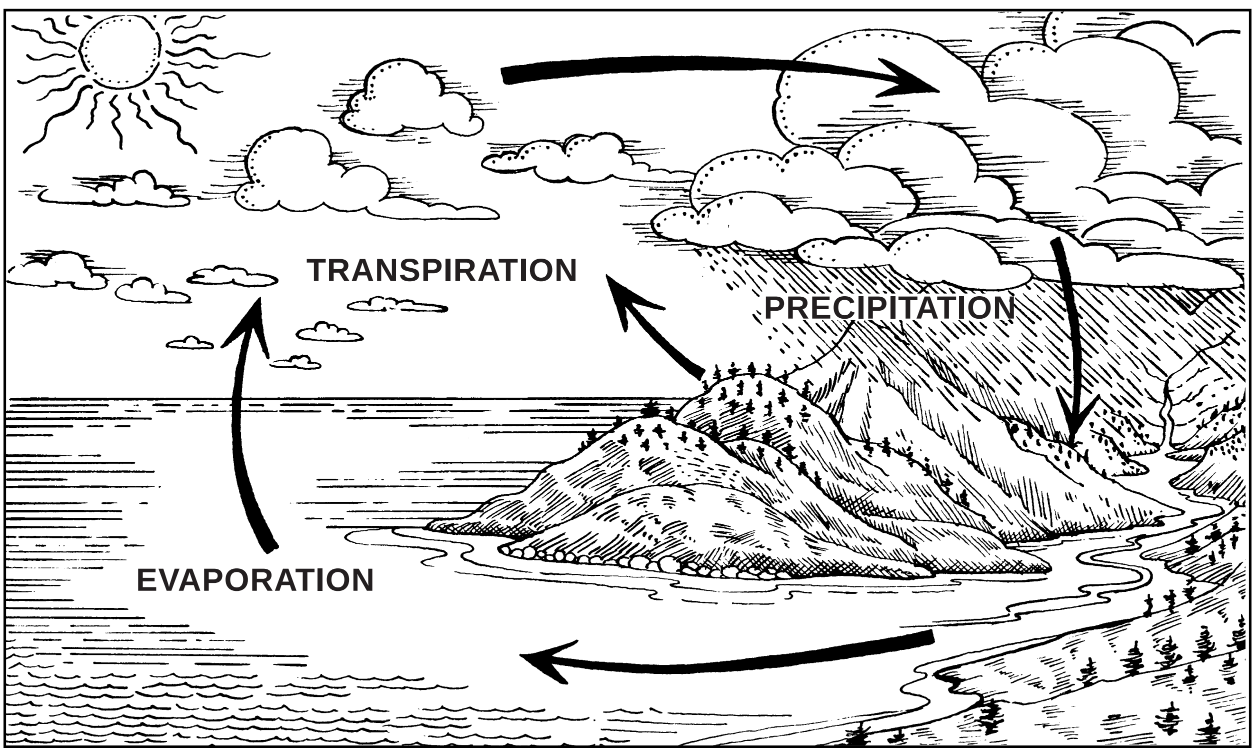
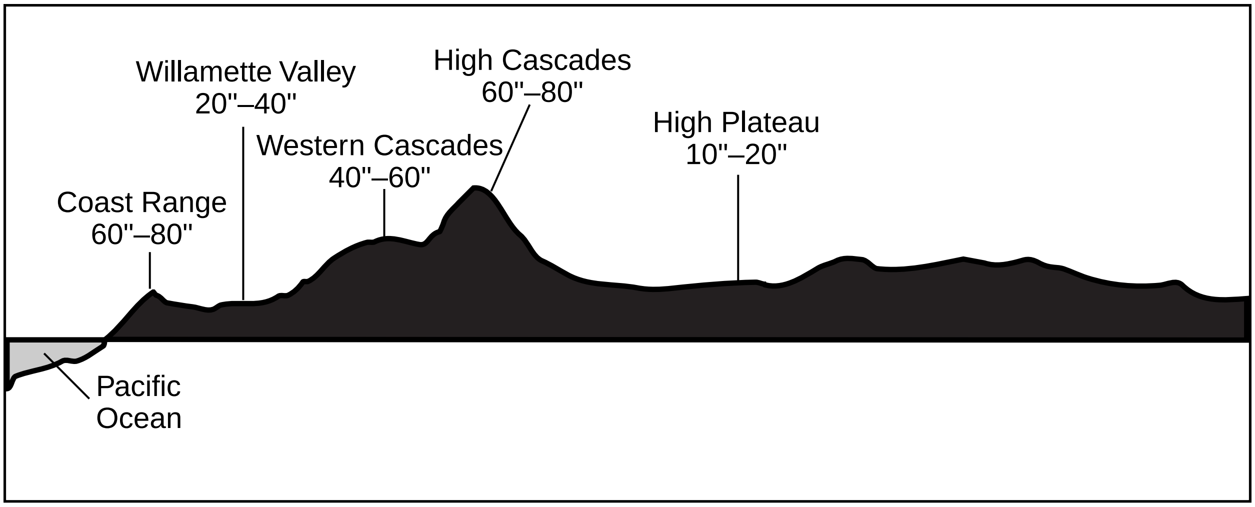


Figure 3. Oregon Average Annual Rainfall



and transpiration is transported by wind, condensed into clouds, and then returned to the earth as **precipitation**. It is estimated that every nine to 12 days, all moisture in the atmosphere falls to earth, making water our most recycled resource.

The largest source of water vapor is evaporation from the oceans, especially those that lie in the warmer parts of the world. The Pacific Ocean is the primary source of water that falls as precipitation on Oregon and the Northwest.

Some of the water that falls as precipitation runs off the land and some soaks into the ground, filling up spaces between soil particles. This is called **ground water infiltration**. Water is moved by gravity through soil and rock layers until it is stopped by solid rock or saturated soil and rock material. Rock or soil areas that hold ground water supplies are called **aquifers**. The top of these aquifers or saturated layers is called the water table. **Water table** levels usually rise and fall as water is added to or removed from the aquifer.

If the upper soil layers are saturated and can no longer hold water, water begins to flow over the land. This overland flow, or **runoff**, collects in surface waters like lakes, ponds, or streams. Unless the receiving water body is in a closed basin (no outlet to the ocean), this water eventually makes its way downstream through an **estuary** and on into the ocean to continue the cycle.

The water cycle is the foundation for examining water in any form. While this process transports and purifies water, its effectiveness may be reduced by such factors as vegetation removal (reducing transpiration) and atmospheric pollution (adding contaminants to otherwise pure vapor).

In Oregon, moisture-laden clouds move from the Pacific Ocean inland (Figure 3). As clouds rise over the Coast Range, their water vapor cools, condenses into drops, and falls as rain. Precipitation continues as the clouds move east, leaving more moisture as they rise over the Cascade Range. Until the clouds reach the Blue, Wallowa, Steens, and other distinct mountain ranges, they are no longer forced to climb into cooler air. Since the Cascades intercept most of the precipitation, a **rainshadow** effect is created in eastern Oregon, making it more arid than the western part.

Extensions

1. "Water Wings," *Aquatic Project WILD*, pp. 4-7. Grades 5-9.
2. "Alice in Waterland," *Aquatic Project WILD*, pp. 182-185. Grades 5-12.
3. "How Wet is Our Planet?" *Aquatic Project WILD*, pp. 8-10. Grades 4-12.
4. "Where Does Water Go After School?" *Aquatic Project WILD*, pp. 82-85. Grades 6-12.
5. "Water's Going On?!" *Aquatic Project WILD*, pp. 304-305. Grades 5-9.
6. "Nature's Waterwheel," *Groundwater: A Vital Resource*, pp. 9-13. Grades 4-6.
7. "All the Water in the World," *Earth: The Water Planet*, pp. 81-84. Grades 4-8.
8. "Put a Cloud in a Bottle," *Earth: The Water Planet*, pp. 60-62. Grades 4-8.
9. "Little People Water Cycle," *The Comprehensive Water Education Book*, pp. 98-106. Grades K-3.
10. "Clouds," *The Comprehensive Water Education Book*, pp. 107-108. Grades K-3.
11. "Precipitation," *The Comprehensive Water Education Book*, pp. 98-106. Grades K-3.
12. "Rain, Snow, Sleet, and Hail," *The Comprehensive Water Education Book*, pp. 111-115. Grades K-6.
13. "Streams, Lakes, and Rivers," *The Comprehensive Water Education Book*, pp. 116-117. Grades K-6.
14. "Underground Water," *The Comprehensive Water Education Book*, pp. 118-119. Grades K-6.
15. "Where Is It At?" *The Comprehensive Water Education Book*, pp. 120-121. Grades 2-6.
16. "The Water Cycle," *The Comprehensive Water Education Book*, pp. 122-126. Grades 4-6.
17. "Clouds," *The Comprehensive Water Education Book*, pp. 127-130. Grades 3-6.
18. "Precipitation," *The Comprehensive Water Education Book*, pp. 131-134. Grades 4-6.
19. "Transpiration," *The Comprehensive Water Education Book*, pp. 135-136. Grades 4-6.
20. "Water That Come Out of the Ground," *The Comprehensive Water Education Book*, pp. 148-150. Grades 4-6.
21. "The Water Budget," *The Comprehensive Water Education Book*, pp. 153-156. Grades 4-6.
22. "Can Water Move Through Solid Rock?" *Earth: The Water Planet*, pp. 4-7. Grades 4-8.
23. "Is It Full Now?" *Earth: The Water Planet*, pp. 12-16. Grades 4-8.
24. "The Rosa Raindrop Water Cycle Game," *4-H Wetland Wonders*, p. 13. Grades 4-5.
25. "The Water Cycle," *4-H Wetland Wonders*, p. 14. Grades 4-5.
26. "Make A Water Cycle," *Make It Work! Rivers*, p. 9. Grades 4-8.
27. "Water Models," *Project WET*, pp. 201-205. Grades 6-8.

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The water cycle

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

Objectives

The student will (1) construct a model of the water cycle, (2) simulate the water cycle by using the constructed model, (3) label the diagram and explain the steps of the water cycle, and (4) answer questions relating water to personal and community experiences.

Method

The student will construct a water cycle model, implement the model and describe the steps of the water cycle as they occur.

For younger students

1. Consult extension activities at the end of the water cycle chapter to address the needs of younger students.
2. Read activity background information aloud to younger students or modify for your students' reading level.
3. Set up the water cycle simulation as a teacher demonstration. Answer the questions as a group.

Materials

- 3-lb. coffee can with lid
- small plastic funnel
- 1" diameter rigid plastic tube
- 5, 16-penny nails
- soup can (label removed)
- 12" piece of wire
- ½"×20"×2" piece of wood (support)
- 2"×8"×8" piece of wood (base)
- can of Sterno
- ice
- hot glue and dispenser
- copies of student sheets (pp. 21-24)

Adapted from Southern Willamette Energy Action Team (SWEAT), Eugene, Ore., and used with permission.

Notes to teacher

A potential for burns exists while using the hot glue dispenser and Sterno fuel. Students should be closely supervised and instructed about associated hazards. Be aware of appropriate first aid procedures for burns.

Background

Do you know . . .

The hydrologic (water) cycle is an endless process of water being exchanged among clouds, land and oceans. The amount of water circulating remains about the same but can follow many different routes.

Water molecules from ocean and land surfaces are warmed by the sun and evaporate into the atmosphere as water vapor. At the lower temperature and pressure of high altitudes, the water vapor condenses to produce precipitation (rain, snow, sleet, hail). About seven-eighths of the precipitation falls directly into the oceans.

On land, the precipitation may run off surfaces into lakes, rivers and streams, or infiltrate into the soil or be absorbed by plants. Water not absorbed by plants becomes groundwater that is

Vocabulary

drought
flood

often pumped back to the surface or may eventually emerge from springs. Through transpiration—evaporation of water through plant processes—water is also recycled into the atmosphere.

Weather, climate and geographic features continuously affect the rate and amounts of water circulated between land, ocean and sky. Rain falls more frequently in latitudes closer to the equator and in areas near large bodies of water. Mountain slopes help produce rain clouds by blocking wind currents and causing warm air to be lifted and cooled.

The hydrologic cycle does not distribute water evenly around the earth. When precipitation is low in a certain area and groundwater levels drop, the condition is called a **drought**. When large amounts of water fall in a short time, the land cannot absorb all of it and rivers cannot hold it within their banks. Water pours over the land, causing a **flood**.

The location and availability of fresh water often influence where people settle and populations prosper. Major cities are often located on or near large bodies of fresh water. This provides easy access to the water supply for drinking, industry, transportation, recreation, and agriculture.

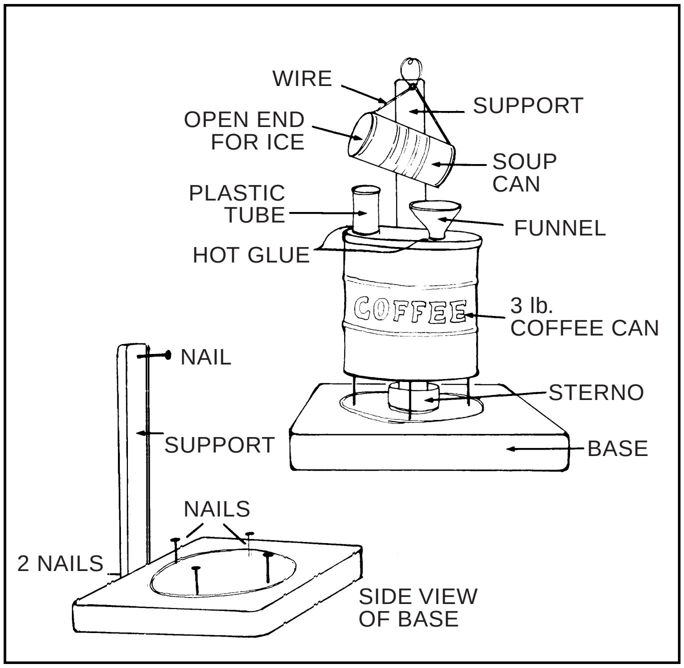
Today, population growth and industrialization throughout the world continue to increase the demand for water. As a result of the great demand and human usage, water can become polluted in several ways—sewage, nutrient chemicals, toxic substances, sediment, and heat. Wise management of this natural resource will determine if we will have the quality (condition of the water) and quantity (amount available for use) to meet future demands.

Procedure

Now it's your turn . . .

How does the water cycle function? In this exercise you will construct the "water cycle" apparatus as shown in the diagram below, or design your own version. Using the completed model you will then simulate the steps in a natural water cycle to demonstrate how the process occurs. Note the following items as you create the model:

- Sterno needs to fit between the wood base and the bottom of the can
- Coffee can needs to sit level on four nails attached to the base
- Hot glue seals and coffee can lid need to be airtight around the base of the funnel and the tube

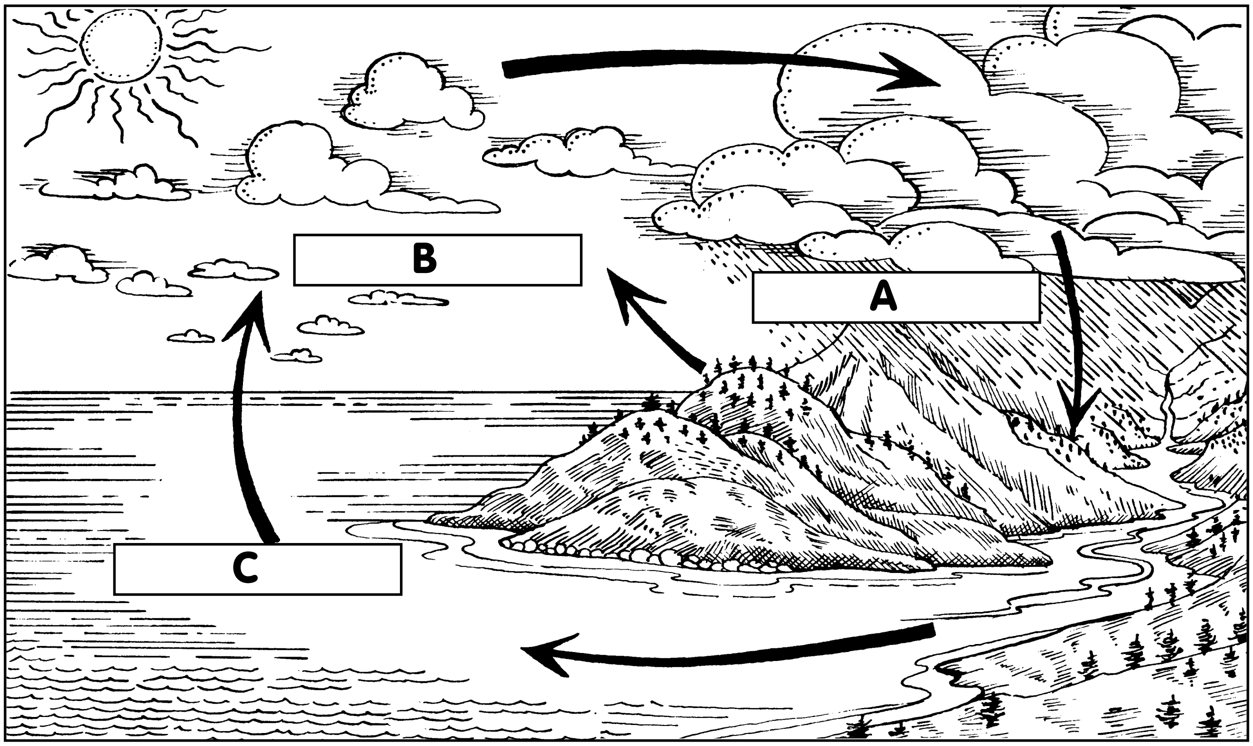


Water cycle simulation

1. Place 1/2" of water in the base of the coffee can.
2. Put one cup of ice cubes in tilted soup can.
3. Light Sterno and place under coffee can.
4. Allow water in coffee can to boil rapidly until steam escapes through chimney (tube). Align the coffee can so the rising steam strikes the soup can just under the opening.

5. Adjust the angle of the soup can so condensing water runs down the length of the can and drips into the funnel.
6. Relate the phase changes of water you have observed to the steps of the water cycle. Label the accompanying diagram and explain what occurs in each step of the water cycle.

Water Cycle



Questions

1. Using letters from the diagram above, label the steps of the water cycle in the blanks provided. Explain what occurs during each step.

   __***C***__ evaporation __***B***__ transpiration __***A***__ precipitation

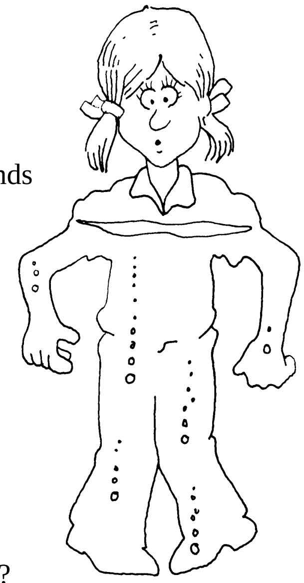
2. What physical parts of the model correspond to the steps of the water cycle shown in the diagram above? Does your model demonstrate the entire water cycle? If not, what is missing?

   The coffee can is the body of water. Sterno represents the sun. The coffee can together with the plastic tube represent evaporation of water vapor into the atmosphere. The soup can with ice represents condensation of water vapor and precipitation that falls back into the system. Transpiration and groundwater infiltration are missing from this model.

3. How did the model increase your understanding of the water cycle?

   Answers will vary but should include some comment about water changing form and moving between the earth and the atmosphere.

4. How many gallons of water are you?
   a. Weigh yourself. ________ pounds
   b. Multiply your weight by 2.
   c. Divide your answer by 3. This answer is the approximate number of pounds of water in your body.
   d. A quart of water weighs about 2 pounds, so divide your last answer by 2.
   e. There are 4 quarts in a gallon, so divide again by 4. Therefore, there are __________ gallons of water in your body.



5. What is the average yearly rainfall in your area or community?
   Answers will vary
6. List twenty ways you use water. Underline the ten most important uses to you. Circle the uses that you could not live without.
   Answers will vary
7. Why do people use more water today per person than was used 50 years ago?
   Answers will vary, but should include population growth and industrial uses.
8. Scientists have determined it takes about 1,400 gallons of water to make a meal of a hamburger, french fries, and a soft drink. List at least four ways that water is used to produce this meal.
   Answers will vary
9. Suppose your town is experiencing a water shortage. You are a member of the town council and the mayor asks you to write an emergency plan to save water. List four rules you might make to help your town save water.
   Answers will vary

Going further

1. Using a 2-liter pop bottle, some soil, water and a light, design an apparatus to model the water cycle. Set up a display to demonstrate how your "water cycle" works.
2. Find out where the water supply for your community originates (river, stream, reservoir, well, etc.). If your community gets its water from a river, are there other cities upstream that use the same water source? How might those cities affect the water quality of your water source? If your local water supply comes from a well, find out which aquifer is used. How deep is the aquifer and are there any groundwater problems in the area that may affect your aquifer?
3. Find out how much water is used in your community each day. How is water routed through your community from its source? How does the community store and track water usage and what procedures does it follow in the event of a water shortage? Prepare a report and present the information to the class.
4. Design an experiment that would compare the length of time it would take your school's football field (or an area of lawn) to receive one inch of rainfall if it fell at the same rate as water from a lawn sprinkler. How many gallons of water are needed to give this same area (the football field or patch of lawn) a one inch equivalent of rainfall? Discuss the implications of this amount of water when considering the entire community's water usage during a water shortage period.
5. Allow students to design their own water cycle model (without a diagram) from the listed materials.

Name

The water cycle

Do you know . . .

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Water molecules from ocean and land surfaces are warmed by the sun and evaporate into the atmosphere as water vapor. At the lower temperature and pressure of high altitudes, the water vapor condenses to produce precipitation (rain, snow, sleet, hail). About seven-eighths of the precipitation falls directly into the oceans.

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Today, population growth and industrialization throughout the world continue to increase the demand for water. As a result of the great demand and human usage, water can become polluted in several ways—sewage, nutrient chemicals, toxic substances, sediment, and heat. Wise management of this natural resource will determine if we will have the quality (condition of the water) and quantity (amount available for use) to meet future demands.

Now it's your turn . . .

How does the water cycle function? In this exercise you will construct the "water cycle" apparatus as shown in the diagram (p. 22), or design your own version. Using the completed model you will then simulate the steps in a natural water cycle to demonstrate how the process occurs. Note the following items as you create the model:

- Sterno needs to fit between the wood base and the bottom of the can
- Coffee can needs to sit level on four nails attached to the base
- Hot glue seals and coffee can lid need to be airtight around the base of the funnel and the tube

Vocabulary

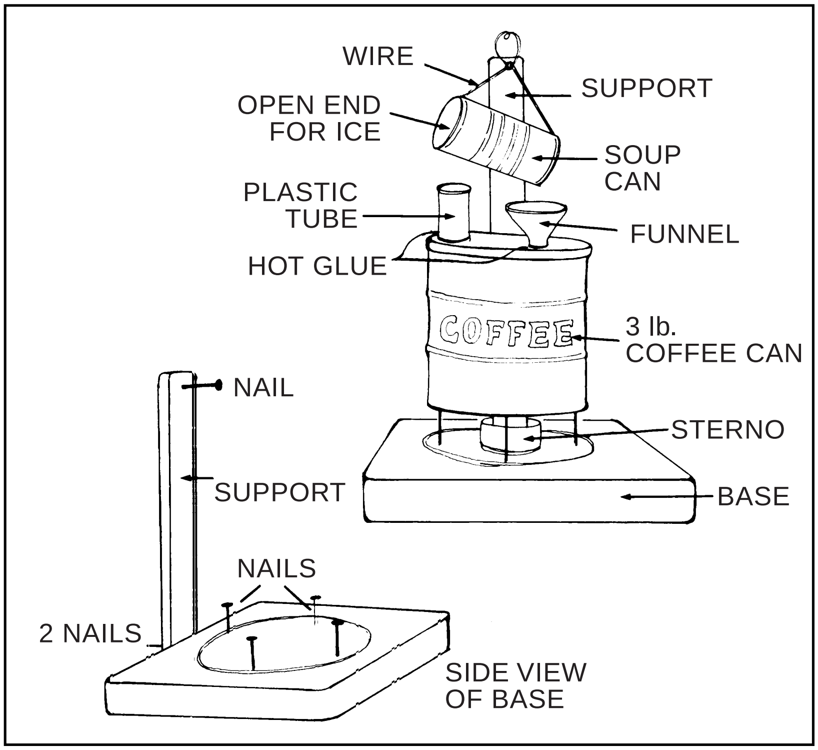
drought
flood

Adapted from Southern Willamette Energy Action Team (SWEAT), Eugene, Ore., and used with permission.

Student sheet

Water cycle simulation

1. Place ½" of water in the base of the coffee can.
2. Put one cup of ice cubes in tilted soup can.
3. Light Sterno and place under coffee can.
4. Allow water in coffee can to boil rapidly until steam escapes through chimney (tube). Align the coffee can so the rising steam strikes the soup can just under the opening.
5. Adjust angle of soup can so condensing water runs down the length of the can and drips into the funnel.
6. Relate the phase changes of water you have observed to the steps of the water cycle. Label the accompanying diagram and explain what occurs in each step of the water cycle.



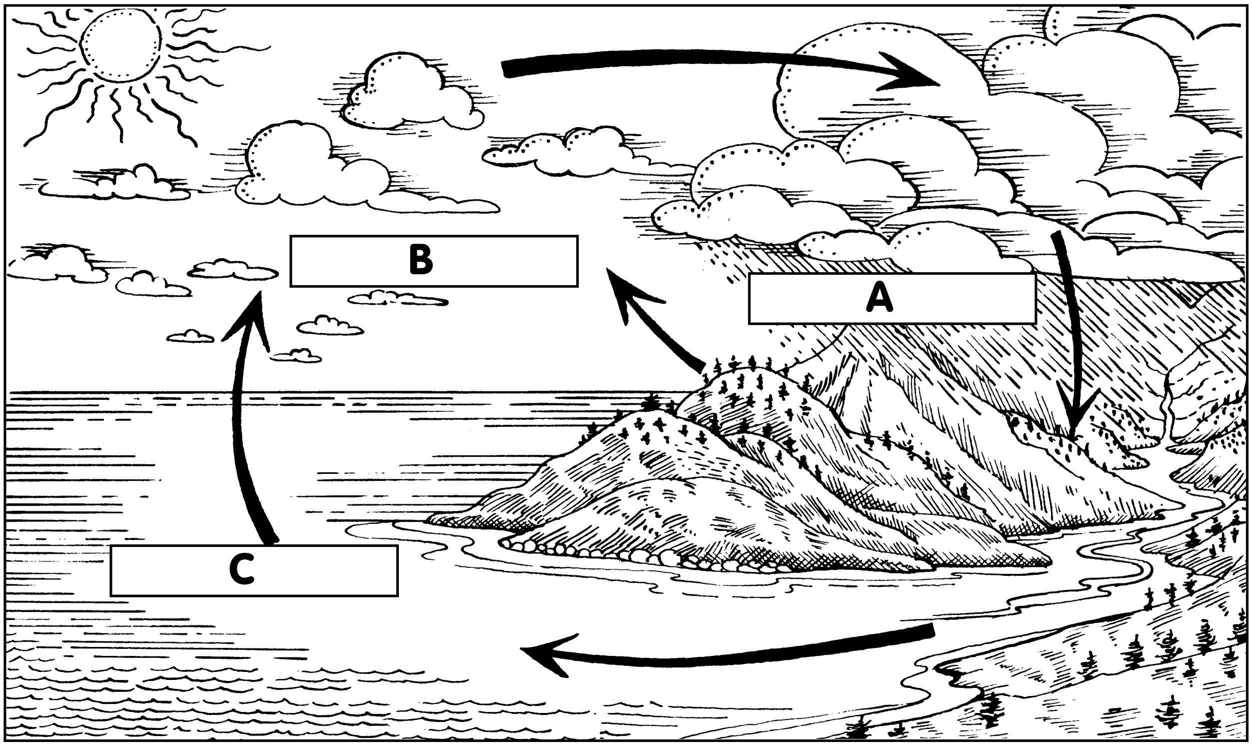
Student sheet

Questions

1. Using letters from the diagram below, label the steps of the water cycle in the blanks provided. Explain what occurs during each step.

   _____ evaporation _____ transpiration _____ precipitation

Water Cycle



2. What physical parts of the model correspond to the steps of the water cycle shown in the diagram above? Does your model demonstrate the entire water cycle? If not, what is missing?

3. How did the model increase your understanding of the water cycle?

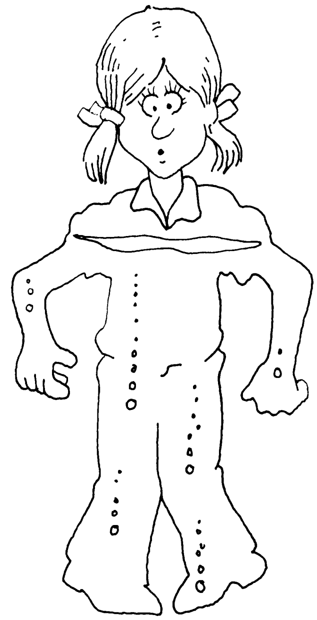
Student sheet

4. How many gallons of water are you?
   a. Weigh yourself. _________ pounds
   b. Multiply your weight by 2.

   c. Divide your answer by 3. This answer is the approximate number of pounds of water in your body.

   d. A quart of water weighs about 2 pounds, so divide your last answer by 2.

   e. There are 4 quarts in a gallon, so divide again by 4. Therefore, there are __________ gallons of water in your body.



5. What is the average yearly rainfall in your area or community?

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8. Scientists have determined it takes about 1,400 gallons of water to make a meal of a hamburger, french fries and a soft drink. List at least four ways that water is used to produce this meal.

9. Suppose your town is experiencing a water shortage. You are a member of the town council and the mayor asks you to write an emergency plan to save water. List four rules you might make to help your town save water.

Water drop crossword puzzle

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

Objectives

The student will demonstrate familiarity and understanding with the basic concepts of the water cycle by completing the crossword puzzle.

Method

Students will complete the crossword puzzle, with or without the accompanying word list at the teacher's discretion.

For younger students

1. In most cases, younger students will require the word list. Using an overhead transparency of the water cycle while discussing the important concepts as a group may enhance this exercise.
2. Work in pairs or as a group to solve the puzzle. Add the first two "Going Further" activities to help younger students grasp the concepts.

Materials

- crossword puzzle, list of clues, and word list (optional)

Background

Do you know . . .

Although you probably have a good idea about how the basic water cycle works, it took a while for scientists to understand how the parts and processes were all connected. A lot of misinformation led to false beliefs. For instance, during the Middle Ages, people thought that water flowed magically from the center of the earth. Now we know that the total amount of water on the earth remains relatively constant. Water does change from one form to another, but it does not go away. There really is no starting point—like what comes first, the chicken or the egg? The glass of water you drink today may have been in the water that floated Noah's ark or maybe part of the last glassful that George Washington drank.

Procedure

Now it's your turn . . .

Do you understand how the water cycle fits into the "watershed" picture? Can you name and describe the three major processes of the water cycle? What do you know about ground water? Use the following crossword puzzle to test your knowledge about the water cycle and to practice the new words you have learned.

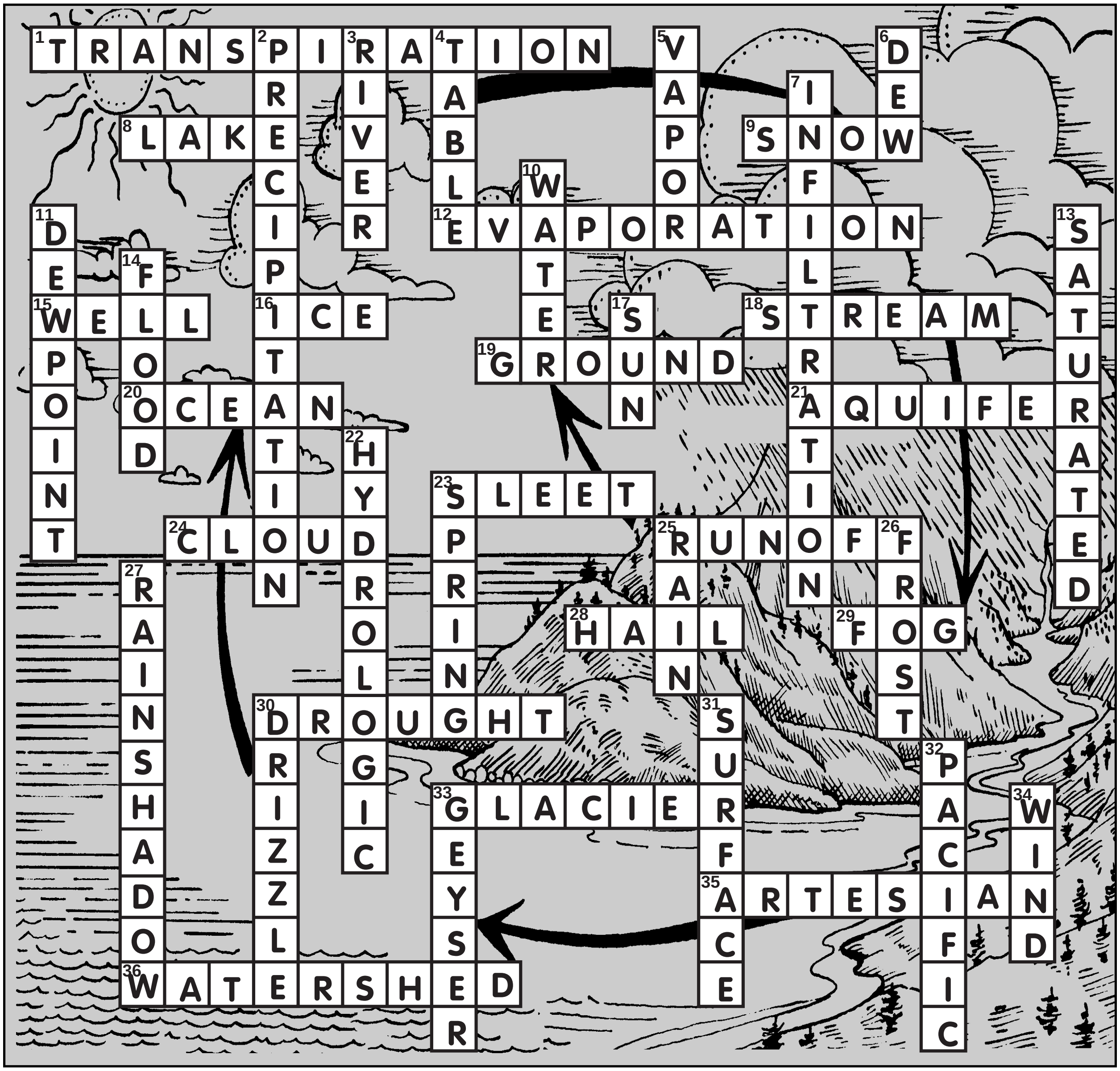
Water drop crossword clues

Across

1. Loss of water from plants through evaporation and as a byproduct of photosynthesis.
8. A ______ is an inland body of water larger than a pond.
9. A form of precipitation that falls to earth as frozen six-sided crystalline flakes.
12. Conversion of water from a liquid form to a vapor.
15. A hole drilled into the earth to get water.
16. Frozen water.
18. A current or flow of water running along the surface of the earth is called a ________.
19. The zone of water infiltration where all the spaces between the rocks and soil particles are filled with water is called ______ water.
20. The largest body of water on the surface of the earth.
21. Layers of porous underground rock that act as water reservoirs.
23. Frozen rain.
24. A large mass of water vapor condensed into billions of fine water droplets is called a ________.
25. Water that drains over the surface of the land.
28. Small rounded pieces of ice that sometimes fall during thunderstorms.
29. A cloud at ground level.
30. Extended period of less than normal precipitation.
33. Large accumulations of ice in the polar areas and at high elevations in the mountains.
35. Well water that flows to the surface under its own natural pressure.
36. All the land area that drains into a particular body of water.

Down

2. Rain, snow, sleet, or hail falling to the ground.
3. A _______ is a natural stream of water, larger than a creek, and often emptying into an ocean or lake.
4. The upper level at which soil is saturated with water is called the water ______.
5. Water ______ is the gaseous form of water.
6. Water vapor condensed into the form of water droplets is called ______.
7. Entry of water into the soil.
10. The ______ cycle is the process of circulating and distributing fresh water on the earth.
11. The temperature at which air is saturated with water vapor.
13. When soils can no longer hold any more water they are called ___________.
14. When a stream channel overflows its banks.
17. The energy for driving the water cycle comes from the ________.
22. The _________ cycle is an endless process of water exchange among clouds, land, and oceans.
23. A point at which groundwater comes to the surface.
25. Precipitation in the form of liquid water drops.
26. Frozen water vapor on the earth's surface.
27. An area that receives less precipitation because of its position on the leeward side of a mountain or other landform (two words).
30. Very light rain.
31. Any water flowing or standing on the ground is called ______ water.
32. The _______ Ocean is the primary source of water vapor that falls as precipitation on Oregon and the Northwest.
33. A special type of spring that ejects warm water under pressure into the air.
34. Air movement, called ______, speeds up the process of evaporation.



Word list

aquifer	geyser	rain	table
artesian	glacier	rain shadow	transpiration
cloud	ground	river	vapor
dew	hail	runoff	water
dewpoint	hydrologic	saturated	watershed
drizzle	ice	sleet	well
drought	infiltration	snow	wind
evaporation	lake	spring	
flood	ocean	stream	
fog	Pacific	sun	
frost	precipitation	surface	

Going further

1. After working the crossword puzzle, alphabetize all of the words.
2. Write one complete sentence using each word in the crossword puzzle.
3. Create a mural of the water cycle using all the words you learned in the puzzle.

Name

Water drop crossword puzzle

Do you know . . .

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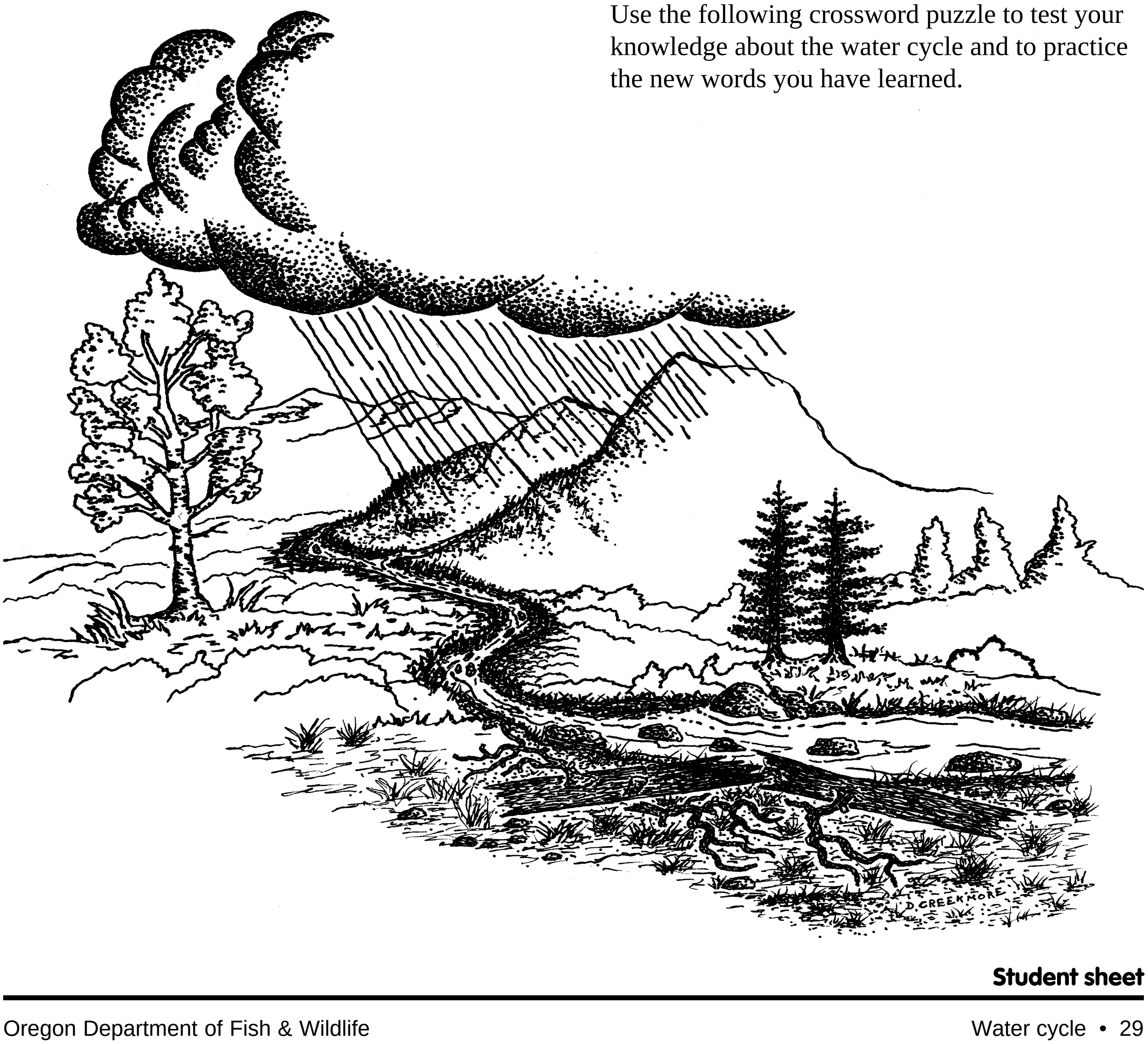

Student sheet

Water drop crossword clues

Across

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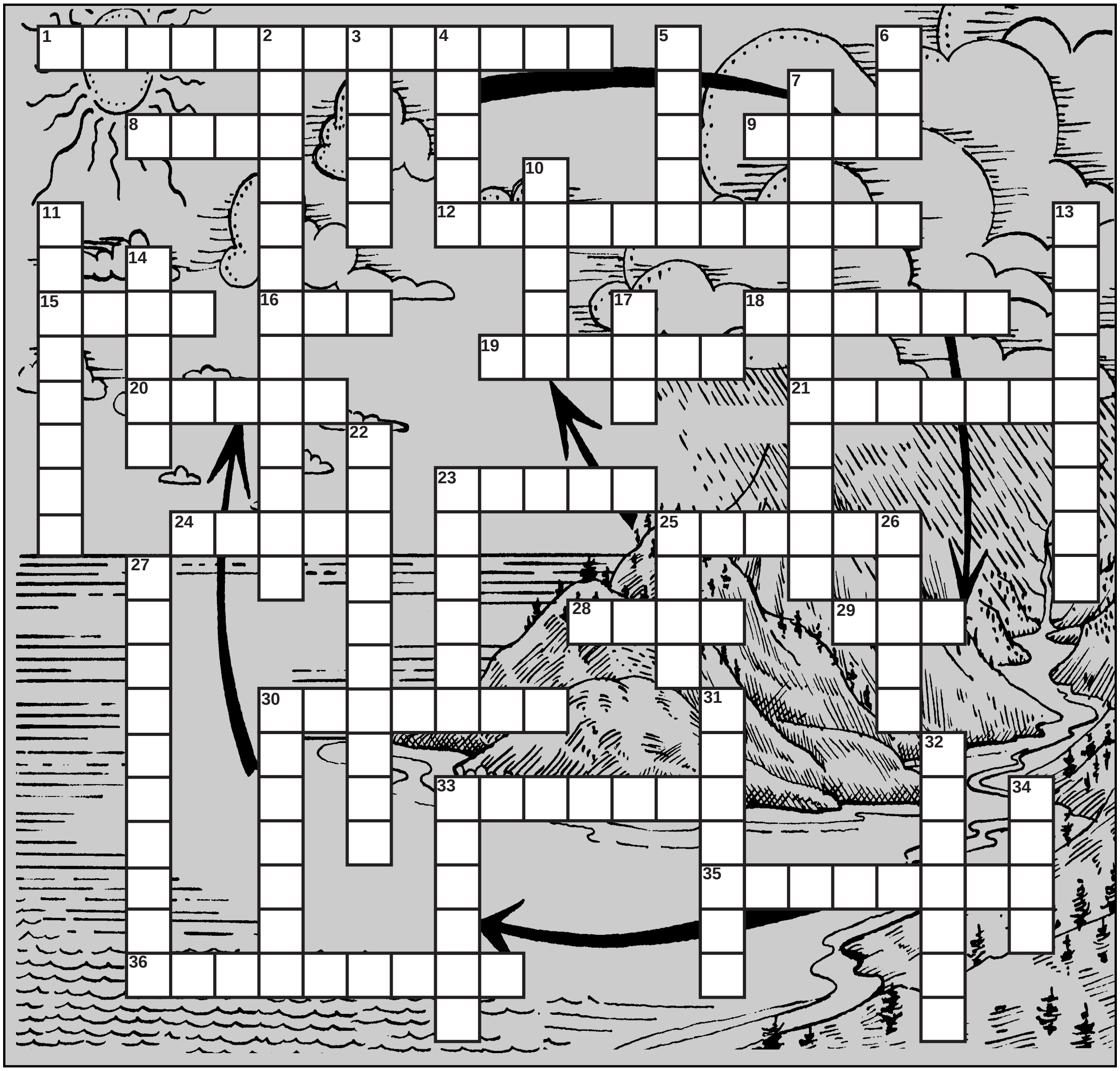
15. A hole drilled into the earth to get water.
16. Frozen water.
18. A current or flow of water running along the surface of the earth is called a ________.
19. The zone of water infiltration where all the spaces between the rocks and soil particles are filled with water is called ______ water.
20. The largest body of water on the surface of the earth.
21. Layers of porous underground rock that act as water reservoirs.
23. Frozen rain.
24. A large mass of water vapor condensed into billions of fine water droplets is called a ________.
25. Water that drains over the surface of the land.
28. Small rounded pieces of ice that sometimes fall during thunderstorms.
29. A cloud at ground level.
30. Extended period of less than normal precipitation.
33. Large accumulations of ice in the polar areas and at high elevations in the mountains.
35. Well water that flows to the surface under its own natural pressure.
36. All the land area that drains into a particular body of water.

Down

2. Rain, snow, sleet, or hail falling to the ground.
3. A _______ is a natural stream of water, larger than a creek, and often emptying into an ocean or lake.
4. The upper level at which soil is saturated with water is called the water ______.
5. Water ______ is the gaseous form of water.
6. Water vapor condensed into the form of water droplets is called ______.
7. Entry of water into the soil.
10. The ______ cycle is the process of circulating and distributing fresh water on the earth.
11. The temperature at which air is saturated with water vapor.
13. When soils can no longer hold any more water they are called ___________.
14. When a stream channel overflows its banks.
17. The energy for driving the water cycle comes from the ________.
22. The _________ cycle is an endless process of water exchange among clouds, land, and oceans.
23. A point at which groundwater comes to the surface.
25. Precipitation in the form of liquid water drops.
26. Frozen water vapor on the earth's surface.
27. An area that receives less precipitation because of its position on the leeward side of a mountain or other landform (two words).
30. Very light rain.
31. Any water flowing or standing on the ground is called ______ water.
32. The _______ Ocean is the primary source of water vapor that falls as precipitation on Oregon and the Northwest.
33. A special type of spring that ejects warm water under pressure into the air.
34. Air movement, called ______, speeds up the process of evaporation.

Student sheet

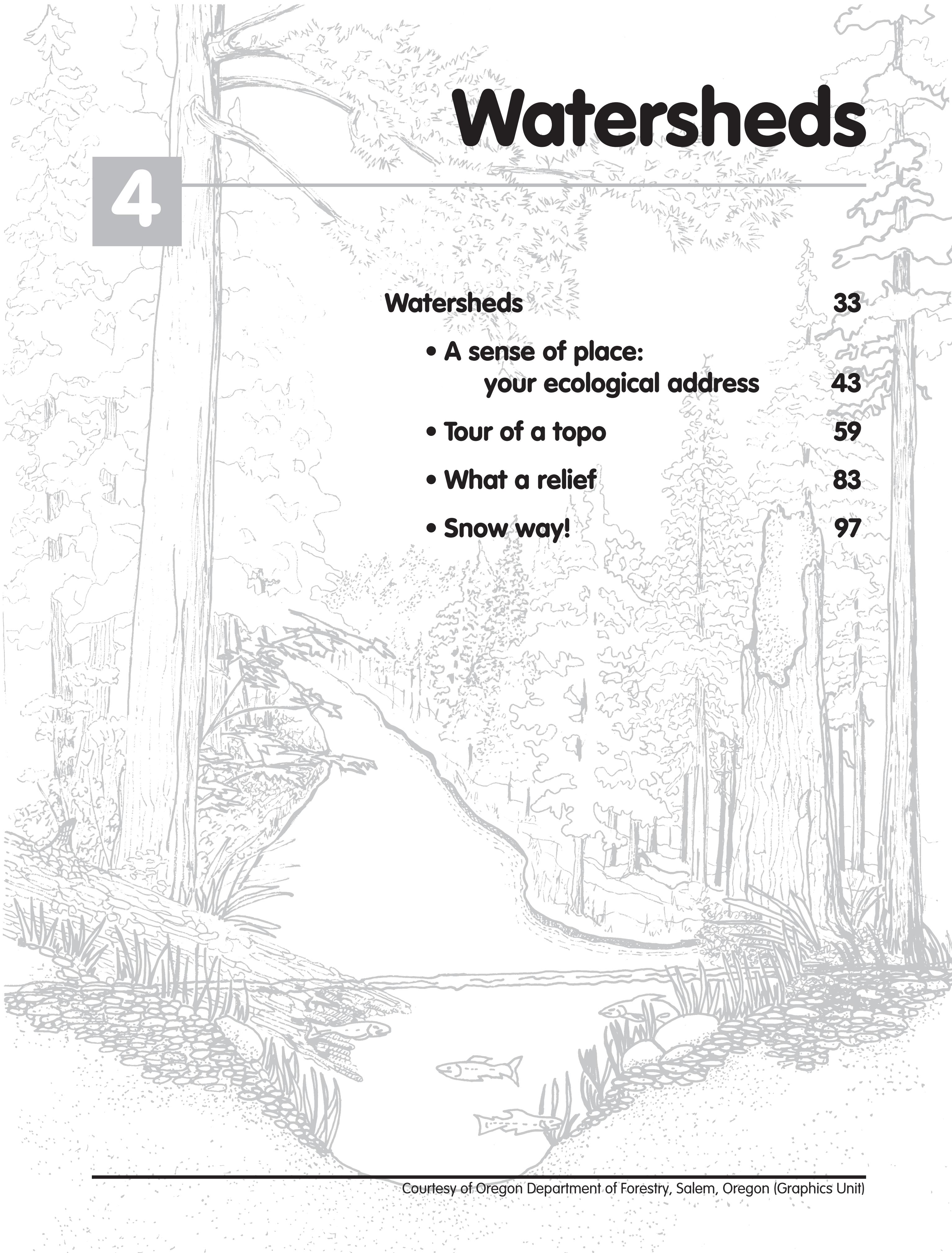


Word list

glacier
well
stream
transpiration
cloud
drizzle
aquifer
watershed
drought
flood
wind
frost
geyser
Pacific
dewpoint
ground
hail
rain
ice
lake
sleet
ocean
precipitation
fog
river
saturated
snow
dew
sun
infiltration
artesian
runoff
surface
table
vapor
rain shadow
spring
hydrologic
water
evaporation

4

Watersheds



Courtesy of Oregon Department of Forestry, Salem, Oregon (Graphics Unit)

Watersheds

4

"The study of rivers is not a matter of rivers, but of the human heart."
— Tanaka Shozo

All land on earth is a **watershed**. Humans and their activities play an important and essential role in watersheds, yet few people understand them. Still fewer know how a watershed works or can describe the boundaries of the ones in which they live.

A watershed is often called a drainage basin. It is the land area drained by a network of channels, called **tributaries**, that increase in size as the amount of water, sediment, and dissolved materials they must carry increases. Each watershed is an interconnected land-water system that conveys water to its outlet—a larger stream, an inland lake, a wetland, an estuary, or the ocean.

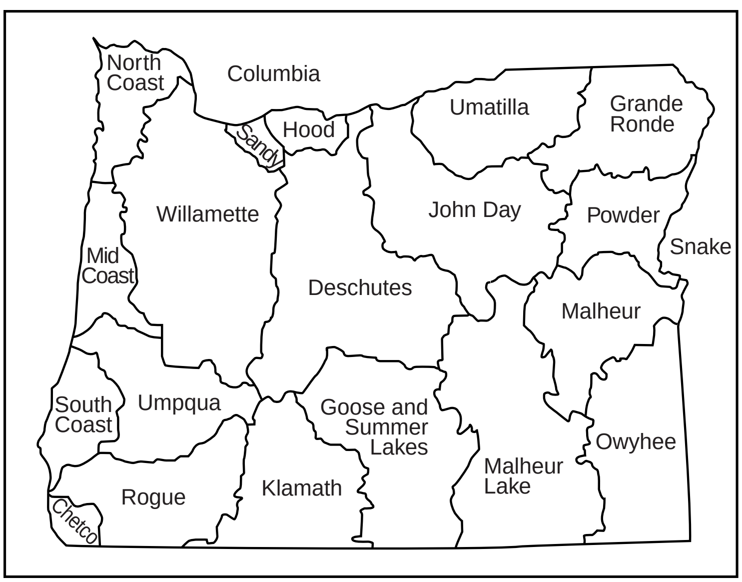
A watershed may be the drainage area surrounding a lake that has no surface outlet, such as Malheur and Harney Lakes in southeast Oregon or a river basin as large as that of the Columbia River. A puddle even has its own watershed.

Within a large watershed tributaries form smaller watersheds called **sub-basins**. Each tributary contributes to overall streamflow for the entire basin. Oregon has 20 major river basins (see Figure 4.)

All watersheds have an aquatic (or water) area, a riparian area, and an upland area. Aquatic areas include standing waters like ponds, lakes, wetlands, bogs and running surface waters such as streams and rivers. The corridor of vegetation next to and influencing the aquatic area is called the **riparian area**.

The point where two watersheds meet is called a **divide**. Connecting the divide with the valley or lowland areas below are the hill slopes or **uplands**. Events in the uplands ultimately

Figure 4. Oregon River Basins



Vocabulary

aquifers	perennial
baseflow	plant associations
climate	radial drainage
dendritic drainage	residual soils
deposition	riparian area
divide	streamflow hydrograph
ephemeral	sub-basins
erosion	sublimation
first-order streams	transported soils
forage	trellis drainage
gradient	tributaries
intermittent	uplands
leaching	water equivalent
parallel drainage	watershed

affect the capture of water on the surface of the land, storage and movement of water below the surface, and release of water to riparian and aquatic areas.

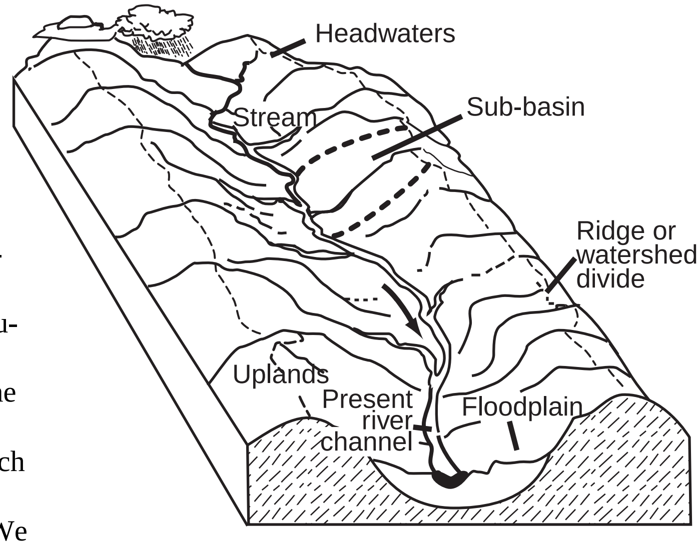
Each stream in a watershed is an ever-changing open-water system. It carves through valleys, collects water and sediments, and conveys the surface runoff generated by rainfall, snowmelt, or groundwater discharge to the estuaries and oceans. The shape and pattern of a stream is a result of the land it is cutting and the sediment it must carry.

Each of us has a "watershed address," which describes our basic relationship with a watershed. One part of our address is our location. We all live in topographic watersheds—areas drained by a common stream. When a raindrop falls on the roof of our house, where is it going? What creeks or rivers will carry it toward the sea?

Some people also live in engineered watersheds, which may not follow topographic lines. When we turn on the faucet in the kitchen sink, what watershed did that water come from? When the water runs down the drain, what watershed is it going to? For example, while rainwater in much of the Portland Metro area flows into the Willamette River, much of Portland's domestic water supply is piped from the nearby Bull Run Watershed, a watershed that flows toward the Columbia River. In this way, one watershed is artificially connected to several other watersheds at once. The watershed of surface flow, the watershed where domestic water originates, and the watershed where wastewater goes are all connected. This means Portland residents live in one watershed and drink water from another, while their wastewater may affect their "home watershed" and others.

Physical features of a watershed

Rain, snow, wind, ice, and temperature variations are all agents of erosion in a watershed. The erosional effects of surface water create stream channels. As streams carve their way through a watershed, they are responsible for most of the "topographic identity" of a watershed.



A watershed is almost like a domicile, a mini-biosphere, with halls of hills and mountains, a floor of river or lake, and a roof of rain clouds. Adapted from *Co-Evolution Quarterly*, Winter 1976/77.

Area

The area of a watershed affects the amount of water that flows from the river or stream that drains it. Generally, with similar climates large watersheds receive more precipitation than small ones. Greater precipitation and runoff may occur on a smaller watershed in a moist climate than on a large watershed in an arid climate.

Shape and slope

Shape and slope of a watershed and its drainage pattern influence surface runoff and seepage in streams draining the watershed. The steeper the slope, the greater the possibility for rapid runoff and erosion. Plant cover is more difficult to establish and infiltration of surface water is reduced on steep slopes.

Orientation

Orientation of a watershed in relation to the direction that storms move across it also affects runoff and peak flows. A rainstorm moving up a watershed from the mouth releases water in such a way that runoff from the lower section has passed its peak before runoff from the higher sections has arrived. A storm starting at the top and moving down a watershed can reverse the process.

Orientation of a watershed relative to sun position affects temperature, evaporation, and transpiration. Soil moisture is more rapidly lost by evaporation and transpiration on steep slopes facing the sun. Watersheds sloping away from the sun are cooler, and evaporation and transpiration are less. Slopes exposed to the sun usually support different plants than those facing away from the sun. Orientation to prevailing winds has similar effects.

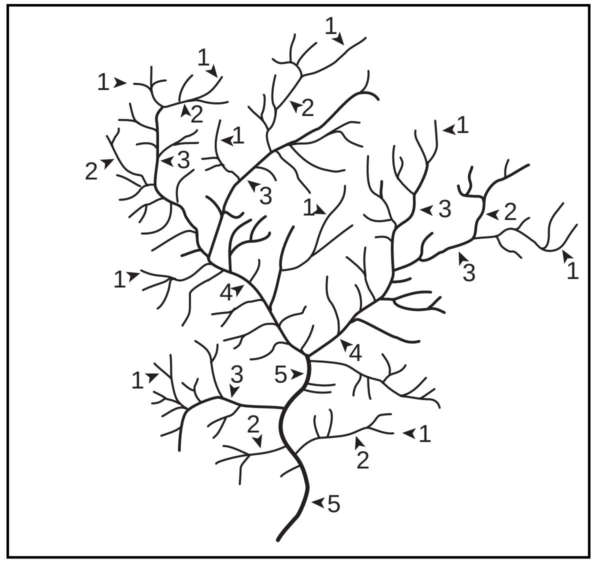
Drainage patterns

Viewed from above, the tributaries of each river system create a distinct pattern. Geology, topography, and climate are responsible for this pattern. Regions with parallel valleys formed by the folding of the earth's surface have a **parallel drainage** pattern. Where the geology is sedimentary rock, fault lines may create a drainage pattern where streams flow parallel to each other and tributaries join at nearly right angles in a **trellis drainage** pattern.

In the Pacific Northwest two of the most common patterns are **radial drainage** and **dendritic** (treelike) **drainage**. When streams drain a central high point, such as a mountain top, they create a pattern similar to the spokes on a wheel radiating out from the central hub. This is radial drainage.

The branching tributaries of a river may also create a pattern similar to the branches of a tree. This is dendritic drainage. Both types may occur within the same watershed. For example, the radial pattern of streams that drain Mount Hood are all within the Columbia Basin, but the drain-

Figure 5. Stream Orders



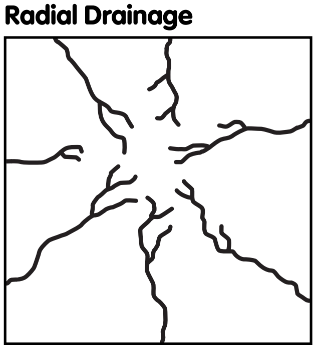
age pattern of the individual sub-basins formed by these streams have a dendritic pattern.

Stream orders

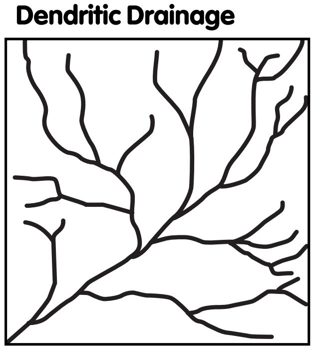
In most cases, a watershed system is almost entirely hillsides, called uplands. Only about one percent of a watershed is stream channels. The smallest channels in a watershed have no tributaries and are called **first-order streams**. When two first-order streams join, they form a second-order stream. When two second-order channels join, a third-order stream is formed, and so on (Figure 5). First- and second-order channels are often small, steep, or **intermittent**. Orders six or greater are larger rivers.

Channels change by **erosion** and **deposition**. Natural channels of rivers increase in size downstream as tributaries enter and add to the flow.

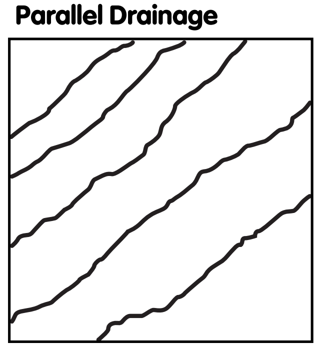
Radial Drainage



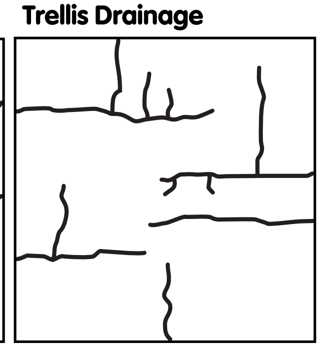
Dendritic Drainage



Parallel Drainage



Trellis Drainage



A channel is neither straight nor uniform, yet its average size changes in a regular and progressive fashion. In upstream reaches, the channel tends to be steeper. **Gradient** decreases downstream as width and depth increase. The size of sediments tends to decrease, often from boulders in the hilly or mountainous upstream portions, to cobbles or gravels in middle reaches. More sand or silt are found downstream. In some cases, large floods cause new channels to form, leaving once-productive streams dry and barren.

Streamflow types

Besides the ordering system previously described, streams may be classified by how much of the year they have flowing water.

- **Perennial** flow indicates a nearly year-round flow (90 percent or more) in a well-defined channel. Most higher order streams are perennial.
- **Intermittent** flow generally occurs only during the wet season (50 percent of the time or less).
- **Ephemeral** flow generally occurs during and shortly after extreme precipitation or snowmelt conditions. Ephemeral channels are not well defined and are usually headwater or low order (1-2) streams.

Factors affecting watersheds

Climate

Land and water are linked directly by the water cycle. Solar energy drives this and other cycles in the watershed. **Climate**—the type of weather a region has over a long period—is the source of water. Water comes to the watershed in seasonal cycles, principally as rain or snow. In some areas, condensation and fog-drip contribute water. The seasonal pattern of precipitation and temperature variation control streamflow and water production.

Some precipitation infiltrates the soil and percolates through porous rock into groundwater storage, which recharges areas called **aquifers**. Natural groundwater discharge, called **baseflow**, is the main contributor to streamflow during dry summer and fall months. Without baseflow, many streams would dry up.

Pumping water from an aquifer for industrial, irrigation, or domestic use reduces the aquifer's volume. Unless withdrawals are modified or recharge increased, the aquifer will eventually be depleted. A drained aquifer can collapse from the settling of the overlying lands.

Collapsed underground aquifers no longer have as much capacity to accept and hold water. Recharge is difficult, volume is less, and yields are considerably reduced. Springs once fed from the water table also dry up.

Land and water are linked directly by the water cycle.

Climate affects water loss from a watershed as well as provides water. In hot, dry, or windy weather, evaporation loss from bare soil and from water surfaces is high.

The same climatic influences that increase evaporation also increase transpiration from plants. Transpiration draws on soil moisture from a greater depth than evaporation because plant roots may reach into an available moisture supply. Transpiration is greatest during the growing season and least during cold weather when most plants are relatively dormant.

Wind also causes erosion, controls the accumulation of snow in sheltered places, and may be a significant factor in snowpack melting. Wind erosion can occur wherever wind is strong and

constant, or where soil is unprotected by sufficient plant cover.

Soils and geology

Soil, a thin layer of the earth's crust, could be called the "skin" of a watershed. It is composed of mineral particles of all sizes and varying amounts of organic materials. It is formed from the breakdown of parent rocks into fine mineral particles. This occurs by:

- freezing and thawing in winter,
- heating expansion and cooling contraction in summer,
- wind and water erosion,
- the grinding action of ice, and
- action of lichens and other plants.

Soils are of two types. **Residual** soils are those developed in place from underlying rock formations and surface plant cover. **Transported** soils include those transported by gravity, wind or water.

Climate, particularly precipitation and temperature, strongly affects soil formation. Rainfall causes **leaching**—movement of dissolved particles through soil by water. Temperature affects both mechanical breakdown of rocks and breakdown of organic material. Soil bacteria, insects, and burrowing animals also play a part in the breakdown and mixing of soil components.

Soil often determines which plants grow in a watershed, which in turn establish a protective vegetative cover. Plants also modify and develop soil. Plant roots create soil spaces and extract water and minerals in solution from their roots. Plant litter adds organic matter to soil. It also slows surface runoff and protects the soil surface from rainfall's beating and puddling effects. Soil depths and moisture-holding capacities are usually less on steep slopes, and plant growth rates are often slower.

Forage, timber, and water are all renewable resources. Water is renewed by cycles of climate. Forage and timber are renewed by growth in seasonal cycles. The availability of these watershed resources is dependent upon soil. Soil is, except over long periods, a nonrenewable resource. It may take more than a century to produce a centimeter of soil and thousands of years to produce enough soil to support a high-yield, high-quality forest, range, or agricultural crop. Soil is the basic watershed resource. Careful management and protection is necessary to preserve its function and productivity.

Vegetation

The variety of plant species and their growth and distribution patterns within a watershed are the result of differences in soil type, light, temperature, moisture, nutrient availability, and human activity. For example, temperatures on the north and south slopes of the same hill may vary considerably. Different light intensities may account for the temperature variation on either side of the hill. Temperature differences in turn affect the moisture levels on each of the slopes. Generally south-facing slopes are warmer and drier than north-facing slopes in the northern hemisphere.

The plant species that are present directly affect the ability of a watershed to capture, store, and release water within that particular habitat. Branches of large conifers effectively intercept snow and rain. Some of the moisture in the precipitation will evaporate before it has a chance to reach the ground but the rest is slowed in its descent, lessening the impact to the soil's surface. Sagebrush and other arid land shrubs, on the other hand, are not as effective in slowing snow or rain. Yet in areas with less precipitation, this adaptation provides the greatest opportunity for moisture to infiltrate. Watersheds covered with dense grass cover help the soil capture water much more effectively than watersheds with sparse vegetation.

Plants directly affect the ability of a watershed to capture, store, and release water.

Groups of plants that have evolved together over time are called **plant associations (or communities)**. Plant associations share specific adaptations to certain watershed conditions—climate, soil type, light and temperature requirements, moisture, and nutrient availability as described above. Knowing the basic plant associations found in a particular watershed can tell you a lot about the health of that watershed.

Fish and wildlife

Each watershed has a diverse mix of wildlife species—mammals, birds, reptiles, amphibians, and invertebrates. Plant communities influence which species are found in a particular watershed. Plants, in some form or another, meet the basic habitat needs of food, water, shelter, or space for most all forms of wildlife. And, all wildlife species, large or small, become part of the interrelationships found within a watershed.

Some wildlife never leave their watershed residence while others move among several adjoining watersheds or even migrate hundreds or thousands of miles to live in a completely different watershed during different times of the year. Wildlife populations within a watershed may vary seasonally and annually. Migration, predation, wildlife management (like hunting seasons), or watershed management decisions (development, timber harvest, mining, recreation, agriculture) can all affect wildlife populations.

Wildlife perform a variety of functions within a watershed. Less commonly known but very important contributions include burrowing activities of animals like worms and mice. Their burrows allow moisture to penetrate deep into the soil, aiding the water storage capabilities of the watershed. Small rodents also collect and store nuts and seeds, many of which sprout and grow to provide more food and ground cover. Rodents are also an important part of many watershed food chains. Birds also help transport seeds. Dams built by beavers help increase water storage in the soil and their activities are often responsible for channel changes within a stream system.

Limited exclusively to the aquatic habitats found within a watershed, fish occupy a unique niche. Fish are part of complex aquatic food chains and, along with the aquatic organisms on which they feed, are indicators of water quality.

A number of factors within the watershed control a stream's ability to produce fish food. When producers such as algae and diatoms are plentiful, the aquatic insects that feed upon them also thrive. They in turn are food for other aquatic invertebrates and fish. Overhanging streamside vegetation also contributes insects to the aquatic dinner plate.

Plants, in some form or another, meet the basic habitat needs of food, water, shelter, or space for most all forms of wildlife.

Studies in recent years show considerable evidence that stream systems with migrating populations of salmon and trout are highly dependent on the nutrients provided by the decaying carcasses that remain after spawning.

Fish populations vary with the quantity and the quality of available water within a watershed. Streams that flow cold and clean throughout the year generally provide the conditions that salmon and trout need to be healthy and productive. Human management activities can affect the quantity and quality of water in streams.

Management objectives in a watershed

A key watershed management objective is to maintain effective vegetative cover and soil characteristics that sustain high quality water supplies. Meeting this objective enhances the usefulness and productivity of the land for other purposes. If the soil is protected and maintained in good condition, then other renewable resources that depend on this most basic form of productivity can be supported.

Timber, forage, minerals, food, and wildlife represent important watershed management considerations. Problems arise when development and use of these resources conflict with the primary objectives of maintaining and protecting high quality water supplies and promoting watershed integrity.

Land ownership is the principal institutional control of a watershed. A private individual or public management agency may be free to apply whatever measures they believe necessary or desirable on their own land. They may regulate access and prevent use and development of associated resources.

All watershed users should know that private actions have public consequences on water quality and quantity.

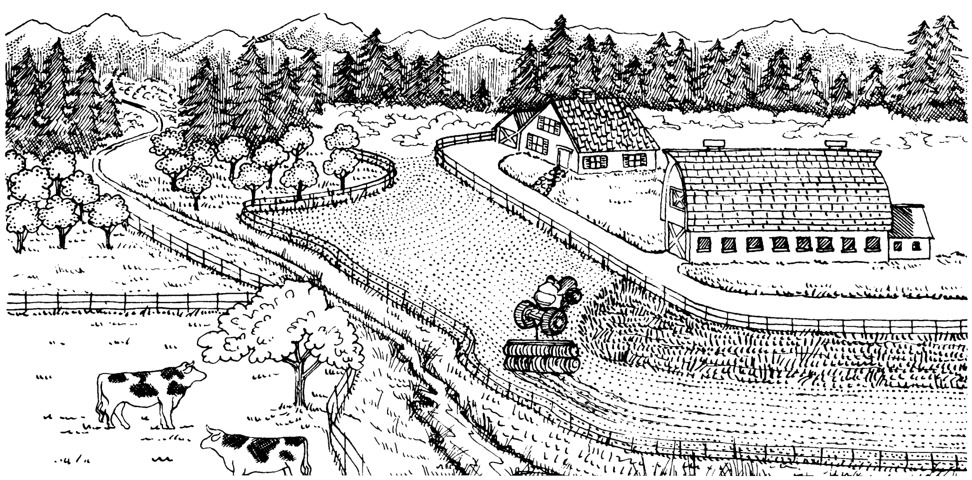
Many watersheds are in public or state ownership. Unless protected by specific legislation or agreement, most are used and developed to take advantage of all resources available for the general public benefit. It is in these multiple-use watersheds that management may face the most serious conflicts and challenges. Protecting the water resources of some of these watersheds may require limiting and balancing development to provide the greatest possible benefits with the least significant disruption of the water resource.

Legislation and government edicts also provide controls that can aid water resource management. These laws may include:

- land use planning,
- zoning,
- permitted and prohibited land uses or types of development,
- restrictions on water use,
- limitations on water development,
- pollution control, or
- fill and removal restrictions.

All watershed users should know that private actions have public consequences on water quality and quantity.

In Oregon, and the Pacific Northwest, watershed councils are a growing voice in guiding the management of local watersheds. These councils are voluntary local advisory groups formed around interest in a particular watershed. Watershed councils use consensus-based decision making (depending on the support of all council members rather than a majority) to foster coordination and cooperation in managing their local watershed. As advisory groups their determinations do not have the force of law, but inform management agencies about the concerns and wishes of those most closely affected by watershed management decisions. In many cases these councils also plan and implement projects for



Adapted from original artwork by Sandra Noel, *Adopting A Stream A Northwest Handbook*, Adopt-A-Stream Foundation, 1988.

watershed protection, improvement, and education.

Watershed councils also play an important role in the Oregon Plan for Salmon and Watersheds. The Oregon Plan establishes local networks and partnerships between citizen groups, communities, local governments, state agencies and others to allow citizens to be proactive and address watershed problems. Currently the Oregon Plan has two parts. The Oregon Coastal Salmon Restoration Initiative, often called the Oregon Salmon Plan, seeks to develop programs to preserve and restore native coho salmon populations in coastal basins. The Healthy Streams Partnership is the second component. Its purpose is to create networks and partnerships to improve water quality throughout the state to meet the federal Clean Water Act standards.

Summary

Rivers, upland areas, mountaintops, and flood-formed bottomlands with their associated riparian areas are all part of one system. All are integrated with each other. Hillside shape controls the rate of water flow. All living elements in the watershed interact with and modify the energy flow through the system. The unique combination of climatic conditions, soil types, topography, vegetative cover, and drainage system define the specific character of each watershed.

Rivers do not stop at state lines or national boundaries. The effects of natural and human processes in a watershed are focused at its outlet, wherever it may be, even if a watershed crosses another state or country's borders. Each watershed is a part of a larger watershed whose downstream portion is affected by upstream influences.

Everyone depends on the resources watersheds provide. As the human population continues to grow, the demand on those resources intensifies. Human uses of land and water resources affect the ecological dynamics of a functioning watershed system, altering natural habitats as well as the quantity and quality of its water supplies. Some changes are improvements. Others are not. It is up to the public at all local, regional, state, and national levels to meet the challenges of balanced, productive watershed management.

Adapted from W.E. Bullard, "Watershed Management Short Course," Oct. 1975, and used with permission.

Extensions

1. "Where Does Water Go After School?" *Aquatic Project WILD*, pp. 82-85. Grades 6-12.
2. "Watershed," *Aquatic Project WILD*, pp. 172-175. Grades 4-12.
3. "To Dam or Not to Dam," *Aquatic Project WILD*, pp. 134-137.
4. "Identifying Your Watershed," *Watershed Uplands Scene*, pp. 17-36. Grades 9-12.
5. "Weather and Climate Investigation," *Watershed Uplands Scene*, pp. 89-108. Grades 9-12.
6. "Branching Out," *Project WET*, pp. 129-132. Grades K-2 and 6-8.
7. "A-Maze-ing Water," *Project WET*, pp. 219-222. Grades 3-8.
8. "Color Me a Watershed," *Project WET*, pp. 223-227. Grades 9-12.
9. "Common Water," *Project WET*, pp. 232-237. Grades K-8.
10. "Dilemma Derby," *Project WET*, pp. 377-381. Grades 6-12.
11. "Get the Ground Water Picture," *Project WET*, pp. 136-143. Grades 6-12.
12. "Irrigation Interpretation," *Project WET*, pp. 254-259. Grades K-8.
13. "A Grave Mistake," *Project WET*, pp. 311-315. Grades 6-12.

14. “The Pucker Effect,” *Project WET*, pp. 338-343. Grades 6-12.
15. “Surface Water,” *The Comprehensive Water Education Book*, pp. 141-143. Grades 4-6.
16. “Floods and Erosion,” *The Comprehensive Water Education Book*, pp. 144-145. Grades 3-6.
17. “Lakes,” *The Comprehensive Water Education Book*, pp. 146-147. Grades 4-6.
18. “Watersheds,” *The Comprehensive Water Education Book*, pp. 151-152. Grades K-6.
19. To make a simple watershed model crumple up a large piece of butcher paper and put it on the floor. Imagine that the paper is the surface of the land, the edges the shoreline, and the floor the sea. Use a permanent marker to trace the ridgelines separating one watershed from another. Then trace the river systems with a various colors of water soluble markers. Spray water on the watershed. Each river system will have its own color, but all colors mix in the estuaries and sea.
20. Since everyone lives in one, a first step in understanding watersheds is to explore your own local watershed by outlining its boundaries. Check with your local library for topographic maps if you cannot determine the boundaries visually.
    a. On a map, trace the lines along the high points that separate your creek or river from the next.
    b. Map the land use in your watershed (e.g., streets, forests, farms, yards, etc.)
    c. List all possible places rain goes in your watershed.
    d. Go outside the school building. What happens to the rain when it falls on the school roof? Does any of it get to a stream or river? How?
    e. Are you ever anywhere that is not in a watershed?
    f. Collect newspaper clippings on watershed management problems in your area.
    g. In small groups have students design their own watershed. Each design should include the location, climate, uses of, abuses to, human impact on, and group perceptions of what a watershed should and should not be. After preparing visuals to depict their watershed, groups present their design to the class. (Contributed by Mary Roberts, 1989)
21. Have students develop an oral history of their watershed. Students should first develop a list of questions they want to research about their watershed, then set up interviews with people in the community. Questions should include past watershed events, both human-caused and natural, how it looked fifty or more years ago, and more. Students can then summarize their research into a written report or verbal presentation or both.

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A sense of place: your ecological address

__Activity Education Standards:__ Note alignment with Oregon Academic Content Standards beginning on p. 483.

Objectives

Students will (1) define watershed, (2) determine boundaries of a watershed on a map, (3) draw a map of their own watershed, (4) identify potential effects of human and natural events on a watershed, (5) calculate the number of miles of streams and rivers in their watershed, and (6) identify potential effects of intermittent streams in the watershed.

Method

Students will brainstorm, create, and illustrate a definition of a watershed, outline watershed boundaries on maps, draw a map of their own watershed, and answer questions about watersheds.

For younger students

1. Consult extension activities at the end of each chapter to address the needs of younger students.
2. Read activity background information aloud to younger students or modify for your students' reading level.
3. A three dimensional model, perhaps of modeling clay, may help younger students visualize a watershed. Then, use the Umatilla Drainage Basin and Mid-Coast Drainage Basin maps (or substitute a map of a local watershed) as overheads along with a teacher-led discussion and inquiry to answer all questions.

This activity is an adaptation of the original *Stream Scene* activity "Does The Earth Wear A Raincoat" and "Finding Your Ecological Address" from *The Fish Hatchery Next Door* by Bill Hastie, et al., Oregon Department of Fish and Wildlife, 1996. The material was also published in "Ecological Address: At Home In Your Watershed," National Science and Technology Week, 1992-93 Packet, National Science Foundation, Washington, D.C.

Materials

For each pair of students

- copies of student sheets pp. 53-58
- copies of Oregon watershed maps (mid-coast drainage basin and Umatilla drainage basin) or a local watershed drainage basin map (see Chapter 14.4 for source of Oregon drainage basin maps.
- paper for illustrating a watershed "definition" and drawing a watershed "map"
- colored pencils or markers
- string or yarn (about one foot per student)

Notes to the teacher:

To set the stage and work through all the parts of this activity may take two or three class periods. You can also choose the parts that are appropriate for your students or that will fit your classroom schedule.

In the procedures that follow, an "ecological address" includes the name of the watershed in which students live as well as each successively larger stream and watershed—up to and including the major river from which the largest watershed usually takes its name. This system also includes the large lakes or the ocean into which that river feeds. Use the Columbia River basin watershed

Vocabulary

divide
intermittent stream
sub-basin
watershed

as an overhead transparency to demonstrate this concept.

Help students understand their "sense of place." Each of us has a place we want to become part of, care about, and want to protect or enhance. Understanding this concept and the responsibilities that go along with it are part of watershed education. When people have a greater understanding of their watershed, they gain awareness of how their personal actions, local laws and regulations, and everyday practices affect the integrity and stability of their ecological address and the larger biological community.

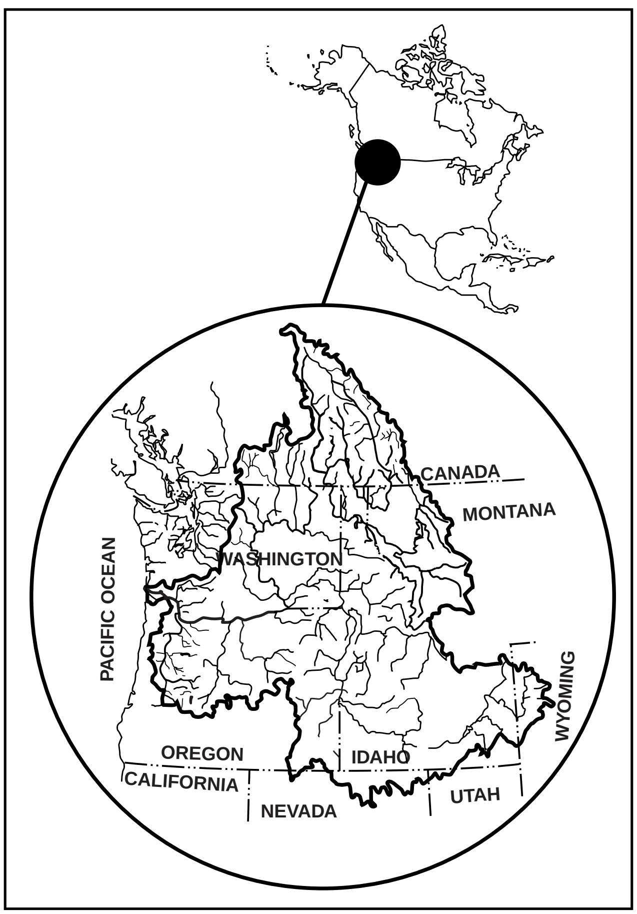
Depending on age level, students will need varying degrees of background information before proceeding with the "brainstorming and definition of a watershed" part of the activity. The activity's background section is appropriate as is a student reading developed from the chapter content.

A simple demonstration may also help students understand the concept of watershed. Trace the outline of your hand, wrist, and part of your arm on the chalkboard. Color in the space between your fingers and label your arm "Muddy River." Tell the students this outline is a model for a watershed area. Your fingers represent streams that feed into the larger river (your arm). The colored space between your fingers is land, where people live. Let students know that a watershed's name is usually taken from the stream or river that serves as the main collector of all the water in the watershed. Ask students what the watershed you just drew would be called (Muddy River Watershed). Write the name on the board. Create names for the finger tributaries and write those on the board, too. Ask students how large they think watersheds can be, then how small they can be. They should recall this from their background reading. Impress upon the students that large watersheds include many small watersheds.

Use maps that parallel the local watershed situation as closely as possible. Substituting local maps for the mid-coast and Umatilla drainage basin maps where appropriate will help students associate more closely with their own watershed and develop their own "sense of place." Modify the procedures to work with the local map. In urban areas a city map may be needed to determine the exact watershed in which a student's home or school might be found. Depending on the proximity of waterways, the watershed named should reflect that students' ecological addresses can have several components, from the smallest watershed they can observe to a larger watershed of which the smaller one is a part.

It is not necessary for the "map" created in Step 7 to be to scale, but it should represent the watershed(s) in which the students live. Use the Five Rivers water-

Columbia River Basin



Based on: Ed Chaney, *A Question of Balance: Water/Energy—Salmon and Steelhead Production in the Upper Columbia River Basin, Summary Report*, Nov. 1978. NW Resource Information Center, Inc.

shed map as an example. As an alternative or additional activity, have the entire class make a larger map of the watershed on large sheets of paper.

Background

Do you know ...

Water runs downhill. We all know that. The instant that a drop of rain hits the earth, it begins its journey to the ocean. If it falls as snow, it has to wait until it melts! Of course, not all water drops make it to the ocean. Some are taken up by plant roots and are transpired into the air through the plant's leaves. Some evaporate in puddles or other areas that hold water. Some filter down into underground areas, moving slowly downhill. But most water drops end up as runoff, the water that finds its way into creeks, streams, and rivers.

This long or short journey to the ocean takes place within a watershed. If you stand in a streambed and look upstream at all the land the stream drains, you are looking at the stream's **watershed**. Almost all the area of a watershed is land—not water! And, almost everything that drains it happens on that land. In other words, all land on earth is in a watershed.

Every body of water, stream, lake, pond, or river, has a watershed. Even a mud puddle has a watershed! Watersheds can be big or small. A mud puddle has a watershed of only a few square feet, while the Columbia River watershed has 258,000 square miles! The biggest watershed in the country is the Mississippi River, which drains all the land between the Rocky Mountains and the Appalachian Mountains.

A raindrop, no matter where it falls in the Columbia River watershed (unless it evaporates), will end up at the mouth of the Columbia River at Astoria. Most large watersheds are made up of many smaller watersheds called **sub-basins**. For instance, the Columbia watershed includes the Snake, John Day, Deschutes, Umatilla, and Willamette watersheds plus many others.

Watersheds are separated by ridges, called **divides**. The Continental Divide of the Unite States, for example, is in the Rocky Mountains. All the rain and snow falling on the west side of the divide flows into the Pacific Ocean. All the rain and snow falling on the east side of the divide, sooner or later, ends up in the Atlantic Ocean.

Procedure

Now it's your turn . . .

1. What is your home mailing or street address? What are the addresses of several other students in your class? These postal addresses have been devised by society—in other words, they are "social" addresses. Social addresses are important because people need to be located within their community by family, friends, and services such as the mail, police, fire, or ambulance.
2. You have another kind of address, called an "ecological address." Ecological refers to the relationship between an organism and its environment. Just as a postal address tells people one way they are connected to the community, the ecological address tells people how they are connected to the land on which they live. In this activity, your "ecological address" is based on an ecological feature you are just now learning about—a watershed.
3. With your partner, brainstorm words or ideas that make you think of a watershed. Write down your thoughts. Using your ideas as a starting point, create a watershed definition. Write your definition in the space provided for Question 1 on the student worksheet. Now, using a piece of paper and markers, draw and color a picture of the watershed you just defined. When all the groups are finished share your definition and drawing with the rest of the class. Post your drawing on the wall. As a class discuss all of the group's definitions and decide on the definition that best states the meaning of a watershed. You may have to combine several

group's definitions to come up with the best answer.

4. Look at your copy of the Mid-Coast Drainage Basin map. Locate a stream called Five Rivers (Five Rivers runs through the communities of Denzer, Fisher, and Paris). Mark the point where Five Rivers runs into the Alsea River. Where does the Alsea River go? **(Pacific Ocean.)**

5. Locate the Crab Creek watershed by drawing a line around it with a colored pencil or marker. Then, locate the Lobster Creek watershed in the same way with another color. With a third color, draw a line around the entire Five Rivers watershed. Check with your teacher to see if you have correctly identified the watersheds. Answer Questions 2, 3, and 4 on the student worksheet from the mid-coast drainage basin map.

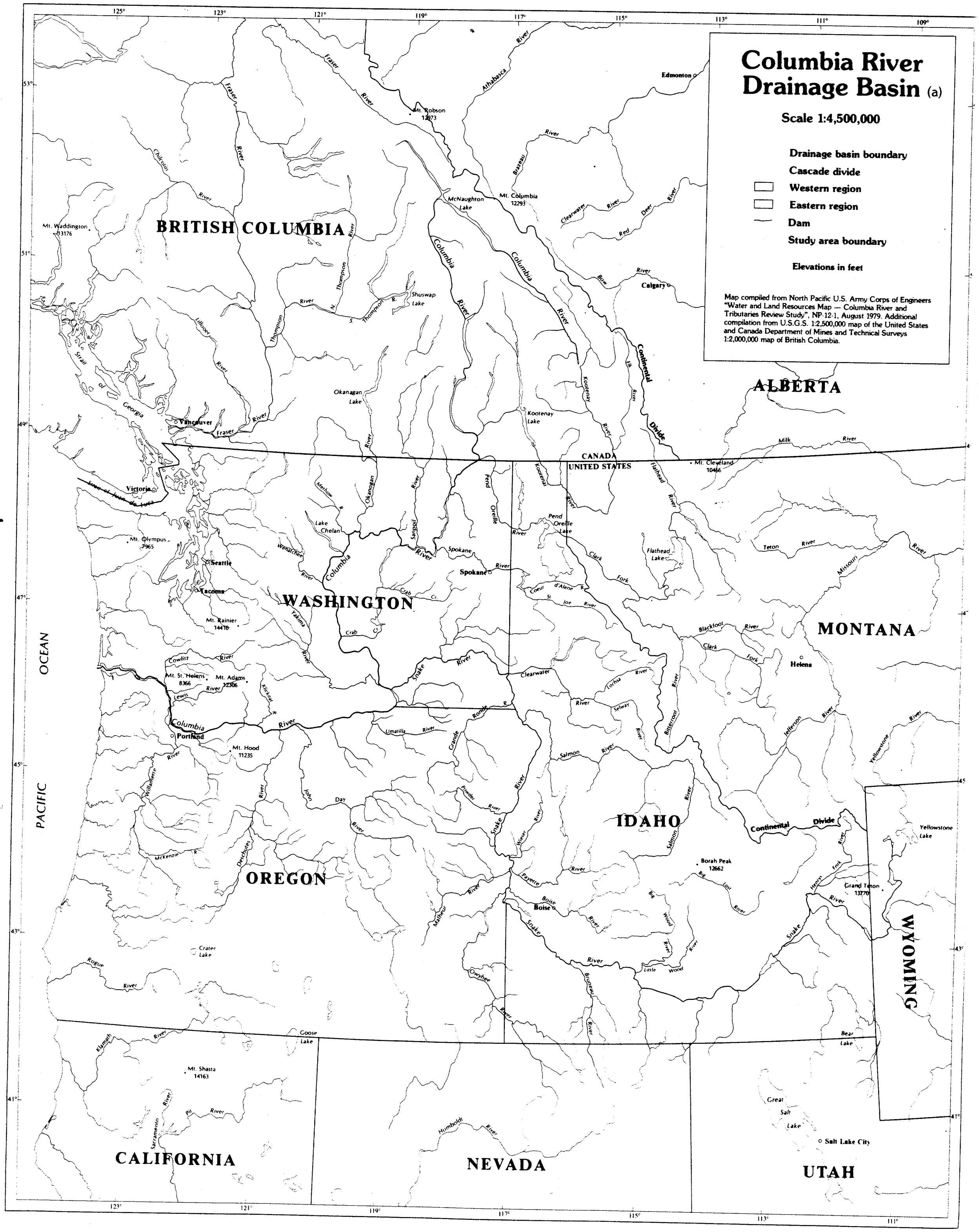
6. Now, look at your copy of the Umatilla drainage basin map. The Umatilla River watershed is in Northeastern Oregon. Locate a stream called Willow Creek (Willow Creek runs through the communities of Heppner, Jordan, and Ione). Locate the Spring Hollow watershed by drawing a line around it with a colored pencil or marker. Then, locate the Rhea Creek watershed in the same way with another color. With a third color, draw a line around as much of the Willow Creek watershed as possible. Answer Questions 5 through 10 on the student worksheet.

7. Using an Oregon state map or local map that shows streams and rivers, name the watershed in which you live. This watershed is your "ecological address." It describes how you are connected to the land and water system that drains it. Share your ecological address while other students follow along on their own map.

8. On the second piece of paper make a "map" of your ecological address. Refer to the Five Rivers or Umatilla drainage basin maps as examples. Label the communities and other important features in your watershed. Share your watershed map with the rest of the class.

9. Brainstorm a list of what you think can happen to water as it moves through a watershed. Use a check to mark the ones caused by human activities. If some items on your list include substances that can get into the water in your watershed, use a marker to trace the path these substances would follow on your watershed map until it empties into larger watershed areas. Repeat this process with another color to mark the effects of non-human influences on watersheds, such as heavy rains, wind, and other natural events. Compare the two lines. Which of the two, human-caused or non-human would have the greatest effect on your watershed? Record your answer has Question 11 on the student worksheet.

10. How many miles of stream and river are in your watershed? Use the "scale of miles" on the published map to determine how many miles are represented by a certain length, usually one or two inches. Use a string to measure that length, then apply the string, following the curves on your map, to measure the distance. Multiply the number of "string lengths" times the map scale to obtain the number of stream miles. Record the number of miles for this step under Question 12 on the worksheet. How many miles of stream were affected by the human-caused events in Step 9? How many miles of stream were affected by non-human events in Step 9? Record your answers on the student worksheet and answer the remaining question.


Columbia River Drainage Basin (a)
Scale 1:4,500,000
Drainage basin boundary
Cascade divide
Western region
Eastern region
Dam
Study area boundary
Elevations in feet
Map compiled from North Pacific U.S. Army Corps of Engineers "Water and Land Resources Map — Columbia River and Tributaries Review Study", NP-12-1, August 1979. Additional compilation from U.S.G.S. 1:2,500,000 map of the United States and Canada Department of Mines and Technical Surveys 1:2,000,000 map of British Columbia.
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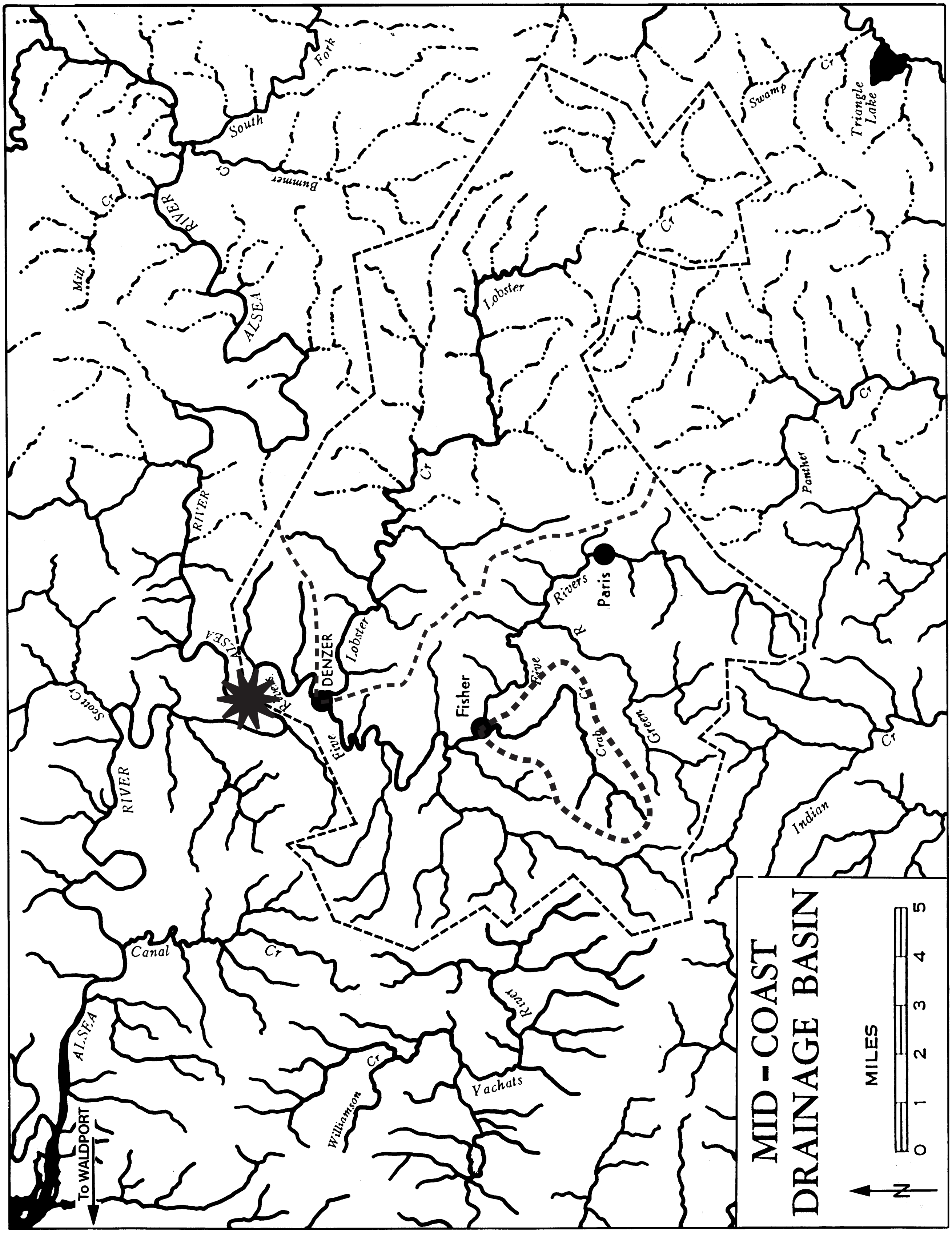
IDAHO
OREGON
WYOMING
CALIFORNIA
NEVADA
UTAH
PACIFIC OCEAN
CANADA
UNITED STATES
Continental Divide
Columbia River
Snake River
Vancouver
Victoria
Seattle
Tacoma
Portland
Spokane
Boise
Helena
Calgary
Edmonton
Salt Lake City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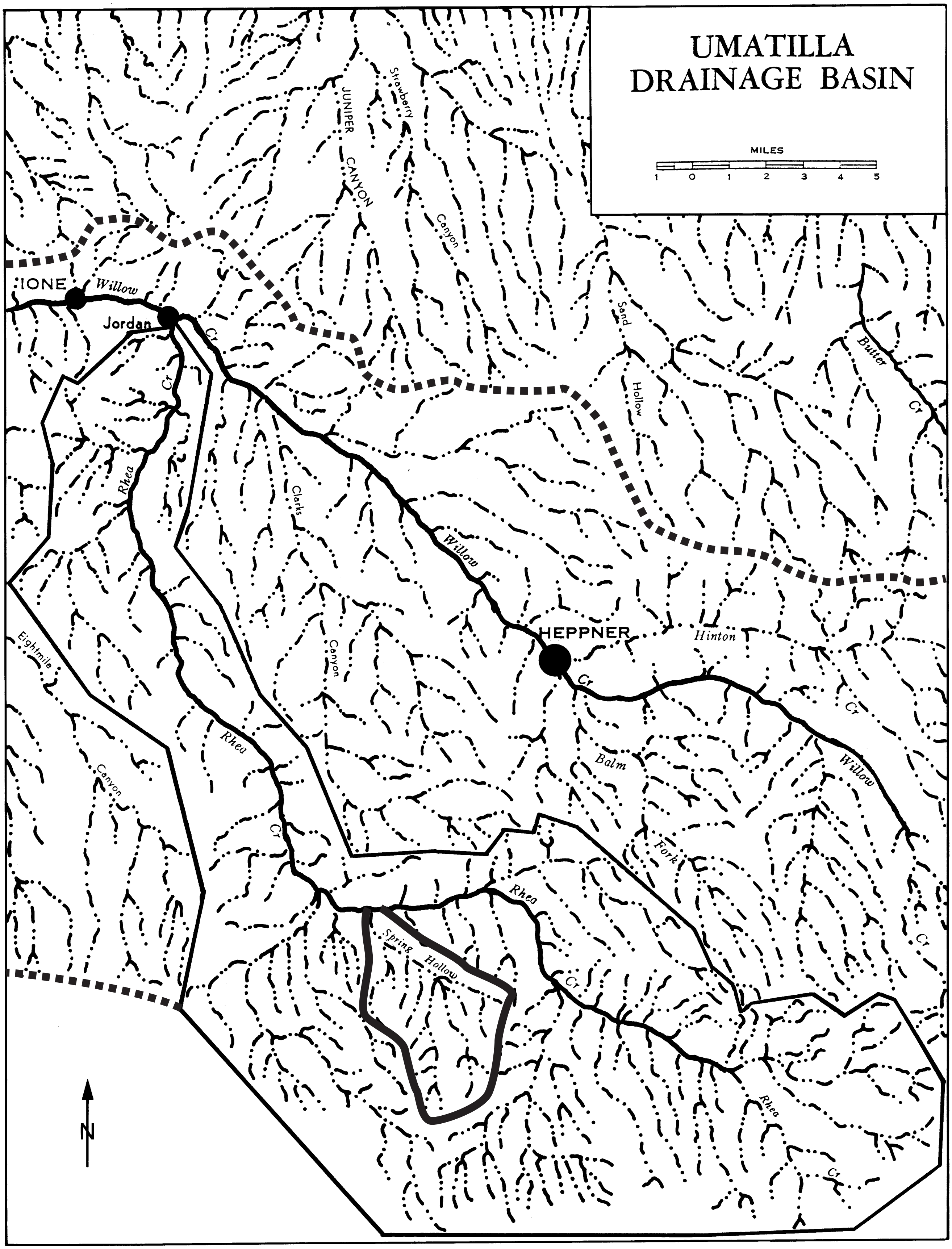
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Clarks
Canyon
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HEPPNER
Hinton
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Eightmile
Canyon
Rhea
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Balm
Fork
Willow
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Rhea
Spring
Hollow
Cr
Rhea
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N

Questions

1. Describe a watershed in your own words.
   Answers will vary, but should approximate all the land area that drains into a particular body of water.
2. If you lived two miles south of the town of Fisher, in which watershed (or sheds) would you live?
   You would actually live in the Crab Creek watershed which is part of the larger Five Rivers watershed. Remind students that a large watershed is made up of many smaller watersheds, and that both Crab Creek or Five Rivers would be correct answers to the question.
3. If you lived in Paris, in which watershed would you live?
   Five Rivers
4. Using the mid-coast drainage basin map as a guide, explain in your own words why the following statement is true. “Everyone lives in a watershed.”
   All land has waterways running through it that drain into larger waterways. This is also true in urban areas where rainwater feeds into storm drains. The drains then feed into nearby streams or rivers.
5. The watersheds on these two maps are similar in size. Compare the two watersheds. What other similarities and differences did you note when outlining the watershed boundaries?
   Each watershed is composed of several smaller watersheds. The Willow Creek watershed has more sub-basins than Five Rivers. The shape of the watersheds depends on the drainage patterns of the streams. It is much harder to outline the watersheds with intermittent streams than it is to outline streams that have year-round water.
6. In which watershed (or sheds) is the community of Jordan found?
   Jordan is located at the mouth of the Rhea Creek watershed which is part of the Willow Creek watershed.
7. If a stream does not have a name on the map does that mean it is not a watershed? Explain your answer.
   No, stream names are only a convenient way to designate different sub-basins within a watershed. Any land areas through which water drains to a larger body of water is a watershed.
8. An **intermittent stream** is a stream that does not flow year-round. These streams are shown on maps as lines separated by dots. List as many reasons as you can why streams do not flow year-round.
   Lack of rainfall, lack of snowmelt, removal of vegetation that holds back moisture (reducing rapid runoff), the topography (flat or steep), the soil type, etc.
9. How would fish be affected by intermittent flow?
   Fish would be forced downstream to where the stream was flowing or would be stranded in small pools where they would eventually die as the stream dried up.
10. How would wildlife living near the stream be affected by intermittent flow?
    Food, cover and drinking water would be absent from the area, forcing wildlife to go elsewhere.

11. Based on the colored lines on your own watershed map, which of the two, human-caused or non-human influences, would have the greatest effect on your watershed? Why?

    Human-caused effects would have the most influence because they are normally carried further throughout the watershed than natural events. Natural events are usually more localized.

12. How many miles of streams and rivers are found on your watershed map? How many miles of stream were affected by the human-caused events in Step 9? How many miles of stream were affected by non-human events in Step 9?

    Answers will vary.

13. What have you learned about your watershed, an ecological address, and a sense of place in this activity?

    Answers will vary.

Going Further

1. Using a topographic map as a reference, build a model of your local drainage basin. (See “What a Relief” activity in this unit.) Design a way to use this or other models of your local watershed to show someone the key features (rock types, soils, rainfall amounts, slope, and other characteristics) of your watershed.
2. Design an experiment to monitor the daily weather patterns in your watershed for several weeks or even months. Develop graphs, displays, and a presentation to share the results of your investigation.
3. Add five structures or features (dams, irrigation canals, industry, vegetation, etc.—it is even better if these are real) that would affect the flow of water on your watershed map. Develop hypotheses about how each of these structures will affect your watershed. How could you test your hypotheses?
4. Build a list of who and what uses your watershed—from people to fish to wildlife. Research the effects each has on the watershed.

Name

A sense of place: your ecological address

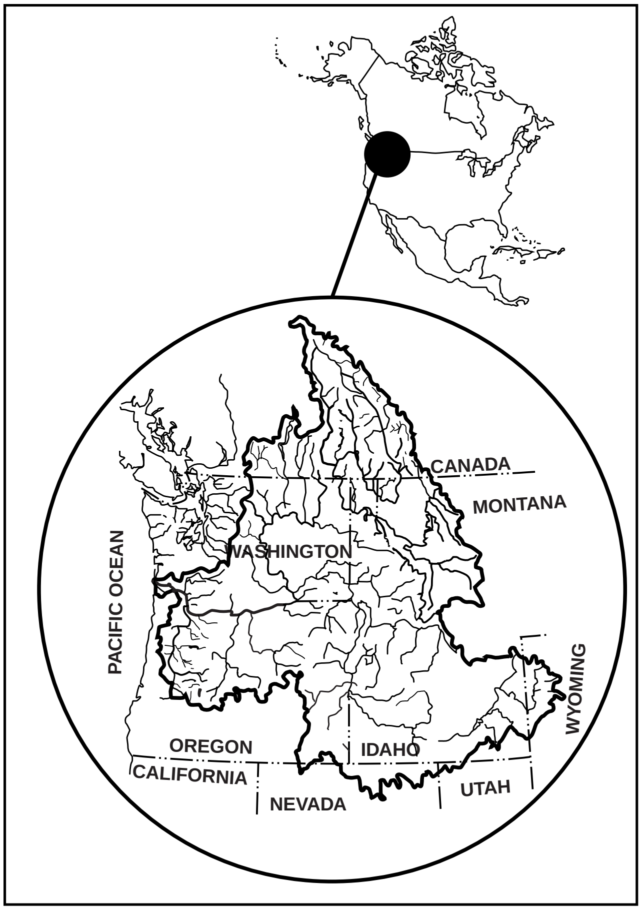
Do you know ...

Water runs downhill. We all know that. The instant that a drop of rain hits the earth, it begins its journey to the ocean. If it falls as snow, it has to wait until it melts! Of course, not all water drops make it to the ocean. Some are taken up by plant roots and are transpired into the air through the plant's leaves. Some evaporate in puddles or other areas that hold water. Some filter down into underground areas, moving slowly downhill. But most water drops end up as runoff, the water that finds its way into creeks, streams, and rivers.

Vocabulary

divide
intermittent stream
sub-basin
watershed

Columbia River Basin



Based on: Ed Chaney, *A Question of Balance: Water/ Energy—Salmon and Steelhead Production in the Upper Columbia River Basin, Summary Report*, Nov. 1978. NW Resource Information Center, Inc.

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This activity is an adaptation of the original *Stream Scene* activity "Does The Earth Wear A Raincoat" and "Finding Your Ecological Address" from *The Fish Hatchery Next Door* by Bill Hastie, et al., Oregon Department of Fish and Wildlife, 1996. The material was also published in "Ecological Address: At Home In Your Watershed," National Science and Technology Week, 1992-93 Packet, National Science Foundation, Washington, D.C.

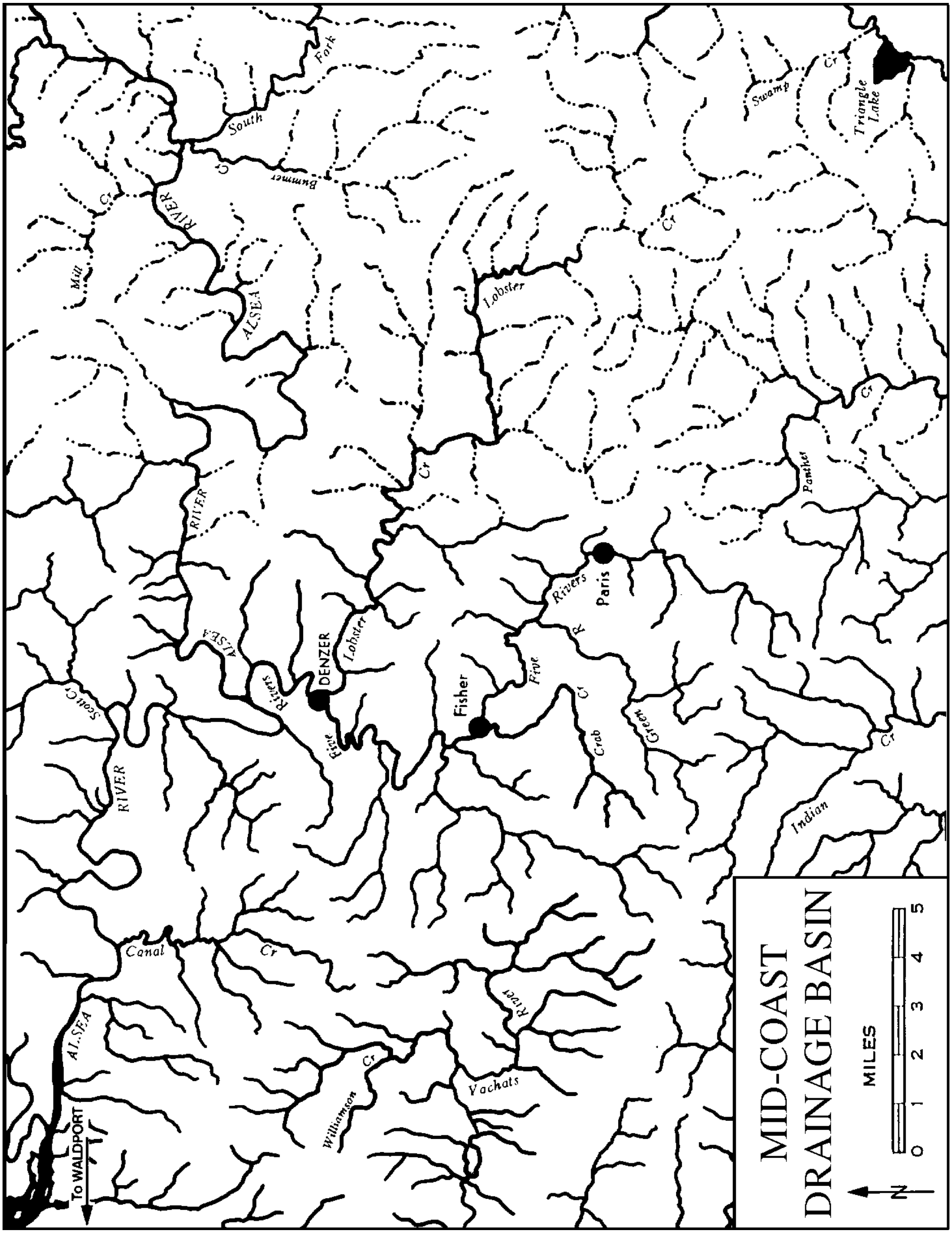
Student sheet

Snake, John Day, Deschutes, Umatilla, and Willamette watersheds plus many others.

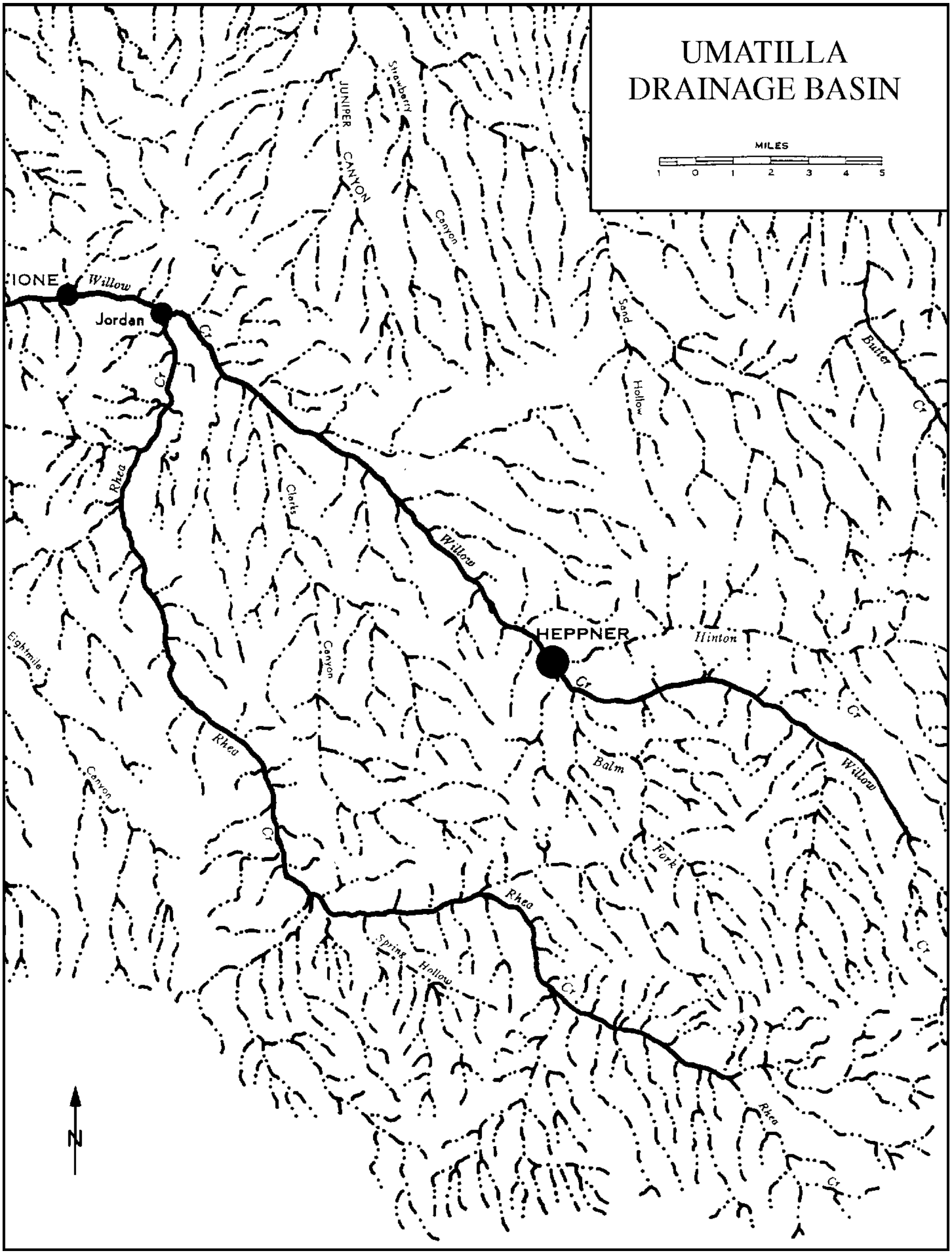
Watersheds are separated by ridges, called **divides**. The Continental Divide of the Unite States, for example, is in the Rocky Mountains. All the rain and snow falling on the west side of the divide flows into the Pacific Ocean. All the rain and snow falling on the east side of the divide, sooner or later, ends up in the Atlantic Ocean.

Now it's your turn . . .

1. What is your home mailing or street address? What are the addresses of several other students in your class? These postal addresses have been devised by society—in other words, they are "social" addresses. Social addresses are important because people need to be located within their community by family, friends, and services such as the mail, police, fire, or ambulance.
2. You have another kind of address, called an "ecological address." Ecological refers to the relationship between an organism and its environment. Just as a postal address tells people one way they are connected to the community, the ecological address tells people how they are connected to the land on which they live. In this activity, your "ecological address" is based on an ecological feature you are just now learning about—a watershed.
3. With your partner, brainstorm words or ideas that make you think of a watershed. Write down your thoughts. Using your ideas as a starting point, create a watershed definition. Write your definition in the space provided for Question 1 on the student worksheet. Now, using a piece of paper and markers, draw and color a picture of the watershed you just defined. When all the groups are finished share your definition and drawing with the rest of the class. Post your drawing on the wall. As a class discuss all of the group's definitions and decide on the definition that best states the meaning of a watershed. You may have to combine several group's definitions to come up with the best answer.
4. Look at your copy of the Mid-Coast Drainage Basin map. Locate a stream called Five Rivers (Five Rivers runs through the communities of Denzer, Fisher, and Paris). Mark the point where Five Rivers runs into the Alsea River. Where does the Alsea River go?
5. Locate the Crab Creek watershed by drawing a line around it with a colored pencil or marker. Then, locate the Lobster Creek watershed in the same way with another color. With a third color, draw a line around the entire Five Rivers watershed. Check with your teacher to see if you have correctly identified the watersheds. Answer Questions 2, 3, and 4 on the student worksheet from the mid-coast drainage basin map.
6. Now, look at your copy of the Umatilla drainage basin map. The Umatilla River watershed is in Northeastern Oregon. Locate a stream called Willow Creek (Willow Creek runs through the communities of Heppner, Jordan, and Ione). Locate the Spring Hollow watershed by drawing a Ione around it with a colored pencil or marker. Then, locate the Rhea Creek watershed in the same way with another color. With a third color, draw a line around as much of the Willow Creek watershed as possible. Answer Questions 5 through 10 on the student worksheet.
7. Using an Oregon state map or local map that shows streams and rivers, name the watershed in which you live. This watershed is your "ecological address." It describes how you are connected to the land and water system that drains it. Share your ecological address while other students follow along on their own map.
8. On the second piece of paper make a "map" of your ecological address. Refer to the Five Rivers or Umatilla drainage basin maps as examples. Label the communities and other



Student sheet



Student sheet

important features in your watershed. Share your watershed map with the rest of the class.

9. Brainstorm a list of what you think can happen to water as it moves through a watershed. Use a check to mark the ones caused by human activities. If some items on your list include substances that can get into the water in your watershed, use a marker to trace the path these substances would follow on your watershed map until it empties into larger watershed areas. Repeat this process with another color to mark the effects of non-human influences on watersheds, such as heavy rains, wind, and other natural events. Compare the two lines. Which of the two, human-caused or non-human would have the greatest effect on your watershed? Record your answer for Question 11 on the student worksheet.

10. How many miles of stream and river are in your watershed? Use the “scale of miles” on the published map to determine how many miles are represented by a certain length, usually one or two inches. Use a string to measure that length, then apply the string, following the curves on your map, to measure the distance. Multiply the number of “string lengths” times the map scale to obtain the number of stream miles. Record the number of miles for this step under Question 12 on the worksheet. How many miles of stream were affected by the human-caused events in Step 9? How many miles of stream were affected by non-human events in Step 9? Record your answers on the student worksheet and answer the remaining question.

Questions

1. Describe a watershed in your own words.

2. If you lived two miles south of the town of Fisher, in which watershed (or sheds) would you live?

3. If you lived in Paris, in which watershed would you live?

4. Using the mid-coast drainage basin map as a guide, explain in your own words why the following statement is true. “Everyone lives in a watershed.”

5. The watersheds on these two maps are similar in size. Compare the two watersheds. What other similarities and differences did you note when outlining the watershed boundaries?

6. In which watershed (sheds) is the community of Jordan found?

7. If a stream does not have a name on the map does that mean it is not a watershed? Explain your answer.

8. An intermittent stream is a stream that does not flow year-round. These streams are shown on maps as lines separated by dots. List as many reasons as you can why streams do not flow year-round.

9. How would fish be affected by intermittent flow?

10. How would wildlife living near the stream be affected by intermittent flow?

11. Based on the colored lines on your own watershed map, which of the two, human-caused or non-human influences, would have the greatest effect on your watershed? Why?

12. How many miles of streams and rivers are found on your watershed map? How many miles of stream were affected by the human-caused events in Step 9? How many miles of stream were affected by non-human events in Step 9?

13. What have you learned about your watershed, an ecological address, and a sense of place in this activity?

Tour of a topo

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

Objectives

The student will demonstrate how to use the information on a topographic map to (1) determine the name; location, and source of a quadrangle map; (2) determine the names of adjacent maps in the series; (3) describe the differences in roads using the map's legend; (4) determine the map's scale; (5) describe and define contour lines and how to find an index contour; (6) describe the difference between True North and magnetic north and how to find the map's declination; (7) determine latitude, longitude, and universal transverse mercator (UTM) coordinates on a map; and (8) describe how to use the Public Lands Survey System to find a specific location on a topographic map.

Method

Using the "Tour of a Topo" descriptions, the student will learn about the information available on a topographic map and will apply this information to answer questions about specific locations on a map.

For younger students

1. Read activity background information aloud to younger students or modify for your students' reading level.
2. Use the "Tour of a Topo" map as an overhead transparency. Work through the tour stops as a class, while students follow along on their copies of a real topographic map. Eliminate the details that are too difficult for younger students to absorb.
3. Modify the list of questions to meet the needs of younger students. Call specific attention to familiar landmarks.

Materials

- copy of "Tour of a Topo" map guide for each student
- local topographic map for each pair of students

Notes to teacher

A topographic map of your local watershed works best for this exercise as students relate well to familiar landmarks and place names.

Vocabulary

base line
contour
contour lines
contour interval
declination
degree of latitude
degree of longitude
equator
geographic north
Global Positioning System (GPS)
hachure
index contour
latitude
legend
longitude
magnetic north
map
map series
meridian
minutes
orientation
prime meridian
Public Land System
quadrangle
range
relief
representative fraction
scale (graphic or verbal)
seconds
section
topographic map
township
true north
universal transverse mercator (UTM)

Tour of a Topo was developed by Michael Goodrich, Director, GeoQuest Publications, PO Box 1665, Lake Oswego, OR 97035, and is used with permission.

Local topographic maps are available from the U.S. Geological Survey (USGS) at 1-800-USA-Maps. An index of Oregon topographic maps is also available from the USGS. The index can help you quickly decide which maps are available for your area. You can also get topographic maps from local sporting good outlets and map stores. Expect to pay $6.00 to $7.00 per map (1999 prices).

Laminate the maps to extend their use. If students are to mark on the laminated maps, use water-based felt marker pens. Maps are easily wiped clean with damp paper towels and are quickly available for the next class' use.

Map symbols used on most topographic maps are not discussed in this activity. The USGS also produces a chart of symbols that is helpful for students involved in map work. Ask for a symbol chart when requesting maps from USGS. Earth-Science textbooks often have USGS topographic map legends in their appendices.

The questions at the end of this activity can be used as a worksheet as students work through the exercise or it can serve as a measure of understanding (or quiz) following the activity.

Background

Do you know . . .

... how to use a map? Do you know how to give a legal description of your school's location or maybe your mom or dad's favorite fishing hole? Do you know how to get the elevation of your favorite ski slope or how to determine the scale of distance a map covers?

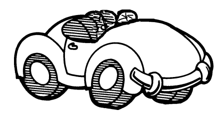
A map gives you a lot of information. With a little practice you can use this information to find out all kinds of things about your local watershed. You can learn a lot by looking at the information outside of your map's boundaries as well as inside.

The first important step in getting to know your watershed is to get a map of it. But, a map isn't a lot of help if you don't know how to use it.

Maps are the "common ground" among all the players in a watershed study. They are important communication tools if working with other groups in the same watershed. Each group needs a copy of the same map, so everyone can talk the same language and keep the same reference points.

Maps are a permanent record of your watershed. You can mark your study sites, important reference points, restoration work sites, land-use designations, pollution sources, historical sites, or other important locations that are part of your watershed study.

Procedure



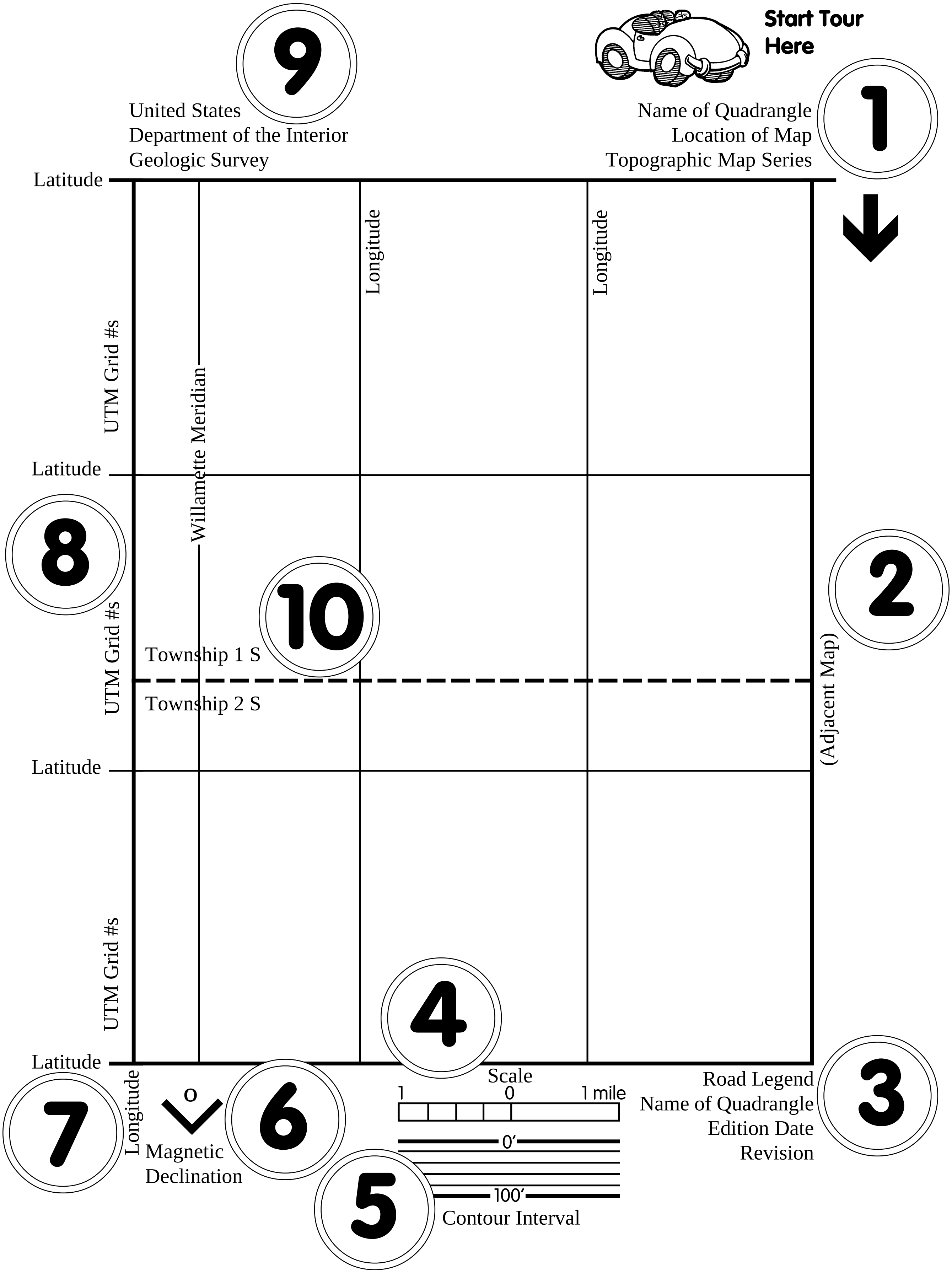
Now it's your turn . . .

Just what can you learn from a map? Join us for a "tour of a topo" and find out.

Use your "Tour of a Topo" tour guide and a local topographic map. Work in pairs and explore the parts of a map and your watershed. Our "tour" begins in the upper right-hand corner of the topographic map. First we will travel around the outside of the map (clockwise) and then go to the inside. We will stop where there is a number on the tour guide. Answer the questions at the end when you are done.

Stop 1: Name, Location, Series

The map we'll be touring is called a **quadrangle** map. It is usually named after a prominent feature in the area—a town, city, mountain or a lake. It is called a quadrangle because it has four (quad is the word prefix that means four) equal sides, each with an equal number of **degrees** of **latitude** and **longitude**. The length of a degree of latitude is about the same throughout the world. Latitude lines are parallel to the equator, run east-west, and are measured in degrees north and south of the equator. The length of a degree of longitude varies with distance from the **equator**. Longitude lines come together at the poles, run north-south, and are measured east and west of the prime meridian, which runs through Greenwich, England (see the globe and chart on p. 62).


Start Tour Here
1
Name of Quadrangle
Location of Map
Topographic Map Series
9
United States
Department of the Interior
Geologic Survey
Latitude
Longitude
Longitude
UTM Grid #s
Willamette Meridian
Latitude
8
10
2
UTM Grid #s
Township 1 S
Township 2 S
(Adjacent Map)
Latitude
UTM Grid #s
4
Latitude
7
Longitude
o
Magnetic
Declination
6
Scale
1
0
1 mile
0′
100′
5
Contour Interval
Road Legend
Name of Quadrangle
Edition Date
Revision
3

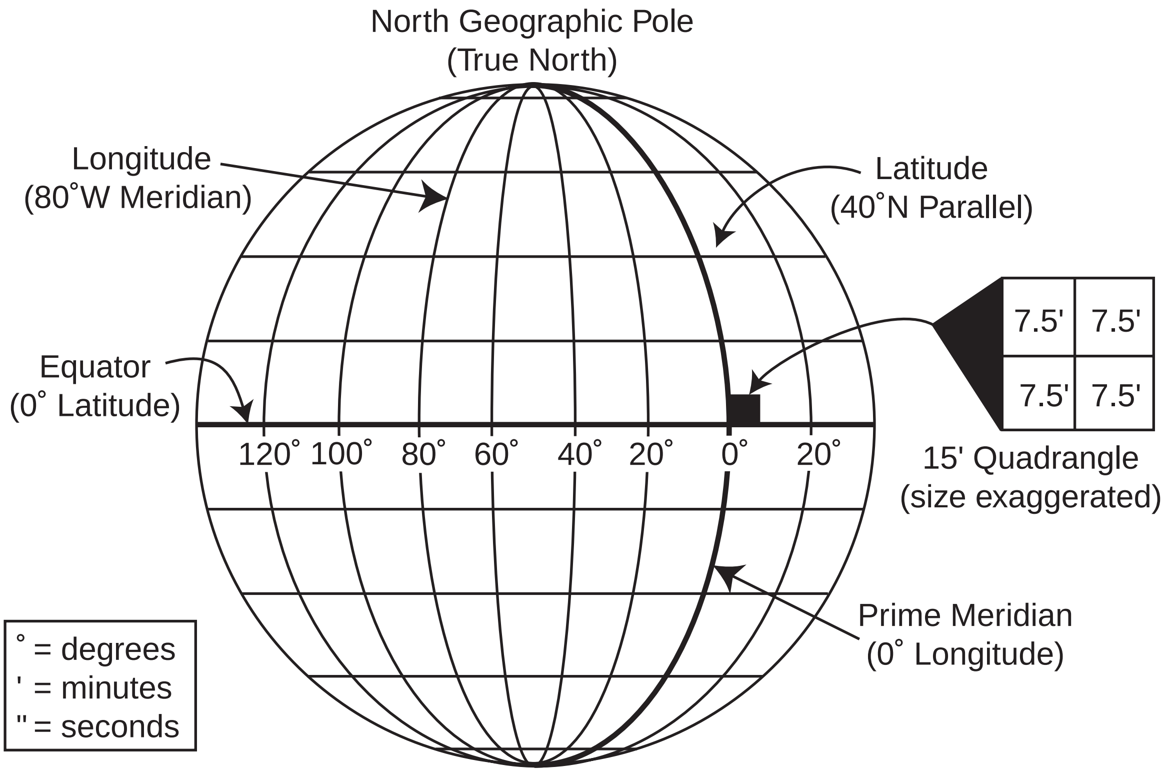
Latitude	*Length (miles) of °Longitude	** Length (miles) of °Latitude	
0 (equator)	69.17	68.71	very close
15	66.83	68.75	↓
30	59.95	68.88	
45	48.99	69.05	
60	34.67	69.23	
75	17.96	69.36	
90 (poles)	0.00	69.40	not close

*Length of a degree of arc along the latitude named.
**Length of a degree of arc centered on the latitude named.
(Table based on the National Geodetic Survey 1980 ellipsoid.)

Looking at your map, however, you'll notice that the map *length* is different than its *width*. That's because the earth is a three-dimensional globe but the map is a flat, two-dimensional picture of a small piece of the earth. A topographic map for land straddling the equator (for example, Ecuador or Indonesia) would be almost square. As you move away from the equator, the map begins to look like a rectangle.

On a map, a degree is a measure of distance. There are 360 degrees in a circle. A line of latitude or longitude circles the earth. A degree of latitude or longitude, then, is 1/360th of the total length of that line. Each degree can be divided into 60 smaller pieces called minutes. Each minute can be divided further into 60 smaller pieces called seconds. There are special symbols for degree, minute, and second. Seventy degrees is written 70º. Thirty minutes is written 30'. Twenty-two seconds is written 22". Minutes and seconds are a measure of distance, just as degrees are. If 1º is equal to approximately 70 miles of latitude, then 30' (half of a degree) is equal to 35 miles, and 30" (half of a minute or one-fourth of a degree) is equal to 15 miles.

We normally think of minutes and seconds as measurements of time. When working with a map, minutes and seconds become fractions of a degree. Therefore, a fraction of a degree is also a measure of distance. If 1º is equal to approxi-



mately 70 miles of latitude, then 30' (half of a degree) is equal to 35 miles.

The *location* of the map gives the state and county where the quadrangle is located. Quadrangle maps are published in several sizes, but the two most common are 15' quadrangle maps and 7.5' quadrangle maps. A 15' quadrangle represents an area bounded by 15 minutes of latitude (one-fourth of a degree) and 15 minutes of longitude (one-fourth of a degree). Each 15' map can be divided into four 7.5' maps. Most of the United States is mapped using the 7.5' series.

If you have any questions about Stop 1, a detour to the bibliography or glossary might be in order. Proceed to Stop 2.

Stop 2: Adjacent maps

What if you wanted to go beyond the borders of your map? The maps that border yours are called adjacent maps. Stop 2 is where you will find information about an adjacent map. There are typically eight maps that border any topographic quadrangle map. Looking below, we see our map in the middle. If the adjacent map to the east (Gladstone #5) is not in parenthesis along the boundary of the map, then the information is included at the bottom of the map.

1	2	3
4	Our Map	5
6	7	8

Adjacent Quadrangles

1. Linnton
2. Portland
3. Mt. Tabor
4. Beaverton
5. Gladstone
6. Sherwood
7. Canby
8. Oregon City

Stop 3: Legend

The symbols used for roads are part of the map's **legend**. Below the legend is the name of the quadrangle and the year the map was made.

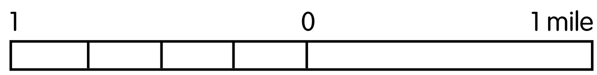
Because maps cannot be updated yearly (a Coast Range quadrangle in Oregon has not been revised since 1949), there is often a date for when the map was revised. You can tell if a map has a partial revision because the revised portion is shown in a different color.

Let's move on to Stop 4.

Stop 4: Scale

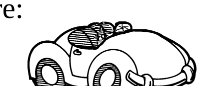
Maps are scale models. To make a model of anything, you must first decide what the scale of the model is going to be. **Scale** is the relationship between distance on the map to distance on the ground. A map scale is given in the form of a **graphic scale** or bar scale, a **representative fraction,** or a **verbal scale**.

The *graphic scale* or bar scale below represents a *total* of two miles. Remember, half the line is one mile. The graphic scale can also be given in kilometers or feet.



Representative fractions, such as 1/24000, are a way of comparing the size of the map to the size of the area the map represents. The "1" could be anything you wish to use as a measuring tool. For example, one of your thumbs on the map would equal 24,000 of your thumbs outside on the ground. Or one inch on the map would equal 24,000 inches outside. This would be inconvenient because no one measures big distances in inches. If your map has a scale stated as a fraction (1/24000), it would mean that the portion of the earth represented has been reduced to 1/24000 of its actual size on the map. These scales are fractions, so remember the larger the number on the bottom, the smaller the scale of the map (1/100th is less than 1/10th). The smaller the scale, the less detail is shown. LARGE is small!

Verbal scales are simply ways of writing out what the scale means. Some common scales and their verbal equivalents are:



Fraction	*Verbal*
1:24,000	1 inch = 0.379 miles
1:62,500	1 inch = 0.986 miles
1:250,000	1 inch = 4.0 miles
1:500,000	1 inch = 7.891 miles

Stop 5: Contours and elevation

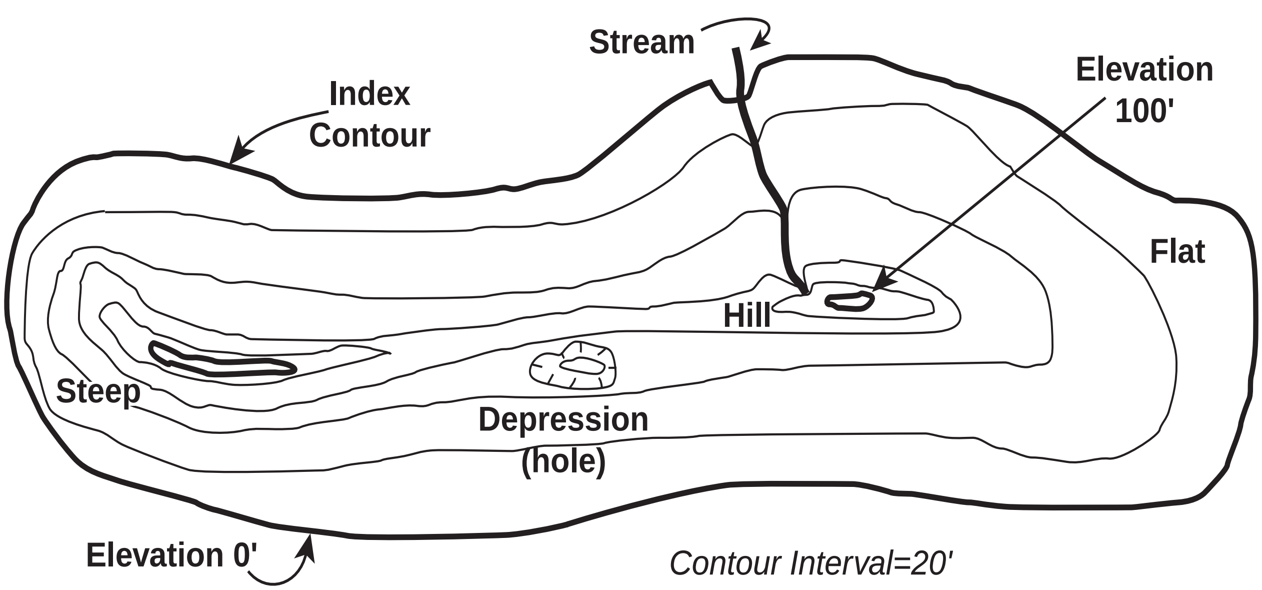
Topographic maps are scaled-down models of the Earth's three-dimensional surface, printed on a two-dimensional piece of paper. You have seen how the two-dimensional map of length and width can be reduced from the real world to a piece of paper. The third dimension—elevation—is shown on a map using **contour lines.**

A contour line connects map points of the same elevation above sea level. If you were driving along the contour, you would stay at the same elevation above sea level. Different elevations are shown by different contour lines. Every fifth contour line is thicker and is called an **index contour**. Index contours are often marked with an elevation.

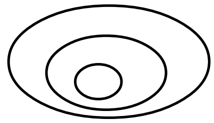
A map's **contour interval** is the vertical distance (height) between two adjacent contour lines. The amount of error in a map's elevation can be no more than half of the map's contour interval. If the contour interval on the map is 10 feet, then the elevations have a margin of error plus (+) or minus (–) 5 feet.

Relief is the difference in elevation between two points on a map. Maps with small contour intervals (10 feet) are generally of low relief. Topographic maps of mountainous areas have large contour intervals (50 feet). If a map has both low relief and high relief within the topographic quadrangle, there are two contour intervals on the map. By finding the closest contour line marked with an elevation label and then counting lines, you can figure out the elevation of a point. Here are some rules to help you interpret the contour lines on a map.

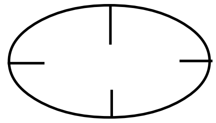
1. The closer together the contour lines, the steeper the slope.
2. When contour lines cross a stream, they form a "V" that points upstream.
3. Contour lines do not cross unless there is an overhanging cliff.
4. The thicker contour lines are called index contours.
5. All contour lines are multiples of the contour interval.
6. Every point along a contour line has exactly the same elevation.
7. Contour lines can merge to form a vertical cliff.



8. A concentric series of contour lines represent a hill.



9. Depression contours have **hachure** marks on the downhill side that represent a depression (hole).



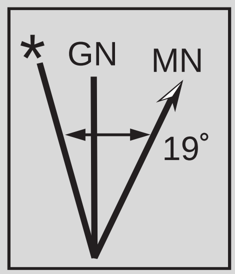
10. There is no beginning or end to a contour line. It is a closed loop with an irregular shape.

The 19° east line shown below shows that the magnetic north is slightly east of geographic north. This defines the amount of **declination** (turning away from magnetic north) in your area. Local declination can be affected by materials within the earth. Iron in rock can affect your magnetic declination. This information is used when you want to set your compass and orient your map. Since the magnetic field of the earth changes, maps are periodically revised.

Stop 6: Declination

The earth has two norths: a **magnetic north** (MN) and a **geographic north** (GN). A compass points to the Earth's magnetic north, which is created by the planet's magnetic core. This magnetic north is not fixed because this point moves with changes in the Earth's magnetic core. In contrast, geographic (true) north is a fixed point at the end of the axis on which the earth spins.

Because magnetic north slowly wobbles about somewhere to the west of Baffin Island, Canada, topographic maps use the fixed geographic north to designate direction. Because the compass points to magnetic north and a map uses geographic north, topographic maps often show compass direction with a diagram or sometimes with a written description. This diagram shows the local difference between magnetic north and true north.



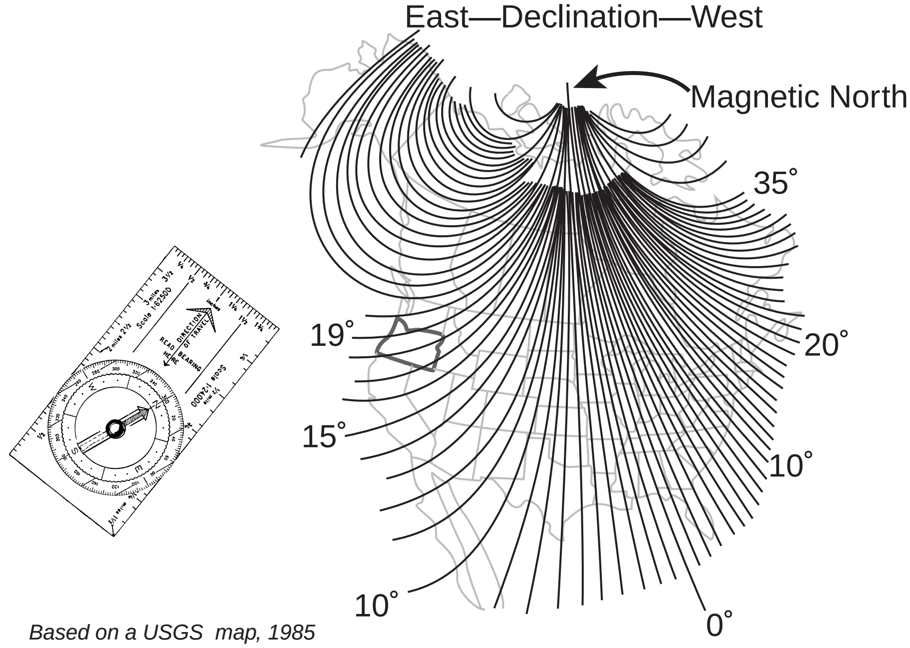
* = direction of geographic north

GN = direction of grid north (Universal Transverse Mercator System)

MN = direction of magnetic north

The magnetic declination for the map is *19°*

Chart showing magnetic declinations



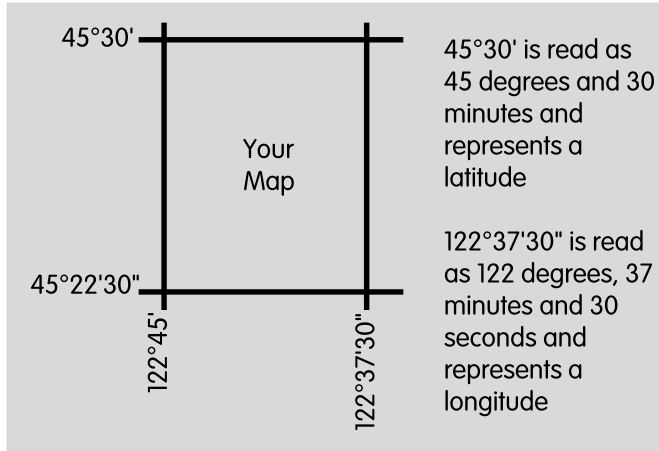
Based on a USGS map, 1985

Stop 7: Latitude and longitude coordinates

In the four corners of the topographic map you will find the degrees longitude and latitude that are used to define the borders of the quadrangle.

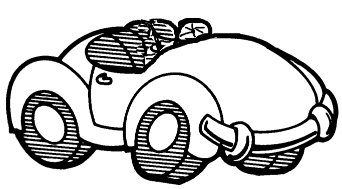
Remember from Stop 1 that there are 360 degrees in a circle, 60 minutes in a degree, and 60 seconds in a minute. Also remember that on a map, degree is a measure of distance and, therefore, a fraction of a degree is also a measure of distance.

The **series** of the map explained at Stop 1 can also be determined by subtracting one latitude from the other (see above right).



	45º30'	latitude
–	45º22'30"	latitude
	7'30"	or 7.5 minutes

Look at the data table at Stop 1 (p. 62) for 45º latitude. You can work out the number of miles from the top of your map to the bottom of your map with reasonable accuracy. According to the table, at 45º north of the equator, each degree of latitude equals 69.05 miles. There are 60 minutes in a degree. Therefore 30 minutes is half a degree, 15 minutes is one-quarter of a degree, and 7.5 minutes is equal to one-eighth (0.125) of a degree. So 0.125 times 69.05 miles is equal to 8.63 miles. This number (8.63) gives you the total distance in miles from the top of the map to the bottom of the map. You could check the results by using the graphic scale at Stop 4.



Stop 8: UTM grid

The fine blue lines along the borders of the map are the Universal Transverse Mercator (UTM) grid “ticks.” These are part of an international reference system. Each tick is separated by one kilometer (1,000 meters) or about five-eighths of a mile, making it a handy scale.

UTM coordinates are commonly used by agencies to locate sampling sites on streams or note locations of culverts or other important parts of the stream. A Global Positioning System (GPS) device helps determine UTM coordinates and can tell you latitude and longitude positions.

If you are interested in the UTM or GPS system, a detour to the bibliography may be in order.

Stop 9: Map source

The United States Department of the Interior’s Geological Survey (USGS) produced the topographic map. An index of Oregon topographic maps is available from the USGS. The index can help you quickly decide which maps are available for your area. You can call the USGS at 1-800-USA-MAPS.

This was a short stop! Let’s travel to the interior of the map.

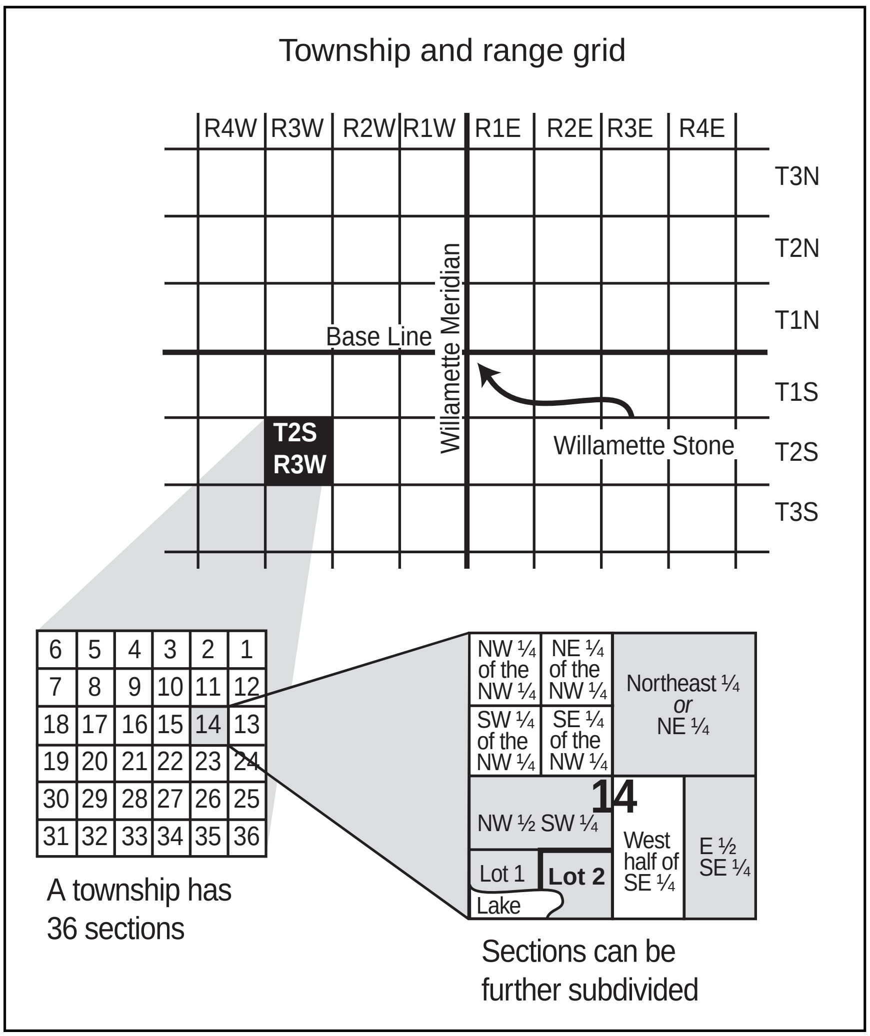
Stop 10: Public land survey system

The U.S. **Public Land Survey System** divides a region into a **township** and **range** grid. The diagram on this page explains this system. The starting points are the Willamette Meridian of longitude and a **base line** that is surveyed perpendicular to it. The Willamette Stone, located in the West Hills of Portland, Oregon, is at the junction of the Willamette Meridian and the base line. Township strips of land run parallel to the base line and are numbered north and south of it (T1N,T1S, etc.). Range strips of land run parallel to the Willamette Meridian and are numbered east and west of it (R1E, R1W, etc.). Each intersection of a township strip with a range strip forms a square, called a township.

Use the following statements to help you understand the Public Land Survey System.

1. Townships are numbered north and south of the base line and are labeled along the right and left margins of the map.
2. In Oregon, ranges are numbered east and west of the Willamette Meridian and are labeled along the top and bottom of the map.
3. Each township is 6 miles square and is divided into 36 sections. Note that the section numbers begin in the upper right hand corner of the township and end at the lower right hand corner of the township.
4. Each section is 1 mile square.

Public land survey map

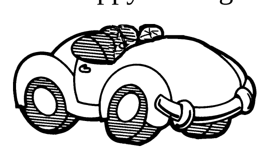


5. A section contains 640 acres that can be subdivided into smaller tracts.
6. A section can also be subdivided into sixteen 40-acre tracts that can be designated by compass directions (for example, SE, NW, etc.)
7. A legal description of the parcel of 40 acres (labeled Lot #2) would read:

SE¼, SW ¼, Section 14, T2S, R3W

Note: Begin the legal description with the smallest designation.

Our tour has ended. Good luck with your watershed explorations. Happy touring!



Glossary

contour: imaginary line on the ground, all points of which are the same elevation above or below a specific datum. A datum is a reference point used in surveying.

contour interval: difference in elevation between two adjacent contours.

declination: angular difference between magnetic north and true (geographic) north at the point of observation; it is not constant but varies with time because of the "wandering" of the magnetic north pole.

hachure: any series of lines used on a map to indicate the general direction and steepness of slopes; these lines are often used to denote a depression (hole) in the land.

latitude: angular distance in degrees, minutes, and seconds, of a point north or south of the equator.

longitude: angular distance in degrees, minutes, and seconds, of a point east or west of the Greenwich meridian.

map: any concrete or abstract representation of the distributions of features that occur on or near the surface of the earth or other celestial bodies.

map, topographic: map that presents the horizontal and vertical positions of the features represented.

meridian: great circle of the surface of the earth passing through the geographical poles and any given point on the earth's surface. All points on a given meridian have the same longitude.

orientation: establishing the correct relationship in direction with reference to points of the compass; the state of being in correct relationship in direction with reference to the points of the compass.

prime meridian: meridian of longitude 0 degrees, used as the origin of measurements of longitude; the meridian of Greenwich, England, is the internationally accepted prime meridian on most charts.

Public Land System: public lands are subdivided by a rectangular system of surveys established and regulated by the Bureau of Land Management. The standard format for subdivision is by townships measuring 6 miles (480 chains) on a side. Townships are further subdivided into 36 numbered sections of 1 square mile (640 acres) each.

quadrangle: four-sided area, bounded by parallels of latitude and meridians of longitude used as an area unit in mapping.

relief: elevations and depressions of the land or sea bottom.

scale: relationship existing between a distance on a map, chart, or photograph and the corresponding distance on the earth.

section: one thirty-sixth of a township.

township: a six square-mile segment of land, the basic unit of the Public Land System Survey.

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Tasa Graphics. *Introduction to Topographic Maps*. Tasa Graphic Arts, Inc., CD, 1994.

Questions:

1. What is the name of your quadrangle map? Where do you find this information on your map?
   Answers will vary. The name of the map is found in the upper right corner and in the lower right corner. Both of these locations are outside of the map's boundaries.
2. How are quadrangle maps named?
   Quadrangle maps are named for some prominent feature within the area of the map.
3. _______________ or meridian lines run north and south and are measured in degrees east and west around the earth from Greenwich, England.
   Longitude
4. _______________ or parallel lines run east and west and are measured in degrees north and south from the equator to the poles.
   Latitude
5. Why are longitude lines more variable in length than latitude lines?
   Because longitude lines converge at the poles. The arc of their distance varies with the distance from the equator.
6. What does it mean when we say that a topographic map is a 7.5 minute map?
   A 7.5 minute map represents an area bounded by 7.5 minutes of latitude (one-eighth of a degree) and 7.5 minutes of longitude (one-eighth of a degree).
7. Which map shows the most detail—a 7.5' or a 15' map?
   A 7.5' map shows more detail even though it covers less surface area than a 15' map.
8. If a location is just outside the boundaries of your topographic map, how would you find out the next map to use?
   Use the adjacent quadrangle map key located at the bottom of the map or look at the adjoining map's name listed in parenthesis along the sides or top and bottom of older quadrangle maps.
9. When was your map produced? If it was revised, when was it revised?
   Answers will vary.
10. What is the scale of your topographic map? What does this mean?
    Most topographic maps are at a scale of 1:24,000, which means that for every 1 unit of measurement on the map, the equivalent distance on land is 24,000 times that amount—one inch to 24,000 inches, or 1 meter to 24,000 meters, etc.
11. What is a contour line?
    A contour line is a line that connects map points at the same elevation above sea level.
12. What is an index contour?
    An index contour is a heavier line on a map that occurs at every fifth contour line.
13. What is contour interval?
    The contour interval is the vertical distance between two contour lines—for example, 20 feet, 40 feet, or 80 feet.
14. What is the contour interval of your map ?

Answers will vary. Some maps may have more than one contour interval; for example, 20 feet in areas of high relief and 40 feet in areas of low relief.

15. What is meant about the topography if the contour lines are very close together on a map?
    The landform in that area is very steep.
16. How do you know which direction a stream is flowing?
    When contour lines cross a stream, they form a "v" that points upstream.
17. What is the difference between "magnetic north" and "true north"? Which should you use to find the most accurate direction?
    "Magnetic north" is the compass direction influenced by the earth's magnetic core. It is not fixed and varies somewhat over time. "True north" or geographic north is the fixed point of the earth as it spins on its axis. Use "true north" as the most accurate direction.
18. Where do you find the declination distance on your map so you can adjust your compass to the most accurate direction?
    Declination information is usually located in the bottom left hand corner of the map.
19. What are the latitude and longitude coordinates in the top left corner of your map?
    Answers will vary.
20. What are the Universal Transverse Mercator (UTM) tick mark designations in the upper left hand corner of your map?
    Answers will vary.
21. What is the total distance in miles from the top to the bottom of your map at 45° latitude? What is the total distance in miles from side to side on your map at the same latitude?
    8.63 miles from top to bottom and 6.12 miles from side to side.
22. What is the Willamette Meridian? Why is it important?
    The Willamette Meridian is the degree of longitude that runs through the Willamette Stone in the West Hills of Portland, Oregon. All of Oregon's range and township lines are measured from this point.
23. Describe the relationship of townships, ranges, and sections in the Public Land Survey System?
    In Oregon, all ranges are measured east or west of the Willamette Meridian. All townships are measured north and south of the Willamette Stone base line. Each township is 6 miles square and contains 36 sections. Each section is one mile square and consists of 640 acres.
24. What is the legal description at the mouth of the main stream closest to your community?
    Answers will vary, but should begin with the smallest designation (quarter section first) and end with township and range designations (for example, SE ¼, SW 1¼, Section 14, T2S, R3W).

Going further

1. Design a set of questions (with an answer key) that could be asked about your local topographic map. Design your questions so that the person answering the questions will have a better understanding of your watershed.
2. A landfill is planned for a site within the boundaries of your local topographic map. As a consultant for the city, give evidence that would support your choice for the placement of that landfill.

Name

Tour of a topo

Do you know . . .

... how to use a map? Do you know how to give a legal description of your school's location or maybe your mom or dad's favorite fishing hole? Do you know how to get the elevation of your favorite ski slope or how to determine the scale of distance a map covers?

A map gives you a lot of information. With a little practice you can use this information to find out all kinds of things about your local watershed. You can learn a lot by looking at the information outside of your map's boundaries as well as inside.

The first important step in getting to know your watershed is to get a map of it. But, a map isn't a lot of help if you don't know how to use it.

Maps are the "common ground" among all the players in a watershed study. They are important communication tools if working with other groups in the same watershed. Each group needs a copy of the same map, so everyone can talk the same language and keep the same reference points.

Maps are a permanent record of your watershed. You can mark your study sites, important reference points, restoration work sites, land-use designations, pollution sources, historical sites, or other important locations that are part of your watershed study.

Now it's your turn . . .

Just what can you learn from a map? Join us for a "tour of a topo" and find out.

Use your "Tour of a Topo" tour guide and a local topographic map. Work in pairs and explore the parts of a map and your watershed. Our "tour" begins in the upper right-hand corner of the topographic map. First we will travel around the outside of the map (clockwise) and then go to the inside. We will stop where there is a number on the tour guide. Answer the questions at the end when you are done.

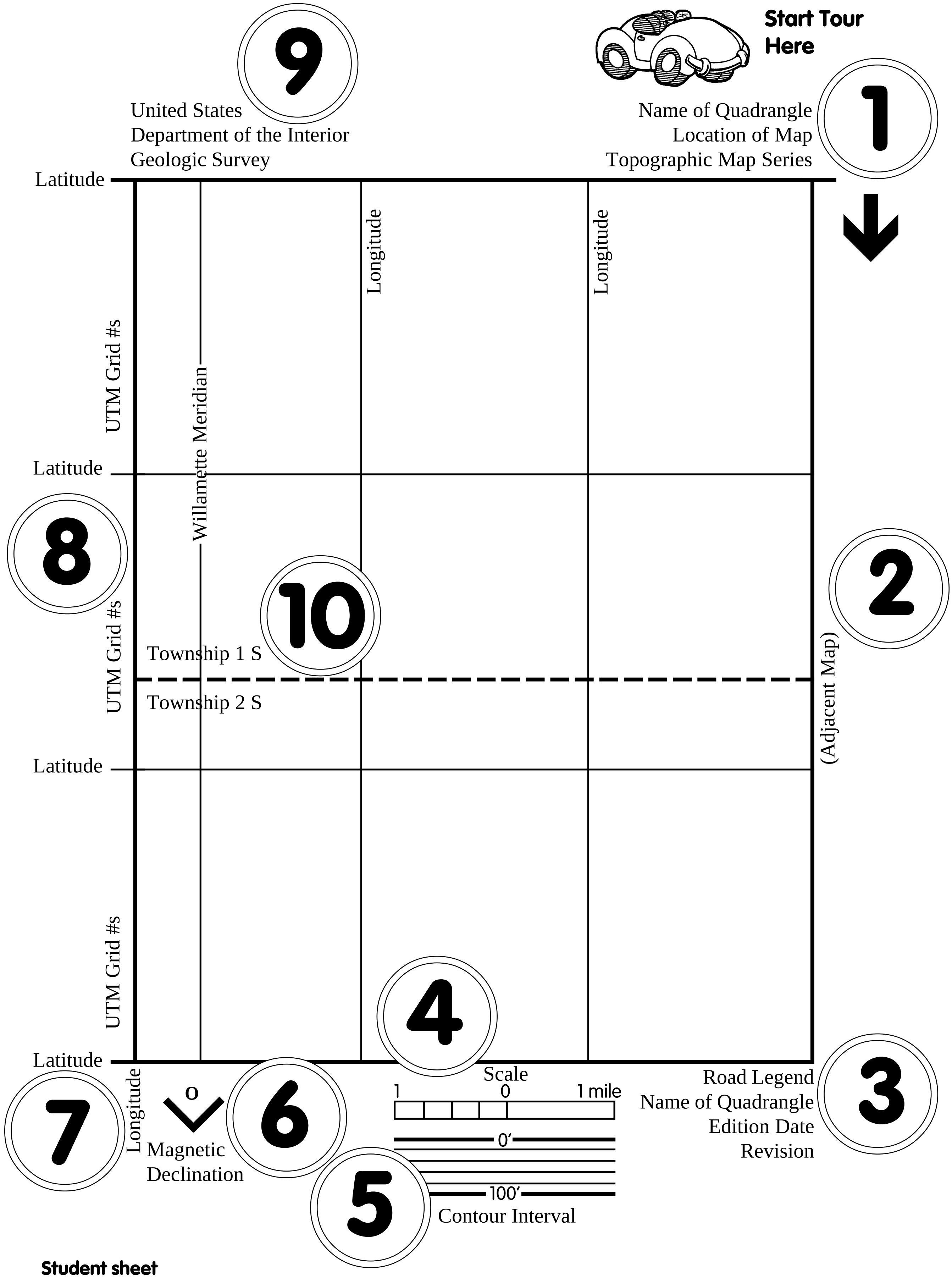
Stop 1: Name, Location, Series

The map we'll be touring is called a **quadrangle** map. It is usually named after a prominent feature in the area—a town, city, mountain or a lake. It is called a quadrangle because it has four (quad is the word prefix that means four) equal sides, each with an equal number of **degrees** of **latitude** and **longitude**. The length of a degree of latitude is about the same throughout the world. Latitude lines are parallel to the equator, run east-west, and are measured in degrees north and

Vocabulary

base line
contour
contour lines
contour interval
declination
degree of latitude
degree of longitude
equator
geographic north
Global Positioning System (GPS)
hachure
index contour
latitude
legend
longitude
magnetic north
map
map series
meridian
minutes
orientation
prime meridian
Public Land System
quadrangle
range
relief
representative fraction
scale (graphic or verbal)
seconds
section
topographic map
township
true north
universal transverse mercator (UTM)

Tour of a Topo was developed by Michael Goodrich, Director, GeoQuest Publications, PO Box 1665, Lake Oswego, OR 97035, and is used with permission.



Student sheet

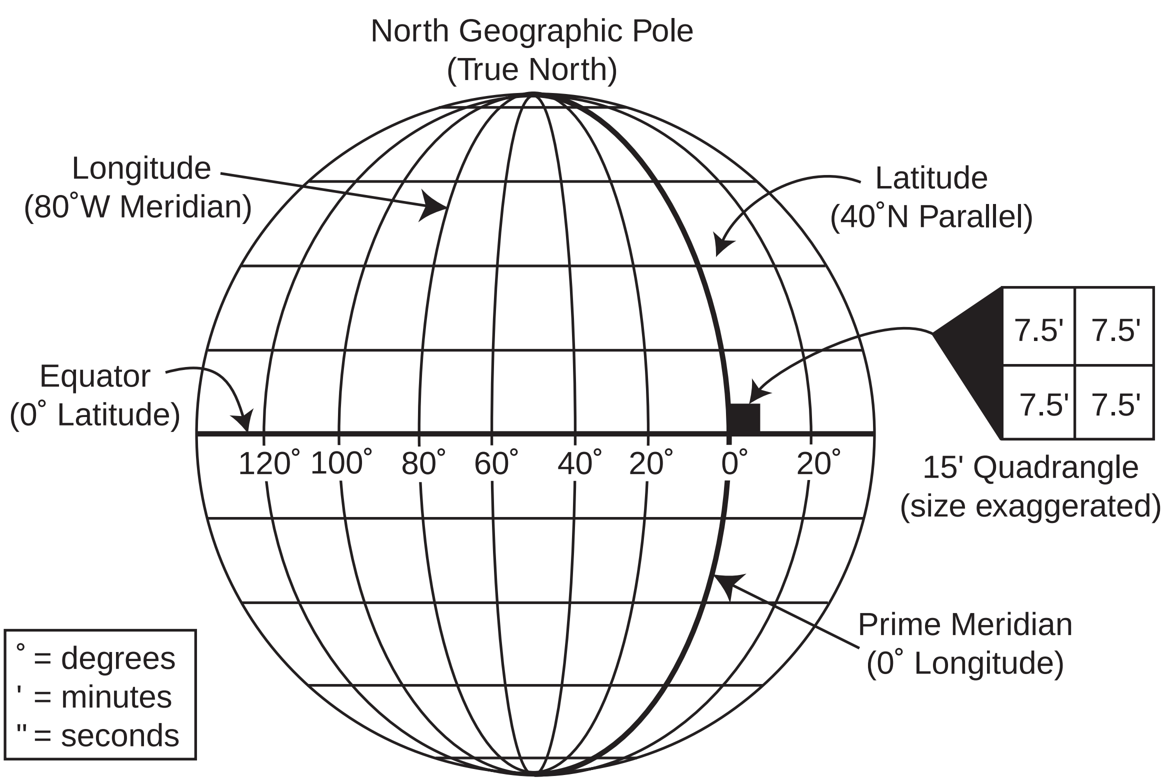
south of the equator. The length of a degree of longitude varies with distance from the **equator**. Longitude lines come together at the poles, run north-south, and are measured east and west of the prime meridian, which runs through Greenwich, England (see the globe and chart on p. 62).

Latitude	*Length (miles) of °Longitude	** Length (miles) of °Latitude	
0 (equator)	69.17	68.71	very close
15	66.83	68.75	↓
30	59.95	68.88	↓
45	48.99	69.05	↓
60	34.67	69.23	↓
75	17.96	69.36	↓
90 (poles)	0.00	69.40	not close

*Length of a degree of arc along the latitude named.
**Length of a degree of arc centered on the latitude named.
(Table based on the National Geodetic Survey 1980 ellipsoid.)

Looking at your map, however, you'll notice that the map *length* is different than its *width*. That's because the earth is a three-dimensional globe but the map is a flat, two-dimensional picture of a small piece of the earth. A topographic map for land straddling the equator (for example, Ecuador or Indonesia) would be almost square. As you move away from the equator, the map begins to look like a rectangle.

On a map, a degree is a measure of distance. There are 360 degrees in a circle. A line of latitude or longitude circles the earth. A degree of latitude or longitude, then, is 1/360th of the total length of that line. Each degree can be divided into 60 smaller pieces called minutes. Each minute can be divided further into 60 smaller pieces called seconds. There are special symbols for degree, minute, and second. Seventy degrees is written 70º. Thirty minutes is written 30'. Twenty-two seconds is written 22". Minutes and seconds are a measure of distance, just as degrees are. If 1º is equal to approximately 70 miles of latitude, then 30' (half of a degree) is equal to 35



Student sheet

miles, and 30" (half of a minute or one-fourth of a degree) is equal to 15 miles.

We normally think of minutes and seconds as measurements of time. When working with a map, minutes and seconds become fractions of a degree. Therefore, a fraction of a degree is also a measure of distance. If 1° is equal to approximately 70 miles of latitude, then 30' (half of a degree) is equal to 35 miles.

The *location* of the map gives the state and county where the quadrangle is located. Quadrangle maps are published in several sizes, but the two most common are 15' quadrangle maps and 7.5' quadrangle maps. A 15' quadrangle represents an area bounded by 15 minutes of latitude (one-fourth of a degree) and 15 minutes of longitude (one-fourth of a degree). Each 15' map can be divided into four 7.5' maps. Most of the United States is mapped using the 7.5' series.

If you have any questions about Stop 1, a detour to the bibliography or glossary might be in order. Proceed to Stop 2.

Stop 2: Adjacent maps

What if you wanted to go beyond the borders of your map? The maps that border yours are called adjacent maps. Stop 2 is where you will find information about an adjacent map. There are typically eight maps that border any topographic quadrangle map. Looking below, we see our map in the middle. If the adjacent map to the east (Gladstone #5) is not in parenthesis along the boundary of the map, then the information is included at the bottom of the map.

1	2	3
4	Our Map	5
6	7	8

Adjacent Quadrangles

1. Linnton
2. Portland
3. Mt. Tabor
4. Beaverton
5. Gladstone
6. Sherwood
7. Canby
8. Oregon City

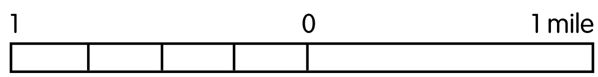
Stop 3: Legend

The symbols used for roads are part of the map's **legend**. Below the legend is the name of the quadrangle and the year the map was made. Because maps cannot be updated yearly (a Coast Range quadrangle in Oregon has not been revised since 1949), there is often a date for when the map was revised. You can tell if a map has a partial revision because the revised portion is shown in a different color.

Let's move on to Stop 4.

Stop 4: Scale

Maps are scale models. To make a model of anything, you must first decide what the scale of the model is going to be. **Scale** is the relationship between distance on the map to distance on the ground. A map scale is given in the form of a **graphic scale** or bar scale, a **representative fraction,** or a **verbal scale**.



The *graphic scale* or bar scale below represents a *total* of two miles. Remember, half the line is one mile. The graphic scale can also be given in kilometers or feet.

Representative fractions, such as 1/24000, are a way of comparing the size of the map to the size of the area the map represents. The "1" could be anything you wish to use as a measuring tool. For example, one of your thumbs on the map would equal 24,000 of your thumbs outside on the ground. Or one inch on the map would equal 24,000 inches outside. This would be inconvenient because no one measures big distances in inches. If your map has a scale stated as a fraction (1/24000), it would mean that the portion of the earth represented has been reduced to 1/24000 of its actual size on the map. These

Student sheet

scales are fractions, so remember the larger the number on the bottom, the smaller the scale of the map (1/100th is less than 1/10th). The smaller the scale, the less detail is shown. LARGE is small!

Verbal scales are simply ways of writing out what the scale means. Some common scales and their verbal equivalents are:

Fraction	*Verbal*
1:24,000	1 inch = 0.379 miles
1:62,500	1 inch = 0.986 miles
1:250,000	1 inch = 4.0 miles
1:500,000	1 inch = 7.891 miles

Stop 5: Contours and elevation

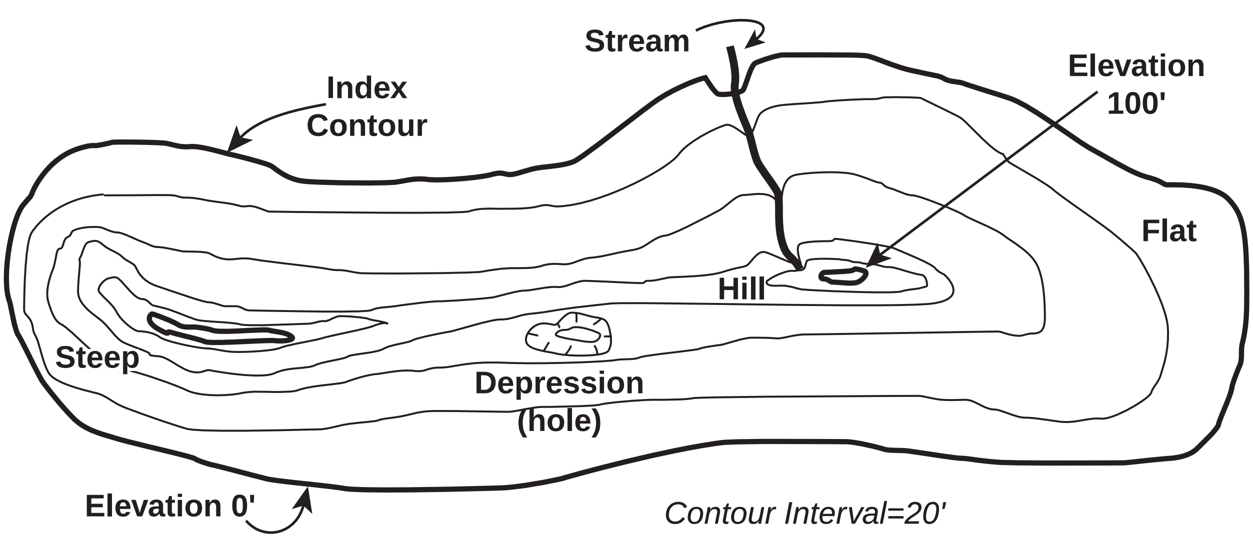
Topographic maps are scaled-down models of the Earth's three-dimensional surface, printed on a two-dimensional piece of paper. You have seen how the two-dimensional map of length and width can be reduced from the real world to a piece of paper. The third dimension—elevation—is shown on a map using **contour lines.**

A contour line connects map points of the same elevation above sea level. If you were driving along the contour, you would stay at the same elevation above sea level. Different elevations are shown by different contour lines. Every fifth contour line is thicker and is called an **index contour**. Index contours are often marked with an elevation.

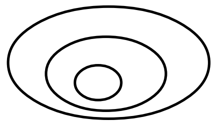
A map's **contour interval** is the vertical distance (height) between two adjacent contour lines. The amount of error in a map's elevation can be no more than half of the map's contour interval. If the contour interval on the map is 10 feet, then the elevations have a margin of error plus (+) or minus (–) 5 feet.

Relief is the difference in elevation between two points on a map. Maps with small contour intervals (10 feet) are generally of low relief. Topographic maps of mountainous areas have large contour intervals (50 feet). If a map has both low relief and high relief within the topographic quadrangle, there are two contour intervals on the map. By finding the closest contour line marked with an elevation label and then counting lines, you can figure out the elevation of a point. Here are some rules to help you interpret the contour lines on a map.

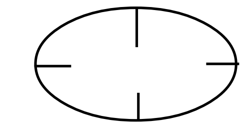
1. The closer together the contour lines, the steeper the slope.
2. When contour lines cross a stream, they form a "V" that points upstream.
3. Contour lines do not cross unless there is an overhanging cliff.
4. The thicker contour lines are called index contours.
5. All contour lines are multiples of the contour interval.



6. Every point along a contour line has exactly the same elevation.
7. Contour lines can merge to form a vertical cliff.
8. A concentric series of contour lines represent a hill.



9. Depression contours have **hachure** marks on the downhill side that represent a depression (hole).



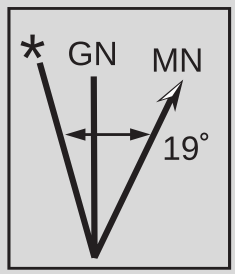
10. There is no beginning or end to a contour line. It is a closed loop with an irregular shape.

Stop 6: Declination

The earth has two norths: a **magnetic north** (MN) and a **geographic north** (GN). A compass points to the Earth's magnetic north, which is created by the planet's magnetic core. This magnetic north is not fixed because this point moves with changes in the Earth's magnetic core. In contrast, geographic (true) north is a fixed point at the end of the axis on which the earth spins.

Because magnetic north slowly wobbles about somewhere to the west of Baffin Island, Canada, topographic maps use the fixed geographic north to designate direction. Because the compass points to magnetic north and a map uses geographic north, topographic maps often show compass direction with a diagram or sometimes with a written description. This diagram shows the local difference between magnetic north and true north.

The 19° east line shown below shows that the magnetic north is slightly east of geographic north. This defines the amount of **declination** (turning away from magnetic north) in your area. Local declination can be affected by materials within the earth. Iron in rock can affect your magnetic declination. This information is used



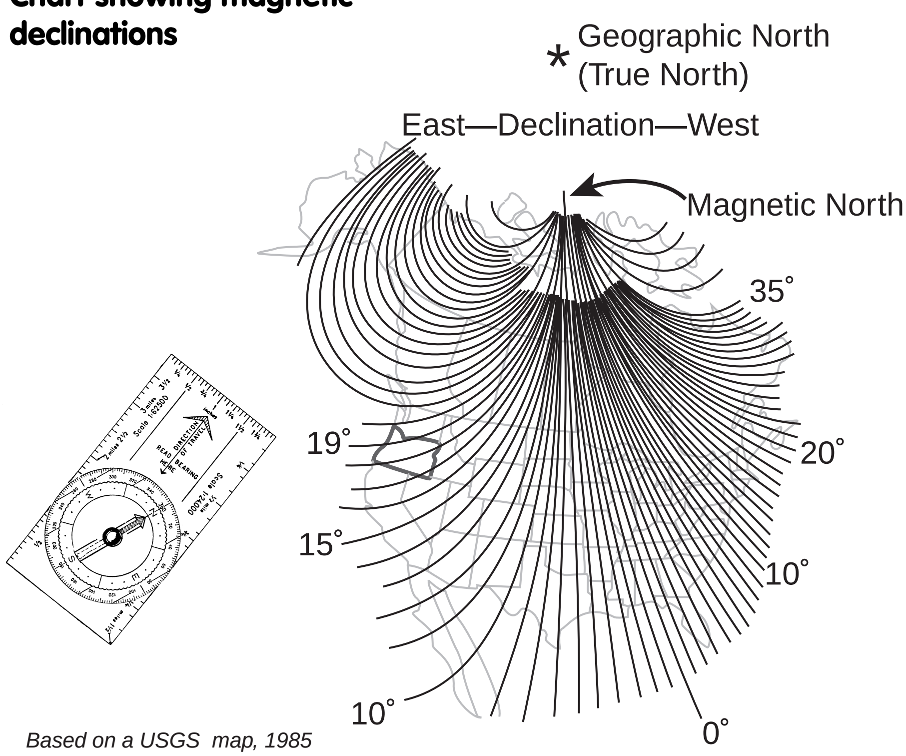
* = direction of geographic north

GN = direction of grid north (Universal Transverse Mercator System)

MN = direction of magnetic north

The magnetic declination for the map is *19°*

Chart showing magnetic declinations



Based on a USGS map, 1985

when you want to set your compass and orient your map. Since the magnetic field of the earth changes, maps are periodically revised.

Stop 7: Latitude and longitude coordinates

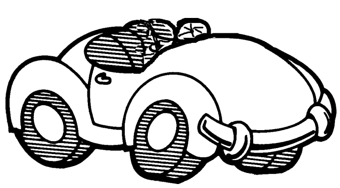
In the four corners of the topographic map you will find the degrees longitude and latitude that are used to define the borders of the quadrangle.

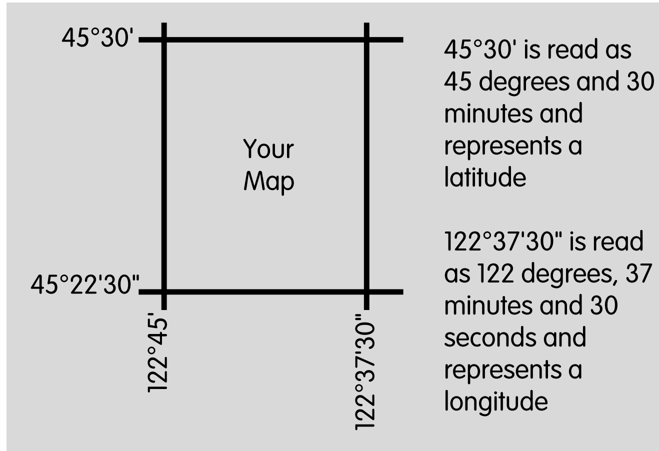
Remember from Stop 1 that there are 360 degrees in a circle, 60 minutes in a degree, and 60 seconds in a minute. Also remember that on a map, degree is a measure of distance and, therefore, a fraction of a degree is also a measure of distance.

The **series** of the map explained at Stop 1 can also be determined by subtracting one latitude from the other (see above right).

	45º30'	latitude
–	45º22'30"	latitude
	7'30"	or 7.5 minutes

Look at the data table at Stop 1 (p. 62) for 45º latitude. You can work out the number of miles from the top of your map to the bottom of your map with reasonable accuracy. According to the table, at 45º north of the equator, each degree of latitude equals 69.05 miles. There are 60 minutes in a degree. Therefore 30 minutes is half a degree, 15 minutes is one-quarter of a degree, and 7.5 minutes is equal to one-eighth (0.125) of a degree. So 0.125 times 69.05 miles is equal to 8.63 miles. This number (8.63) gives you the total distance in miles from the top of the map to the bottom of the map. You could check the results by using the graphic scale at Stop 4.





Stop 8: UTM grid

The fine blue lines along the borders of the map are the Universal Transverse Mercator (UTM) grid “ticks.” These are part of an international reference system. Each tick is separated by one kilometer (1,000 meters) or about five-eighths of a mile, making it a handy scale.

UTM coordinates are commonly used by agencies to locate sampling sites on streams or note locations of culverts or other important parts of the stream. A Global Positioning System (GPS) device helps determine UTM coordinates and can tell you latitude and longitude positions.

If you are interested in the UTM or GPS system, a detour to the bibliography may be in order.

Stop 9: Map source

The United States Department of the Interior’s Geological Survey (USGS) produced the topographic map. An index of Oregon topographic maps is available from the USGS. The index can help you quickly decide which maps are available for your area. You can call the USGS at 1-800-USA-MAPS.

This was a short stop! Let's travel to the interior of the map.

Stop 10: Public land survey system

The U.S. **Public Land Survey System** divides a region into a **township** and **range** grid. The diagram on this page explains this system. The starting points are the Willamette Meridian of longitude and a **base line** that is surveyed perpendicular to it. The Willamette Stone, located in the West Hills of Portland, Oregon, is at the junction of the Willamette Meridian and the base line. Township strips of land run parallel to the base line and are numbered north and south of it (T1N,T1S, etc.). Range strips of land run parallel to the Willamette Meridian and are numbered east and west of it (R1E, R1W, etc.). Each intersection of a township strip with a range strip forms a square, called a township.

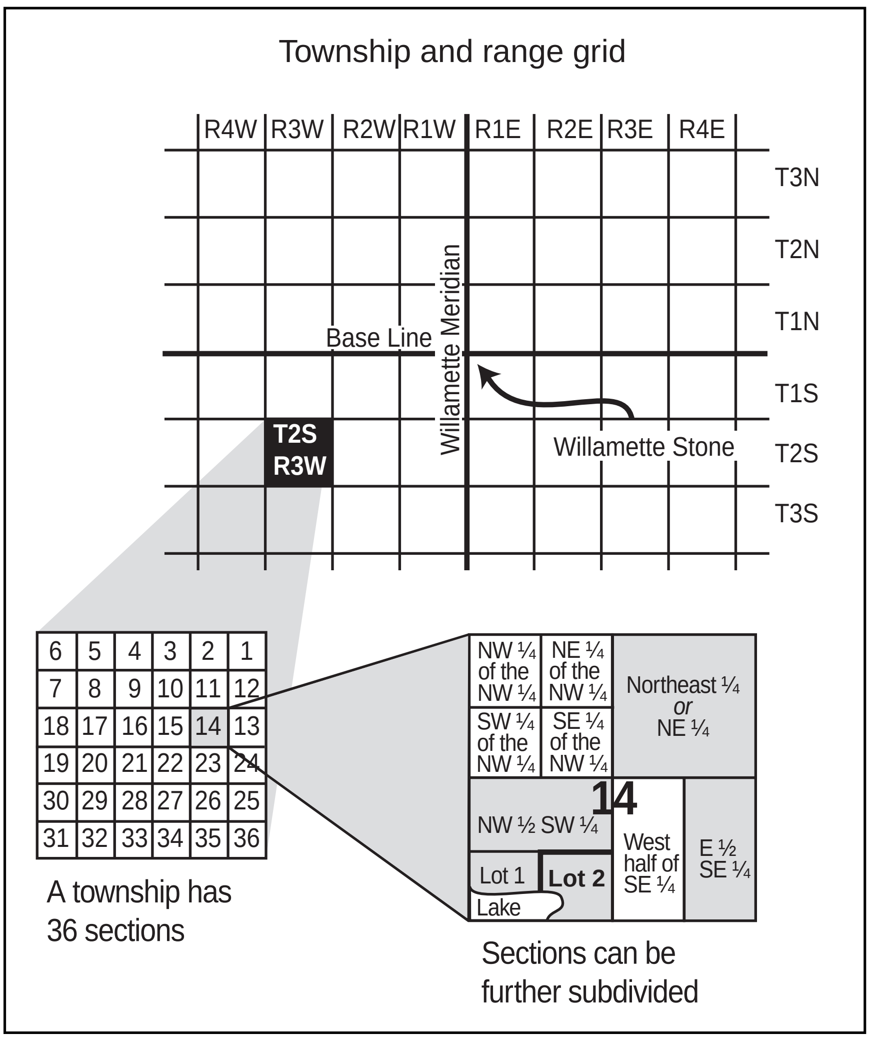
Use the following statements to help you understand the Public Land Survey System.

1. Townships are numbered north and south of the base line and are labeled along the right and left margins of the map.
2. In Oregon, ranges are numbered east and west of the Willamette Meridian and are labeled along the top and bottom of the map.
3. Each township is 6 miles square and is divided into 36 sections. Note that the section numbers begin in the upper right hand corner of the township and end at the lower right hand corner of the township.
4. Each section is 1 mile square.
5. A section contains 640 acres that can be subdivided into smaller tracts.
6. A section can also be subdivided into sixteen 40-acre tracts that can be designated by compass directions (for example, SE, NW, etc.)
7. A legal description of the parcel of 40 acres (labeled Lot #2) would read:

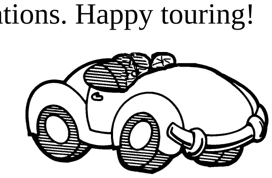
SE¼, SW ¼, Section 14, T2S, R3W

Note: Begin the legal description with the smallest designation.

Public land survey map



Our tour has ended. Good luck with your watershed explorations. Happy touring!



Student sheet

Glossary

contour: imaginary line on the ground, all points of which are the same elevation above or below a specific datum. A datum is a reference point used in surveying.

contour interval: difference in elevation between two adjacent contours.

declination: angular difference between magnetic north and true (geographic) north at the point of observation; it is not constant but varies with time because of the “wandering” of the magnetic north pole.

hachure: any series of lines used on a map to indicate the general direction and steepness of slopes; these lines are often used to denote a depression (hole) in the land.

latitude: angular distance in degrees, minutes, and seconds, of a point north or south of the equator.

longitude: angular distance in degrees, minutes, and seconds, of a point east or west of the Greenwich meridian.

map: any concrete or abstract representation of the distributions of features that occur on or near the surface of the earth or other celestial bodies.

map, topographic: map that presents the horizontal and vertical positions of the features represented.

meridian: great circle of the surface of the earth passing through the geographical poles and any given point on the earth’s surface. All points on a given meridian have the same longitude.

orientation: establishing the correct relationship in direction with reference to points of the compass; the state of being in correct relationship in direction with reference to the points of the compass.

prime meridian: meridian of longitude 0 degrees, used as the origin of measurements of longitude; the meridian of Greenwich, England, is the internationally accepted prime meridian on most charts.

Public Land System: public lands are subdivided by a rectangular system of surveys established and regulated by the Bureau of Land Management. The standard format for subdivision is by townships measuring 6 miles (480 chains) on a side. Townships are further subdivided into 36 numbered sections of 1 square mile (640 acres) each.

quadrangle: four-sided area, bounded by parallels of latitude and meridians of longitude used as an area unit in mapping.

relief: elevations and depressions of the land or sea bottom.

scale: relationship existing between a distance on a map, chart, or photograph and the corresponding distance on the earth.

section: one thirty-sixth of a township.

township: a six square-mile segment of land, the basic unit of the Public Land System Survey.

Questions:

1. What is the name of your quadrangle map? Where do you find this information on your map?

2. How are quadrangle maps named?

3. _______________ or meridian lines run north and south and are measured in degrees east and west around the earth from Greenwich, England.

4. _______________ or parallel lines run east and west and are measured in degrees north and south from the equator to the poles.

5. Why are longitude lines more variable in length than latitude lines?

6. What does it mean when we say that a topographic map is a 7.5 minute map?

7. Which map shows the most detail—a 7.5' or a 15' map?

8. If a location is just outside the boundaries of your topographic map, how would you find out the next map to use?

9. When was your map produced? If it was revised, when was it revised?

10. What is the scale of your topographic map? What does this mean?

11. What is a contour line?

12. What is an index contour?

13. What is contour interval?

14. What is the contour interval of your map?

15. What is meant about the topography if the contour lines are very close together on a map?

16. How do you know which direction a stream is flowing?

17. What is the difference between “magnetic north” and “true north”? Which should you use to find the most accurate direction?

18. Where do you find the declination distance on your map so you can adjust your compass to the most accurate direction?

19. What are the latitude and longitude coordinates in the top left corner of your map?

20. What are the Universal Transverse Mercator (UTM) tick mark designations in the upper left hand corner of your map?

21. What is the total distance in miles from the top to the bottom of your map at 45° latitude? What is the total distance in miles from side to side on your map at the same latitude?

22. What is the Willamette Meridian? Why is it important?

23. Describe the relationship of townships, ranges, and sections in the Public Land Survey System?

24. What is the legal description at the mouth of the main stream closest to your community?

What a relief!

__Activity Education Standards:__ Note alignment with Oregon Academic Content Standards beginning on p. 483.

Objectives

Students will (1) choose a stream segment to investigate, (2) define the word *relief*, (3) use a topographic map to construct a three-dimensional model of a watershed, (4) explain and demonstrate how contour lines on a topographic map are related to features on a three-dimensional map, and (5) determine what kinds of information are best displayed using the topographic relief model.

Method

Students will construct a three-dimensional relief model of a local watershed and answer questions about the use and effectiveness of the model.

For younger students

1. Read activity background information aloud to younger students or modify for your students' reading level. Use props to demonstrate the key concepts.
2. Try "Branching Out," Project WET, pp. 129-132. This activity eliminates safety concerns associated with younger students using X-Acto knives.

What a Relief was developed by Michael Goodrich, Director, GeoQuest Publications, PO Box 1665, Lake Oswego, OR 97035, and is used with permission.

Materials

- copies of student sheets
- scissors
- white paste (such as Elmer's)
- ¼" foamboard or cardboard
- 7.5 minute topographic map
- dot grids (from engineering or forestry supply company)
- pencil
- X-Acto knife or utility knife
- paint or colored pencils

Background

Do you know . . .

... how to use a **topographic map**? Maps are flat, but the areas they show can have mountains, valleys, hills, or plains. Topographic maps show the shape and elevation of land forms with **contour lines**. All points along any one contour line are at the same **elevation**. The lines allow **cartographers** to show what the land looks like in three dimensions (3-D). This is important. It gives us clues about the slope of the land and suggestions about the geological history of the area. It is also necessary information for managing watersheds.

Some maps and globes are made with raised surfaces. This helps us read maps because things

Vocabulary

cartographer	scale
contour/contour lines	topographic map
declination	USGS
index contour	watershed
reach, stream	wetlands
relief	

like mountains and valleys are more easily recognized when the relief of the area is raised and highlighted. **Relief** is the difference in elevation between the high and low points on land.

On computer screens it is possible to make a 3-D picture of a landscape. These pictures can be moved around. You can look at them from close up or from far away and from ground level or from above, like in a plane.

A stream does not exist apart from the land that surrounds it. When studying watersheds, you must look at the entire watershed. Rock and soil types, vegetation, slope, and human-made structures all affect watersheds and their streams. Making topographic 3-D models can help you better understand all parts of your watershed.

Procedure

Now it's your turn . . .

How do you create a 3-D topographic model of a watershed? First, do some careful planning *before* you begin this project.

- Use a topographic map published by the United States Geographical Survey (USGS).
- Different scales of topographic maps cover different sized areas of the earth's surface. The most detailed maps from the USGS are part of the 7.5 minute series. A map from this series has a scale of 1:24,000 (one inch on the map equals 24,000 inches on the ground). The area of a 7.5 minute map is approximately 7 miles long and 7 miles wide.
- Choose the watershed your class will study, preferably one that is close to your school.
- Determine the watershed boundaries. (See the activity "A Sense of Place: Your Ecological Address" in the watershed chapter, pages 43-52.)
- Determine the area of the watershed. The dot grid method for determining the area of a watershed is a simple technique and does not require expensive equipment. Dot grids are sheets of acetate or Mylar that have a series of dots (about the size of a period at the end of a sentence) printed on them. They are available from engineering and forestry supply companies. Ask for the grid that fits the scale of your map. Place a dot grid on the map over the area you want to measure. Counts the dots that fall within the area of the watershed and then multiply by the conversion factor noted on the grid sheet to determine the area.
- Determine the stream order for your stream. See page 35 in the Watershed chapter.
- Determine where any political boundaries (county, city, or state) cross your watershed. USGS topographic maps indicate these boundaries with a system of lines. See the legend on your map.
- Note any water surface features such as lakes, **wetlands**, **springs**, and **seeps**.
- Check with local authorities to see if the houses near the stream are on septic tanks or sewers.
- Ultimately, where does the water in your stream end up?
- Are there any issues past or present that may affect the stream you are about to study?
- Establish a climate base for your watershed by collecting temperature and precipitation data for the past few years. State climatologists archive this information. The following Web site offers addresses, phone numbers, and Internet sites for the state climatologists: *http://www.people.virginia.edu/~climate/state_climatologists.htm.*

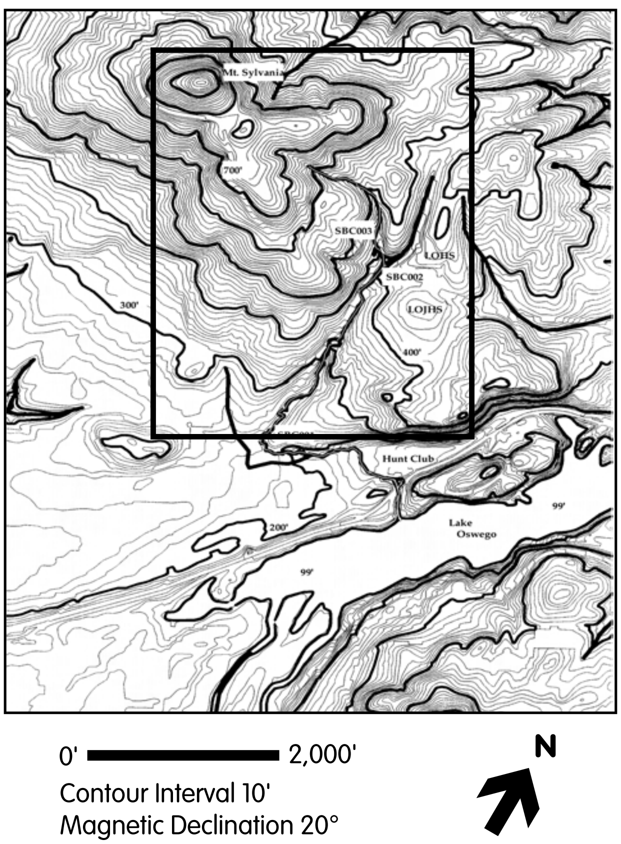
Next, decide which specific stream section or tributary to research. When choosing a stream section, consider access and safety. Within that section, which **stream reach** will you study? A reach is a length of stream defined by some common characteristic. A reach may simply be the section surveyed. More frequently, reaches are defined by the distances between named tributaries, by major changes in valley and channel form, vegetation, or by changes in land use ownership. Locate your reach by longitude and latitude. Use your topographic map and the exercise "A Sense of Place," pages 43-52, or a GPS Satellite Navigator.

You are now ready to construct a 3-D topographic model.

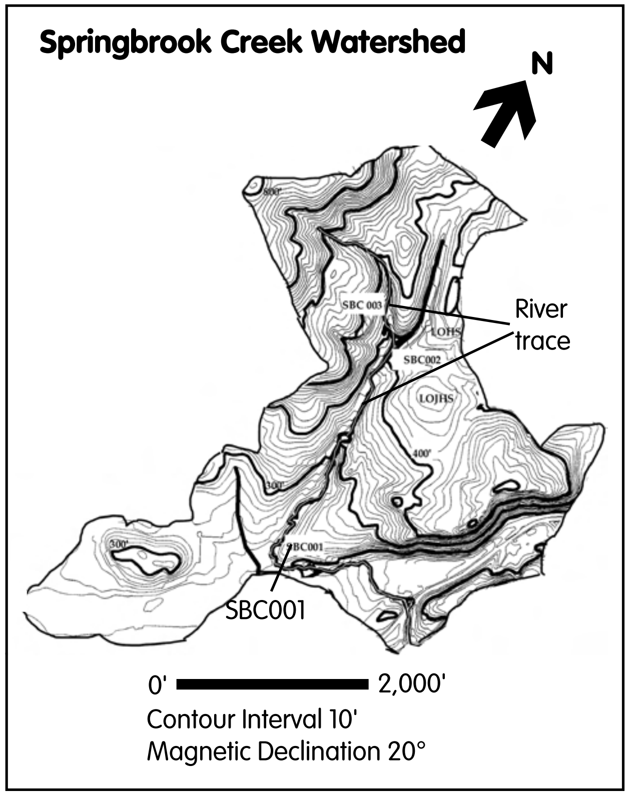
Watershed site selection

1. Photocopy and enlarge the watershed map.
2. Copy the scale along with the map. The scale on the map to the right is shown graphically as a line: 0'————2,000'.
3. Record or copy the magnetic declination noted on the map. This is shown graphically: ⁄20°, or as part of the text.
4. Next trace the river system with a dark pencil.
5. Decide which reach you will study in more detail.

Finding the cutting edge



Watershed site selection

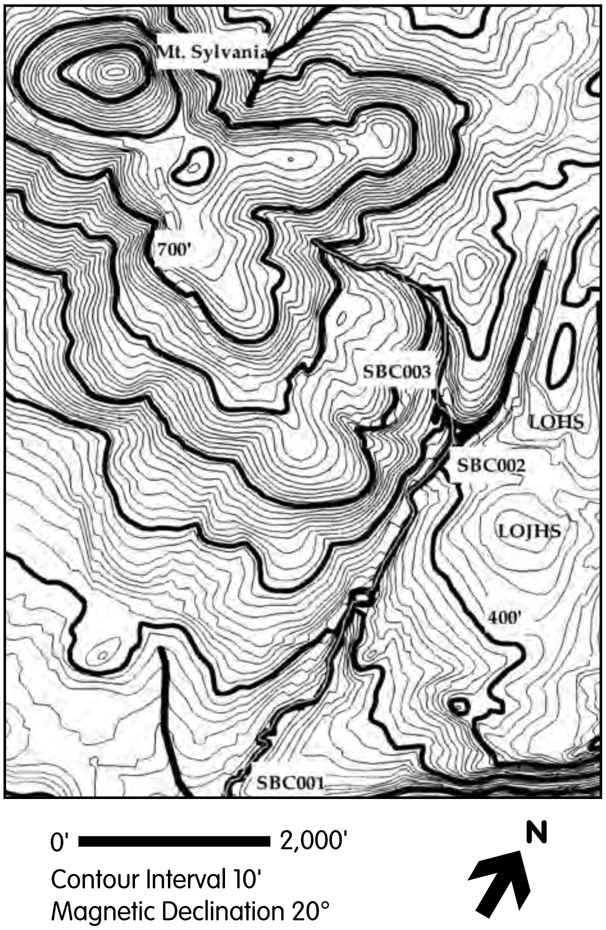


6. Mark the reach on the map and give it a number. On the example, SBC 001 stands for Springbrook Creek Reach number 1.
7. Include upstream areas in the 3-D model as those areas can affect your reach.

Finding the cutting edge

8. The area to be included in the 3-D model is outlined on the example map to the left.
9. Place the map with the selected area outlined in a photocopy machine. Enlarge it to a suitable size (8½"×11"). The example on these pages was enlarged three times. Make several copies.
10. Cut out the enlarged outlined area and set it aside. It will become your 3-D model.
11. Cut out the scale and any other pertinent data and set it aside.

Enlargement of study area



Contours: getting elevated

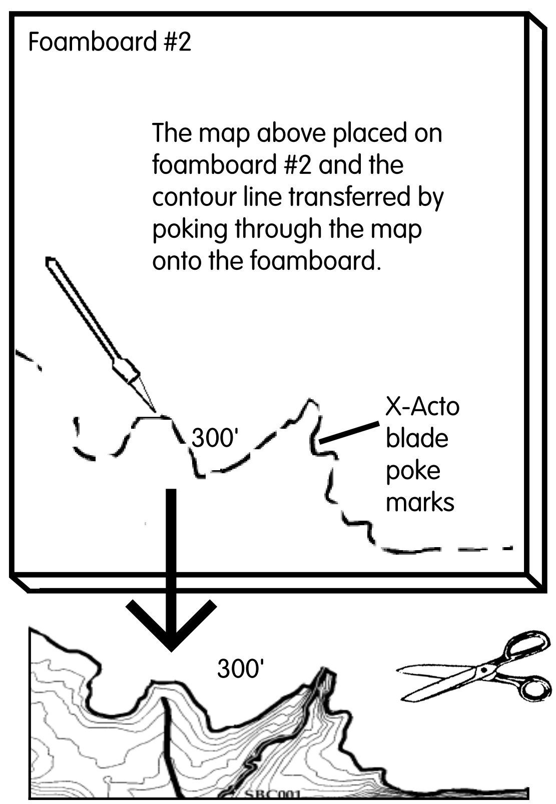
12. The enlarged map area (see above) is used for the model.
13. Choose either foamboard or cardboard for the 3-D model. Foam board comes in a variety of thicknesses and is easy to cut with an X-Acto knife.
14. In areas with less relief, consider exaggerating the elevation of your 3-D model so the changes in elevation will show better. Using ¼" foamboard with a 7.5 minute topographic map results in no vertical exaggeration. Using ½" foamboard, provides an exaggeration of two times (2×).

Contours: cutting up

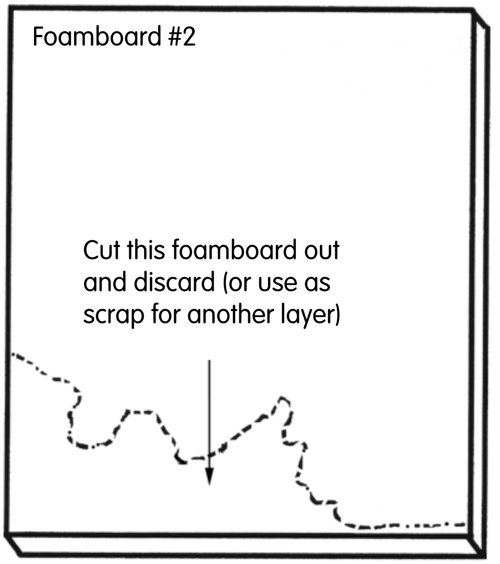
15. Count how many index contour lines are on your map. On the example map, the indexed contours lines (the heavier lines) are 300', 400', 500', 600', 700', 800', and 900'. On this example there are seven index contour lines.

    Using a utility knife with a razor blade or an X-Acto knife, cut foamboard pieces to the size of your enlarged area (the example map is 8½"×11"). But cut foamboard pieces for only half the number of index contours on the map. For the example map, we would cut four foamboards measuring 8½"×11". Cutting only half the number of index contour lines allows you to use as much of the foamboard as possible. **One of the foamboards will become layer #1—your base—and will not be cut**.
16. Set the map on one of the foamboards (#2). Using your X-Acto knife, poke into the foamboard along the contour line that represents the lowest elevation on the map. Be careful with the X-Acto knife! Check to

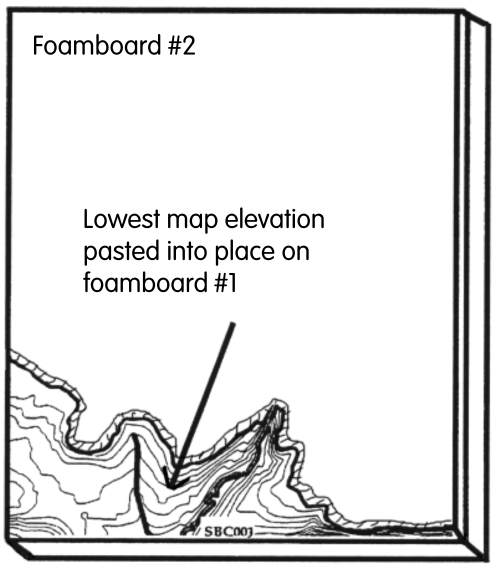
Steps 16–17



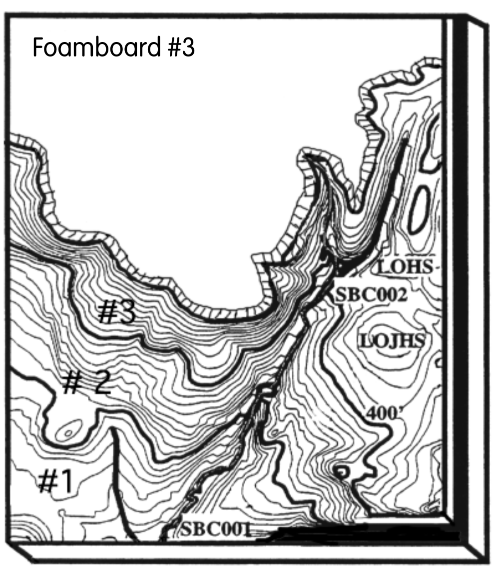
Step 18



Steps 19–20



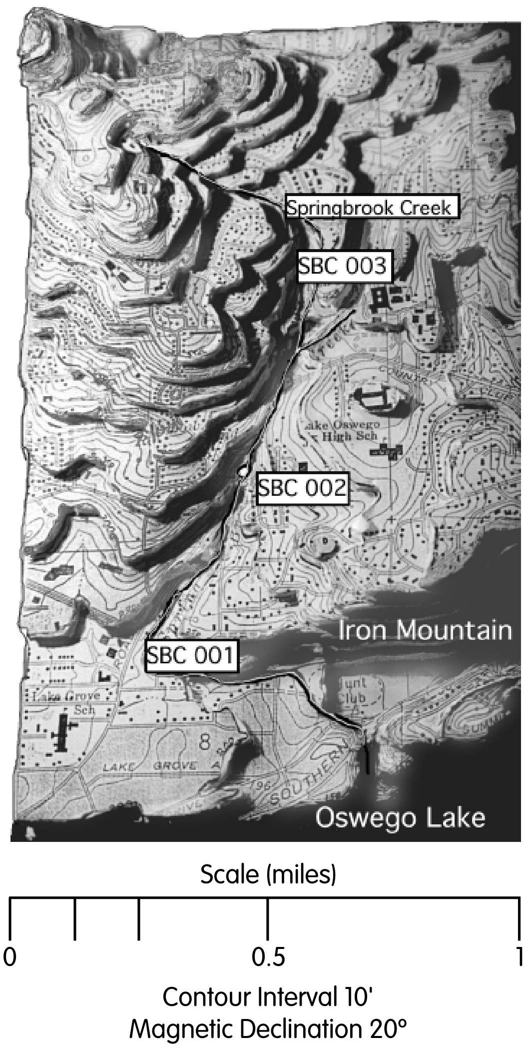
Step 21



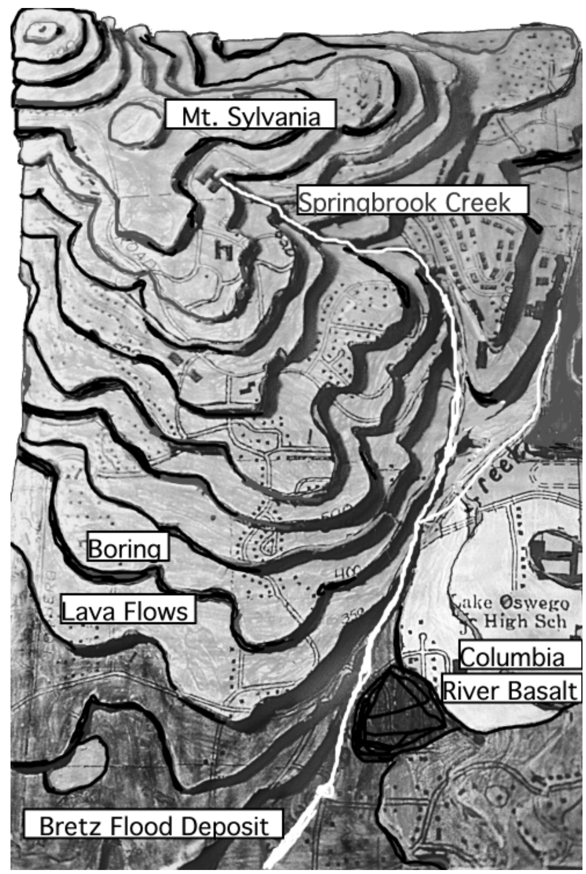
see if there is more than one contour line on the map that has that same elevation (there may be two or more contour lines of equal elevation on different parts of the map indicating the lowest places on the map). If this occurs, poke into the foamboard along both contours.

17. Using scissors cut out the lowest contour(s) on the map. The lowest elevation on this example map (300') occurs only once.
18. Cut out the dotted area on the foamboard with your X-Acto knife and discard or use as a scrap piece for another layer.
19. Place foamboard #2 on top of foamboard #1 (the base). Glue the two boards together with white paste.
20. Take the *map* piece you just cut out (lowest elevation) and paste it on foamboard #1 (base) in the space left for it.
21. Repeat this procedure for each contour elevation. The bottom diagram shows three layers completed.
22. When you have completed the entire model and have glued down each layer, attach the magnetic declination, scale and contour interval. Add your name to the model and indicate when the model was built. See page 88 for an example of a completed model.
23. By coloring the appropriate sections in different colors, you can use the model to show the slope of the land, the rock units in the area, or the soil types. All this information helps us understand our watersheds. If you plan to include all three of the above, make three separate models. On page 88 is an example of a 3-D topographic map that includes rock units.
24. To protect your map, spread some white paste over the surface. The paste will dry clear.

Completed 3-D Topographic Model of the Springbrook Watershed



Rock Units in the Springbrook Watershed



Questions

1. What have you learned about maps during the construction of your model?

   Answers will vary.

2. How could you use your model to show someone the features of your watershed?

   Answers will vary, but should include some discussion of how "relief" shows high and low points and different ways map models are used to show certain features, i.e. rock types, land use, slope, and others.

Going further

1. Using a geologic map, soils map, and topographic map as a reference, construct a series of 3-D models that reflect (a) the slope of the land, (b) the rock units and faults, (c) the soil types, and (d) the dominant vegetation. Using your models, discuss the effect the landscape has on the "built environment" and the "integrity of the stream."
2. A 3-D model of the earth's surface has some advantages over the use of a topographic map when studying a watershed. What are some of the advantages and how might these advantages be used to better understand your watershed?

Glossary

cartographer: a person who makes maps.

contour/contour lines: lines on maps that pass through points of the same elevation.

declination: the angular difference between true north and magnetic north.

elevation: distance above or below sea level.

index contour: the thicker brown lines on a topographic map; these lines usually have an associated number that indicates the elevation along the line.

reach, stream: a length of stream defined by some common characteristic.

relief: the difference in elevation between the highest points and lowest points on a map; the configuration of the earth's surface.

scale: relationship between the distance on a map and the distance it represents on the earth (1:24000 or 1" to 24,000").

topographic map: a map that uses contour lines and symbols to represent the human-created and natural features of a mapped area.

USGS: the United States Geological Survey is a branch of the federal government's Department of the Interior responsible for creating many types of maps.

watershed: the land area from which water flows toward a common stream in a natural basin.

wetlands: lands where water saturation is the dominant factor determining the nature of soil development and the types of plant and animal communities—sloughs, ponds, marshes.

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Name

What a relief!

Do you know . . .

... how to use a **topographic map**? Maps are flat, but the areas they show can have mountains, valleys, hills, or plains. Topographic maps show the shape and elevation of land forms with **contour lines**. All points along any one contour line are at the same **elevation**. The lines allow **cartographers** to show what the land looks like in three dimensions (3-D). This is important. It gives us clues about the slope of the land and suggestions about the geological history of the area. It is also necessary information for managing watersheds.

Some maps and globes are made with raised surfaces. This helps us read maps because things like mountains and valleys are more easily recognized when the relief of the area is raised and highlighted. **Relief** is the difference in elevation between the high and low points on land.

On computer screens it is possible to make a 3-D picture of a landscape. These pictures can be moved around. You can look at them from close up or from far away and from ground level or from above, like in a plane.

A stream does not exist apart from the land that surrounds it. When studying watersheds, you must look at the entire watershed. Rock and soil types, vegetation, slope, and human-made structures all affect watersheds and their streams. Making topographic 3-D models can help you better understand all parts of your watershed.

What a Relief was developed by Michael Goodrich, Director, GeoQuest Publications, PO Box 1665, Lake Oswego, OR 97035, and is used with permission.

Now it's your turn . . .

How do you create a 3-D topographic model of a watershed? First, do some careful planning *before* you begin this project.

- Use a topographic map published by the United States Geographical Survey (USGS).
- Different scales of topographic maps cover different sized areas of the earth's surface. The most detailed maps from the USGS are part of the 7.5 minute series. A map from this series has a scale of 1:24,000 (one inch on the map equals 24,000 inches on the ground). The area of a 7.5 minute map is approximately 7 miles long and 7 miles wide.
- Choose the watershed your class will study, preferably one that is close to your school.
- Determine the watershed boundaries. (See the activity "A Sense of Place: Your Ecological Address" in the watershed chapter, pages 53-58.)
- Determine the area of the watershed. The dot grid method for determining the area of a watershed is a simple technique and does not require expensive equipment. Dot grids are sheets of acetate or Mylar that have a series of dots (about the size of a period at the end of a sentence) printed on them. They are available from engineering and forestry supply companies. Ask for the grid that fits the scale of your

Vocabulary

cartographer	relief
contour lines	scale
declination	topographic map
elevation	USGS
index contour	watershed
reach, stream	wetlands

Student sheet

map. Place a dot grid on the map over the area you want to measure. Counts the dots that fall within the area of the watershed and then multiply by the conversion factor noted on the grid sheet to determine the area.

- Determine the stream order for your stream. See page 35 in the watershed chapter.
- Determine where any political boundaries (county, city, or state) cross your watershed. USGS topographic maps indicate these boundaries with a system of lines. See the legend on your map.
- Note any water surface features such as lakes, **wetlands**, **springs**, and **seeps**.
- Check with local authorities to see if the houses near the stream are on septic tanks or sewers.
- Ultimately, where does the water in your stream end up?
- Are there any issues past or present that may affect the stream you are about to study?
- Establish a climate base for your watershed by collecting temperature and precipitation data for the past few years. State climatologists archive this information. The following Web site offers addresses, phone numbers, and Internet sites for the state climatologists: *http://www.people.virginia.edu/~climate/state_climatologists.htm.*

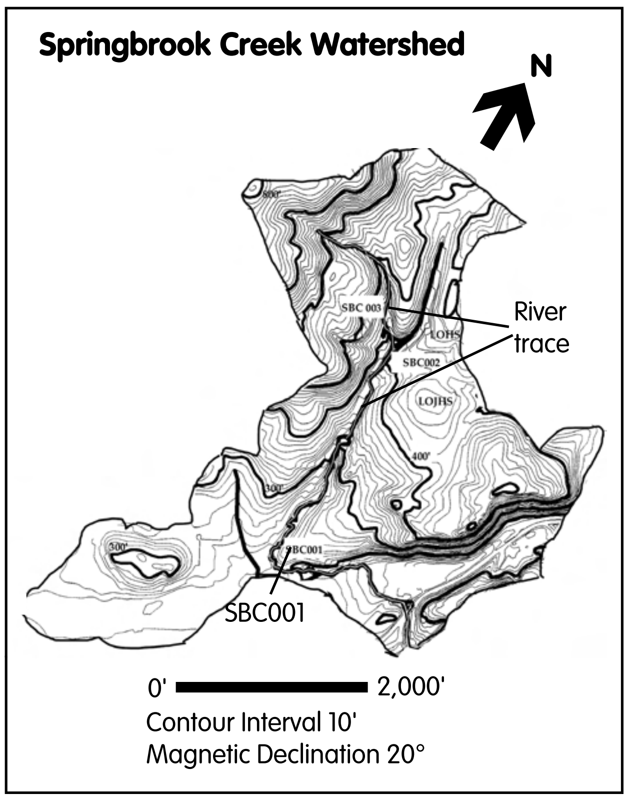
Next, decide which specific stream section or tributary to research. When choosing a stream section, consider access and safety. Within that section, which **stream reach** will you study? A reach is a length of stream defined by some common characteristic. A reach may simply be the section surveyed. More frequently, reaches are defined by the distances between named tributaries, by major changes in valley and channel form, vegetation, or by changes in land use ownership. Locate your reach by longitude and latitude. Use your topographic map and the exercise "A Sense of Place," pages 53-58 or a GPS Satellite Navigator.

You are now ready to construct a 3-D topographic model.

Watershed site selection

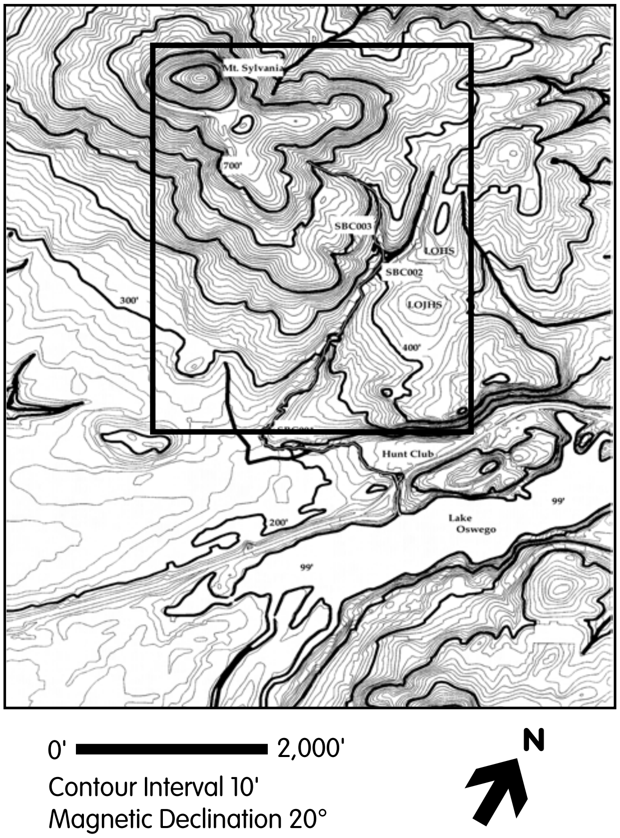
1. Photocopy and enlarge the watershed map.
2. Copy the scale along with the map. The scale on the map to the right is shown graphically as a line: 0'————2,000'.
3. Record or copy the magnetic declination noted on the map. This is shown graphically: ⁄⁄20°, or as part of the text.
4. Next trace the river system with a dark pencil.
5. Decide which reach you will study in more detail.
6. Mark the reach on the map and give it a number. On the example, SBC 001 stands for Springbrook Creek Reach number 1.
7. Include upstream areas in the 3-D model as those areas can affect your reach.

Watershed site selection



Student sheet

Finding the cutting edge



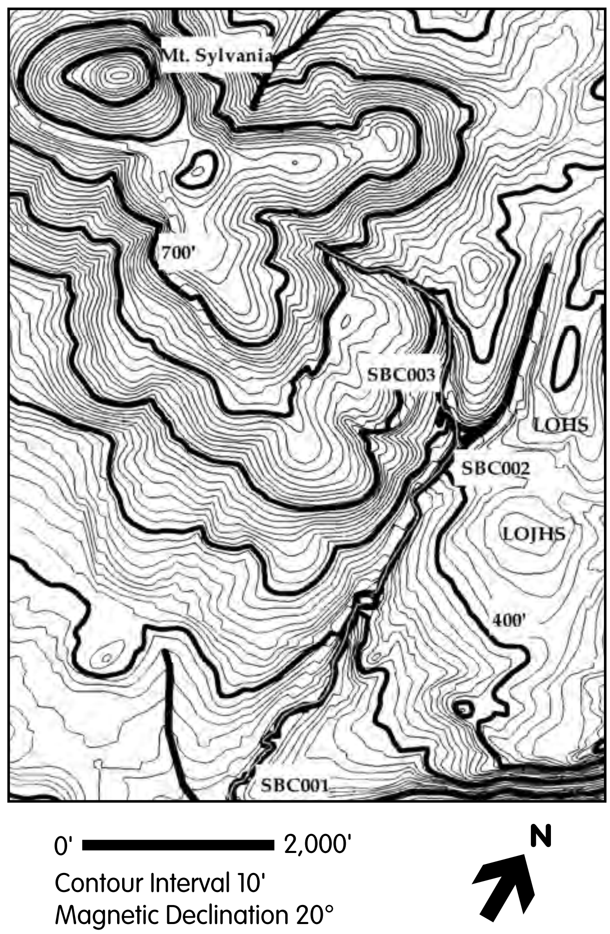
Finding the cutting edge

8. The area to be included in the 3-D model is outlined on the example map to the left.
9. Place the map with the selected area outlined in a photocopy machine. Enlarge it to a suitable size (8½"×11"). The example on these pages was enlarged three times. Make several copies.
10. Cut out the enlarged outlined area and set it aside. It will become your 3-D model.
11. Cut out the scale and any other pertinent data and set it aside.

Contours: getting elevated

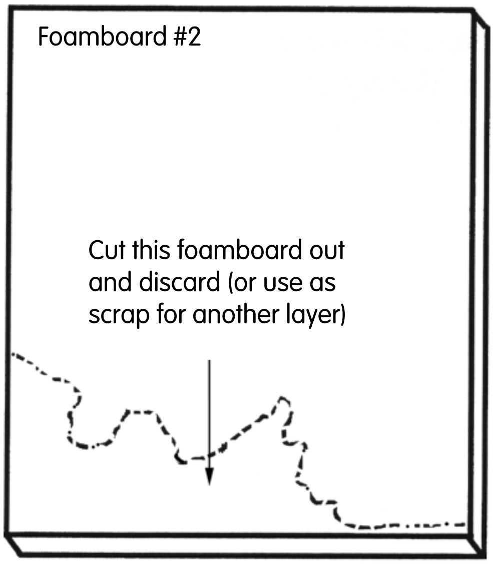
12. The enlarged map area to above is used for the model.
13. Choose either foamboard or cardboard for the 3-D model. Foam board comes in a variety of thicknesses and is easy to cut with an X-Acto knife.
14. In areas with less relief, consider exaggerating the elevation of your 3-D model so the changes in elevation show better. Using ¼" foamboard with a 7.5 minute topographic map results in no vertical exaggeration. Using ½" foamboard, provides an exaggeration of two times (2×).

Enlargement of study area

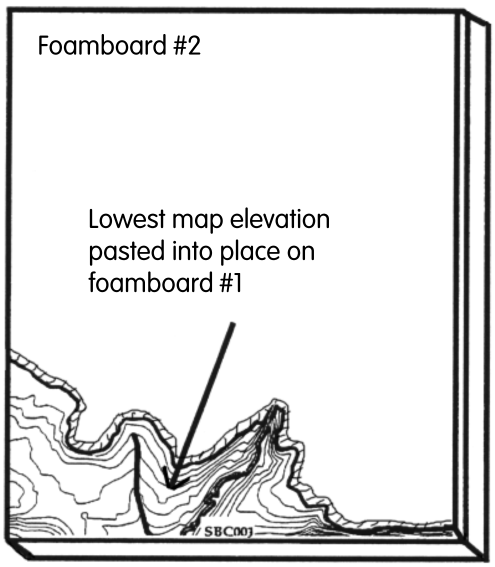


Student sheet

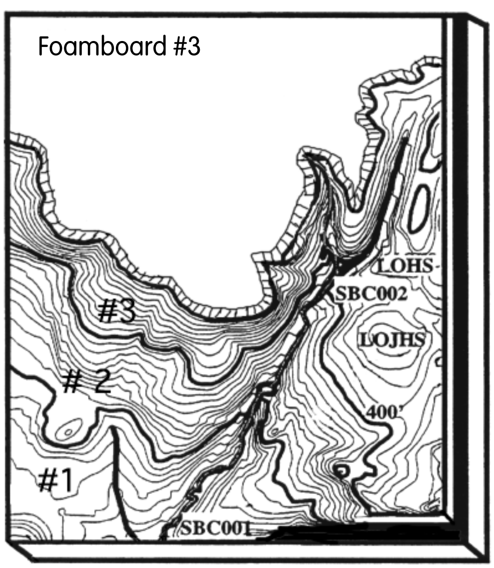
Step 18



Steps 19–20



Step 21



Contours: cutting up

15. Count how many index contour lines are on your map. On the example map, the indexed contours lines (the heavier lines) are 300', 400', 500', 600', 700', 800', and 900'. On this example there are seven index contour lines.

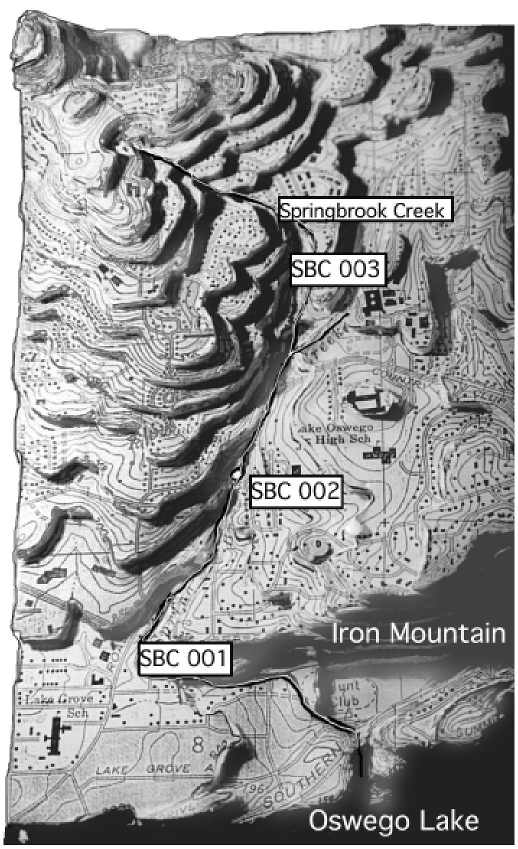
    Using a utility knife with a razor blade or an X-Acto knife, cut foamboard pieces to the size of your enlarged area (the example map is 8½"×11"). But cut foamboard pieces for only half the number of index contours on the map. For the example map, we would cut four foamboards measuring 8½"×11". Cutting out half the number of index contour lines allows you to use as much of the foamboard as possible. **One of the foamboards will become layer #1—your base—and will not be cut**.

16. Set the map on one of the foamboards (#2). Using your X-Acto knife, poke into the foamboard along the contour line that represents the lowest elevation on the map. Be careful with the X-Acto knife! Check to see if there is more than one contour line on the map that has that same elevation (there may be two contour lines of equal elevation on different parts of the map indicating the lowest places on the map). If this occurs, poke into the foamboard along both contours.
17. Using scissors cut out the lowest contour(s) on the map. The lowest elevation on this example map (300') occurs only once.
18. Cut out the dotted area on the foamboard with your X-Acto knife and discard or use as scrap piece for another layer.
19. Place foamboard #2 on top of foamboard #1 (the base). Glue the two boards together with white paste.
20. Take the *map* piece you just cut out (lowest elevation) and paste it on foamboard #1 (base) in the space left for it.

Student sheet

21. Repeat this procedure for each contour elevation. The bottom diagram shows three layers completed.
22. When you have completed the entire model and have glued down each layer, attach the magnetic declination, scale and contour interval. Add your name to the model and indicate when the model was built. See below for an example of a completed model.
23. By coloring the appropriate sections in different colors, you can use the model to show the slope of the land, the rock units in the area, or the soil types. All this information helps us to understand our watersheds. If you plan to include all three of the above, make three separate models. An example of a complete 3-D topographic map that includes rock units is shown below.
24. To protect your map, spread some white paste over the surface. The paste will dry clear.

Completed 3-D Topographic Model of the Springbrook Watershed



Scale (miles)
0 0.5 1
Contour Interval 10'
Magnetic Declination 20°

Glossary

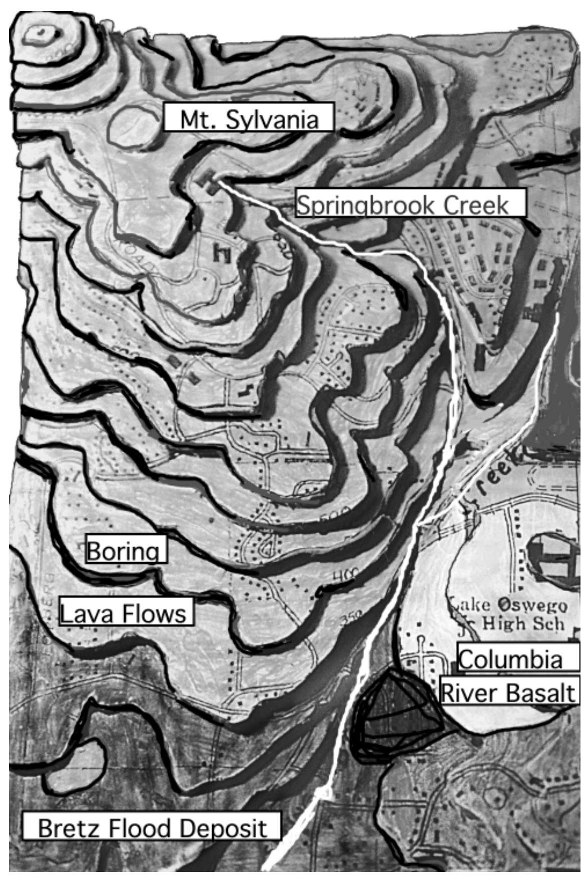
cartographer: a person who makes maps.

contour/contour lines: lines on maps that pass through points of the same elevation.

declination: the angular difference between true north and magnetic north.

elevation: distance above or below sea level.

Rock Units in the Springbrook Watershed



Student sheet

index contour: the thicker brown lines on a topographic map; these lines usually have an associated number that indicates the elevation along the line.

reach, stream: a length of stream defined by some common characteristic.

relief: the difference in elevation between the highest points and lowest points on a map; the configuration of the earth's surface.

scale: relationship between the distance on a map and the distance it represents on the earth (1:24000 or 1" to 24,000").

topographic map: a map that uses contour lines and symbols to represent the features (human created and natural) of the mapped area.

topographic profile: a side view of the land along a specific line; a profile of a stream would show the stream's slope.

topographic cross section: a side view of the land along a specific line; a cross section would show you the profile of the valley that the stream passes through.

USGS: the United States Geological Survey is a branch of the federal government's Department of the Interior responsible for creating many types of maps.

watershed: the land area from which water flows toward a common stream in a natural basin.

wetlands: lands where water saturation is the dominant factor determining the nature of soil development and the types of plant and animal communities—sloughs, ponds, marshes.

Questions

1. What have you learned about maps during the construction of your model?

2. How could you use your model to show someone the features of your watershed?

Student sheet

Snow way!

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

Objectives

Students will (1) graph the annual rainfall for a basin, (2) graph annual snowpack for the same basin, (3) graph streamflow during the same period, and (4) analyze and describe the response of the stream to various types of precipitation.

Method

Students will graph rainfall, snowpack, and streamflow data for Silver Creek near Silver Lake in Lake County, Oregon. Students will then draw conclusions about the response of a watershed to various types of precipitation.

For younger students

1. This activity can also be done as a group.
2. Younger students may need graphing practice prior to this activity.

Materials

- copies of student sheets (pp. 101-104)

Notes to the teacher

Ask the students to describe the direct correlations shown on the graph. For example, peak snowpack is in February and March. At this time, streamflows are at their lowest. Then, as snowmelt occurs, streamflows increase as shown when lines cross and go in opposite directions. When streamflows are highest, precipitation is lowest. Notice that the streamflow peaks in September but continues to provide good flows throughout the warmest months of the year because of baseflow (groundwater recharge).

Background

Do you know . . .

. . . in many places snow is an important part of the total precipitation of a watershed? It is the main source of water for streams in the mountainous West. Melting snow may affect streamflow long after it falls as precipitation. Snow may melt slowly, creating streamflow throughout the otherwise dry summer. Or it may melt rapidly, creating floods.

During the spring and fall, temperature fluctuations can cause recent snowfall to melt. When this happens it creates runoff and streamflow affects similar to rainstorms. During the winter, snow may stay on the ground for long periods. This stores the water in snow until later in the year. Streams fed by melting snow often flow for much longer periods than streams fed only by rain.

Mountain snowpacks are measured to predict how much water will be available when it melts later in the year. To evaluate how much water is in snow it is important to measure not only its depth, but its **water equivalent**. This is the amount of water that would be released if all of the snow melted.

Snow disappears in other ways besides melting. In a process known as **sublimation** snow can pass directly from frozen form to vapor. Wind blowing directly across snow evaporates it. Blowing snow is especially prone to sublimation.

Vocabulary

water equivalent
sublimation
streamflow hydrograph

Procedure

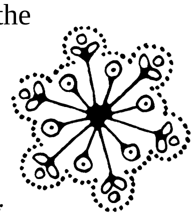
Now it's your turn . . .

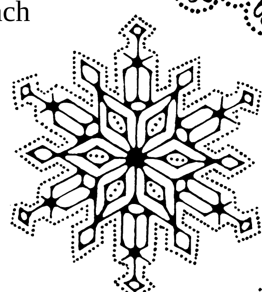
The information in the following table shows annual precipitation and snowpack amounts and streamflow for a basin in southeastern Oregon. The data for precipitation includes snowfall. Even though it falls as precipitation, snow may not affect streamflow until later in the year. When temperatures are below freezing, snow is stored in the watershed rather than being captured in, or stored by, soils. The data given for snowpack shows the accumulated amounts over a season.

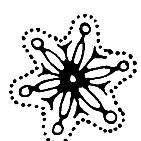
Snowpack was measured near the top of the Silver Creek watershed. Precipitation and streamflow were measured near the mouth of Silver Creek.

On the graph provided, create a line graph by plotting the annual precipitation and snowpack of the Silver Creek basin near Silver Lake in Lake County. Repeat the process for the streamflow data. This graph is called a **streamflow hydrograph**.

Use a different color for each line. Be sure to mark a legend with the color representing each line.



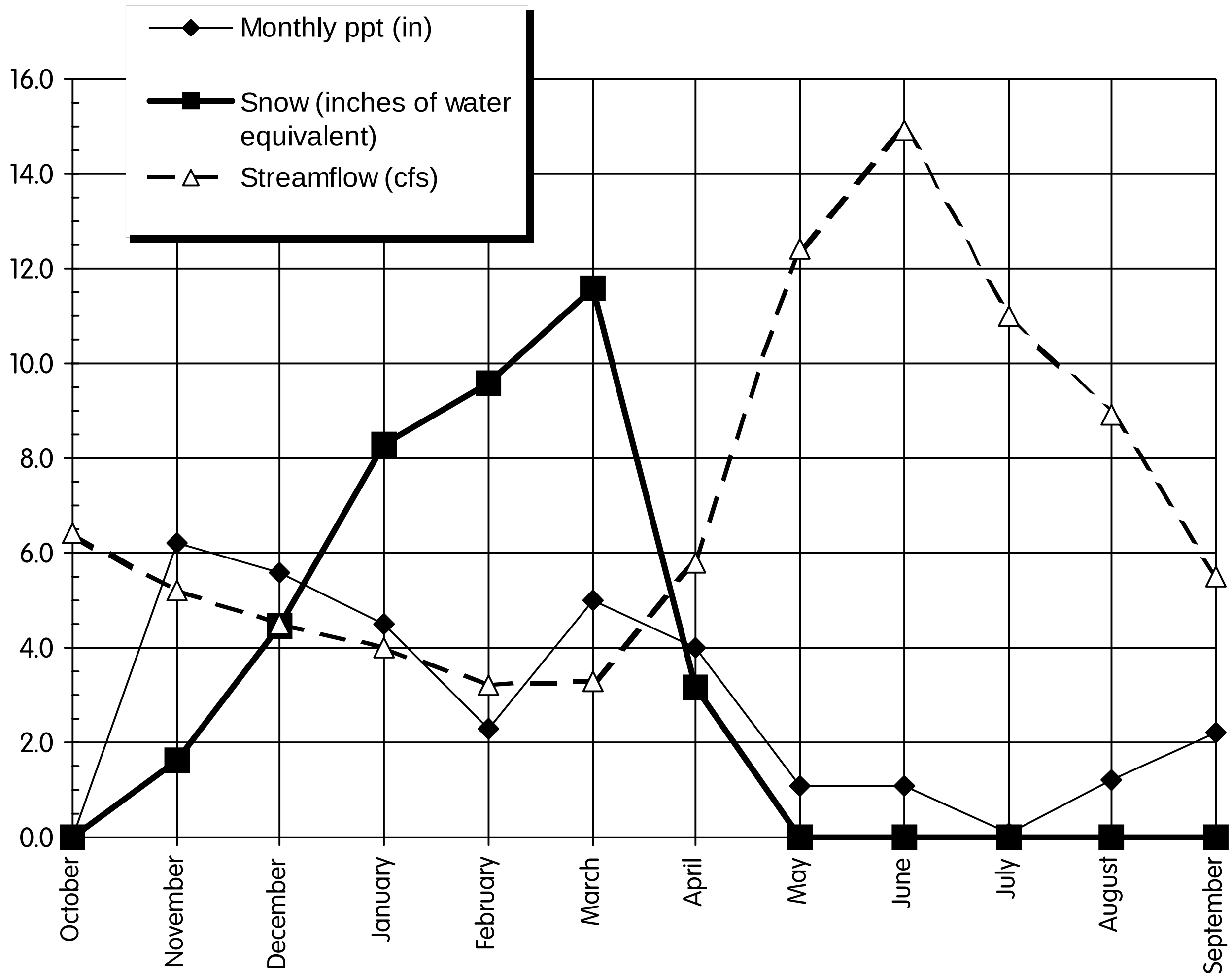




Silver Creek is a tributary of Silver Lake, in Lake County, Oregon. The drainage area of Silver Creek is 180 square miles.

1989	Monthly ppt (in)	Snow (inches of water equivalent)	Streamflow (cfs)
October	0.0	0.00	6.4
November	6.2	1.63	5.2
December	5.6	4.47	4.5
January	4.5	8.31	4.0
February	2.3	9.60	3.2
March	5.0	11.59	3.3
April	4.0	3.15	5.8
May	1.1	0.00	12.4
June	1.1	0.00	14.9
July	0.1	0.00	11.0
August	1.2	0.00	8.9
September	2.2	0.00	5.5

Silver Creek Streamflow Hydrograph



Questions

1. Which month had the greatest precipitation? The most water stored as snow? The highest streamflow?

   Precipitation was highest in November. The peak snowpack was in March. June was the month with the highest streamflow.

2. How long was it from the precipitation peak to the streamflow peak.

   The period between the precipitation peak and streamflow peak is November to June, or about 7 months.

3. How long was it from the peak storage of snow to the streamflow peak.

   The period between the snow storage peak and streamflow peak is March to June, or about 3 months

4. Which has a greater influence on the peak streamflow of Silver Creek, total precipitation or snow storage? Why?

   Snow storage has a greater effect on the flow of Silver Creek. The amount of water stored as snow may be relatively small compared to the total precipitation in the watershed, but it's rapid melt moves it into the stream relatively quickly.

5. Use the concepts of "capture, store, and safe release" to explain where the water from the melting snow was between the time it melted and when it reached to stream?

   Snow on the uplands was "captured" when it melted and infiltrated into the soil. It was then stored there for several days while it percolated downhill to the stream. When it reached the stream it was released as streamflow.

Going further

1. Design an experiment that will determine the water equivalent of snow. Collect information about snow water equivalence, monthly precipitation, and streamflow data for your own watershed. Develop a streamflow hydrograph for your own stream, based on your research.
2. What relationship exists between "stream order" and the lag time for the stream to reflect a sudden snow-melt event in the spring?
3. The activity "Winter Watersheds!" (pp. 131-152) can be used as an extension of this activity.

Name

Snow way!

Do you know . . .

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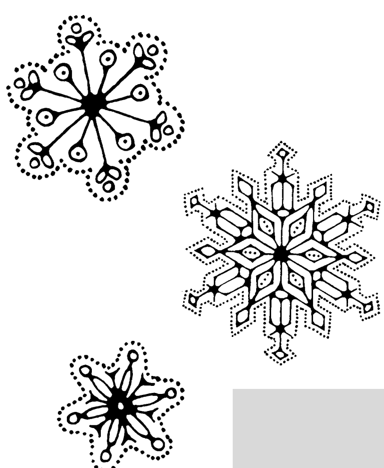

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The information in the following table shows annual precipitation and snowpack amounts and streamflow for a basin in southeastern Oregon. The data for precipitation includes snowfall. Even though it falls as precipitation, snow may not affect streamflow until later in the year. When temperatures are below freezing, snow is stored in the watershed rather than being captured in, or stored by, soils. The data given for snowpack shows the accumulated amounts over a season.

Snowpack was measured near the top of the Silver Creek watershed. Precipitation and streamflow were measured near the mouth of Silver Creek.

On the graph provided, create a line graph by plotting the annual precipitation and snowpack of the Silver Creek basin near Silver Lake in Lake County. Repeat the process for the streamflow data. This graph is called a **streamflow hydrograph**.

Use a different color for each line. Be sure to mark a legend with the color representing each line.

Vocabulary

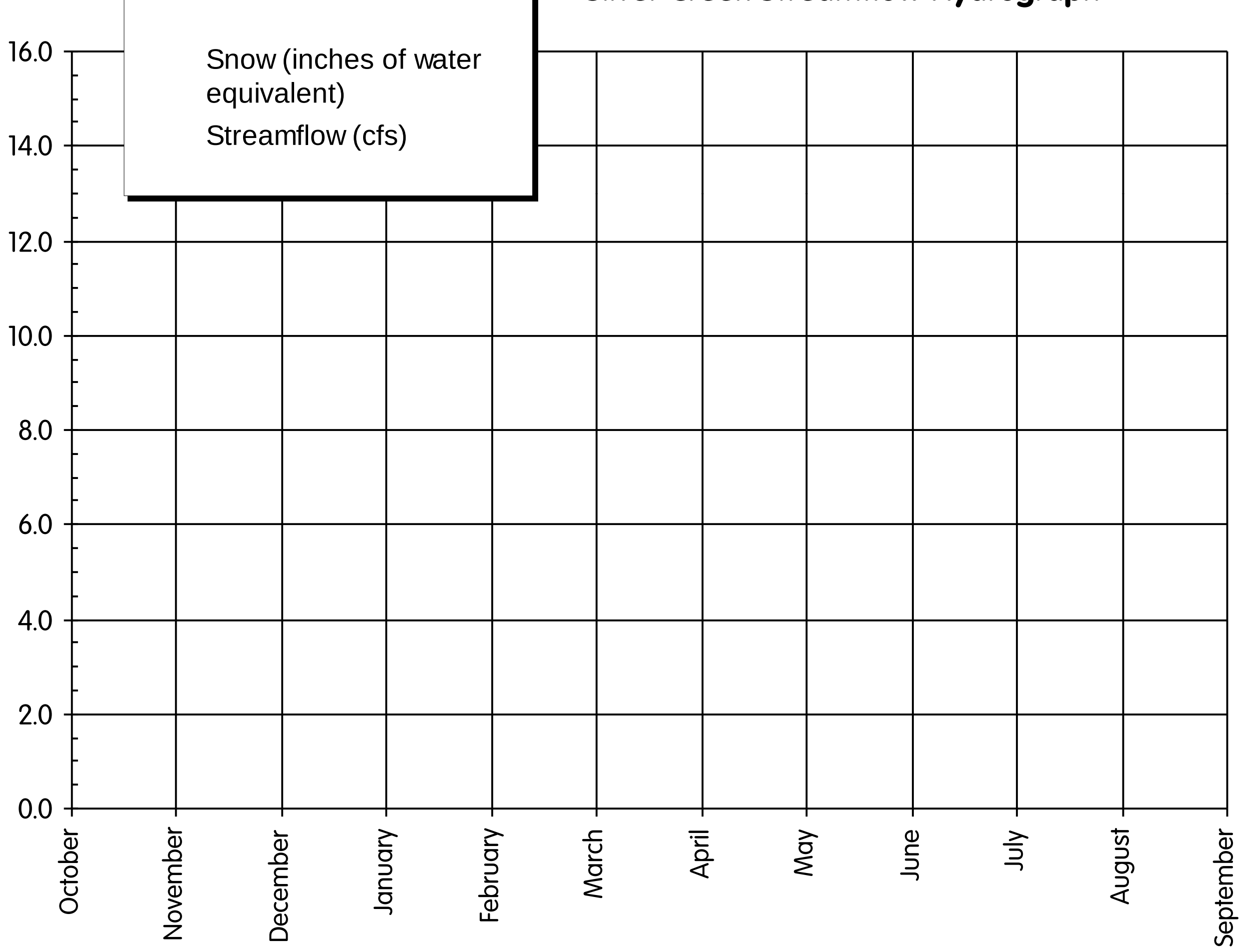
water equivalent
sublimation
streamflow hydrograph

Student sheet

Silver Creek is a tributary of Silver Lake, in Lake County, Oregon. The drainage area of Silver Creek is 180 square miles.

1989	Monthly ppt (in)	Snow (inches of water equivalent)	Streamflow (cfs)
October	0.0	0.00	6.4
November	6.2	1.63	5.2
December	5.6	4.47	4.5
January	4.5	8.31	4.0
February	2.3	9.60	3.2
March	5.0	11.59	3.3
April	4.0	3.15	5.8
May	1.1	0.00	12.4
June	1.1	0.00	14.9
July	0.1	0.00	11.0
August	1.2	0.00	8.9
September	2.2	0.00	5.5

Silver Creek Streamflow Hydrograph



Student sheet

Questions

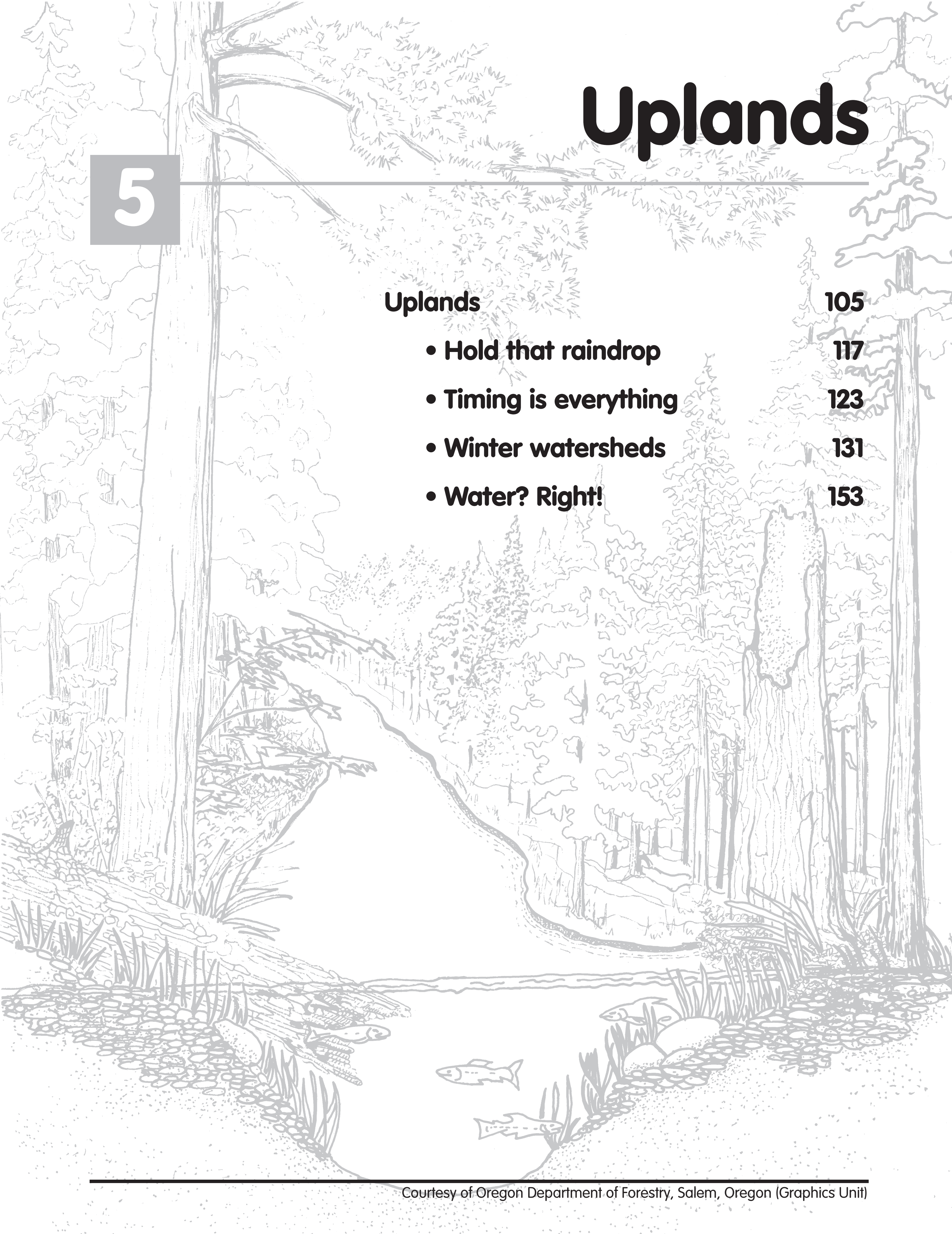
1. Which month had the greatest precipitation? The most water stored as snow? The highest streamflow?

2. How long was it from the precipitation peak to the streamflow peak.

3. How long was it from the peak storage of snow to the streamflow peak.

4. Which has a greater influence on the peak streamflow of Silver Creek, total precipitation or snow storage? Why?

5. Use the concepts of “capture, store, and safe release” to explain where the water from the melting snow was between the time it melted and when it reached to stream?



Uplands

5

Courtesy of Oregon Department of Forestry, Salem, Oregon (Graphics Unit)

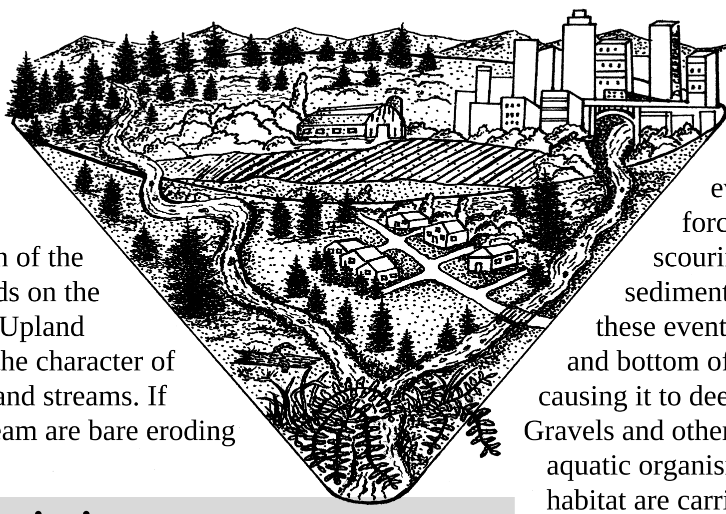
Uplands

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

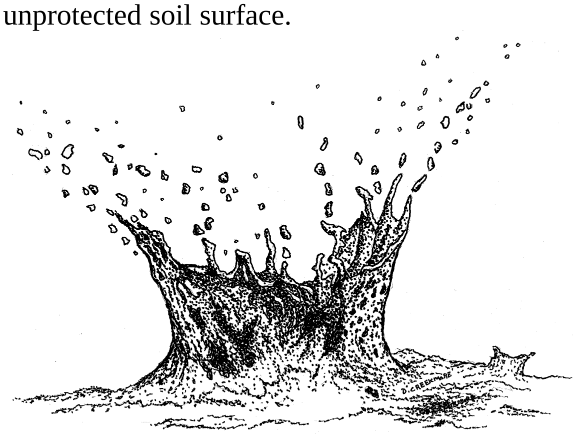
the soil. The activities of burrowing rodents, earthworms, and other organisms create holes, depressions, and increase surface roughness that promotes ponding.

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.

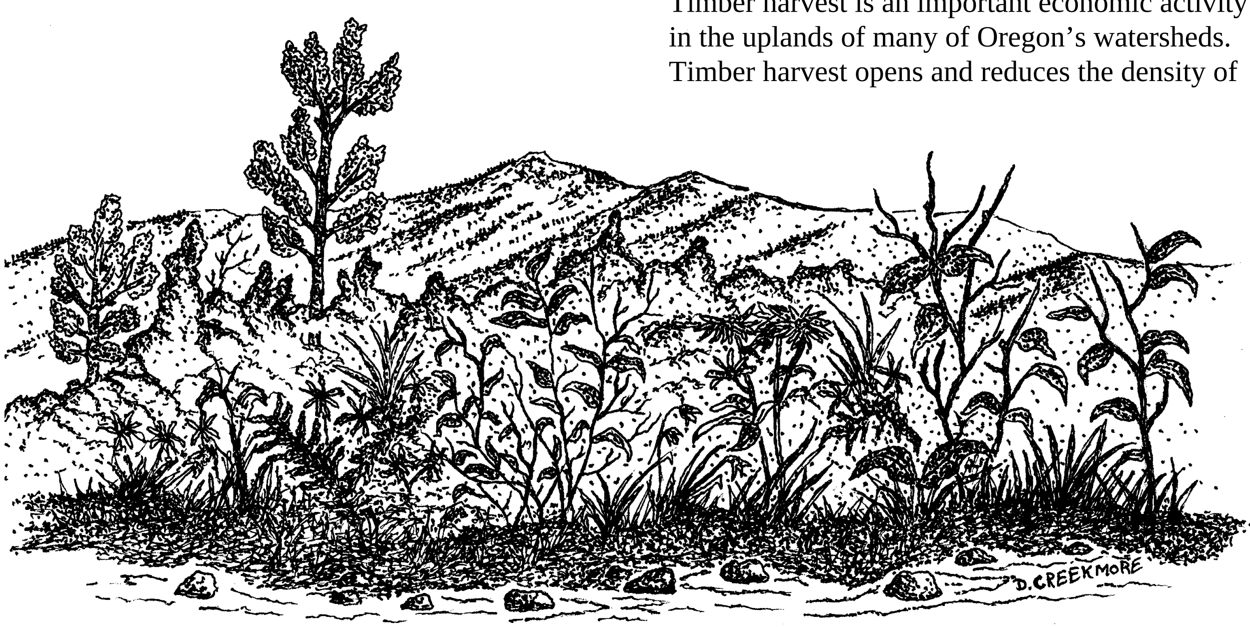
Areas too **arid** to support forests have a different community structure. On dry lands there is not enough rainfall to support an uninterrupted layer of plants to cover the soil. Between individual plants there are areas that may be bare or covered with plant litter. The organic material from shrubs, 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.

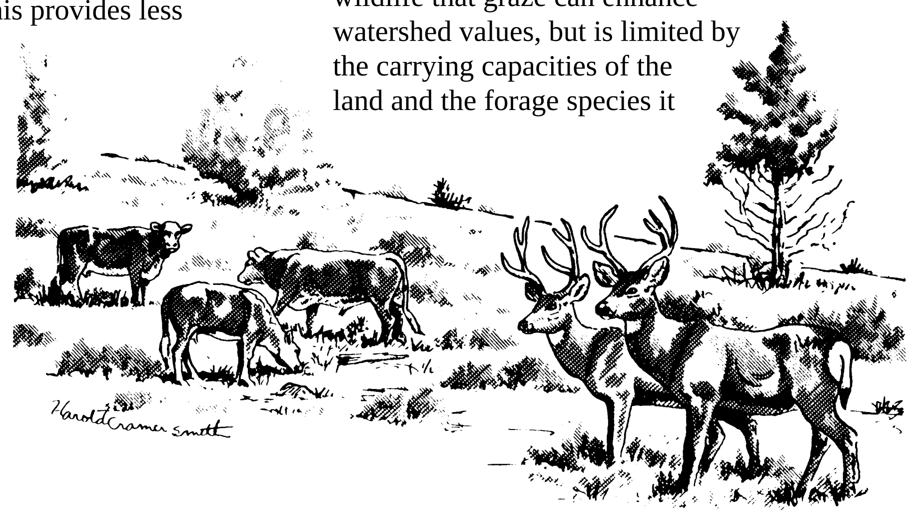
Livestock grazing

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

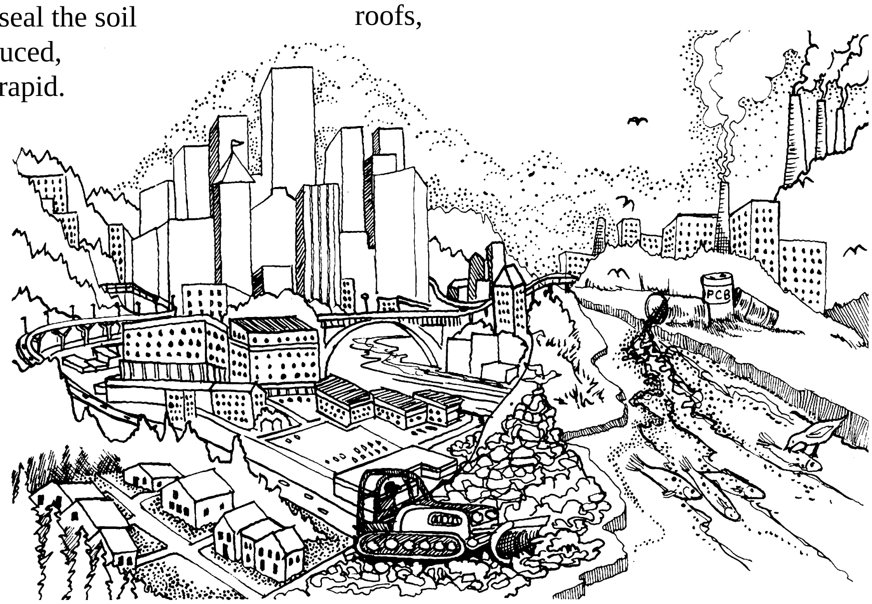
Mining requires opening the earth to remove mineral resources. It is done by stripping off the surface soil and rock layers or by drilling tunnels into the earth to reach minerals.

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.

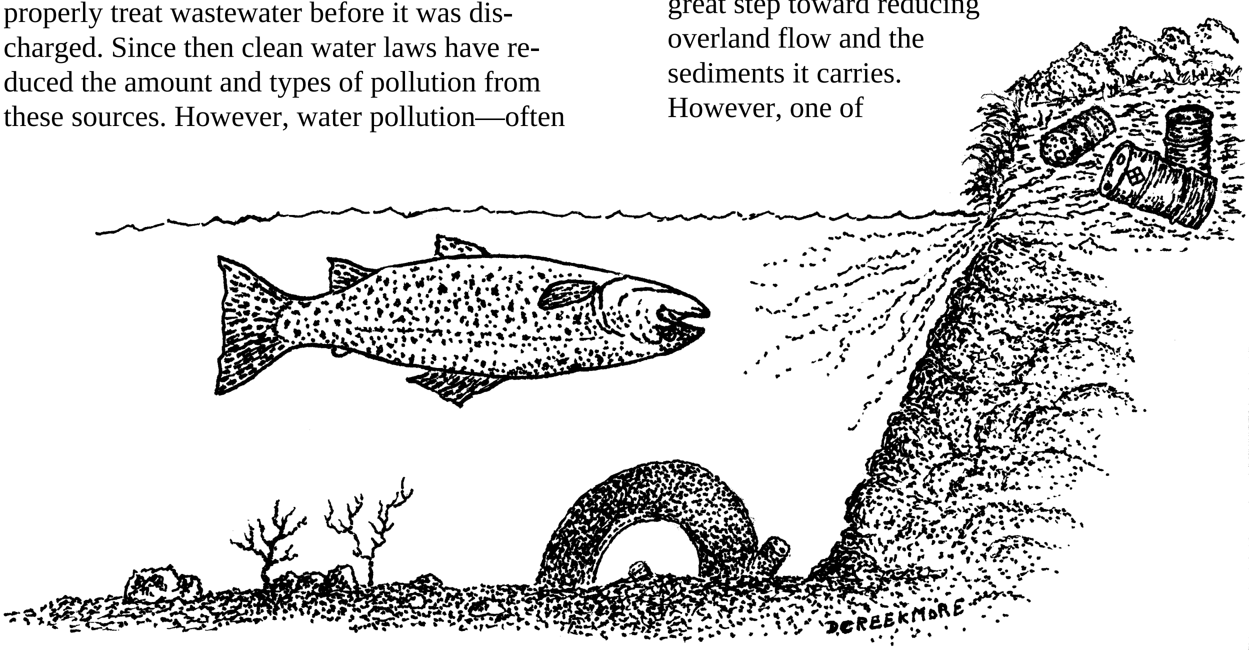
Railroads and airports have similar effects. Power lines and pipelines require open paths through the watershed and access roads for construction and maintenance.

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.

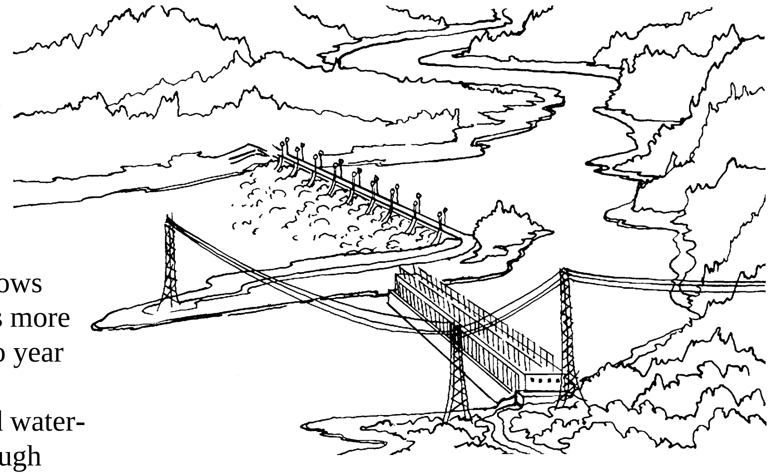
Dams and reservoirs

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. 22-25. 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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Hold that raindrop

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

Objectives

The student will (1) measure the rate and volume of drainage from inorganic and organic soils and (2) describe the affect of organic material on the capture, storage, and safe release of rainwater.

Method

Students will demonstrate and collect data on capture, store, and safe release. They will investigate the role organic matter plays in capturing and storing rainfall to slow its release into streams.

For younger students

1. Consult extension activities at the end of each chapter to address the needs of younger students.
2. Read activity background information aloud to younger students or modify for your students' reading level.
3. The modeling portion of this activity may also be done as a demonstration. Depending on the age and abilities of students they may then do the graphing portion on their own, or it may be done as a group.
4. Depending on level of students, some initial set up is required. Adults can punch holes in cans, assist with accurate measurements of water, sand, and peat moss. Students may need some background for measuring fractional parts when comparing water run-off. Rephrase some questions (possibly number 4) or answer as part of a group discussion.

Vocabulary

baseflow
groundwater storage
infiltrate
organic material
porous
stormflow
subsurface flow
surface runoff

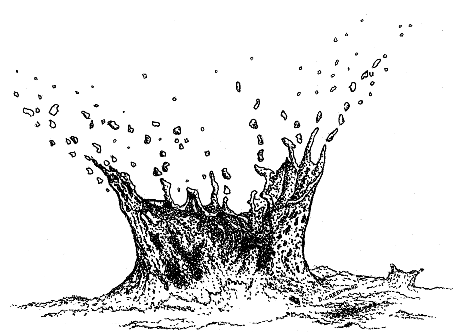
Materials

- large vegetable juice or fruit cans (two per team)
- 1 nail
- 1 hammer
- screen ("noseeum" tent netting works well)
- sand
- peat moss
- pan (one per team)
- stopwatch (one per team)
- water
- copies of student sheets (pp. 121-122)

Notes to the teacher

Select two cans of the same size and diameter for each team. With the nail and hammer punch the same number of holes in the bottom of each can. This activity will work best if the holes are punched from the inside of the can. However be aware that the metal edges of the holes on the outside of the can will be sharp.

Once students have completed this activity they may want to repeat the experiment with soils from local uplands and other areas. Compare and discuss the results from these various tests.



Background

Do you know . . .

A healthy watershed captures a raindrop where it falls, stores it in the ground, and releases it safely to the stream over time. To capture a raindrop, the surface it falls on must allow it to soak, or **infiltrate**, 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 move into. When infiltration rates cannot keep up with rainfall rates, water begins to flow over the top of the soil. This is called **surface runoff**. Surface runoff is rainfall that does not infiltrate into the soil, but flows over the surface until it reaches the stream.

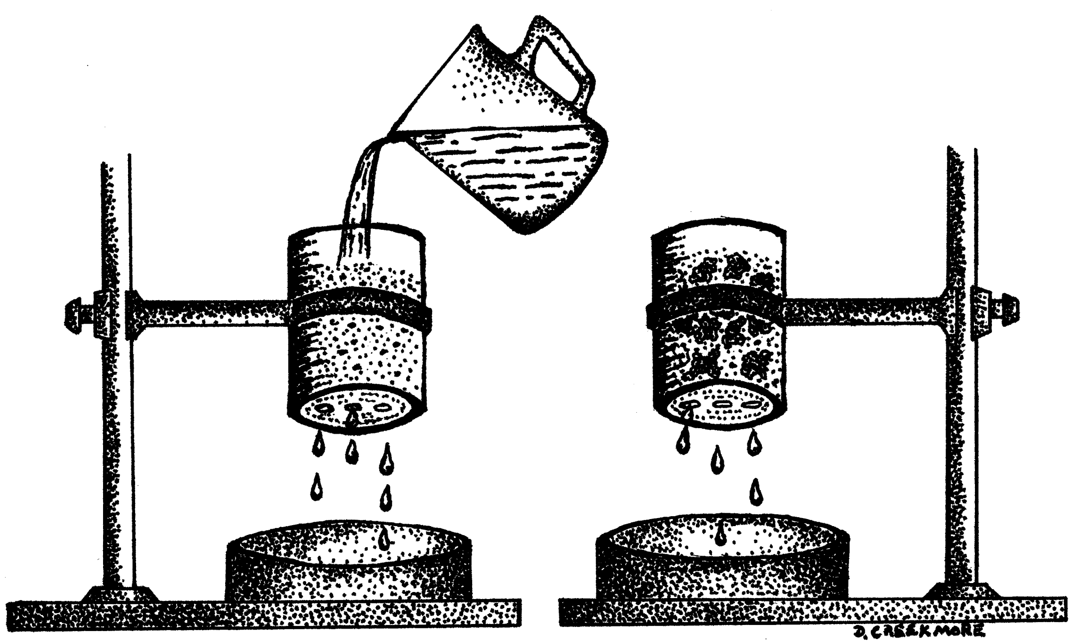
Organic material in soils can act like a sponge to hold onto water, increasing the ability of soil to store it. When the soil has taken in as much water as it can store, the rest of the infiltrated water begins to percolate (drain) through the soil to be stored in the ground (**groundwater storage**) or 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. This increases the period of time any one storm contributes water to the stream. The water that percolates through the soil to the stream is called **subsurface flow**. Subsurface flow is much slower than overland flow.

Procedure

Now it's your turn . . .

How do the soils and plants of a healthy watershed capture and store rainwater, and then release it to a stream over time? In this investigation you will model a rainstorm and then calculate the difference in time between **stormflow** and **baseflow**, and the amount of water retained by soils.

1. Select two cans of the same size and diameter for each team. With the hammer and nail punch the same number of holes in the bottom of each can. Try to place the holes in approximately the same position in each can.
2. Line the bottom of each can with screen.
3. Place 4 cups of sand in the bottom of one can.



4. Mix 2 cups of sand and 2 cups of peat moss together and place in the bottom of the second can.
5. Place the first can—the one with only sand—over a pan to catch the drainage. Pour one measured quart of water into the first can all at once, and begin timing. Record how long it takes for the water to quit dripping from the bottom of the can.
6. Measure the amount of water that drained from the can. Record the information on the data sheet
7. Place the second can—the one with the mixture of sand and peat moss—over a pan to catch the drainage. Pour one measured quart of water into the second can all at once, and begin timing. Record how long it takes for the water to quit dripping from the bottom of the can.
8. Measure the amount of water that drained from the can. Record the information on the data sheet.
9. Answer the questions provided.

Observations

	Drainage time	Amount of water
Sand only		
Peat moss and sand		

Questions

1. Which took longer to drain, sand alone or the mixture of sand and peat moss?
   The sand and peat moss mixture should take longer to drain.
2. Was there a difference between the amount of water you added to the can and the amount that drained from the can? If so, what happened to the "missing" water?
   There should be a difference. The water was stored in the soil.
3. Which held onto more water, sand alone or the mixture of sand and peat moss?
   The sand and peat moss mixture should retain more water.
4. Which took longer to drain, sand alone or the mixture of sand and peat moss?
   The mixture of sand and peat moss should take longer to drain.
5. What role do plants and organic material—such as peat moss—play in capturing, storing, and releasing rainwater to streams over time?
   Organic material acts as a sponge to capture rainwater and store it in the soil. Soils with organic material both hold onto more water, and release it more slowly.

Going further

1. Redo the experiment with soils from at least six sites in the uplands and other areas in your watershed. Compare the water holding capacity of these samples with the examples you tested in the previous experiment. Predict the results before beginning the second set of tests. What might account for the differences, if any?

Name

Hold that raindrop

Do you know . . .

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Now it's your turn . . .

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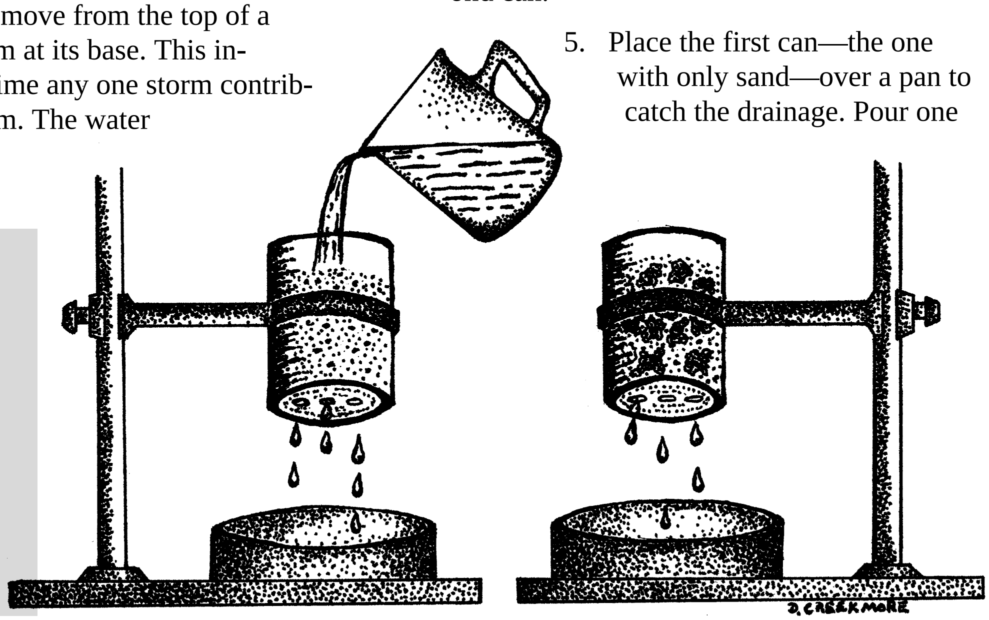
1. Select two cans of the same size and diameter for each team. With the hammer and nail punch the same number of holes in the bottom of each can. Try to place the holes in approximately the same position in each can.
2. Line the bottom of each can with screen.
3. Place 4 cups of sand in the bottom of one can.
4. Mix 2 cups of sand and 2 cups of peat moss together and place in the bottom of the second can.
5. Place the first can—the one with only sand—over a pan to catch the drainage. Pour one



Vocabulary

baseflow
groundwater storage
infiltrate
organic material
porous
stormflow
subsurface flow
surface runoff

Student sheet

measured quart of water into the first can all at once, and begin timing. Record how long it takes for the water to quit dripping from the bottom of the can.

6. Measure the amount of water that drained from the can. Record the information on the data sheet

7. Place the second can—the one with the mixture of sand and peat moss—over a pan to catch the drainage. Pour one measured quart of water into the second can all at once, and begin timing. Record how long it takes for the water to quit dripping from the bottom of the can.

8. Measure the amount of water that drained from the can. Record the information on the data sheet.

9. Answer the questions provided.

Observations

	Drainage time	Amount of water
Sand only		
Peat moss and sand		

Questions

1. Which took longer to drain, sand alone or the mixture of sand and peat moss?

2. Was there a difference between the amount of water you added to the can and the amount that drained from the can? If so, what happened to the “missing” water?

3. Which held onto more water, sand alone or the mixture of sand and peat moss?

4. Which took longer to drain, sand alone or the mixture of sand and peat moss?

5. What role do plants and organic material—such as peat moss—play in capturing, storing, and releasing rainwater to streams over time?

as an overhead transparency to demonstrate this concept.

Help students understand their "sense of place." Each of us has a place we want to become part of, care about, and want to protect or enhance. Understanding this concept and the responsibilities that go along with it are part of watershed education. When people have a greater understanding of their watershed, they gain awareness of how their personal actions, local laws and regulations, and everyday practices affect the integrity and stability of their ecological address and the larger biological community.

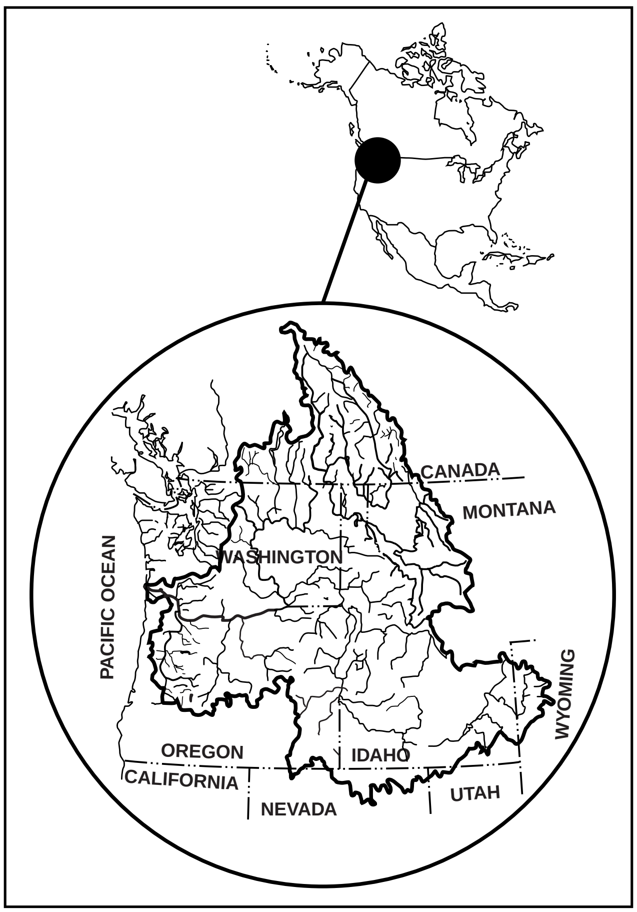
Depending on age level, students will need varying degrees of background information before proceeding with the "brainstorming and definition of a watershed" part of the activity. The activity's background section is appropriate as is a student reading developed from the chapter content.

A simple demonstration may also help students understand the concept of watershed. Trace the outline of your hand, wrist, and part of your arm on the chalkboard. Color in the space between your fingers and label your arm "Muddy River." Tell the students this outline is a model for a watershed area. Your fingers represent streams that feed into the larger river (your arm). The colored space between your fingers is land, where people live. Let students know that a watershed's name is usually taken from the stream or river that serves as the main collector of all the water in the watershed. Ask students what the watershed you just drew would be called (Muddy River Watershed). Write the name on the board. Create names for the finger tributaries and write those on the board, too. Ask students how large they think watersheds can be, then how small they can be. They should recall this from their background reading. Impress upon the students that large watersheds include many small watersheds.

Use maps that parallel the local watershed situation as closely as possible. Substituting local maps for the mid-coast and Umatilla drainage basin maps where appropriate will help students associate more closely with their own watershed and develop their own "sense of place." Modify the procedures to work with the local map. In urban areas a city map may be needed to determine the exact watershed in which a student's home or school might be found. Depending on the proximity of waterways, the watershed named should reflect that students' ecological addresses can have several components, from the smallest watershed they can observe to a larger watershed of which the smaller one is a part.

It is not necessary for the "map" created in Step 7 to be to scale, but it should represent the watershed(s) in which the students live. Use the Five Rivers water-

Columbia River Basin



Based on: Ed Chaney, *A Question of Balance: Water/Energy—Salmon and Steelhead Production in the Upper Columbia River Basin, Summary Report*, Nov. 1978. NW Resource Information Center, Inc.

shed map as an example. As an alternative or additional activity, have the entire class make a larger map of the watershed on large sheets of paper.

Background

Do you know ...

Water runs downhill. We all know that. The instant that a drop of rain hits the earth, it begins its journey to the ocean. If it falls as snow, it has to wait until it melts! Of course, not all water drops make it to the ocean. Some are taken up by plant roots and are transpired into the air through the plant's leaves. Some evaporate in puddles or other areas that hold water. Some filter down into underground areas, moving slowly downhill. But most water drops end up as runoff, the water that finds its way into creeks, streams, and rivers.

This long or short journey to the ocean takes place within a watershed. If you stand in a streambed and look upstream at all the land the stream drains, you are looking at the stream's **watershed**. Almost all the area of a watershed is land—not water! And, almost everything that drains it happens on that land. In other words, all land on earth is in a watershed.

Every body of water, stream, lake, pond, or river, has a watershed. Even a mud puddle has a watershed! Watersheds can be big or small. A mud puddle has a watershed of only a few square feet, while the Columbia River watershed has 258,000 square miles! The biggest watershed in the country is the Mississippi River, which drains all the land between the Rocky Mountains and the Appalachian Mountains.

A raindrop, no matter where it falls in the Columbia River watershed (unless it evaporates), will end up at the mouth of the Columbia River at Astoria. Most large watersheds are made up of many smaller watersheds called **sub-basins**. For instance, the Columbia watershed includes the Snake, John Day, Deschutes, Umatilla, and Willamette watersheds plus many others.

Watersheds are separated by ridges, called **divides**. The Continental Divide of the Unite States, for example, is in the Rocky Mountains. All the rain and snow falling on the west side of the divide flows into the Pacific Ocean. All the rain and snow falling on the east side of the divide, sooner or later, ends up in the Atlantic Ocean.

Procedure

Now it's your turn . . .

1. What is your home mailing or street address? What are the addresses of several other students in your class? These postal addresses have been devised by society—in other words, they are "social" addresses. Social addresses are important because people need to be located within their community by family, friends, and services such as the mail, police, fire, or ambulance.

2. You have another kind of address, called an "ecological address." Ecological refers to the relationship between an organism and its environment. Just as a postal address tells people one way they are connected to the community, the ecological address tells people how they are connected to the land on which they live. In this activity, your "ecological address" is based on an ecological feature you are just now learning about—a watershed.

3. With your partner, brainstorm words or ideas that make you think of a watershed. Write down your thoughts. Using your ideas as a starting point, create a watershed definition. Write your definition in the space provided for Question 1 on the student worksheet. Now, using a piece of paper and markers, draw and color a picture of the watershed you just defined. When all the groups are finished share your definition and drawing with the rest of the class. Post your drawing on the wall. As a class discuss all of the group's definitions and decide on the definition that best states the meaning of a watershed. You may have to combine several

group's definitions to come up with the best answer.

4. Look at your copy of the Mid-Coast Drainage Basin map. Locate a stream called Five Rivers (Five Rivers runs through the communities of Denzer, Fisher, and Paris). Mark the point where Five Rivers runs into the Alsea River. Where does the Alsea River go? **(Pacific Ocean.)**

5. Locate the Crab Creek watershed by drawing a line around it with a colored pencil or marker. Then, locate the Lobster Creek watershed in the same way with another color. With a third color, draw a line around the entire Five Rivers watershed. Check with your teacher to see if you have correctly identified the watersheds. Answer Questions 2, 3, and 4 on the student worksheet from the mid-coast drainage basin map.

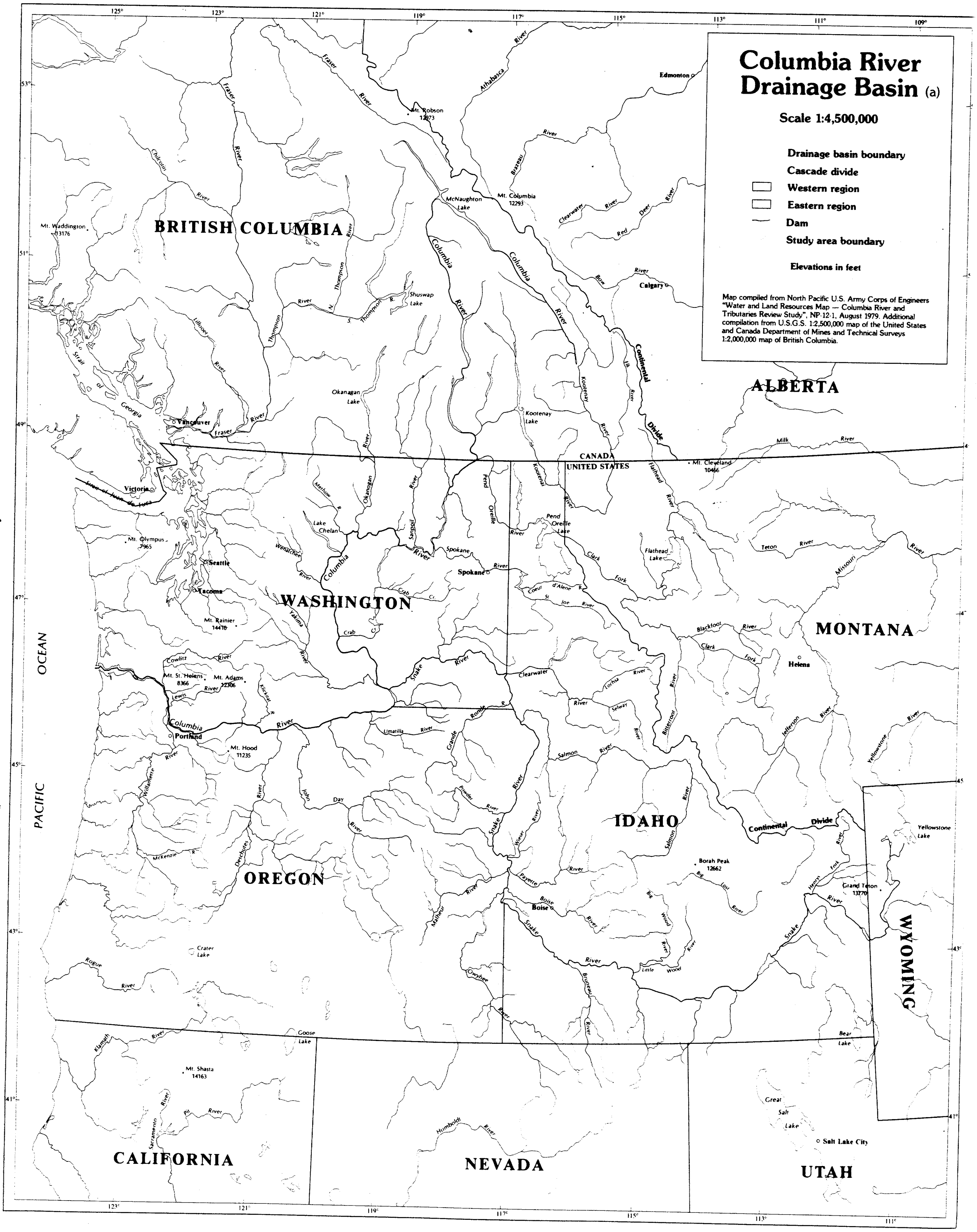
6. Now, look at your copy of the Umatilla drainage basin map. The Umatilla River watershed is in Northeastern Oregon. Locate a stream called Willow Creek (Willow Creek runs through the communities of Heppner, Jordan, and Ione). Locate the Spring Hollow watershed by drawing a line around it with a colored pencil or marker. Then, locate the Rhea Creek watershed in the same way with another color. With a third color, draw a line around as much of the Willow Creek watershed as possible. Answer Questions 5 through 10 on the student worksheet.

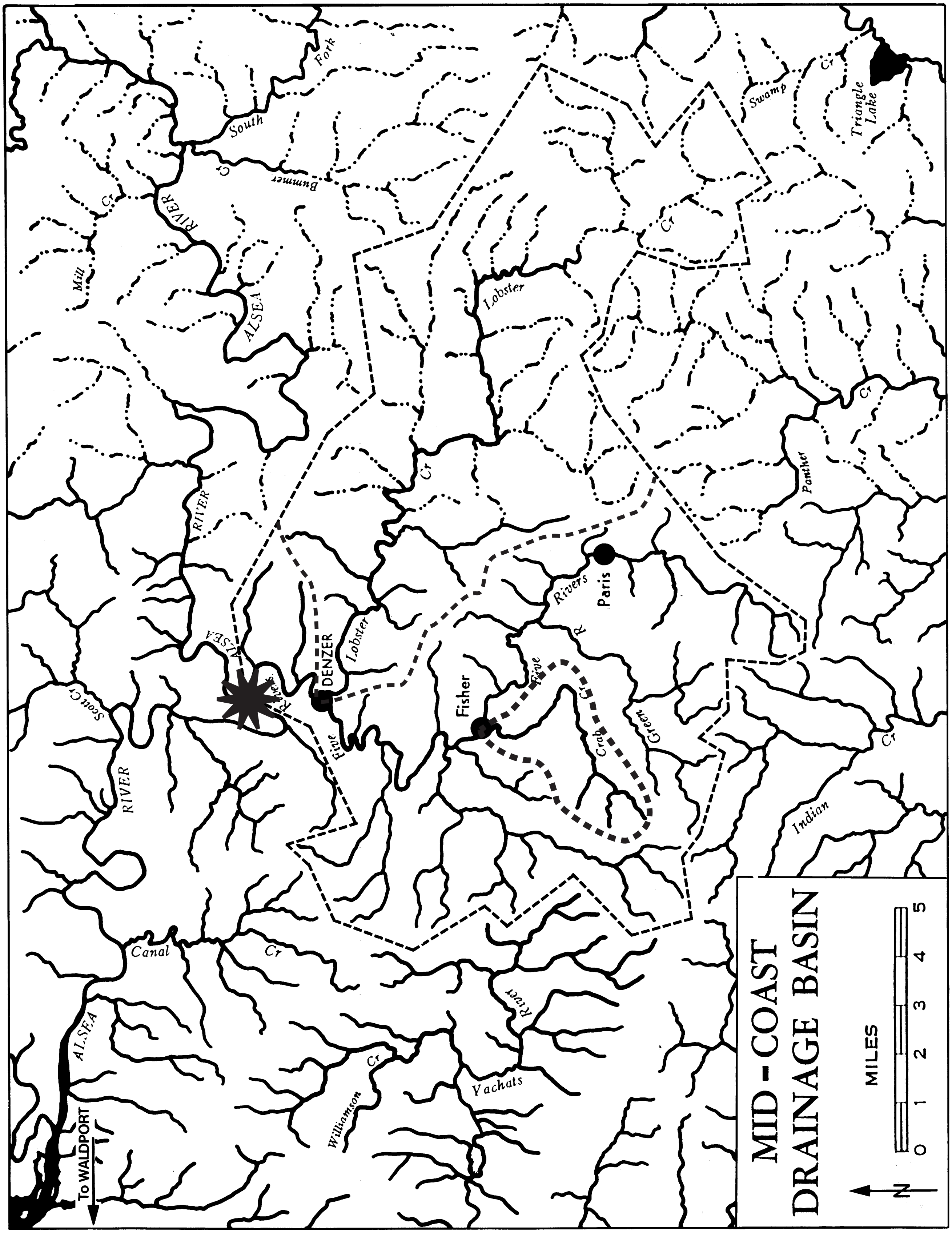
7. Using an Oregon state map or local map that shows streams and rivers, name the watershed in which you live. This watershed is your "ecological address." It describes how you are connected to the land and water system that drains it. Share your ecological address while other students follow along on their own map.

8. On the second piece of paper make a "map" of your ecological address. Refer to the Five Rivers or Umatilla drainage basin maps as examples. Label the communities and other important features in your watershed. Share your watershed map with the rest of the class.

9. Brainstorm a list of what you think can happen to water as it moves through a watershed. Use a check to mark the ones caused by human activities. If some items on your list include substances that can get into the water in your watershed, use a marker to trace the path these substances would follow on your watershed map until it empties into larger watershed areas. Repeat this process with another color to mark the effects of non-human influences on watersheds, such as heavy rains, wind, and other natural events. Compare the two lines. Which of the two, human-caused or non-human would have the greatest effect on your watershed? Record your answer has Question 11 on the student worksheet.

10. How many miles of stream and river are in your watershed? Use the "scale of miles" on the published map to determine how many miles are represented by a certain length, usually one or two inches. Use a string to measure that length, then apply the string, following the curves on your map, to measure the distance. Multiply the number of "string lengths" times the map scale to obtain the number of stream miles. Record the number of miles for this step under Question 12 on the worksheet. How many miles of stream were affected by the human-caused events in Step 9? How many miles of stream were affected by non-human events in Step 9? Record your answers on the student worksheet and answer the remaining question.


Columbia River Drainage Basin (a)
Scale 1:4,500,000
Drainage basin boundary
Cascade divide
Western region
Eastern region
Dam
Study area boundary
Elevations in feet
Map compiled from North Pacific U.S. Army Corps of Engineers "Water and Land Resources Map — Columbia River and Tributaries Review Study", NP-12-1, August 1979. Additional compilation from U.S.G.S. 1:2,500,000 map of the United States and Canada Department of Mines and Technical Surveys 1:2,000,000 map of British Columbia.
BRITISH COLUMBIA
ALBERTA
WASHINGTON
MONTANA
IDAHO
OREGON
WYOMING
CALIFORNIA
NEVADA
UTAH
PACIFIC OCEAN
CANADA
UNITED STATES
Continental Divide
Edmonton
Calgary
Vancouver
Victoria
Seattle
Tacoma
Spokane
Portland
Helena
Boise
Salt Lake City
Mt. Robson 12973
Mt. Columbia 12293
Mt. Waddington 13176
Mt. Olympus 7965
Mt. Rainier 14410
Mt. St. Helens 8366
Mt. Adams 12306
Mt. Hood 11235
Mt. Cleveland 10466
Borah Peak 12662
Grand Teton 13770
Mt. Shasta 14163
McNaughton Lake
Shuswap Lake
Okanagan Lake
Kootenay Lake
Lake Chelan
Pend Oreille Lake
Flathead Lake
Crater Lake
Goose Lake
Yellowstone Lake
Bear Lake
Great Salt Lake
Columbia River
Fraser River
Snake River
Clark Fork
Kootenay River
Yakima River
Willamette River
Deschutes River
John Day River
Salmon River
Clearwater River
Missouri River
Yellowstone River
Humboldt River
Rogue River
Klamath River
Strait of Georgia
Strait of Juan de Fuca


MID-COAST
DRAINAGE BASIN
MILES
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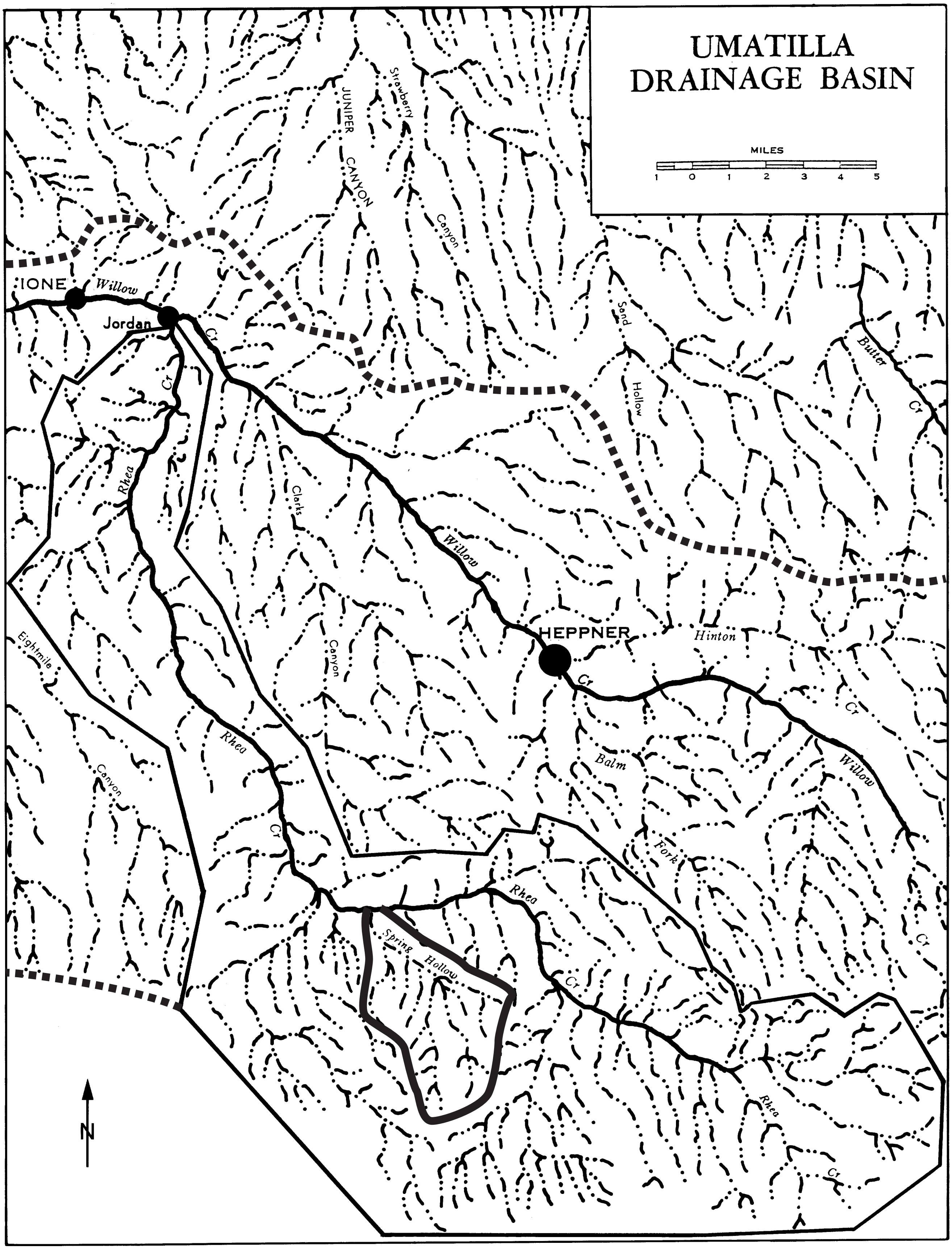
N
To WALDPORT
DENZER
Paris
Fisher
ALSEA
RIVER
South Fork
Lobster
Five Rivers
Crab Cr
Green
Panther
Indian
Swamp
Triangle Lake
Canal
Yachats
Williamson
Scott Cr
Mill
Cr


UMATILLA
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1 0 1 2 3 4 5
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Strawberry
Canyon
Sand
Hollow
Butter
Cr
Rhea
Cr
Clarks
Willow
HEPPNER
Hinton
Cr
Eightmile
Canyon
Canyon
Rhea
Balm
Fork
Willow
Cr
Cr
Rhea
Spring
Hollow
Cr
Rhea
Cr
N

Questions

1. Describe a watershed in your own words.
   Answers will vary, but should approximate all the land area that drains into a particular body of water.
2. If you lived two miles south of the town of Fisher, in which watershed (or sheds) would you live?
   You would actually live in the Crab Creek watershed which is part of the larger Five Rivers watershed. Remind students that a large watershed is made up of many smaller watersheds, and that both Crab Creek or Five Rivers would be correct answers to the question.
3. If you lived in Paris, in which watershed would you live?
   Five Rivers
4. Using the mid-coast drainage basin map as a guide, explain in your own words why the following statement is true. "Everyone lives in a watershed."
   All land has waterways running through it that drain into larger waterways. This is also true in urban areas where rainwater feeds into storm drains. The drains then feed into nearby streams or rivers.
5. The watersheds on these two maps are similar in size. Compare the two watersheds. What other similarities and differences did you note when outlining the watershed boundaries?
   Each watershed is composed of several smaller watersheds. The Willow Creek watershed has more sub-basins than Five Rivers. The shape of the watersheds depends on the drainage patterns of the streams. It is much harder to outline the watersheds with intermittent streams than it is to outline streams that have year-round water.
6. In which watershed (or sheds) is the community of Jordan found?
   Jordan is located at the mouth of the Rhea Creek watershed which is part of the Willow Creek watershed.
7. If a stream does not have a name on the map does that mean it is not a watershed? Explain your answer.
   No, stream names are only a convenient way to designate different sub-basins within a watershed. Any land areas through which water drains to a larger body of water is a watershed.
8. An **intermittent stream** is a stream that does not flow year-round. These streams are shown on maps as lines separated by dots. List as many reasons as you can why streams do not flow year-round.
   Lack of rainfall, lack of snowmelt, removal of vegetation that holds back moisture (reducing rapid runoff), the topography (flat or steep), the soil type, etc.
9. How would fish be affected by intermittent flow?
   Fish would be forced downstream to where the stream was flowing or would be stranded in small pools where they would eventually die as the stream dried up.
10. How would wildlife living near the stream be affected by intermittent flow?
    Food, cover and drinking water would be absent from the area, forcing wildlife to go elsewhere.

11. Based on the colored lines on your own watershed map, which of the two, human-caused or non-human influences, would have the greatest effect on your watershed? Why?

    Human-caused effects would have the most influence because they are normally carried further throughout the watershed than natural events. Natural events are usually more localized.

12. How many miles of streams and rivers are found on your watershed map? How many miles of stream were affected by the human-caused events in Step 9? How many miles of stream were affected by non-human events in Step 9?

    Answers will vary.

13. What have you learned about your watershed, an ecological address, and a sense of place in this activity?

    Answers will vary.

Going Further

1. Using a topographic map as a reference, build a model of your local drainage basin. (See "What a Relief" activity in this unit.) Design a way to use this or other models of your local watershed to show someone the key features (rock types, soils, rainfall amounts, slope, and other characteristics) of your watershed.
2. Design an experiment to monitor the daily weather patterns in your watershed for several weeks or even months. Develop graphs, displays, and a presentation to share the results of your investigation.
3. Add five structures or features (dams, irrigation canals, industry, vegetation, etc.—it is even better if these are real) that would affect the flow of water on your watershed map. Develop hypotheses about how each of these structures will affect your watershed. How could you test your hypotheses?
4. Build a list of who and what uses your watershed—from people to fish to wildlife. Research the effects each has on the watershed.

Timing is everything

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

Objectives

Students will (1) graph the rainfall during a storm, (2) graph streamflow during the same period, and (3) analyze and describe the response of a watershed to a rainstorm.

Method

Students will graph rainfall and streamflow data for a storm on the Crooked River near Prineville. This storm was part of the historic flooding in Oregon in late December 1964. Students will then draw conclusions about the response of a watershed and its stream to rainstorms.

For younger students

1. Consult extension activities at the end of each chapter to address the needs of younger students.
2. Read activity background information aloud to younger students or modify for your students' reading level.
3. Provide students with background vocabulary before assigning questions. Younger students may need graphing practice prior to this activity. Rephrase some questions or answer as part of a group discussion.
4. This activity can also be done as a group.

Vocabulary

infiltration rates
percolate
streamflow hydrograph
subsurface flow
surface runoff

Materials

- copies of student sheets (pp. 127-130)

Notes to the teacher

The activity "Hold That Raindrop" (pp. 117-120) is a good introduction to this activity.

Background

Do you know . . .

The capture, storage and safe release of rainfall on a watershed affects the volume and timing of streamflow. Rainfall captured by the watershed first soaks into the soil's surface. Some of the rain is stored in the soil but once the soil can hold no more, the captured water begins to **percolate** down through the soil toward the stream. When **infiltration rates** cannot keep up with rainfall rates, water begins to flow over the top of the soil. This is called **surface runoff**, or **overland flow**. Surface runoff is rainfall that does not infiltrate into the soil, but flows over the surface until it reaches the stream.

It can take a long time for water to move through the soil from the top of a watershed to the stream at its base. This increases the period of time any one storm contributes water to the stream. The water that percolates through the soil to the stream is called **subsurface flow**. Subsurface flow is much slower than overland flow.

The amount of water in a stream is a combination of rainfall, runoff, and subsurface flow. During a storm, surface runoff increases the amount of water carried by the stream. After the surface runoff stops, the entire flow of the stream comes from ground water storage. In most streams the majority of the water comes from subsurface flow. Because subsurface flow takes longer than overland flow, storms often have a delayed effect on streamflow.

Procedure

Now it's your turn . . .

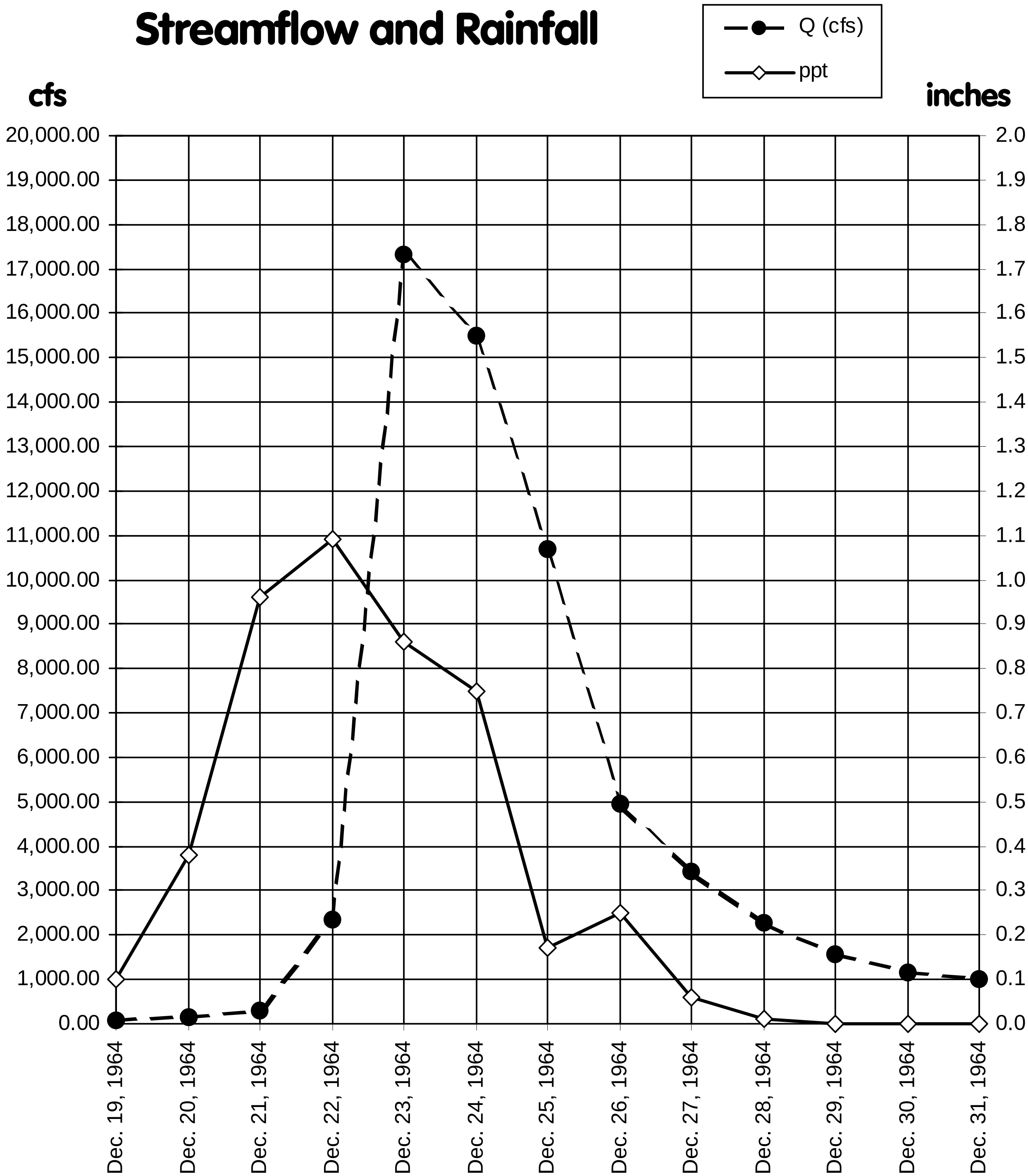
The information in the table shows daily rainfall amounts and streamflow for a rainstorm. This particular storm was in late December 1964 and was a part of historic flooding that happened in Oregon at that time. The precipitation data was measured at Prineville in central Oregon. The streamflow was measured on the Crooked River above Prineville, near Post, Oregon.

On the graph provided, create a line graph by plotting the daily streamflow of the Crooked River near Post, Oregon. This graph is called a **streamflow hydrograph**. Repeat the process for the rainfall data measured at Prineville.

Use a different color for each line. Be sure to mark a legend with the color representing each line. Plot rainfall against streamflow on the following graph.

	Q (cfs)	ppt (in)
Dec. 19, 1964	70	0.10
Dec. 20, 1964	135	0.38
Dec. 21, 1964	313	0.96
Dec. 22, 1964	2,330	1.09
Dec. 23, 1964	17,300	0.86
Dec. 24, 1964	15,500	0.75
Dec. 25, 1964	10,700	0.17
Dec. 26, 1964	4,960	0.25
Dec. 27, 1964	3,420	0.06
Dec. 28, 1964	2,260	0.01
Dec. 29, 1964	1,550	T
Dec. 30, 1964	1,150	T
Dec. 31, 1964	997	T

Q=streamflow, ppt=precipitation (rainfall), T=trace (an unmeasurable amount)


Streamflow and Rainfall
Q (cfs)
ppt
cfs
inches
20,000.00
19,000.00
18,000.00
17,000.00
16,000.00
15,000.00
14,000.00
13,000.00
12,000.00
11,000.00
10,000.00
9,000.00
8,000.00
7,000.00
6,000.00
5,000.00
4,000.00
3,000.00
2,000.00
1,000.00
0.00
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Dec. 19, 1964
Dec. 20, 1964
Dec. 21, 1964
Dec. 22, 1964
Dec. 23, 1964
Dec. 24, 1964
Dec. 25, 1964
Dec. 26, 1964
Dec. 27, 1964
Dec. 28, 1964
Dec. 29, 1964
Dec. 30, 1964
Dec. 31, 1964

Questions

1. Which reached its peak first, rainfall or streamflow? How many days are between the rainfall peak and the streamflow peak?
   Rainfall. One day.
2. Why was there a difference between the rainfall peak and the streamflow peak?
   Whether water moves as surface flow or subsurface flow it takes time for water to move from the uplands to the stream.
3. What other factors might increase or decrease the difference in timing between the rainfall peak and the streamflow peak?

   The ability of the soil to absorb water, which is influenced by the type of soil and its condition (including how saturated with water the soil already is), the amount of vegetative cover on the uplands, subsurface layers of rock or clay, and other factors.
4. Water can move to the stream as surface runoff or subsurface flow. Which do you think contributed more to the peak streamflow? Why?
   Surface runoff. It moves more rapidly than subsurface flow.
5. Use the concepts of "capture, store, and safe release" to explain where the water was located between the time it fell to the ground as rain and when it reached to stream?
   Rain on the uplands was "captured" when it infiltrated into the soil. It was then stored there for several days while it percolated downhill to the stream. When it reached the stream it was released.
6. Compare the stream flow for the first day graphed and the last day graphed. Describe the difference between the streamflow on these two dates.
   Even though the rainfall had stopped, the streamflow remained higher than at the beginning.
7. Why did the streamflow remain higher, even though the rainfall had stopped? What type of flow is still bringing water to the stream?
   Subsurface flow takes time to reach the stream. Even after the storm it continues to bring water to the stream. This is called baseflow.
8. The storm in this example caused flooding. Very large rainstorms may deliver rain much faster than the watershed can safely process it. What can be done to help increase a watershed's ability to process rainstorms? List as many ways as you can.
   Answers will vary, but may include both biophysical solutions such as increasing plant cover and engineering solutions such as building flood control dams.

Going further

1. Design an activity to compare the areas on your school ground that do not allow water infiltration (parking lots, buildings, etc.) with areas where water does infiltrate. Prepare a report about your findings and share with the class. (See "Where Does Water Go After School," *Aquatic Project WILD*, pp. 82-85.)
2. See "Water Works," *Project Wet*, pp. 274-278.

Name

Timing is everything

Do you know . . .

The capture, storage and safe release of rainfall on a watershed affects the volume and timing of streamflow. Rainfall captured by the watershed first soaks into the soil's surface. Some of the rain is stored in the soil but once the soil can hold no more, the captured water begins to **percolate** down through the soil toward the stream. When **infiltration rates** cannot keep up with rainfall rates, water begins to flow over the top of the soil. This is called **surface runoff**, or **overland flow**. Surface runoff is rainfall that does not infiltrate into the soil, but flows over the surface until it reaches the stream.

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The amount of water in a stream is a combination of rainfall, runoff, and subsurface flow. During a storm, surface runoff increases the amount of water carried by the stream. After the surface runoff stops, the entire flow of the stream comes from ground water storage. In most streams the majority of the water comes from subsurface flow. Because subsurface flow takes longer than overland flow, storms often have a delayed effect on streamflow.

Vocabulary

infiltration rates
percolate
streamflow hydrograph
subsurface flow
surface runoff

Now it's your turn . . .

The information in the following table shows daily rainfall amounts and streamflow for a rainstorm. This particular storm was in late December 1964 and was a part of historic flooding that happened in Oregon at that time. The precipitation data was measured at Prineville in central Oregon. The streamflow was measured on the Crooked River above Prineville, near Post, Oregon.

On the graph provided, create a line graph by plotting the daily streamflow of the Crooked River near Post, Oregon. This graph is called a **streamflow hydrograph**. Repeat the process for the rainfall data measured at Prineville.

Use a different color for each line. Be sure to mark a legend with the color representing each line. Plot rainfall against streamflow on the following graph.

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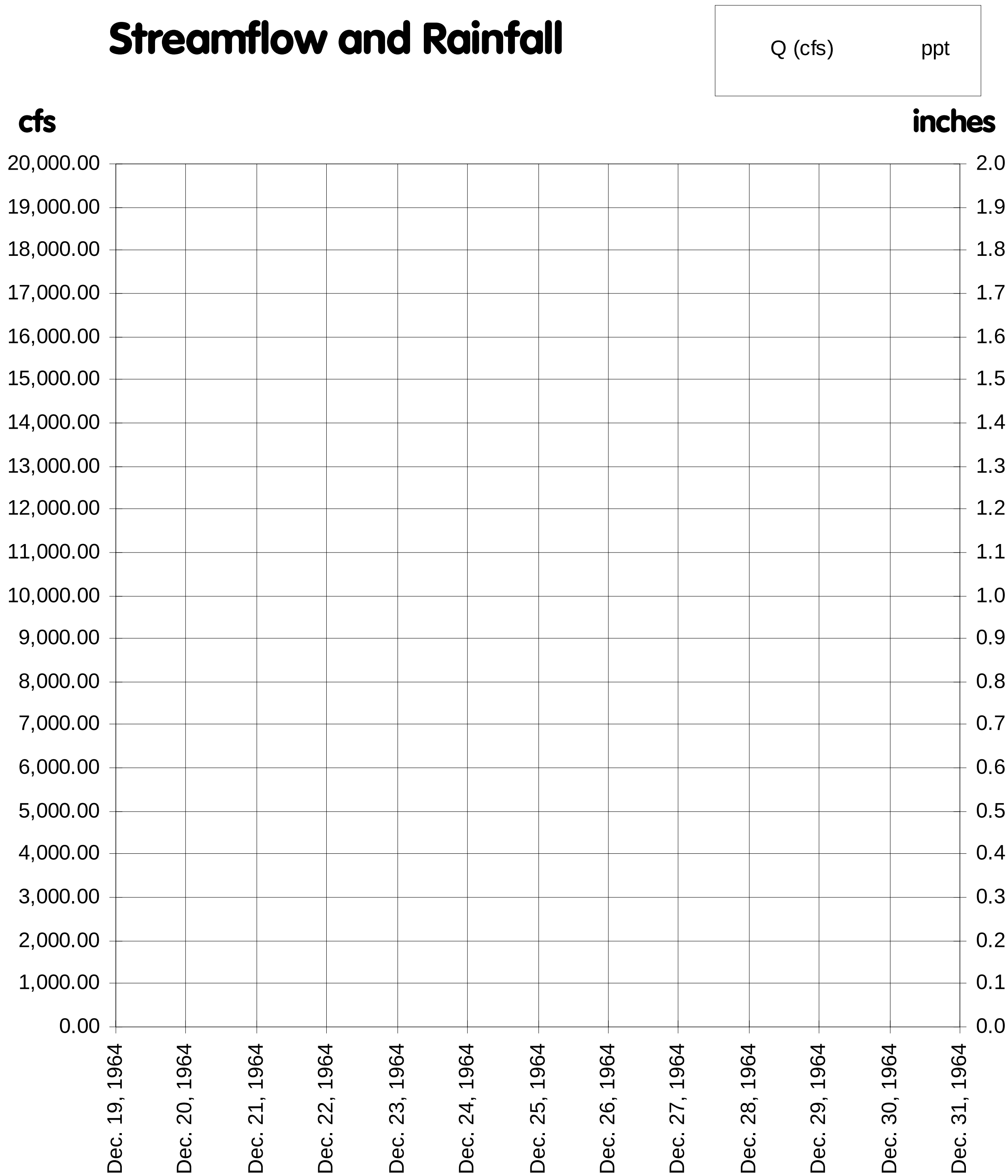
Q=streamflow, ppt=precipitation (rainfall), T=trace (an unmeasurable amount)

Streamflow and Rainfall



Questions

1. Which reached its peak peak first, rainfall or streamflow? How many days are between the rainfall peak and the streamflow peak?

2. Why was there a difference between the rainfall peak and the streamflow peak?

3. What other factors might increase or decrease the difference in timing between the rainfall peak and the streamflow peak?

4. Water can move to the stream as surface runoff or subsurface flow. Which do you think contributed more to the peak streamflow? Why?

5. Use the concepts of "capture, store, and safe release" to explain where the water was located between the time it fell to the ground as rain and when it reached to stream?

6. Compare the stream flow for the first day graphed and the last day graphed. Describe the difference between the streamflow on these two dates.

7. Why did the streamflow remain higher, even though the rainfall had stopped? What type of flow is still bringing water to the stream?

8. The storm in this example caused flooding. Very large rainstorms may deliver rain much faster than the watershed can safely process it. What can be done to help increase a watershed's ability to process rainstorms? List as many ways as you can.

Winter watersheds

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

Objectives

The student will (1) collect snow samples, (2) determine the snow water content of the snow samples, (3) test the pH values of the snow samples, (4) calculate the snow water content of a model watershed, and (5) answer questions about snow water content.

Method

Students collect snow samples, calculate the snow water content of each sample, test the pH of each sample and apply that information to a model watershed.

For younger students

1. Consult extension activities at the end of each chapter to address the needs of younger students.
2. Read activity background information aloud to younger students or modify for your students' reading level.
3. Younger students can practice their addition and subtraction by figuring daily, weekly, or monthly precipitation totals obtained from local SNOTEL sites. Check the Internet for this data at http://crystal.or.nrcs.usda.gov/snowsurveys/.
4. Construct a large vertical scale on a bulletin board or against a wall for both precipitation and snow water equivalent (both in inches). Place the "0" mark at floor level so it is clear that it means zero accumulation. Make sure the two scales are side by side for easy comparisons. Using the Internet as a source of data from a SNOTEL site near your area, ask students to mark the total accumulations for each (precipitation and snow water equivalent) on a daily or weekly basis during the standard seasonal snowfall period—October 1 through April 1. Use a colorful, moveable pointer to mark the locations on the scale and post the date for the reading in a prominent location. Students may want to compare two SNOTEL sites in this manner or compare their school site with a SNOTEL site. As the snowmelt season begins and progresses, students can see the snow water decrease while the accumulated precipitation may remain the same or increase. Large decreases in snow water are usually related to warm weather and/or rainfall.
5. Use the discussion about SNOTEL sites and how professionals get information from snow courses as a lead-in to the topic of winter safety. What to do if you are lost, frost bite, and hypothermia are all appropriate topics. Ask the school nurse to assist with this safety presentation.

Parts of this activity are adapted from *Snow Chemistry and Air Pollution*, Burris, Frank, Rena McFarlane and Peter Stortz, Alaska Cooperative Extension, Fairbanks, Alaska, 1996, and used with permission. Additional information obtained and adapted from *Snow Surveys and Water Supply Forecasting*, U.S. Department of Agriculture, Soil Conservation Service, Agriculture Information Bulletin 536, June 1988.

Vocabulary

- acid rain
- acid shock
- fry
- organic matter
- pH
- snow courses
- snow water content
- sublimation
- telemetry

6. To help younger students understand the concept of acid rain, use the first exercise in the "Deadly Skies" activity from *Aquatic Project WILD*, pp. 142-145.

7. Once students understand the concept of acidity and alkalinity, use pH test paper to sample a number of familiar liquid products (coke, orange juice, milk, etc.). Move the discussion to include water bodies and how pollutants falling into a water body can influence its acidity. Conclude the discussion with a collection of snow samples that they can sample for the presence of pollutants, using pH values as indicators of impurities.

Materials

- snow tube (a polypropylene 1,000 milliliter graduated cylinder, with a one-quarter-inch hole drilled into the tube near its connection with the base); one per team
- 1,000 milliliter graduated cylinder *without* a hole drilled near its base; one per team
- 3 one-gallon ziptop plastic bags for each sample team; if a team is collecting at more than one sample site, a different set of three bags is needed for each location
- permanent marking pen
- flat, stiff piece of plastic, or a tile, to slide across the opening of the snow tube to keep snow from falling out when it is moved
- data sheets
- clipboard or hard writing surface
- pencil
- pack (or cooler) for carrying supplies to the sample sites; it must be large enough to accommodate the snow samples on the return trip to the classroom
- small shovel
- thermometer
- large measuring stick (yardstick or meter stick)
- wide range pH test paper, pH test kit, or water quality test kit

Notes to the teacher

The snow sampling procedures outlined in this activity are highly simplified but sufficient to develop the concepts. For example, the part of the activity on snow water content portrays a simple ratio. A certain level of snow yields a certain amount of water. For example, a volume of 500 milliliters of unmelted snow yields 50 milliliters of water. This ratio—10 ml of snow to 1 ml of water—produces a conversion factor (0.1) that can be applied to a larger amount of snow and generalized to an entire watershed. Other factors, like density differences and other variables, obviously come into play, but the basic translation will help students understand the concept that snowmelt contributes to streamflow.

Drilling the hole in the plastic graduated cylinder allows air to escape when the snow tube is pushed into the snow. If you live in an area where snow fall is only an occasional event and snow depths are rarely more than a few inches, a much smaller polypropylene graduated cylinder works just as well.

Students can also use data posted on SNOTEL sites on the Internet to compare snowpacks and potential water supplies for various basins throughout Oregon and the western states. The Natural Resources Conservation Service (NRCS) also has an Adopt-A-SNOTEL-Site program that may be suitable for your students. For more information contact your local or statewide office of the NRCS.

Pollutants can contribute to acidity in water, and they are easily detected in snow samples with simple pH testing equipment (litmus paper, wide range paper test strips, or a water quality test kit) or pH meters, which work well but are very expensive. Students will explore pH in depth in Chapter 8, "Water Quality."

You can approach the topic of acid snow simply as information related to watersheds, current events related to weather, or environmental news that could affect your local area (nonpoint pollution fallout from contaminated air). This method does not involve field work or equipment.

Background: Part 1

Do you know . . .

Millions of Americans enjoy snow-covered landscapes for their beauty or as a winter playground. But snow also plays a vital role. It is a primary source of the water supply in the western United States.

The West's high mountain ranges hold a vast snowpack that provides 50% to 80% of the water supply for the year. But, melting snow does not provide an uninterrupted, dependable source of water for all the downstream needs. Reservoirs and other water storage facilities help store water for the growing needs of agriculture, industry, and communities. Successful water management begins with knowledge of the primary source of water in the West—snow.

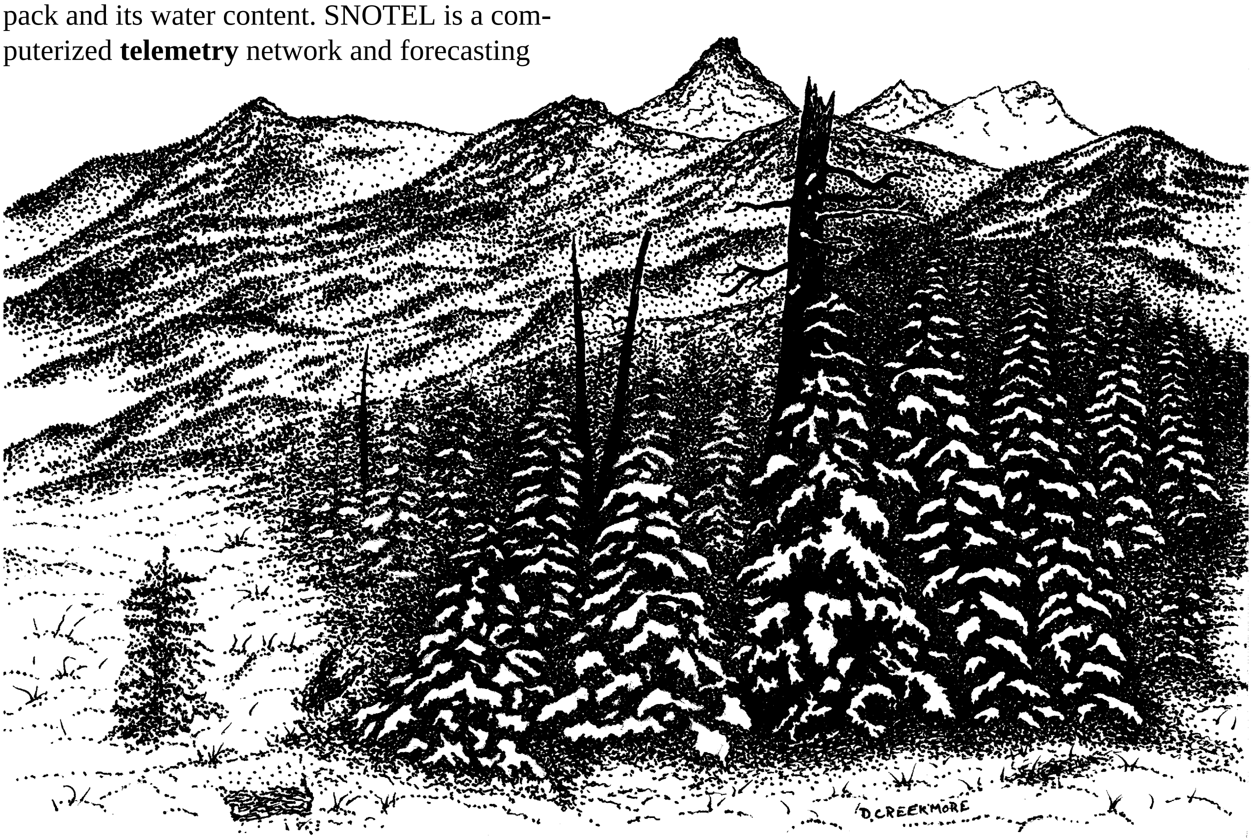
Specially trained people from federal, state, and private cooperative snow survey programs work with the Natural Resources Conservation Service (NRCS). They create accurate and timely information on the amount of mountain snowpack and its water content. SNOTEL is a computerized **telemetry** network and forecasting system for collecting data on snowpack. It can provide daily, or more frequent, information about streamflow potentials. The information is especially valuable during periods of flood or drought.

The relationship between snowpack and the amount of snowmelt runoff is complex. It depends on many factors, primarily:

- moisture content of soil,
- ground water contributions,
- precipitation patterns,
- changes in air temperature,
- use of water by plants, and
- the frequency of storms.

These factors change from year to year and vary from one location to another.

How wet the soil is in early winter—before the snowpack develops—affects the runoff in the following spring. Dry soils soak up more water than wet soils. The soil—for example, sand or clay—as well as the precipitation determines how much moisture can be absorbed. Wind, air temperature, storm frequency, and the amount of moisture in the atmosphere determine the accu-



mulation of the snowpack. As the snow depth increases, its density increases as the lower layers are compressed. Density affects how fast the snowpack melts and how much water it yields.

Air temperature and atmospheric moisture determine how "wet" or "dry" the snow is. Typically, the west slope of the Cascade Range, in response to the Pacific Ocean's strong influence, receives heavy, wet snow. One foot of that newly fallen snow can produce up to 1.5 inches of water. But one foot of snow in the mountains of central Utah is much drier. It is light and powdery—excellent for skiing—but may only contain an inch of water.

Mountain snowpacks do not melt steadily. Melting varies with weather, ground temperature, and exposure to the sun. Snow begins to melt when its temperature from top to bottom is equal at 32°F. Before reaching the isothermal state, the snowpack is different temperatures at different depths. Ground temperature, air temperature, and the sun affect how quickly it becomes isothermal. South-facing slopes and open areas receive the most solar radiation and have the fastest melt rates.

Procedure

Now it's your turn . . .

Most of the usable water in western North America begins as mountain snowfall. Many years ago local communities recognized that monitoring snowfall was important for predicting water supply. So a system of snow surveys was organized. A snow survey is an inventory of the total snow covering of a specific watershed and the resulting effects on local water supplies. This information is used to predict floods, regulate reservoir storage, determine hydropower potential at dams, forecast community water supplies, assess agricultural productivity, and other applications. The Natural Resources Conservation Service (NRCS) coordinates these cooperative surveys.

Information about snow surveys throughout the West is available on the Internet at http://crystal.or.nrcs.usda.gov/snowsurveys/. Information from remote automated snow telemetry (SNOTEL) sites is updated regularly at this website. Another good website for snow survey information and maps is http://www.wrcc.dri.edu/snotel.html.

Conventional snow surveys are made at designated sites known as **snow courses**. In Oregon there are 110 SNOTEL sites plus many more snow courses where snowpack information is collected.

In this activity you will collect snow samples, calculate the **snow water content** of each sample and apply that information to a model watershed. If you have time, save your snow samples and continue with Part 2 of this activity. In Part 2 you will research possible sources of air pollutants in your community or part of the state. And you will test your snow samples to see if the snowpack in your area is affected by airborne pollutants.

Collecting a snow sample

Choose an undisturbed area free of animal (or human) tracks, twigs, fallen branches, leaves, cones, animal droppings, fur, feathers, or extra snow from overhead branches. Try to avoid areas of drifted snow or where the wind continually moves the snow.

1. Select a coding system for the snow samples before marking the ziptop bags. A good system includes the sample date, the sample number, the site number, and a description of the site (see example). Mark the code on the outside of each bag *before* going into the field.

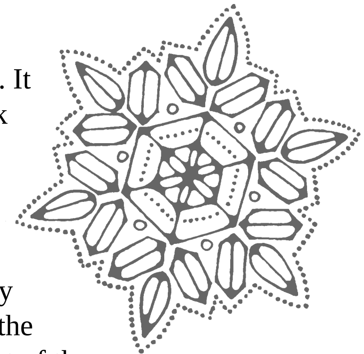
2. Make sure all equipment is gathered and ready before leaving for the field. Design a checklist to make this an easy process each time you collect snow samples. As you work, be sure not to touch the snow samples with your hands.

3. If snow is crusted over and more than a foot deep, use a shovel to dig a small pit (about 24 inches square) down to the ground surface next to where you want to sample snow. The pit makes it easier to remove the snow tube. Disturb no more snow than necessary so you can use this site again if you plan to take more samples throughout the snowpack season.

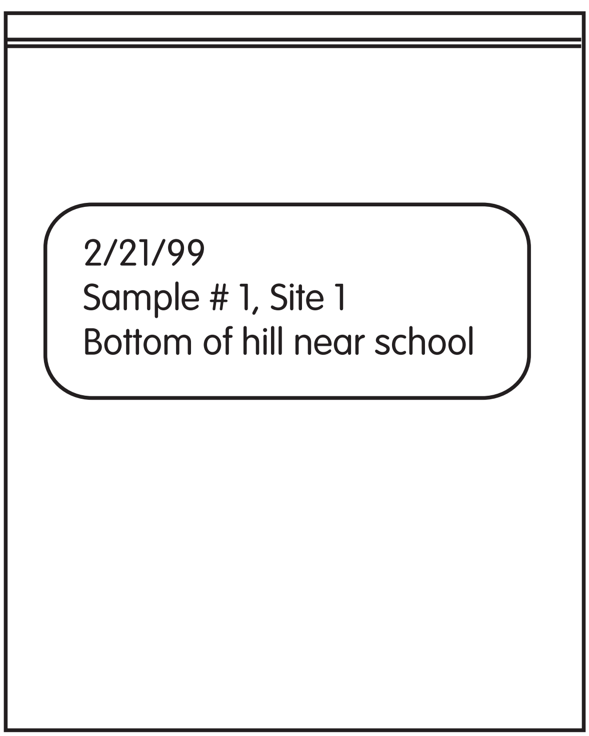
4. Pick a spot that looks representative of the sample area. Using a ruler or meter stick read the depth of the snow to the nearest half inch (or centimeter). You can make several measurements to find a representative depth, but record only one snow depth measurement per sample site on the data sheet.

5. Using the following procedure, collect at least three samples to get an average of the snowpack conditions at each individual sample site.

6. Shove the snow tube, open end down, vertically through the snow just beyond the edge of the pit. Do not push the snow tube into the soil or vegetation layer. It is important not to pack the snow in the tube. If the snow is deeper than the snow tube is long, stop before the snow tube is completely full. Carefully remove the tube and empty that part of the sample into your sample bag. Return the empty tube to where you stopped the sample and collect the rest of the column of snow.



Labeled Ziptop Bag



7. Move snow away from the wall of the cylinder on the pit side. From the side, carefully insert a flat, stiff object (tile, rigid plastic, or small flat aluminum shovel) under the bottom of the snow tube to prevent snow from falling out when the tube is moved. Make sure the cap is not too close to the ground where it could pick up soil and plant debris that could contaminate the sample. If any samples come in contact with **organic matter**, discard the sample and take another near the original sample location. This part of the process is important if you plan to continue with Part 2.

8. Holding the cap in place, tilt the snow tube and its cap into the pit. Be careful not to spill any of the snow core. Invert the snow tube so the snow core slides to the bottom. Using the scale on the graduated cylinder snow tube, note the height of the snow core and record that amount on the data sheet (p. 136). Repeat the process for the other two samples. Add the three amounts and divide by the number of samples taken (3). Record the average height of the snow core in the appropriate column on the data sheet.

   If the snow is hard or crusty or deeper than the length of your snow tube, remove the snow core in the same way, but in stages. Add the stage amounts to get the total height of the snow core.

9. Be careful not to spill snow from the tube and do not touch the snow with your hands. Empty the snow into the pre-labeled ziptop

plastic bags. Make sure the sample goes into the correctly labeled bag. Press as much air out of the bag as possible and close the bag tightly. Do not allow the snow to melt. Prolonged contact with the air can mix carbon dioxide with the snow water, forming a solution of carbonic acid. This acid will lower the **pH** levels of your snow sample, if you are planning to complete Part 2 of the activity. Impurities on your hands can also affect the pH of the snow sample.

10. Record air temperature, the temperature at the snow surface, and time taken on the data sheet. Return indoors to melt the snow core.

Handling snow samples in the classroom

Note: If you are going to do the pH activity in Part 2 it is very important to keep the snow samples frozen until ready to proceed with the melting process. Do not thaw samples overnight. Warming can stimulate biological organisms in the sample to become more active. Their respiration can add carbon dioxide to the sample and potentially change the acidity.

Agitate the samples as little as possible after thawing because this stirring process increases the contact with carbon dioxide in the atmosphere. (You can do this deliberately to determine the effect. First, take a pH reading following the exact directions in Part 2 below. Then expose the sample to air for an hour or more. Unless the snow is very acidic, the second reading should show a lower pH, or more acidic value.) To avoid contamination of the sample, reduce the handling time and do not touch the melted sample with your hands.

1. Transfer a snow sample from the ziptop bag to the 1,000 milliliter graduated cylinder (one without a hole near its base). Let snow samples melt at room temperature. This can take a while. Monitor the progress so water depth can be recorded soon after the disappearance of all ice.

Snow Survey Data Sheet

Sample site # ________

Date:	Watershed:	Team members:
Time:	Air temp:	
	Surface temp:	Nearest community:
Notes: (description of sample site, weather conditions, other observations)		

Sample No.	Average snow depth at site	Snow level in tube	Average snow tube level	Snow water content	Average snow water content	pH of snow water	Remarks
1							
2							
3							

2. Read the water level in the graduated cylinder as soon as possible after thawing. Record the amount to the nearest milliliter. Repeat for the other two samples. Add the three amounts and divide by the number of samples taken (3). Record the snowpack water content amount in the appropriate average column on the data sheet.
3. Calculate the snow water content conversion factor. To do this, first calculate a total volume for all three snow samples and the total volume of water they produced. Then simply divide the volume of water by the volume of snow. For example, if 500 milliliters of unmelted snow produced 50 milliliters of water, then divide 50 by 500. The answer, in this case 0.1, is the snow water content conversion factor for the area and time you sampled. Now you can convert any snow depth for that area to a water depth by multiplying the snow depth by the conversion factor.

Conversion factor: ____________

4. To give your data a watershed perspective, complete the worksheet below. Show your work as you complete the calculations.

Note to the teacher: If you cannot collect your own snow samples, use information from the two Internet sites to develop a data sheet and worksheet for student calculations. Use the process to orient students to the kind of information available, how it is obtained, and how it is applied.

Student Worksheet

	Example
(a) Determine the area of a football field if it is 120 feet long and 60 feet wide. Area of a rectangle (ft^2) = length × width.	**7,200 ft^2**
(b) If using metric measurements for average snow depth, convert from centimeters to inches by multiplying the number of centimeters by 0.4. If measurements are in inches, conversion is not necessary.	**For example: If your snow depth at the site measured 75 centimeters, it converts to 30 inches.**
(c) Convert snow depth from inches to feet by dividing by 12.	**For example: 30 inches converts to 2.5 feet.**
(d) Find the total volume of snow (in cubic feet) on the football field by multiplying the answer from (a) by the answer from (c).	**$7,200\ ft^2 \times 2.5\ ft = 18,000\ ft^3$**
(e) If the entire football field "watershed" has the same snowpack depth (# from average snow depth column on your data sheet), what would be the total snow water content of the snowpack on the football field "watershed?" (Multiply the volume from (d) by the snow water content conversion factor).	**For example: if your snow water content conversion factor was 0.15, the answer would be:** **$18,000\ ft^3 \times 0.15 = 2,700\ ft^3$**
(f) How many gallons is this? (To convert cubic feet to gallons, multiply by 7.48).	**$2,700\ ft^3 \times 7.48 = 20,196$ gals**

5. The following chart shows information from snow surveys for eight SNOTEL sites in the Rogue/Umpqua Basin on March 19, 1999. This information is from the Internet at http://www.wrcc.dri.edu/snotel.html. Check out the website for snowpack information in other Oregon watersheds or basins in other western states. Compare the average snow water equivalent and the percent of average data for those states. Consider how this information correlates to long-term weather patterns.

The snow water equivalent percent of average represents the snow water equivalent found at selected SNOTEL sites in or near the basin compared to the average value for those sites on this day. The reference period for average conditions is 1961-90.

The snow water equivalent information collected at SNOTEL sites or along snow courses is much more complicated than the simple procedures outlined in your snow sampling activity. However, the concept is the same in that the snowpack can contain varying amounts of water. Knowledge of that amount of water is valuable information for residents of a watershed.

Proceed to Part 2 if your teacher directs you to do so.

SNOTEL Site	Elevation (feet)	Current snow water equivalent (inches)	Average snow water equivalent (inches)	Percent of average (%)
Bigelow	5,120	36.1	11.7	309
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King Mountain	4,000	15.1	2.3	657
Sevenmile Marsh	6,200	46.1	31.5	146
Basin wide percent of average				**184**

Questions: Part 1

1. From what direction do the prevailing winds come during the major precipitation months in your area? How does this correspond to areas of greatest snow concentrations in your area?
   Answers will vary.
2. Is the snow water content of your samples the same as those obtained by another group? Explain.
   Answers will vary depending on degree of compaction, snow water content at different sites, and accuracy of measurement.
3. Would the snow water content of compacted snow be the same as that of loosely packed snow? Explain.
   Generally, more compacted snow samples would contain a higher snow water content because compacted snow is more dense. Because of sublimation, the amount of snow water content can be less if samples are collected later in the snow. On the other hand, if it continues to snow, more water in the form of snow, continues to accumulate.
4. From the exercise in Step 4 above you can see that even a football field "watershed" covered with snow has the potential to contribute vast amounts of water to a stream system during thawing periods. The snow water equivalent table in Step 5 also provides information about water content. How could you apply the information learned in Steps 4 and 5 to your local watershed?
   Snow surveys provide an inventory of the total snow covering in a specific watershed and the resulting effects on local water supplies. This information is used to predict floods, regulate reservoir storage, determine hydropower potential at dams, forecast community water supplies, assess agricultural productivity, and other applications.
5. Why is it important to have a number of SNOTEL sites at different elevations in a watershed?
   Snow depths usually vary by elevation, as can snow water equivalents. Getting information from a variety of sites at different elevations provides a broad picture of the water potential in the watershed.
6. What does the percent of average figure tell you about the Rogue/Umpqua Basins in 1999 just prior to snowmelt?
   Year 1999 is an exceptionally high water year with snow water equivalents that are 184% of average when using the reference period 1961 through 1990 as a comparison. This could indicate a high potential for flooding during spring runoff.

Background: Part 2

Do you know . . .

… that the quality of water in our streams and lakes can depend on the quality of water in rain and snow? Like rain, snow may be contaminated with airborne pollutants. But unlike **acid rain**, pollutants carried with snow do not enter streams with each storm. Instead pollutants are stored in snow until the snowpack melts. When polluted snow melts, it can release large "pulses" of pollutants into local land and water environments. If the pollutants are acidic, this pulse of concentrated polluted water can create **acid shock**. Acid shock can harm fish, wildlife, and other organisms in the affected areas. Some fish and aquatic insects are killed outright by the rapid and extreme change in acidity. Although some adult fish can survive these pulses, eggs and **fry** cannot. A local fish population's entire annual reproduction can be wiped out. And, the loss of sensitive aquatic insects can disrupt the food chain fish depend on.

Often the effects of acid shock can be relatively brief and localized. As water from melting snow mixes with water already in streams and rivers, it is diluted, making it less harmful.

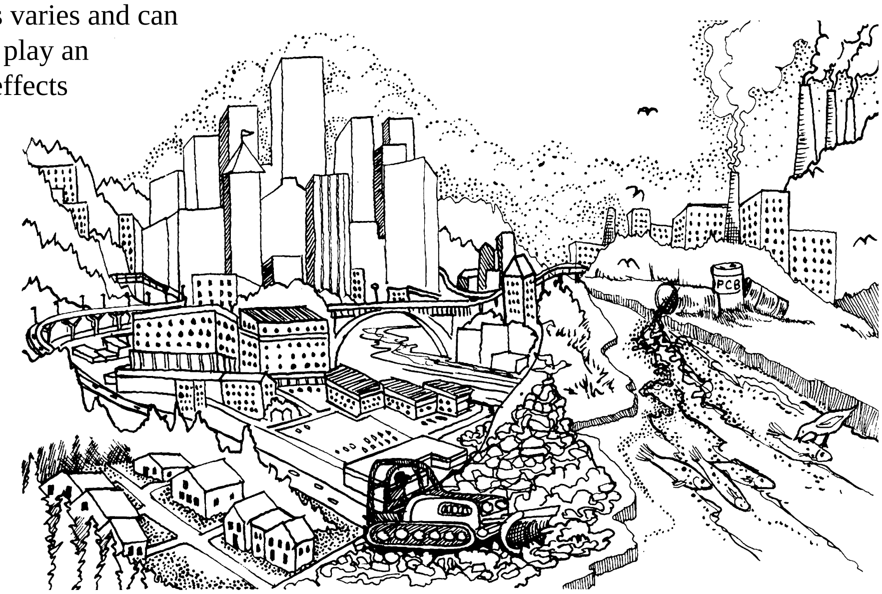
Other things, primarily calcium, in soils or water can buffer acidity by neutralizing the pollutants that reduce the pH of water in streams. The amount of buffering agents varies and can eventually be used up, but they play an important role in reducing the effects of pollutants in streams. Researchers are exploring how this affects the survival of terrestrial plants, aquatic invertebrates, and some fish species.

Where do snow pollutants come from? Pollutants can get into snow in several ways. The heaviest particles simply fall out of the atmosphere and land on the earth's surface or on the surface of the snow. High winds may carry these particles for a short distance, but they are usually deposited close to their source.

Gaseous forms of pollutants, very fine particles, and salt mists can happen in high concentrations in the atmosphere. Most of these pollutants first dissolve into airborne moisture and fall out of the atmosphere as rain or snow. How much and how fast this occurs depends on how often it rains or snows when pollutant concentrations are high.

Pollutants from human sources—hydrocarbons from the combustion of fossil fuels, heavy metals from industrial processes, and dust—are the most common forms of pollutants found in snow. When sulfur or nitrogen compounds from these sources combine with oxygen in the atmosphere, a mild solution of sulfuric or nitric acid forms. When it rains or snows these acids are washed out of the atmosphere and collect in local water bodies or in the snowpack on the ground.

Local pollution sources are often a problem in winter. More fuel is burned to provide heat, putting more pollutants to the air over a community. As a result, snow quality changes from one location to another depending on the size of the community, their source of heat or electricity, how close they are to urban areas or the ocean, prevailing weather patterns, and the frequency of temperature inversions in winter that trap pollutants in the layer of air next to the snow. Local



sources of pollutants include power plants, airports, coal, oil, and wood-burning stoves, and local transportation. Regional sources might include ocean mists, volcanic debris, and dust generated by large scale surface mining.

Contaminated snow can be a serious hazard to both land and water habitats. Some snow evaporates directly into the air through the process of **sublimation**, leaving pollutants behind in even greater concentrations. When temperatures are below freezing for long periods the pollutants in snow may be stored until the spring thaw.

Procedure

Now it's your turn . . .

Does Oregon have a problem with acid rain? Is there the potential for acid shock in Oregon streams fed by melting snow? You can help find out. Snow sampling and testing may help answer this question.

Much of Oregon's annual precipitation, including snow, falls when the chances for polluted air is high in certain areas of the state. Although industries have tight air quality regulations, other sources of pollution may contribute to air quality alerts, especially in basins surrounded by mountains like the Klamath Basin or the upper Rogue River Valley near Medford. Since much of the snowpack in the higher mountains rarely thaws during the winter, pollutants accumulate throughout the snow season, making them easier to detect. Because access to high mountain areas is difficult, however, little testing is completed to determine these pollution levels.

1. Brainstorm possible sources of pollutants in your community or part of the state. Make a list of these sources and describe the kind of airborne pollutant that may result.
2. Consider the role of snowfall in Oregon's watersheds. How do Oregon's mountain ranges affect distribution of precipitation throughout the state? Do specific mountain ranges affect the weather patterns in your area? If so, how?
3. Pollutants are usually more concentrated in samples collected later in the winter. Samples collected in or near a community may show the effects of local pollution. Samples gathered farther from the community may provide information about pollution carried by winds from regional sources.
4. Use the water samples collected during Part 1 of this activity or collect new samples using the same procedures. If possible, avoid waiting more than one hour after the snow has melted to sample for pH. For each sample, dip one strip of wide-range pH test paper into the snow water. Match the resulting color on the test strip with the color scale on the package. Record the pH of each sample on the data sheet. (You can also use a pH test kit for this process.)

Questions: Part 2

1. Compare the pH values of your samples with samples from other groups. Are there any differences? What may have caused the differences?

   Answers will vary depending on snow sample locations and other variables. Samples taken from an area downwind of an industrial area or near a community whose residents primarily use coal or wood-burning for winter heating may detect changes in pH.

2. How do you think the pH levels of your snow samples would compare if you had data from both early winter and late winter? Explain?

   In areas of long-term snow coverage, the pH levels are likely lower (more acidic) as more pollutants have accumulated over time. Sublimation, snow compaction, and extended temperatures below freezing usually concentrate the levels of pollutants causing an increase in acidity.

Going further

1. Conductivity investigations with a conductivity meter are not included in this exercise, but are a good way to extend the activity further. Conductivity, or the ability of a liquid to conduct an electrical charge, is also used to test for impurities in snow samples. Since many pollutants are negatively charged (anions) or positively charged (cations), as their concentrations increase, there is a corresponding increase in the conductivity of the melted snow sample. Although both pH and conductivity provide evidence of impurities in snow samples, neither method identifies or measures the concentrations of specific impurities causing the low pH (high acidity) or high conductivity. Many impurities in snowmelt will not cause high acidity but they can cause high conductivity.

   Conductivity meters may be available for loan through water quality management offices or can be bought.

2. What role does snow density play in the calculation of snow water equivalents and potential runoff?

3. Try the “Deadly Skies” activity from *Aquatic Project WILD*, pp. 142-145.

4. Sample snow near all known and probable local pollution sites in and around the community. Record pH (and conductivity) measurements and source of impurity. On a map mark the values at the site where you collected the sample. Draw a line connecting all near identical values to see if there are high or low acidity “spots” in the area. (This is the same idea as connecting identical topographic elevations.) Can you tell when a local source gradually loses its effect with distance?

5. After determining the pH of the snowmelt in your samples, create water samples with similar pH levels. Keep salmon eggs or fry in them (with help from the Oregon Department of Fish and Wildlife’s Salmon-Trout Enhancement Program; see Chapter 11) to see how these “pollutants” affect their growth rate, development, or survival.

6. Chart depth and water content of snow throughout the snow season for a SNOTEL site near your area. If snow level decreases and water content remains the same, what factor is responsible? (**Compaction.**) If water content decreases as snow level decreases, what factor is responsible? (**Sublimation.**)

Name

Winter watersheds

Part 1

Do you know . . .

Millions of Americans enjoy snow-covered landscapes for their beauty or as a winter playground. But snow also plays a vital role. It is a primary source of the water supply in the western United States.

The West's high mountain ranges hold a vast snowpack that provides 50% to 80% of the water supply for the year. But, melting snow does not provide an uninterrupted, dependable source of water for all the downstream needs. Reservoirs and other water storage facilities help store water for the growing needs of agriculture, industry, and communities. Successful water management begins with knowledge of the primary source of water in the West—snow.

Specially trained people from federal, state, and private cooperative snow survey programs work with the Natural Resources Conservation Service (NRCS). They create accurate and timely information on the amount of mountain snowpack and its water content. SNOTEL is a computerized **telemetry** network and forecasting system for collecting data on snowpack. It can provide daily, or more frequent, information about streamflow potentials. The information is especially valuable during periods of flood or drought.

The relationship between snowpack and the amount of snowmelt runoff is complex. It depends on many factors, primarily:

- moisture content of soil,
- ground water contributions,
- precipitation patterns,
- changes in air temperature,
- use of water by plants, and
- the frequency of storms.

Parts of this activity are adapted from *Snow Chemistry and Air Pollution,* Burris, Frank, Rena McFarlane and Peter Stortz, Alaska Cooperative Extension, Fairbanks, Alaska, 1996, and used with permission. Additional information obtained and adapted from *Snow Surveys and Water Supply Forecasting,* U.S. Department of Agriculture, Soil Conservation Service, Agriculture Information Bulletin 536, June 1988.

Vocabulary

acid rain
acid shock
fry
organic matter
pH
snow courses
snow water content
sublimation
telemetry

Student sheet

These factors change from year to year and vary from one location to another.

How wet the soil is in early winter—before the snowpack develops—affects the runoff in the following spring. Dry soils soak up more water than wet soils. The soil—for example, sand or clay—as well as the precipitation determines how much moisture can be absorbed. Wind, air temperature, storm frequency, and the amount of moisture in the atmosphere determine the accumulation of the snowpack. As the snow depth increases, its density increases as the lower layers are compressed. Density affects how fast the snowpack melts and how much water it yields.

Air temperature and atmospheric moisture determine how "wet" or "dry" the snow is. Typically, the west slope of the Cascade Range, in response to the Pacific Ocean's strong influence, receives heavy, wet snow. One foot of that newly fallen snow can produce up to 1.5 inches of water. But one foot of snow in the mountains of central Utah is much drier. It is light and powdery—excellent for skiing—but may only contain an inch of water.

Mountain snowpacks do not melt steadily. Melting varies with weather, ground temperature, and exposure to the sun. Snow begins to melt when its temperature from top to bottom is equal at 32°F. Before reaching the isothermal state, the snowpack is different temperatures at different depths. Ground temperature, air temperature, and the sun affect how quickly it becomes isothermal. South-facing slopes and open areas receive the most solar radiation and have the fastest melt rates.

Now it's your turn . . .

Most of the usable water in western North America begins as mountain snowfall. Many years ago local communities recognized that monitoring snowfall was important for predicting water supply. So a system of snow surveys was organized. A snow survey is an inventory of the total snow covering of a specific watershed and the resulting effects on local water supplies. This information is used to predict floods, regulate reservoir storage, determine hydropower potential at dams, forecast community water supplies, assess agricultural productivity, and other applications. The Natural Resources Conservation Service (NRCS) coordinates these cooperative surveys.

Information about snow surveys throughout the West is available on the Internet at *http://crystal.or.nrcs.usda.gov/snowsurveys/*. Information from remote automated snow telemetry (SNOTEL) sites is updated regularly at this website. Another good website for snow survey information and maps is *http://www.wrcc.dri.edu/snotel.html*.

Conventional snow surveys are made at designated sites known as **snow courses**. In Oregon there are 110 SNOTEL sites plus many more snow courses where snowpack information is collected.

In this activity you will collect snow samples, calculate the **snow water content** of each sample and apply that information to a model watershed. If you have time, save your snow samples and continue with Part 2 of this activity. In Part 2 you will research possible sources of air pollutants in your community or part of the state. And you will test your snow samples to see if the snowpack in your area is affected by airborne pollutants.

Collecting a snow sample

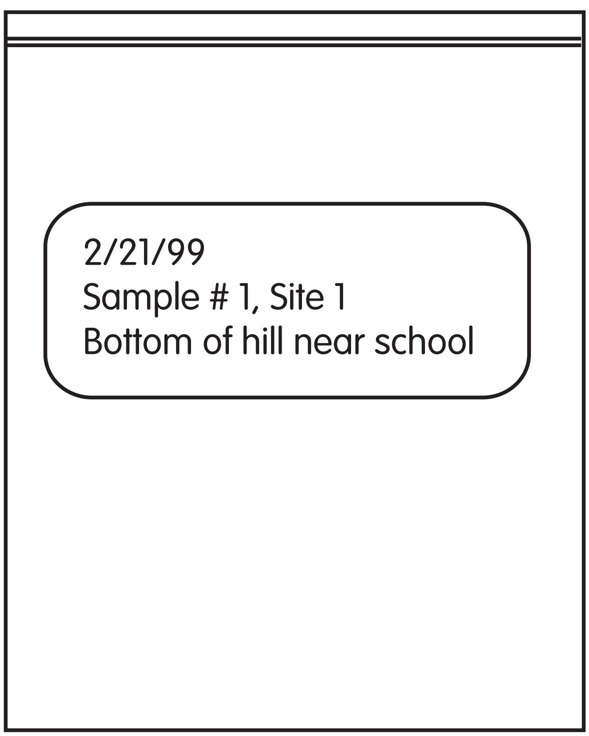
Choose an undisturbed area free of animal (or human) tracks, twigs, fallen branches, leaves, cones, animal droppings, fur, feathers, or extra snow from overhead branches. Try to avoid areas of drifted snow or where the wind continually moves the snow.

1. Select a coding system for the snow samples before marking the ziptop bags. A good system includes the sample date, the sample number, the site number, and a description of the site (see example). Mark the code on the outside of each bag *before* going into the field.

2. Make sure all equipment is gathered and ready before leaving for the field. Design a checklist to make this an easy process each time you collect snow samples. As you work, be sure not to touch the snow samples with your hands.

3. If snow is crusted over and more than a foot deep, use a shovel to dig a small pit (about 24 inches square) down to the ground surface next to where you want to sample snow. The pit makes it easier to remove the snow tube. Disturb no more snow than necessary so you can use this site again if you plan to take more samples throughout the snowpack season.

Labeled Ziptop Bag



4. Pick a spot that looks representative of the sample area. Using a ruler or meter stick read the depth of the snow to the nearest half inch (or centimeter). You can make several measurements to find a representative depth, but record only one snow depth measurement per sample site on the data sheet.

5. Using the following procedure, collect at least three samples to get an average of the snowpack conditions at each individual sample site.

6. Shove the snow tube, open end down, vertically through the snow just beyond the edge of the pit. Do not push the snow tube into the soil or vegetation layer. It is important not to pack the snow in the tube. If the snow is deeper than the snow tube is long, stop before the snow tube is completely full. Carefully remove the tube and empty that part of the sample into your sample bag. Return the empty tube to where you stopped the sample and collect the rest of the column of snow.

7. Move snow away from the wall of the cylinder on the pit side. From the side, carefully insert a flat, stiff object (tile, rigid plastic, or small flat aluminum shovel) under the bottom of the snow tube to prevent snow from falling out when the tube is moved. Make sure the cap is not too close to the ground where it could pick up soil and plant debris that could contaminate the sample. If any samples come in contact with **organic matter**, discard the sample and take another near the original sample location. This part of the process is important if you plan to continue with Part 2.

8. Holding the cap in place, tilt the snow tube and its cap into the pit. Be careful not to spill any of the snow core. Invert the snow tube so the snow core slides to the bottom. Using the scale on the graduated cylinder snow tube, note the height of the snow core and record

that amount on the data sheet (p. 146). Repeat the process for the other two samples. Add the three amounts and divide by the number of samples taken (3). Record the average height of the snow core in the appropriate column on the data sheet.

If the snow is hard or crusty or deeper than the length of your snow tube, remove the snow core in the same way, but in stages. Add the stage amounts to get the total height of the snow core.

9. Be careful not to spill snow from the tube and do not touch the snow with your hands. Empty the snow into the pre-labeled ziptop plastic bags. Make sure the sample goes into the correctly labeled bag. Press as much air out of the bag as possible and close the bag tightly. Do not allow the snow to melt. Prolonged contact with the air can mix carbon dioxide with the snow water, forming a solution of carbonic acid. This acid will lower the **pH** levels of your snow sample, if you are planning to complete Part 2 of the activity. Impurities on your hands can also affect the pH of the snow sample.

10. Record air temperature, the temperature at the snow surface, and time taken on the data sheet. Return indoors to melt the snow core.

Handling snow samples in the classroom

Note: If you are going to do the pH activity in Part 2 it is very important to keep the snow samples frozen until ready to proceed with the melting process. Do not thaw samples overnight. Warming can stimulate biological organisms in the sample to become more active. Their respiration can add carbon dioxide to the sample and potentially change the acidity.

Agitate the samples as little as possible after thawing because this stirring process increases the contact with carbon dioxide in the atmosphere. (You can do this deliberately to determine the effect. First, take a pH reading following the exact directions in Part 2 below.

Snow Survey Data Sheet

Sample site # ________

Date:	Watershed:	Team members:
Time:	Air temp:	
	Surface temp:	Nearest community:
Notes: (description of sample site, weather conditions, other observations)		

Sample No.	Average snow depth at site	Snow level in tube	Average snow tube level	Snow water content	Average snow water content	pH of snow water	Remarks
1							
2							
3							

Student sheet

Then expose the sample to air for an hour or more. Unless the snow is very acidic, the second reading should show a lower pH, or more acidic value.) To avoid contamination of the sample, reduce the handling time and do not touch the melted sample with your hands.

1. Transfer a snow sample from the ziptop bag to the 1,000 milliliter graduated cylinder (one without a hole near its base). Let snow samples melt at room temperature. This can take a while. Monitor the progress so water depth can be recorded soon after the disappearance of all ice.

2. Read the water level in the graduated cylinder as soon as possible after thawing. Record the amount to the nearest milliliter. Repeat for the other two samples. Add the three amounts and divide by the number of samples taken (3). Record the snowpack water content amount in the appropriate average column on the data sheet.

3. Calculate the snow water content conversion factor. To do this, first calculate a total volume for all three snow samples and the total volume of water they produced. Then simply divide the volume of water by the volume of snow. For example, if 500 milliliters of unmelted snow produced 50 milliliters of water, then divide 50 by 500. The answer, in this case 0.1, is the snow water content conversion factor for the area and time you sampled. Now you can convert any snow depth for that area to a water depth by multiplying the snow depth by the conversion factor.

Conversion factor: ______

Student Worksheet

(a) Determine the area of a football field if it is 120 feet long and 60 feet wide. Area of a rectangle (ft^2) = length × width.	
(b) If using metric measurements for average snow depth, convert from centimeters to inches by multiplying the number of centimeters by 0.4. If measurements are in inches, conversion is not necessary.	
(c) Convert snow depth from inches to feet by dividing by 12.	
(d) Find the total volume of snow (in cubic feet) on the football field by multiplying the answer from (a) by the answer from (c).	
(e) If the entire football field "watershed" has the same snowpack depth (# from average snow depth column on your data sheet), what would be the total snow water content of the snowpack on the football field "watershed?" (Multiply the volume from (d) by the snow water content conversion factor).	
(f) How many gallons is this? (To convert cubic feet to gallons, multiply by 7.48).	

Student sheet

4. To give your data a watershed perspective, complete the worksheet below. Show your work as you complete the calculations.
5. The following chart shows information from snow surveys for eight SNOTEL sites in the Rogue/Umpqua Basin on March 19, 1999. This information is from the Internet at http://www.wrcc.dri.edu/snotel.html. Check out the website for snowpack information in other Oregon watersheds or basins in other western states. Compare the average snow water equivalent and the percent of average data for those states. Consider how this information correlates to long-term weather patterns.

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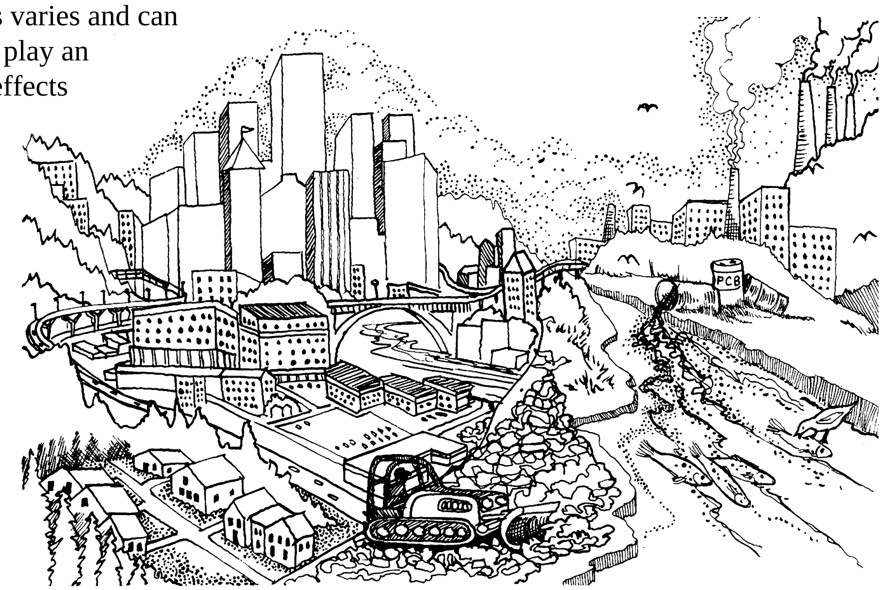

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Questions: Part 2

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2. How do you think the pH levels of your snow samples would compare if you had data from both early winter and late winter? Explain?

Water? Right!

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

Objectives

Students will (1) describe how water rights allocate water resources and (2) demonstrate a water rights allocations system.

Method

Students will experience limited water resources, generate lists of water uses and allocate resources.

For younger students

1. Consult extension activities at the end of each chapter to address the needs of younger students.
2. Read activity background information aloud to younger students or modify for your students' reading level.
3. You may want to explore how the usage numbers were devised; see extensions for this section. Very young students will need familiarity with a calculator or help to calculate large numbers. Modify some questions and vocabulary, for example: "hydroelectric use" could be explained as "dam usage."

Materials

Introduction

- paper cups (one per student)
- water jug (plastic gallon container)
- 3"×5" cards

Activity

- copies of student pages (pp. 157-160)

Notes to the teacher

The introduction is a demonstration activity. As an introduction to the Riparian Rights Doctrine of water rights, begin by placing a partially full water jug on the floor. Then have students arrange their chairs in a circle around the jug. Distribute paper cups to the students. Whoever is closest to the jug has the first priority and may take all the water they need. Have that student pass the jug to the next closest person. Continue around the circle, moving farther and farther away from the original water source until the jug has gone all the way around the circle, or the jug is empty. If some students did not get water, ask them how they feel about it. If the jug did complete the circle, discuss how some would have felt if the water ran out before it got to them. Discuss this method of water rights. Is it fair? What are its problems? What are its benefits?

To introduce Prior Appropriation Doctrine, have all students write their birth date on a 3"×5" card. Next, have them arrange their chairs in a line from oldest to youngest. Give the water jug to the oldest student. Tell that student to take all they need and then pass it on to the next oldest, and so on down the line. Discuss the problems and benefits of this system of water rights.

Ask the students to compare the two systems. Then ask them to improve on these two systems. Can they come up with a system that solves the problems of either of these systems of water rights? What factors (e.g., fairness, predictability, most important uses, etc.) are the most important in a system of water rights?

Vocabulary

Prior Appropriation Doctrine
Riparian Rights Doctrine
water rights

If students have trouble agreeing about priorities it may be useful to point out that this is also a problem for society. Everyone does not agree on what is the fairest system of water rights.

Background

Do you know . . .

Water rights are a legal system for allocating water. A water right does not give anyone 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. Even fish and wildlife can have legal water rights.

The system of water rights is not the same in all areas of the United States. The water rights system generally used in the eastern United States gives people who own land next to the stream the right to use water from it. This is called the **Riparian Rights Doctrine**.

In most of the western United States a different legal system is used to decide who has the right to use water. This system, sometimes called the **Prior Appropriation Doctrine**, gives the first person to use water a "prior" right to use it. This "first-come, first-served" system of rights, also called "first in time, first in right," means that if all of the water in a stream is already allocated there can be no new users.

Procedure

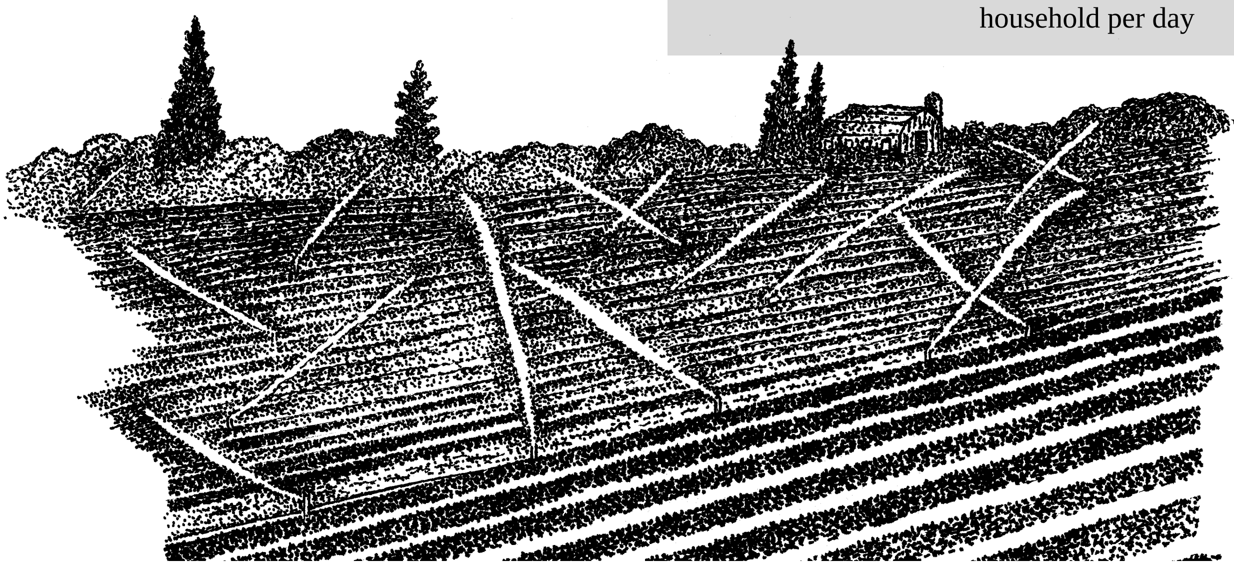
Now it's your turn . . .

Everbody needs water. We use water in our homes, to grow our food, in our industries, for generating power, for recreation, and to support forests, fish and wildlife. But there is not always enough water to go around.

Sometimes there is not enough water when supplies change because of droughts or other natural events. At other times there is not enough water because there are simply too many users. When there is not enough water people must make decisions about who will get the water that is available. What is a fair way to decide who gets the water?

Below is a table listing amounts of water used for different purposes. Use these figures when answering the questions.

Use	**Amount**
Home use	900 gallons per household per day
Industrial use	450 gallons per household per day
Minimum stream flow ...	1,000,000 gallons per day
Irrigation	450 gallons per household per day
Hydroelectric use	900 gallons per household per day



Questions

1. Why is it important to maintain minimum streamflows?
   Minimum streamflows protect fish, wildlife, and other aquatic organisms.

2. Including support services and not counting the amount of water needed to maintain minimum stream flows, how many gallons are needed each day to support each household?
   2,700 gallons. Home use + Industrial use + Irrigation + Hydroelectrice use

3. Including the amount needed to maintain minimum streamflows, how many gallons per day are needed to support a town of 1,000 households? 2,000 households? 5,000 households?
   1,000 households = 3,700,000 gallons
   2,700 gals/household × 1,000 households = 2,700,000 gals
   2,700,000 gals + 1,000,000 gals (minimum stream flow) = 3,700,000 gals
   2,000 households = 6,400,000 gallons (2,700,000 × 2 + 1,000,000)
   5,000 households = 14,500,000 gallons (2,700,000 × 5 + 1,000,000)
   Note: the minimum streamflow is always only 1,000,000 gals.

4. If the river this town depends on has an average flow of 34,000,000 gallons per day, how many households can it support? Round to the nearest whole thousand without going over the available water supply.
   12,000 households
   34,000,000 gals/day - 1,000,000 minimum streamflow = 33,000,000
   33,000,000 gals/day ÷ 2,700 gals/day = 12,222, rounded down to 12,000

5. The amount of rainfall can vary from year to year. If a drought caused the average streamflow to drop by half how many households could it support? Round to the nearest whole thousand without going over the available water supply.
   5,000 households.

   34,000,000 gals/day ÷ 2 = 17,000,000
   17,000,000 - 1,000,000 (min. stream flow) = 16,000,000
   16,000,000 ÷ 2,700 = 5,925.9259 but rounded down to 5,000

6. Sometimes water may be used, but not used up. For example, part of the water that enters households as domestic water leaves as sewage. Which uses can return water to a river? Why?
   Home use—most water is returned
   Industrial use—most water is returned
   Irrigation—little water is returned
   Hydroelectric use—most water is returned

7. For each of the returns you discussed above, does anything need to be done to the returned water before it is returned to the river?
   Water from household, industrial, and irrigation uses needs to be cleaned before it is returned.

8. If there is not enough water for all users, what are some ways a town could try to get more? If no more is available, how could they distribute the available water? Which uses have the highest priorities? Why?
   Answers will vary.

8. Design your own system of water rights. How should water be distributed? Who has the first priority for water use? Why?
   Answers will vary.

Going further

1. See “Water Court,” *Project Wet*, pp. 413-419.
2. Design an experiment that would detect if someone was taking more irrigation water from the river than the amount allowed by their water right.
3. Design an experiment to test the efficiency of a common lawn sprinkler.
4. See “Water Works,” *Project Wet*, pp. 274-278.
5. Is your local water system supported by wells? If so, investigate the recharge and use capacity of the local water system. Design a hypothetical situation where drought reduces the local water supply by one-half. Hypothesize how the community would solve this water shortage dilemma.
6. Using precipitation, and potential evapotranspiration data obtained from your local hydrologist, graph the precipitation, the actual evapotranspiration, and the potential evapotranspiration. Discuss usage, recharge, and deficit as it relates to the watershed. How might this affect the streamflow over a period of a year?

Name ____________________

Water? Right!

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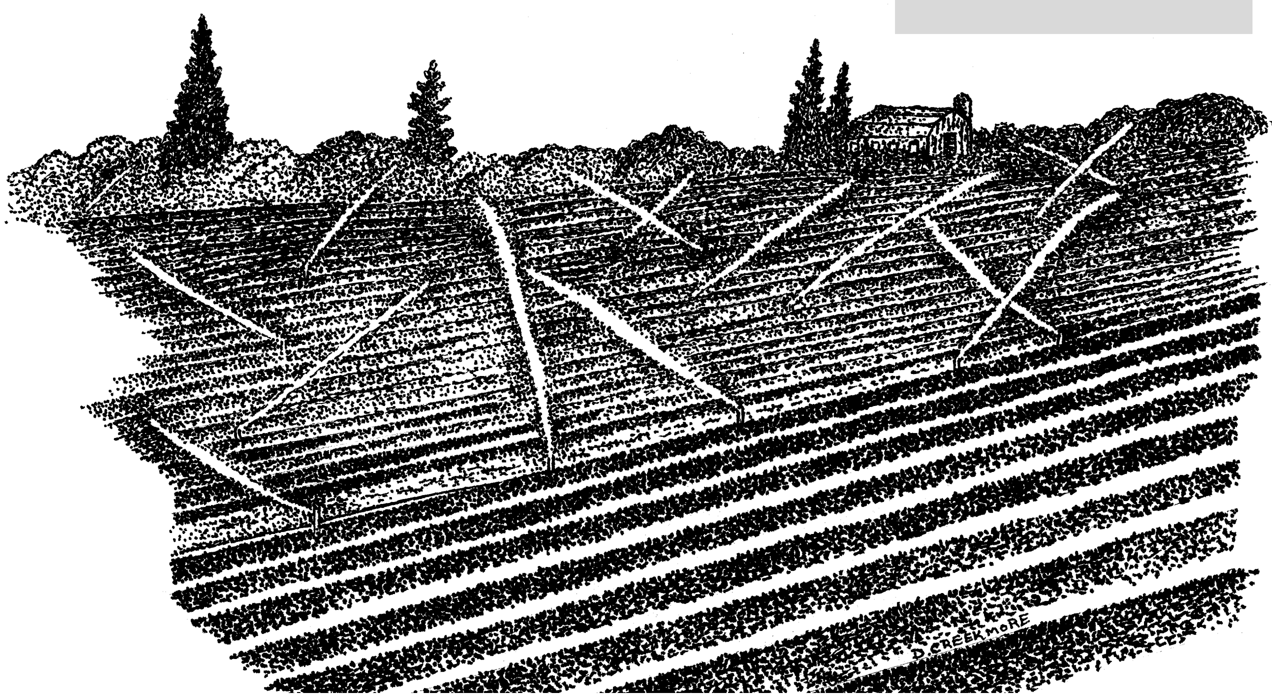
Vocabulary

Prior Appropriation Doctrine
Riparian Rights Doctrine
water rights



Questions

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Hydroelectric use	900 gallons per household per day

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3. Including the amount needed to maintain minimum streamflows, how many gallons are needed each day to support a town of 1,000 households? 2,000 households? 5,000 households?

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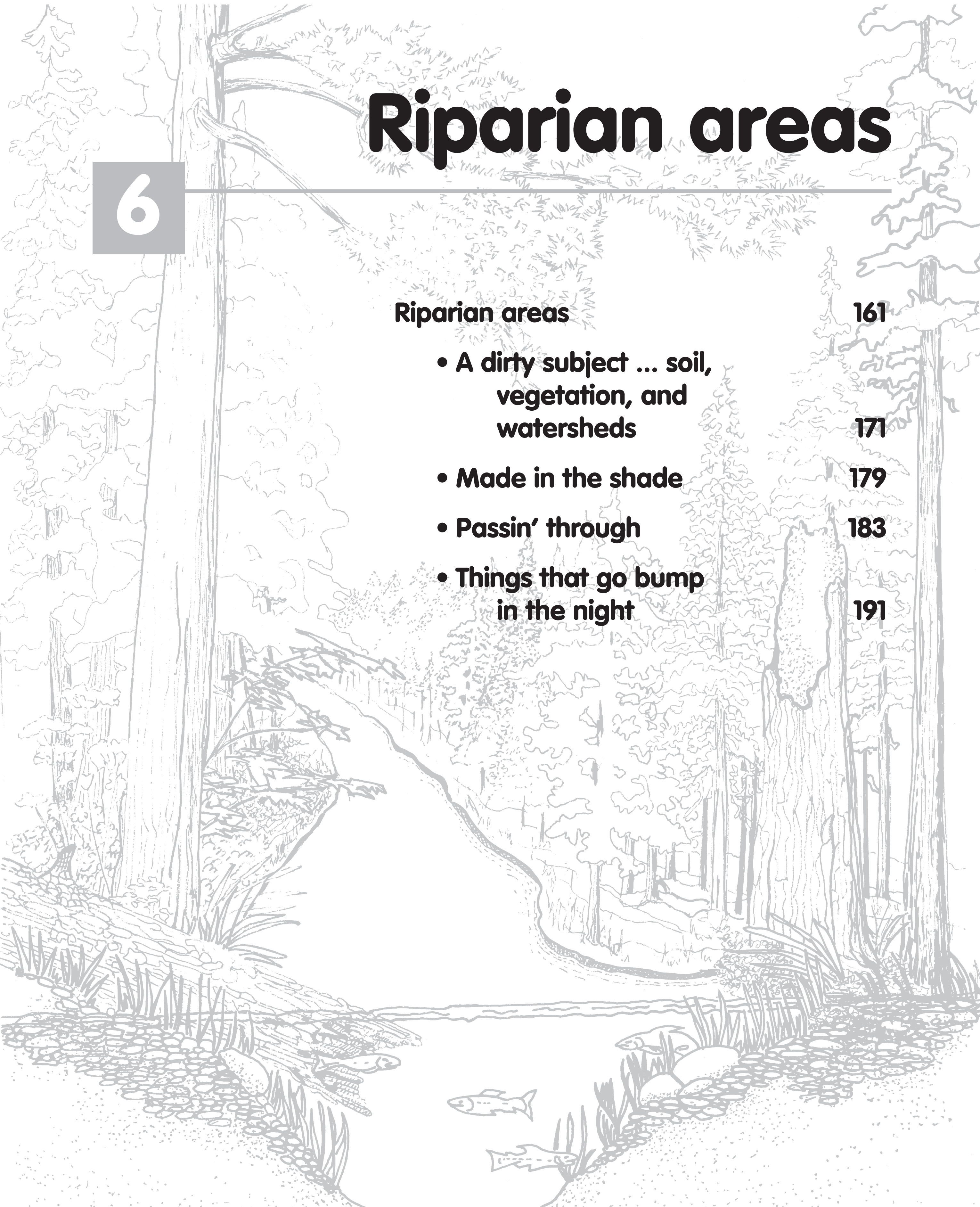
9. Design your own system of water rights. How should water be distributed? Who has the first priority for water use? Why?

Riparian areas

6



Courtesy of Oregon Department of Forestry, Salem, Oregon (Graphics Unit)

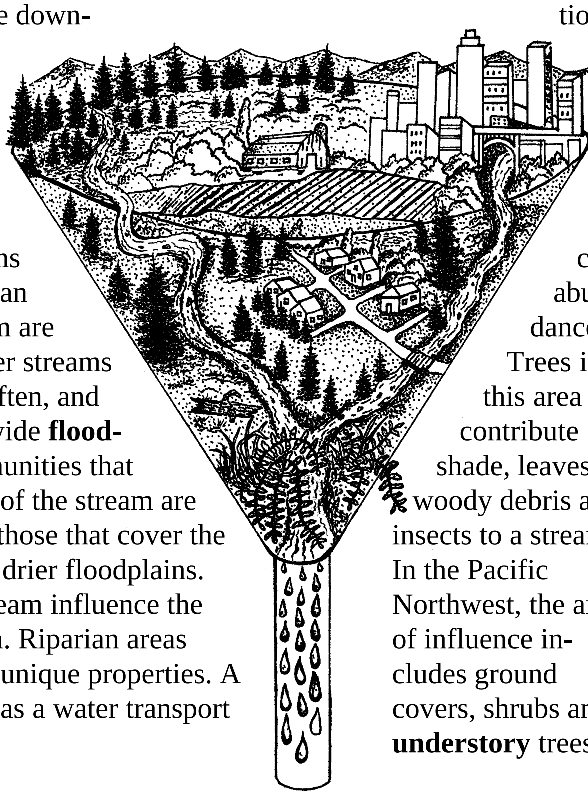
Riparian areas

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.

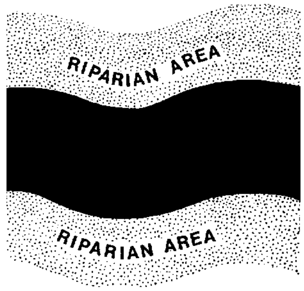
Riparian area: The riparian area is a terrestrial zone where annual and intermittent water, a high water table, and wet soils influence vegetation and microclimate.

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

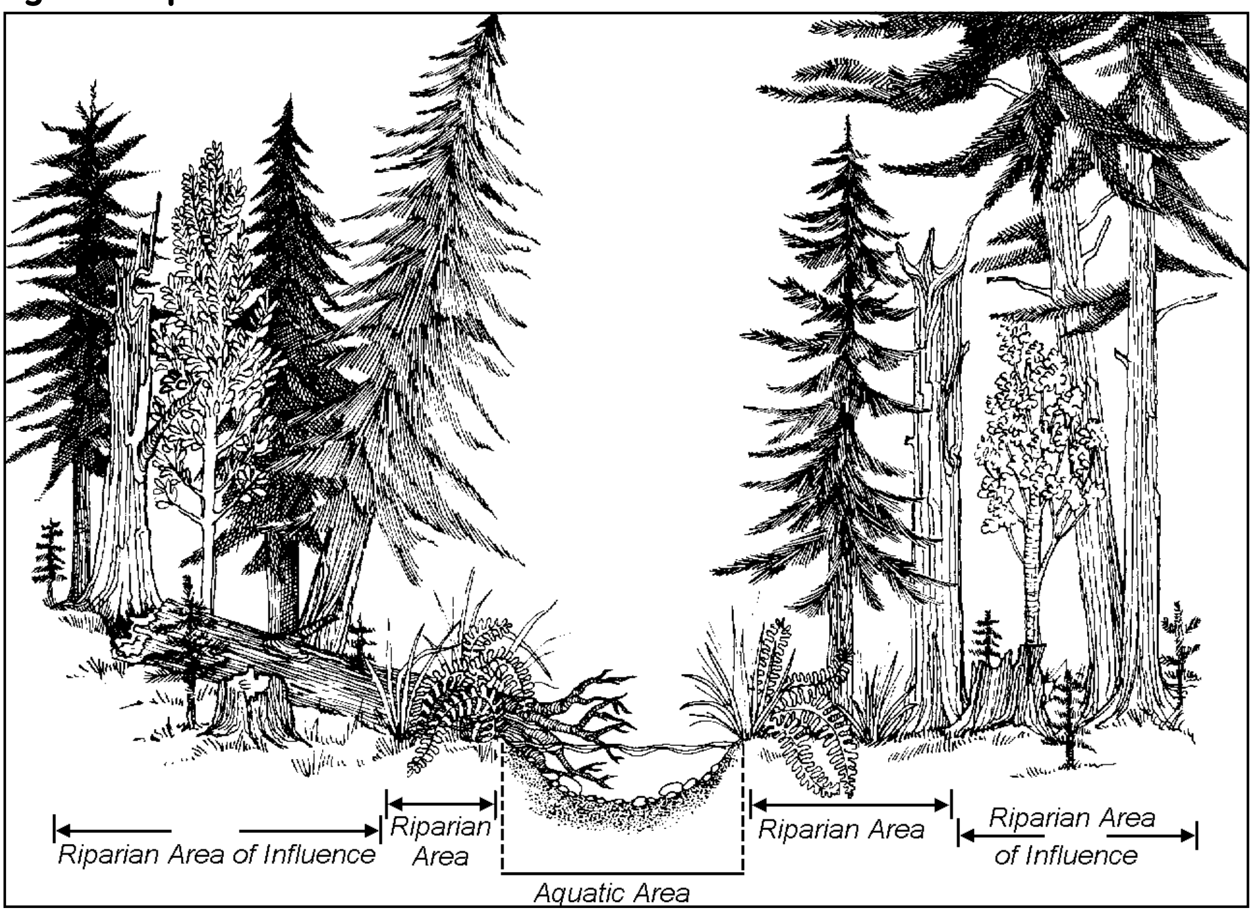
Riparian plant communities (Table 1) provide cover for aquatic and terrestrial animals. Shade created by the riparian vegetation moderates water and air temperatures. This vegetation limits water contamination, slows water velocities and filters and collects large amounts of sediment and debris. Uncontrolled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

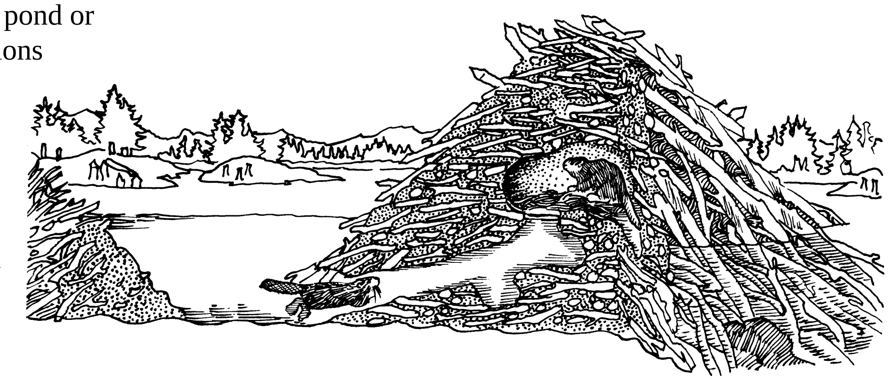
Wildlife in riparian areas

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.

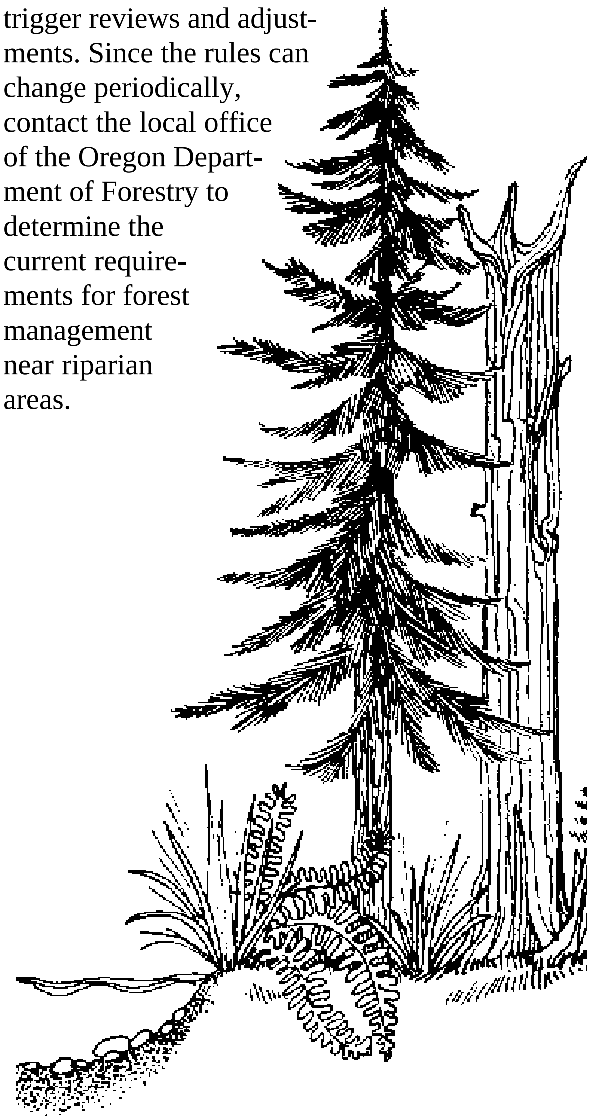
Besides maintaining vegetation, there are a number of other requirements for the management of riparian areas along fish-bearing streams. For example, all downed trees in aquatic habitats and within the riparian management area must remain. This assures that large woody debris in streams or on the ground 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. 34-36. Grades 6-12.
2. "The Edge of Home," *Aquatic Project WILD*, pp. 68-71. Grades 4-12.
3. "Riparian Zone," *Project WILD*, pp. 206-210. Grades 7-12.
4. "Blue Ribbon Niche," *Aquatic Project WILD*, pp. 72-75. Grades 5-12.
5. "Porosity and Permeability," *Groundwater: A Vital Resource*, pp. 24-26. Grades 7-12.
6. "Farmers and Water Pollution," *Groundwater: A Vital Resource*, pp. 47-48. Grades 9-12.
7. "Municipal Waste Contamination of Groundwater," *Groundwater: A Vital Resource*, pp. 53-55. Grades 7-9.
8. "How Much Water Can Different Soils Hold?," *Earth: The Water Planet*, pp. 17-22. Grades 4-8.
9. "Back to the Future," *Project WET*, pp. 293-299. Grades 3-12.
10. "Get the Ground Water Picture," *Project WET*, pp. 136-141. Grades 6-12.
11. "A Grave Mistake," *Project WET*, pp. 311-314. Grades 6-12.
12. "Humpty Dumpty," *Project WET*, pp. 316-321. Grades 3-8.
13. "Irrigation Interpretation, *Project WET*, pp. 254-259. Grades K-8.
14. "Wish Book," *Project WET*, pp. 460-464. Grades 6-12.
15. 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.)

16. 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. Continue 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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A dirty subject ...
soil, vegetation and watersheds

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

Objectives

The student will (1) measure the rate of water infiltration in compacted and non-compacted soils, and (2) describe the relationships between soils, vegetation, runoff, and wildlife in riparian habitats.

Method

The student will collect, compare, and interpret data on the rate of water infiltration (inches/minute) in sites with compacted and non-compacted soils.

For younger students

1. Consult extension activities at the end of each chapter to address the needs of younger students.
2. Read activity background information aloud to younger students or modify for your students' reading level.
3. When doing Step 1 in the procedure, have students mark the 2-inch mark *before* taking off the can ends, to avoid students handling sharp edges as they mark.
4. Students need previous experience with reading rulers and determining measurements. Using each group's data, calculate the infiltration rate formula as a class. Rephrase some questions or answer as part of a group discussion.

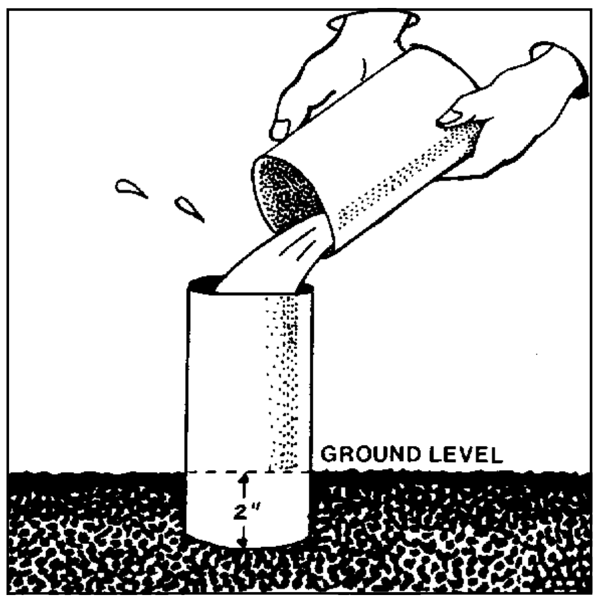
A Dirty Subject is adapted from *Conservation Activities for Girl Scouts,* U.S. Dept. of Agriculture, PA-1009, Natural Resources Conservation Service, 1972.

Materials

- copies of student sheets (pp. 175-178)
- large fruit or vegetable juice cans of uniform size (two cans per team)
- 1, 12-inch ruler per team
- 1 board (approximately 12"×4"×2") per team
- 1 hammer
- 1 watch or clock with second hand
- 1 quart liquid measure
- water (amount will vary with site)

Notes to the teacher

Select two cans of the same size and diameter for each team. Cut the bottoms out of each can just above the rim. This leaves a sharp edge that will drive easily into the ground. Cut out the other



Vocabulary

organic materials
infiltration rate

end of the can with a standard can opener, leaving the rim intact for added strength. Mark the outside of each can 2 inches from the sharp end. (See diagram below.)

Introduce the topics in the "Do you know…" section to set the stage for later discussion. Demonstrate the activity described below for your students. This activity is ideal for working in teams, with individuals taking measurements, making observations, and recording data.

Try to locate an area with compacted soil (a playground, trail or other heavy traffic zone) near non-compacted soil of the same type. (It can be difficult to drive cans into compacted soil without smashing them, so you may want to try out the sites first.) In each selected spot, students will place the sharp end of the can on the ground, place the board on top of the can and gently tap with the hammer until the 2-inch mark is reached. Older students can select their own sites and drive the cans themselves. You may want to drive in the cans ahead of time for younger students to avoid having students handle the sharp edges. (Option: If more than one soil type is available, you may want to conduct several trials in compacted and uncompacted spots within each soil type, allowing comparison between soils.)

By pouring a measured quantity of water in the cans (do a test run to determine the amount of water needed at the site), and measuring the time it takes for the water to infiltrate into the soil, students can obtain data relating soil compaction (or soil type, using the option mentioned above) to water storage and rate of runoff. The entire activity should be done on the same day so the soil moisture will be approximately the same at all test sites.

Compare the rates of water infiltration between student groups. Ask students what might account for these differences. What will happen to water that cannot penetrate the soil? (It will run off quickly to lakes and streams.) What will happen to water that infiltrates the soil easily? (It will soak into the ground.) How will this affect the nearest stream? (Fast runoff will cause the stream to flood, later drying up because no water was stored in the ground.) How might this affect wildlife? (Many answers are possible: relating water storage to streamflow, allowing water to run longer, affecting water temperature, oxygen, fish, vegetation, land animals, and more.)

Background

Do you know . . .

Soils are much more than just dirt. Soils contain different amounts of minerals, and both decaying and living organic materials (those with carbon which are or once were part of a living thing). This means each soil is different in its ability to:

- provide nutrients for plants,
- absorb water, and
- store water.

Plants greatly affect soils. Their growing roots break up large soil particles into smaller ones. Their leaves, stems and flowers fall to the ground and decay, adding organic materials (nutrients) to the soil. Soils are protected from water and wind erosion by plants. Plants help soils store water temporarily by slowing down runoff.

Plants, in turn, are affected by the soils in which they grow. Soils with organic matter and the ability to store water support healthy plant communities. A watershed with both good cover (plants) and good soils (soils not compacted by vehicles, foot traffic, or animals) retain water and release it slowly, allowing streams to run all year.

Watersheds with compacted soils, little vegetation, or both, shed water rapidly, allowing little time for rainwater or melting snow to infiltrate into the ground. Such rapid runoff increases erosion, stripping away vegetation and soils that might otherwise store water.

Soils and vegetation in a watershed, in turn, have much influence over:

- what fish and wildlife live there (provide food and cover for both fish and wildlife),
- runoff and streamflow (determine how fast water runs off).
- amount of oxygen and sediments in watershed streams (plants hold sediments and

cool the stream so the water can carry more oxygen), and

- water temperature (plants provide shade for the stream).

Everything in a watershed is connected to everything else—soils, plants, fish, and wildlife. The amount of water slowed and stored by the soil and vegetation is a key element in the whole system. When one part of the system breaks down (e.g., loss of vegetation), the whole watershed is affected.

Procedure

Now it's your turn . . .

Just how much water can soil absorb? In this investigation you will measure the rate of water infiltration for soils in your area.

Using the materials provided, measure the rate of infiltration of water into soil at two different sites—one compacted, one not compacted.

1. Select two cans of the same size and diameter for each team. Cut the bottoms out of each can just above the rim. This leaves a sharp edge that will drive easily into the ground. Cut out the other end of the can with a standard can opener, leaving the rim intact for added strength. Mark the outside of each can 2 inches from the sharp end.
2. Try to locate an area with compacted soil (a playground, trail, or other heavy traffic zone) near non-compacted soil on the same type. Place one can on the compacted site, and another on the uncompacted site.
3. In each spot selected, place the sharp end of the can on the ground. Place the board on the dull end of the can, and tap *gently* with the hammer until the two-inch mark on the can is reached. Avoid spots where rocks or sticks make it difficult to drive the can down. Do not disturb the plant material or organic matter in the can.
4. Pour a measured amount of water into the can all at once, and begin timing the rate of infiltration. Immediately measure the distance in inches from the top of the can to the water level and record your observations on the data table. (**Note:** If a retrial is needed for some reason, move your can to a new spot. Once water has been poured into a can, the soil moisture has been changed, affecting the outcome. Do not attempt to do a retrial in a "used" test location.)
5. Measure the amount of water that has moved downward at the end of each minute for the first 10 minutes.
6. Using your completed data table, determine the rate of infiltration in inches per minute (in/min). Share your rates of infiltration with other students, and get their figures. Combine your rate of infiltration with the rates found by other teams. Determine an average rate for the compacted and non-compacted sites.
7. Answer the questions provided.

Data tables

I. Infiltration rate: Record the rate of downward movement of water (inches) every minute for 10 minutes. Begin measurements immediately after pouring water into the can.

Minutes	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Site I (inches) (compacted soils)											
Site II (inches) (non-compacted soils)											

Infiltration rate (inches/minute) = $\frac{\text{Downward movement (inches)}}{\text{Time elapsed (minutes)}}$

A. Total downward movement = ______________________

B. Total time (minutes) = ______________________

C. Infiltration (inches/min) = ______________________

D. Class averages = Site I: ______________ (compacted soils) Site II: ______________ (non-compacted soils)

II. Observations:

	Site I (compacted soils)	**Site II** (non-compacted soils)
A. Location description (field, pasture, trail, etc.)		
B. Description of soil (loose, compact, sandy, etc.)		
C. Organic materials (leaves, sticks, other?)		
D. Vegetation (grass, shrub, tree, etc.)		

Questions

1. What might account for any difference in infiltration rates between test sites?
   Different soil types are able to absorb water at different rates. Soils that are compacted have fewer spaces to fill with water.
2. What will happen to the water that cannot penetrate the soil?
   It will run off quickly to lakes and streams.
3. What will happen to the water that penetrates the soil more easily?
   It will soak into the ground and be temporarily stored.
4. How are streams affected by vegetation, soil, and rates of runoff?
   Fast runoff will cause the stream to flood, later drying up because no water was stored in the ground.
5. In what ways might wildlife be affected by vegetation, soil, and runoff?
   Many answers are possible relating to streamflow, allowing water to run longer, affecting water temperature, oxygen, fish, vegetation, land animals, and more.

Going further

1. Redo the experiment with soils from at least six sites in the uplands and other areas in your watershed. Compare the water infiltration ability of these samples with the examples you tested in the previous experiment. Predict the results before beginning the second set of tests. What might account for the differences, if any? Based on your results, identify areas needing improvement. Then research and design a project to improve the water infiltration capability of compacted soils in those areas.

Name

A dirty subject ...
soil, vegetation and watersheds

Do you know . . .

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- provide nutrients for plants,
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Plants greatly affect soils. Their growing roots break up large soil particles into smaller ones. Their leaves, stems and flowers fall to the ground and decay, adding organic materials (nutrients) to the soil. Soils are protected from water and wind erosion by plants. Plants help soils store water temporarily by slowing down runoff.

Plants, in turn, are affected by the soils in which they grow. Soils with organic matter and the ability to store water support healthy plant communities. A watershed with both good cover (plants) and good soils (soils not compacted by vehicles, foot traffic, or animals) retain water and release it slowly, allowing streams to run all year.

Watersheds with compacted soils, little vegetation, or both, shed water rapidly, allowing little time for rainwater or melting snow to infiltrate into the ground. Such rapid runoff increases erosion, stripping away vegetation and soils that might otherwise store water.

A Dirty Subject is adapted from *Conservation Activities for Girl Scouts*, U.S. Dept. of Agriculture, PA-1009, Natural Resources Conservation Service, 1972.

Soils and vegetation in a watershed, in turn, have much influence over:

- what fish and wildlife live there (provide food and cover for both fish and wildlife),
- runoff and streamflow (determine how fast water runs off).
- amount of oxygen and sediments in watershed streams (plants hold sediments and cool the stream so the water can carry more oxygen), and
- water temperature (plants provide shade for the stream).

Everything in a watershed is connected to everything else—soils, plants, fish, and wildlife. The amount of water slowed and stored by the soil and vegetation is a key element in the whole system. When one part of the system breaks

Vocabulary

organic materials
infiltration rate

Student sheet

down (e.g., loss of vegetation), the whole watershed is affected.

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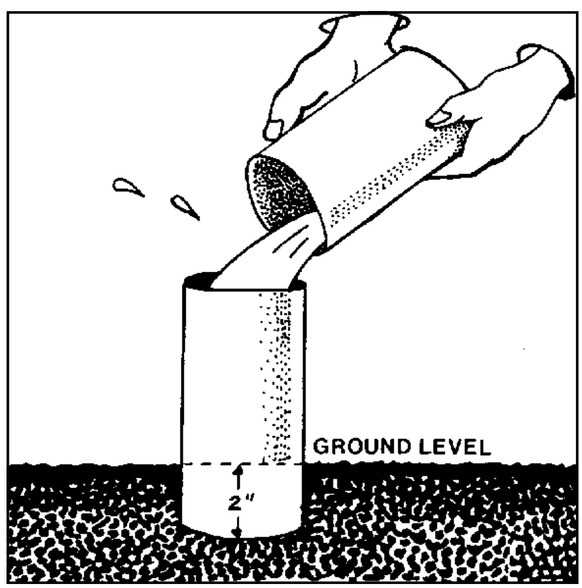
4. Pour a measured amount of water into the can all at once, and begin timing the rate of infiltration. Immediately measure the distance in inches from the top of the can to the water level and record your observations on the data table. (**Note:** If a retrial is needed for some reason, move your can to a new spot. Once water has been poured into a can, the soil moisture has been changed, affecting the outcome. Do not attempt to do a retrial in a "used" test location.)
5. Measure the amount of water that has moved downward at the end of each minute for the first 10 minutes.
6. Using your completed data table, determine the rate of infiltration in inches per minute (in/min). Share your rates of infiltration with other students, and get their figures. Combine your rate of infiltration with the rates found by other teams. Determine an average rate for the compacted and non-compacted sites.
7. Answer the questions provided.



Student sheet

Data tables

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Site I (inches) (compacted soils)											
Site II (inches) (non-compacted soils)											

$$\text{Infiltration rate (inches/minute)} = \frac{\text{Downward movement (inches)}}{\text{Time elapsed (minutes)}}$$

A. Total downward movement = ______________________

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A. Location description (field, pasture, trail, etc.)		
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C. Organic materials (leaves, sticks, other?)		
D. Vegetation (grass, shrub, tree, etc.)		

Questions

1. What might account for any difference in infiltration rates between test sites?

2. What will happen to the water that cannot penetrate the soil?

3. What will happen to the water that penetrates the soil more easily?

4. How are streams affected by vegetation, soil, and rates of runoff?

5. In what ways might wildlife be affected by vegetation, soil, and runoff?

Made in the shade

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

Objectives

The student will (1) demonstrate the effect of solar radiation in heating water, (2) demonstrate how shade helps keep water cool by limiting solar radiation, and (3) describe the influence of riparian vegetation in keeping streams cool.

Method

Students place two pans of water, one shaded and one unshaded, in a sunny location and record the changes in temperature over time.

For younger students

1. Consult extension activities at the end of each chapter to address the needs of younger students.
2. Read activity background information aloud to younger students or modify for your students' reading level.

Materials

- 2 pans of equal size and shape (for each team)
- water
- aluminum foil
- thermometer (one for each team)
- copies of student sheets (pp. 181-182)

Background

Do you know . . .

… that just as a hat shades your head and keeps it cooler on a hot summer day, shade provided by riparian plants helps keep a stream cooler in the summer. Cool water is important to the animals and plants that live in the stream. If water temperatures become too warm, they may become ill or die.

Riparian areas are important temperature regulators for streams. The plants in the riparian area shade and protect the stream and its banks from the heat of the sun. Warm air temperatures may still transfer some heat to the stream, but less total heat energy reaches the stream than if it was unshaded.

Procedure

Now it's your turn . . .

How much does shade affect water temperature? Try the following experiment to find out.

1. Add the same measured amount of water to each of the pans. Cover one pan with aluminum foil with the shiny side up. This represents a shaded stream while the uncovered pan represents an unshaded stream.
2. Place the pans side by side in a sunny place.
3. Check the temperature of each pan every 10 minutes.
4. Record the information you collect on the data sheet.

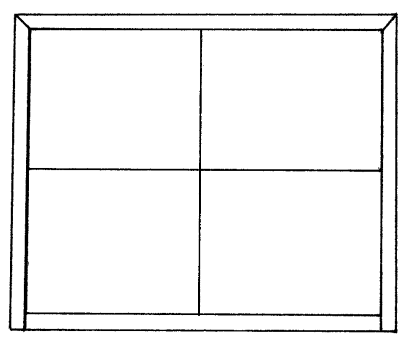
Time elapsed	0 min.	10 min.	20 min.	30 min.	40 min.	50 min.	60 min.
Unshaded temperature							
Shaded temperature							

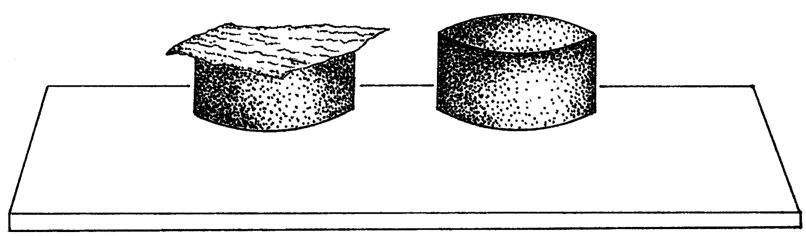
Questions

1. Which pan heated more quickly, the shaded or unshaded one?
   The unshaded pan heated more quickly.
2. Why are cool stream temperatures important?
   Many aquatic organisms, such as salmon, trout and some other aquatic organisms, need cool water to live. Within this cooler range of temperatures, an organism's metabolism is more efficient and the species has a greater chance for success.
3. Besides plants, what else can help shade a stream?
   Answers will vary, but should include shade from adjacent hills or stream banks (topographic shading) as well as debris (logs, rocks, leaves) in the stream. A stream's orientation to the path of the sun can also affect the amount of solar radiation it gets, i.e. a stream that flows north-south does not receive as much solar radiation as a stream that flows east-west. A stream's valley form (broad valley versus narrow valley) also affects the amount of solar radiation it receives.
4. In the northern hemisphere the summer sun is slightly to the south rather than directly overhead. If a stream in this part of the world runs east-west, which side of the stream needs the most protection from solar radiation? Along with a written description, sketch your interpretation of this answer.
   Since the sun is slightly to the south, plants on the south bank will shade the stream more effectively than plants on the north bank.

Going further

1. Do different amounts and types of shade make a difference in the cooling effects of the shade?
2. Does a completely unshaded pan heat up twice as fast as a pan that is only half shaded?
3. Is debris (bark or leaves) floating on the top of the water effective in keeping water cooler?
4. Which heats more quickly, a pan tightly covered with foil or loosely covered with foil?
5. How does the amount of water (deep or shallow) affect the rate at which the water warms?
6. How does turbulence affect how quickly the water warms?
7. How does shade affect the water temperature once the water is warm?





Name

Made in the shade

Do you know . . .

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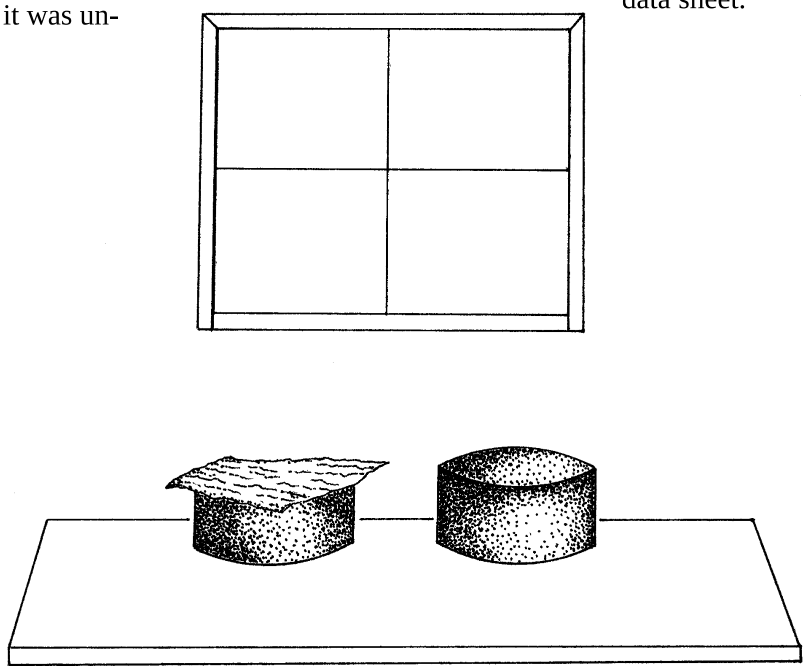
Riparian areas are important temperature regulators for streams. The plants in the riparian area shade and protect the stream and its banks from the heat of the sun. Warm air temperatures may still transfer some heat to the stream, but less total heat energy reaches the stream than if it was unshaded.

Now it's your turn . . .

How much does shade affect water temperature? Try the following experiment to find out.

1. Add the same measured amount of water to each of the pans. Cover one pan with aluminum foil with the shiny side up. This represents a shaded stream while the uncovered pan represents an unshaded stream.
2. Place the pans side by side in a sunny place.
3. Check the temperature of each pan every 10 minutes.
4. Record the information you collect on the data sheet.



Time elapsed	0 min.	10 min.	20 min.	30 min.	40 min.	50 min.	60 min.
Unshaded temperature							
Shaded temperature							

Student sheet

Questions

1. Which pan heated more quickly, the shaded or unshaded one?

2. Why are cool stream temperatures important?

3. Besides plants, what else can help shade a stream?

4. In the northern hemisphere the summer sun is slightly to the south rather than directly overhead. If a stream in this part of the world runs east-west, which side of the stream needs the most protection from solar radiation? Along with a written description, sketch your interpretation of this answer.

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. 68-71. 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.

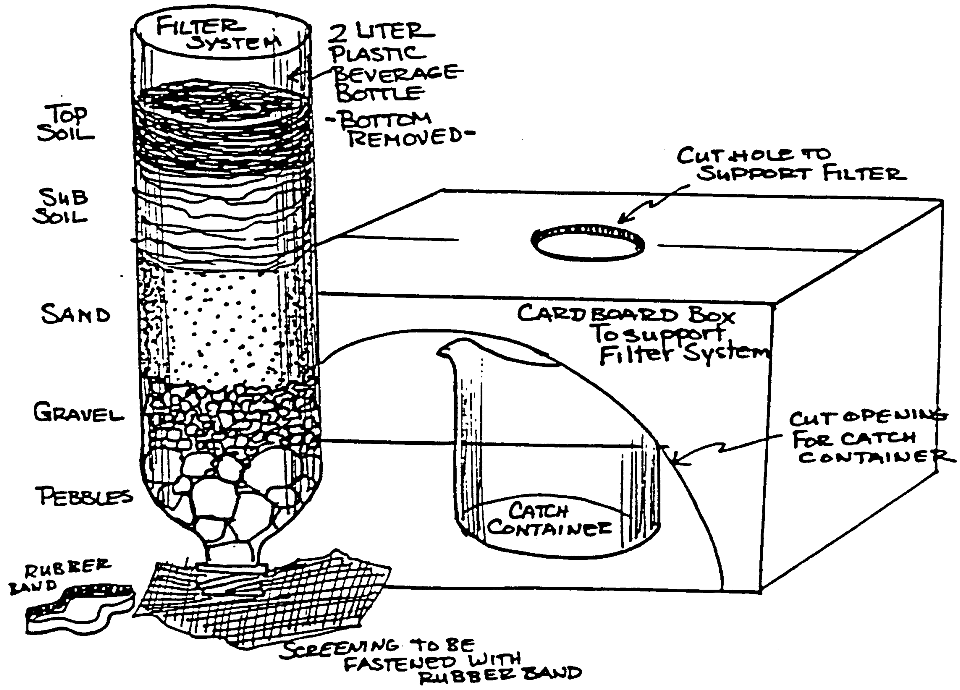
Procedure

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

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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.

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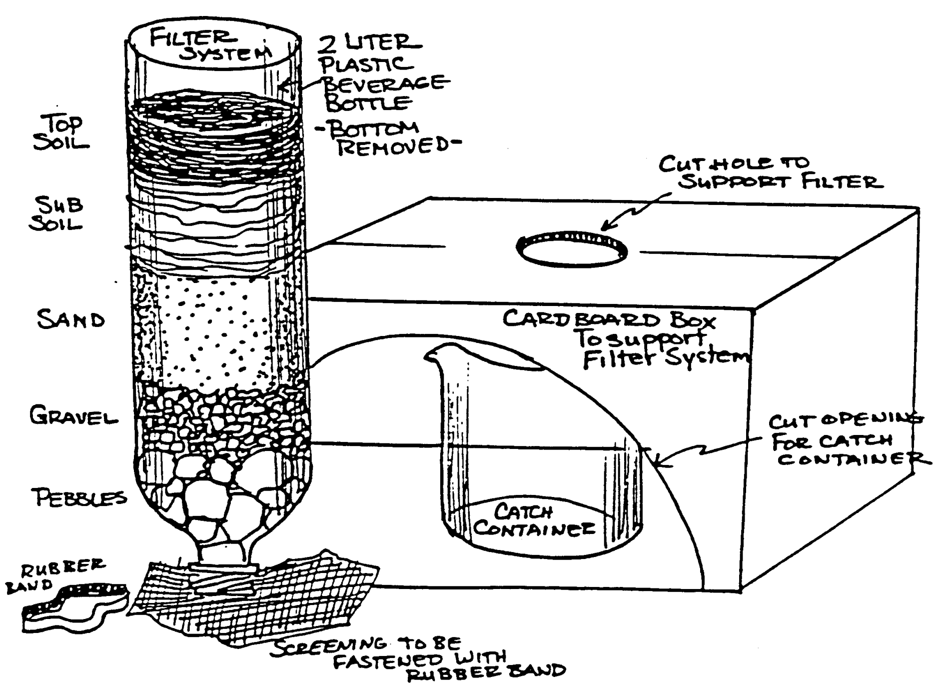

Vocabulary

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.

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?

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Things that go "bump" in the night

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

Objectives

Students will (1) describe how small mammal populations in a riparian area are sampled, and (2) calculate (as part of a simulation exercise) the estimated small mammal population in an area, using the Lincoln Index.

Method

Students will learn how small mammals are captured to estimate their population size in a particular area. Students will then use a simulation activity to model the procedure for using the Lincoln Index in estimating population size.

For younger students

1. Consult extension activities at the end of each chapter to address the needs of younger students.
2. Read activity background information aloud to younger students or modify for your students' reading level.

Materials

- 200-300 poker chips or beans (to represent mice)
- plastic bag (to represent habitat where mice live)
- copies of student sheets (pp. 195-198)

Adapted from Hastie, Bill, "Things That Go 'Bump' In The Night" and "Figuring Wildlife Populations," *Oregon Wildlife*, September 1983 and October 1983.

Notes to the teacher

1. You may want to combine data from all teams to show the effect of a larger sample size.
2. Graphing the results of each team's data and subsequent trials provides a good opportunity for discussion of small mammal population dynamics. Subsequent trials can introduce factors such as mortality, immigration, emigration, or other factors affecting trapping success.

Background

Do you know . . .

. . . what those sounds are around you as you lie under a tree in a sleeping bag trying to go to sleep? Have you ever really listened and wondered what kind of "critter" was making those sounds? These sounds, like the trees around you, attempt to hide in the darkness. But they do not remain unnoticed.

Many of these sounds are made by small mammals that are most active at night and rest during the day. Such animals are said to be **nocturnal.**

Riparian areas provide the essentials of good wildlife habitat—food, water, and cover. If you are camping in the riparian area along a stream, the trees and shrubs under which you sleep also serve as cover, roosting, nesting, and feeding areas for birds; shelter and food for small mammals; and provide increased humidity and shade for all animals. Small rodents, such as mice, are

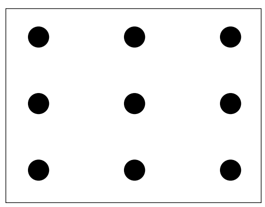
Vocabulary

Lincoln Index	population
nocturnal	riparian area

an important part of many riparian area food chains. It is likely these are the small rodents you hear as you are trying to sleep.

One way to find out which animals explore the area as you sleep is to trap the animals as they go about their nightly search for food. To find out what kind of small rodents inhabit an area and how many are present, biologists use live traps that do not injure the animal. They set and bait a number of traps and wait for darkness to come. Later that night, traps are checked, and captured animals are identified and immediately released back into the area. Biologists are very careful when handling these animals to avoid bites and scratches that may transmit animal diseases.

One of the common problems field biologists face is estimating the size of a **population** (group of individuals of a specific kind in a given area at a given time). A census of the human population of the United States is taken every few years by counting all the people that live there. Because counting small nocturnal mammals (like mice) is very hard to do, biologists use other methods to estimate the size of such a population.



The **Lincoln Index** is a common method used by biologists to estimate the size of a small animal population. Using traps similar to the one in the drawing, they trap and mark animals, release them, and then reset their traps. By noting the number of marked animals recaptured, the biologist can apply the Lincoln Index equation to estimate the population size.

Traps are baited with oatmeal, peanut butter or other grain or nut products and set out in a grid arrangement as shown, at least one yard apart. Because most small mammals are active at night, traps are set out one to two hours before dusk and checked every four hours. **Animals are not left in the traps overnight.**

Procedure

Now it's your turn . . .

How can you find out what animals and how many live in the riparian area next to your stream? You could volunteer to work with a local wildlife biologist to run a small-mammal trapline in your area, see what you capture, and estimate the size of their population.

Biologists would normally handle trapped animals to identify, mark, and release them. Since small mammals sometimes carry diseases transferred to humans through a bite, **we do not recommend that you handle the animals**. Instead, use the following activity as a model to simulate the results of a trapping program and use of the Lincoln Index.

- Place 200 to 300 poker chips (which represent members of a population of white-footed deer mice) in a plastic bag. The bag represents the area in which the mice live.

- "Capture" a handful of mice (poker chips) from the bag. Mark those captured with a piece of masking tape.
- Write down the number of mice captured and release them back into the area where they were caught (the bag). Mix them evenly with the mice not captured.
- Make another "handful" capture from the area. Record the total number captured and the number of these animals that were captured the first time (those marked with tape).

Total population (N)	**Total No. individuals captured 1st catch (M)**	**Total No. individuals captured 2nd catch (n)**	**No. recaptured individuals 2nd catch (m)**

- Now, using the data you have recorded, apply it to the following formula.

$$\frac{N}{M} = \frac{n}{m}$$

or

$$\frac{\text{Total population (N)}}{\text{Number of individuals captured, marked and counted the first time (M)}} = \frac{\text{Total of the second catch (marked and and unmarked) (n)}}{\text{Number of individuals recaptured (marked) in the second catch (m)}}$$

Example:
Forty-two mice were captured the first time. On the second try, 36 mice were captured, 12 of which were also captured the first time (marked).

$M = 42$
$n = 36$
$m = 12$
$\frac{N}{42} = \frac{36}{12}$

Cross-multiplying to solve for N: 12N = 42×36 (or 1,512)
Dividing 12 into 1,512 = 126, so N = 126
Using the Lincoln Index we have found the population of mice for a given area to be 126.
Remember this is not an exact number. It is only an estimate. In this case, the actual number of individuals (poker chips) in the area we sampled (the bag) was known, so it is possible to see how accurate the Lincoln Index can be in estimating population size.

Questions

1. Why is it necessary for biologists to use formulas like the Lincoln Index to estimate populations of animals which live in a riparian area or other habitat within a watershed?
   It is nearly impossible to count small animals like mice because of their small size, secretive lifestyle, and nocturnal habits.
2. How accurate was your population estimate (the population you calculated versus the actual number of mice (chips) in the bag?
   Answers will vary.

3. What factors could influence or affect the population size estimate obtained by using this model?
   The size of the sample (big hands versus small hands), accuracy of counting, and accuracy of calculation. Generally, the larger the sample size, the more accurate the estimate.

4. List as many factors as you can that could influence or affect the population size estimate in actual mark/recapture sampling procedures done in the field?
   The size of the sample, mortality of marked or unmarked animals, weather factors which might affect the activity level of animals being trapped, immigration or emigration of animals to or from the study area, or "catchability" of the animals (some are "trap happy" or more easily caught then others).

5. Why are small mammals, like mice, important to a riparian area?
   Small mammals are an important part of riparian area food chains.

References

Burt, William H., and Richard B. Grossenheider. *A Field Guide to Mammals* (Third Edition). Boston: Houghton Mifflin Co., 1978.

Whitaker, John O. *The Audubon Society Field Guide to North American Mammals*. New York: Alfred A. Knopf, 1980.

Going further

1. Design an experiment to compare small-animal populations within a riparian area and outside of a riparian area. Research how small animals contribute to the functioning of a healthy riparian area. Prepare a report and share the information with the class.

Name

Things that go "bump" in the night

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. . . what those sounds are around you as you lie under a tree in a sleeping bag trying to go to sleep? Have you ever really listened and wondered what kind of "critter" was making those sounds? These sounds, like the trees around you, attempt to hide in the darkness. But they do not remain unnoticed.

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One way to find out which animals explore the area as you sleep is to trap the animals as they go about their nightly search for food. To find out what kind of small rodents inhabit an area and how many are present, biologists use live traps that do not injure the animal. They set and bait a number of traps and wait for darkness to come. Later that night, traps are checked, and captured animals are identified and immediately released back into the area. Biologists are very careful when handling these animals to avoid bites and scratches that may transmit animal diseases.

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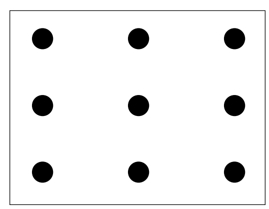

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Vocabulary

Lincoln Index
nocturnal
population
riparian area

Student sheet

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Student sheet

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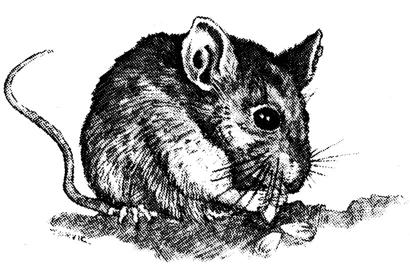
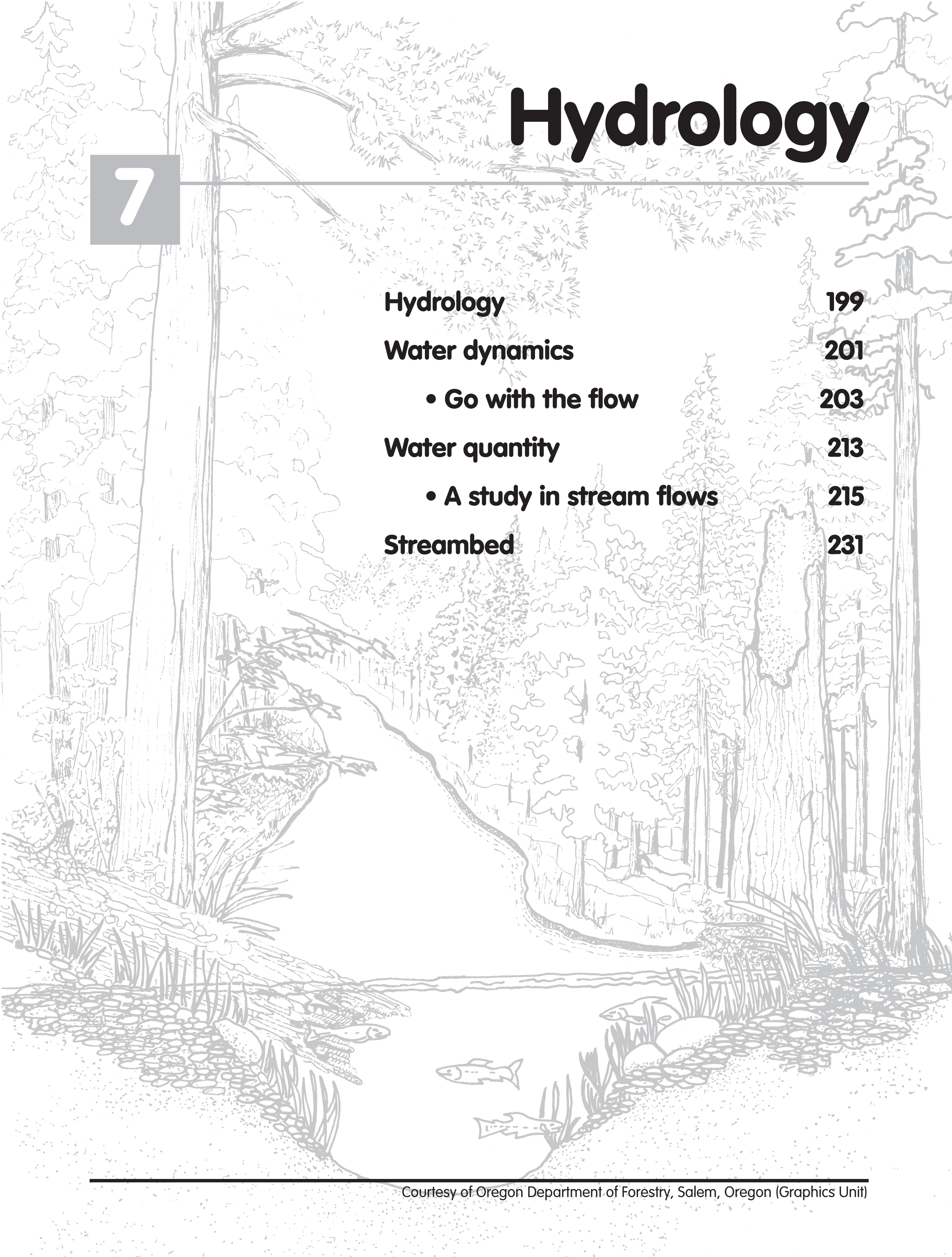


Student sheet

7 Hydrology



Courtesy of Oregon Department of Forestry, Salem, Oregon (Graphics Unit)

Hydrology

7

"The river hides itself in motion. It holds layers of meaning, and so it adds mystery to the landscape, a sense of complexity and risk, a sense that the important facts are hidden from view."
— Kathleen Dean Moore

In the broadest sense, **hydrology** is the study of water—its properties, where it comes from, how it circulates, and how it is distributed. Hydrology is a broad field of study with several specialty areas. One specialty area studies water flowing in streams and rivers. How water carves channels and carries materials is the primary focus of this field of study.

Another field of hydrology looks at water in specific types of watersheds, such as forest hydrology, wetland hydrology, or range hydrology. Hydrologists in these fields study how vegetation and land management affect water quantity and quality, **erosion**, and **sedimentation**.

To make the connections between land and water, upstream and downstream, and precipitation, groundwater, and streamflow, one must understand the basic concepts and interactions of hydrology. These include gravity, friction, **velocity**, **scouring** and **deposition**.

An understanding of hydrology is also essential to manage natural resources in a watershed. It is hard to understand how to reduce erosion if the connections between plants, soils, and the way water moves across the landscape are unclear. How water moves to a stream and how it moves through a stream are necessary to understand seasonal flows and the frequency and size of floods. This link also determines how well a stream meets the needs of **salmonids** and other aquatic organisms.

Vocabulary

erosion
hydrology
salmonids
sedimentation
velocity
scouring
deposition

Water dynamics

7.1

"The larger streams run still and deep,
Noisy and swift the small brooks run,…"
— Edna St. Vincent Millay

Structures in streams, whether fallen logs, boulders, root wads, or artificial placements, provide habitat diversity and help meet the needs of fish. To understand how these structures function, you must understand the basics of stream hydraulics.

The principal forces acting on water in a stream channel are gravity and friction. Gravity propels water downstream, and friction between the water, streambed, and banks resists this flow.

Water velocity is influenced by:

- steepness of slope,
- size of substrate materials,
- type and amount of riparian area and stream vegetation,
- shape, depth and frequency of pools and riffles,
- meanders of the stream, and
- obstructions.

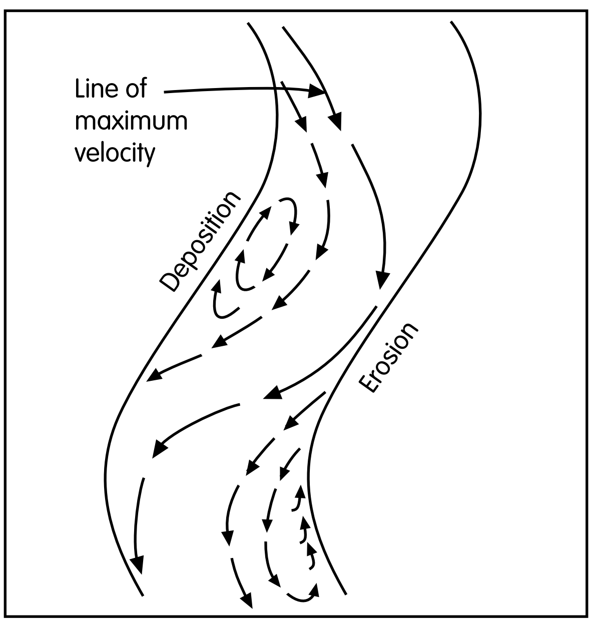
As velocity increases, these factors provide more resistance to flow. This causes eddies, chutes and waterfalls that can dislodge and move objects downstream.

There are three basic stream forms:

1. **straight**—relatively straight or nonmeandering channels,
2. **braided**—channels that meet and re-divide, and
3. **meandering**—single channels with "S"-shaped channel patterns.

A stream will naturally meander whenever possible. In larger streams, a line of maximum velocity, called the **thalweg**, wanders back and forth across a channel in response to streambed configuration. Thalwegs are generally found near the center of a water column because of friction with the streambed and surface tension.

Figure 7. Line of Maximum Velocity



Source: Adapted from Marie Morisawa, *Streams: Their Dynamics and Morphology*, 1968.

Water spiral

Friction between water and streambanks causes water to move in a corkscrew fashion down the channel. This

Vocabulary

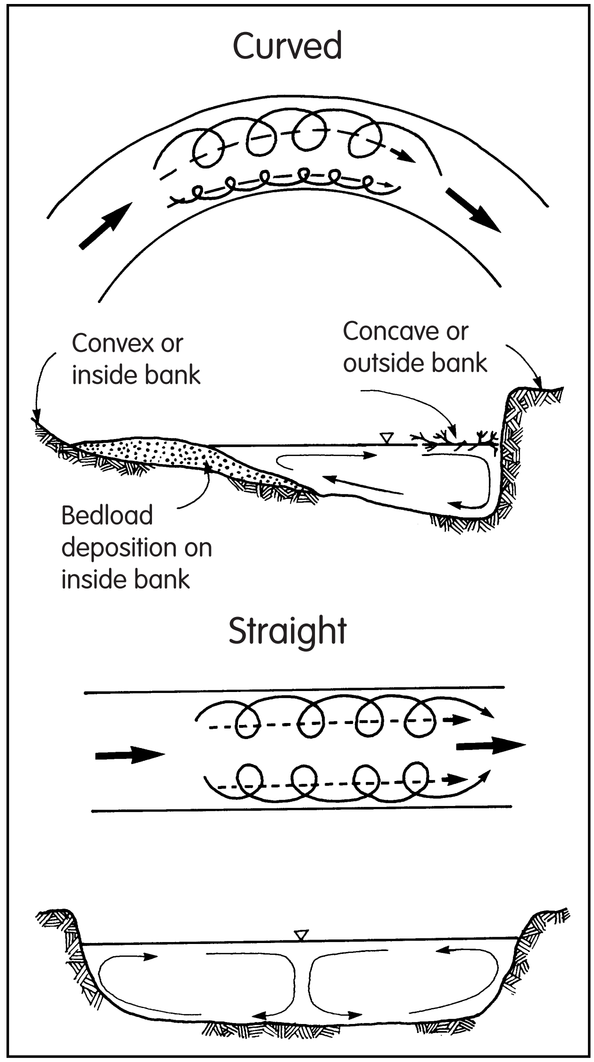
thalweg
water spiral
straight
braided
meandering

corkscrew, or helical flow, is called a **water spiral**. As changes occur in the stream channel (straight or curved, high or low gradient, or as a result of instream structures), the water spiral will change.

A water spiral slows and becomes smaller as it moves along the inside of a curve in a stream channel. As velocity decreases, suspended material carried by the current drops out of the flow and settles along the bend. This change in velocity forms gravel bars and deposits spawning gravel.

A water spiral enlarges and accelerates as it moves around the outside of a curve or an obstruction, such as a boulder. The force of the water is dispersed over a larger area. Thus, increased velocity scours or digs pools during high flows. These pools provide excellent feeding and rearing habitat for fish during low flow periods.

Figure 8. Water Spiral



Source: Adapted from John W. Anderson, "Nuts and Bolts of Stream Rehabilitation," presentation, 1986; and Province of British Columbia, *Stream Enhancement Guide*, 1980.

Extensions

1. The helical flow of water is not constant. It is altered by changes in volume and speed of water. This can be shown with a squeeze bottle of colored water and a pane of glass. Tilt the glass and, using constant pressure on the bottle, squeeze a stream of water onto the raised end.

   Vary the volume of water and angle of the glass to show the effects of changing gradients and flows. Performing this demonstration over the stage of an overhead projector with a pan to collect runoff projects the process onto a screen.

   Note: Be aware of the danger from electrical shock when using water near electrical equipment.

Bibliography

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Binns, N. Allen. *Habitat Quality Index Procedures Manual*. Wyoming Game and Fish Department, 1982.

Leopold, Luna B., et al. *Fluvial Processes in Geomorphology*. New York: W.H. Freeman, 1964.

Morisawa, Marie. *Streams: Their Dynamics and Morphology*. New York: McGraw Hill, 1968.

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Go with the flow!

__Activity Education Standards:__ Note alignment with Oregon Academic Content Standards beginning on p. 483.

Objectives

The student will explain how water contributes to the process of erosion and demonstrate four ways that streams carry sediments.

Method

Students will build a model stream and observe four different ways streams move sediments:

- in solution (salt dissolved in the water)
- as a colloidal suspension (clay particles in suspension)
- by saltation (the bouncing motion of sand particles)
- by rolling and sliding (how large rocks move in real streams)

For younger students:

1. Perform the demonstration in the Extensions on page 202 to teach younger students about flows, speed of flow, and slope before attempting this activity.
2. Help younger students understand the vocabulary in this exercise before beginning the exercise. Modify as needed.
3. Do the activity as a demonstration.

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Materials

Each group will need:

- copies of student sheets pp. 209-212
- stream set-up
  - stream trough (24" length of plastic gutter)
  - collecting pan
  - 1 gallon jug
  - pencils
  - supports (set up as shown in illustration)
- sediments
  - sand
  - round pebbles (light weight, between ½" to 1" in size)
  - flat pebbles (light weight, between ½" to 1" in size)
  - powdered clay (china clay, kaolin, or pottery clay)
  - ion mixture (a saturated solution of table salt and water).
- eyedropper
- mixing jar (paper cup, baby food jar, or other container)
- stirring rod (pencil or a plastic straw)
- clean glass microscope slide
- magnifying glass
- ruler
- water source
- rags, paper towels, or sponges for cleaning up

Note: The teacher will provide a bucket to collect all wet sediments. Do not dump sediments in a sink–they will clog the drain.

Vocabulary

collodial suspension	sediments
saltation	suspended sediments

Notes to the teacher

Use a pencil or screwdriver to punch one hole near a corner of the gallon-size plastic milk jug. Locate the center of the hole about three-quarters of an inch above the jug's base. If want to use two holes to create greater flow, add a second hole about an inch away from the first at the same height.

The holes must be small enough so that a pencil stopper can make the jug water tight. Test the jug for leaks by placing a pencil in the hole and filling it with water. Remove the pencil to see if the holes are large enough to allow water to flow freely from the jug. Use sharp scissors to trim the flaps of plastic around the edges of the hole if necessary.

Ideally, the sand, round pebbles, and flat pebbles should all be quartz or materials of similar density. The point of this activity is to vary particle size, not composition.

Mix a saturated salt solution as follows: Add salt to one-half cup (Approximately 100 ml) of water and stir. Continue adding salt and stirring until no more salt dissolves. Allow the undissolved salt to settle on the bottom of the container. Pour off the clear salt solution above the salt granules without disturbing the undissolved salt.

If you do not have ready access to dry clay from which to make the colloidal suspension called for in Step 7, you can make an acceptable substitute as follows. Take a fist-sized clump of soil that contains some clay, break it up into small pieces, and place it in about two and one-half cups (500 ml) of water. Stir the soil and water vigorously. The smallest particles of the soil (the clay components) will become suspended in the water, making it appear cloudy. The particles in this type of mixture are less than 1/256 mm in diameter. They settle out of the water extremely slowly unless chemicals (such as alum) are added to clump them together.

Pour off the top layer of cloudy water from the container, and use it in Step 6. When decanting the cloudy water, avoid disturbing the larger particles of soil that sink to the bottom. Skim off any organic material that floats to the top.

You may want to discuss the definitions of clay, sand, and pebbles with students before performing this activity.

Background

Do you know . . .

… that streams move more than water from the mountains to the sea? In this activity, you will investigate how a stream carries **sediments**. All streams carry a load of sediments including sand, pebbles, dissolved minerals, and **organic materials**. Flowing water can quite literally move mountains—one small piece at a time—to a river delta or an ocean basin.

Sediments are the fragments of rocks, minerals, and organic material produced by weathering and erosion. Sediments can be as large as huge boulders moved by flooding streams, as small as atom-sized minerals dissolved as ions or salts in stream water, or anywhere in between.

Fast, rain-swollen streams carry heavy sediment loads; wherever they slow down, part of that load is deposited on the streambed. The largest particles fall to the bottom first. Smaller particles suspended in the water eventually settle to the bottoms of lakes or ocean basins. All streams carry sediments in an endless trip from dry land to the ocean basins, where the lower layers of sediments are slowly transformed back into rock by the pressure of overlying sediments.

Water is an important agent of erosion. Water running over the surface of the ground or in streams is constantly lowering and leveling the land above sea level. Waterborne sediments are the tools of the streams, carving out valleys and canyons as they move along. As anyone who has noticed the smooth, rounded rocks in a swift-running mountain stream may know, the tumbling and scraping tends to smooth and round the sediments as they move downstream.

Procedure

Now it's your turn . . .

Use the illustration to help you set up the stream. Set the stream trough with the upper end elevated about 2½ inches above the table surface. Place the collecting pan at the lower end. Adjust the level of the jug supports so that the base of the jug is about 4 inches above the table (1½ inches above the end of the trough). Place the pencils in the holes in the jug. Fill it with water and set it on the support.

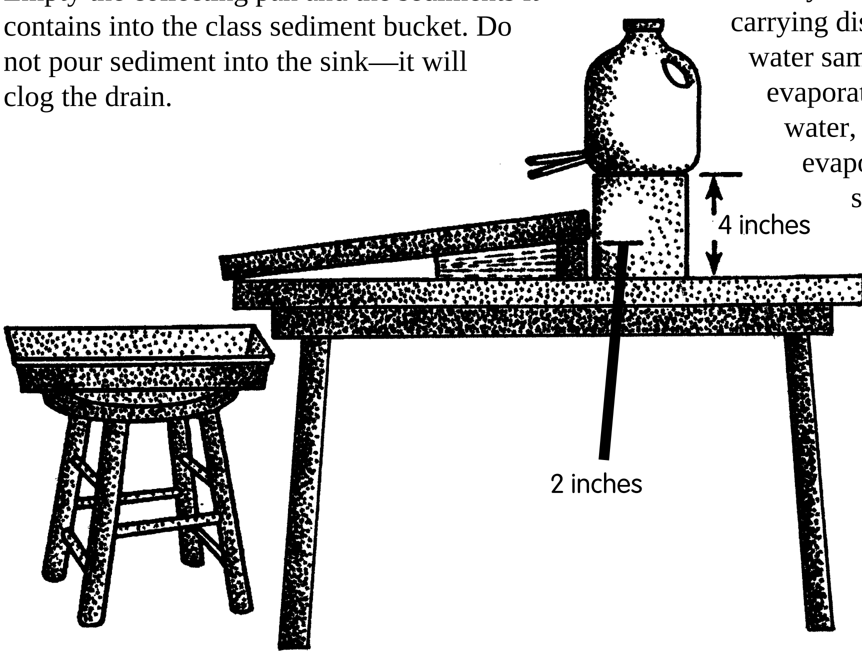
Sand

Allow water to flow from the hole in the jug. Drop a pinch of sand (no more than you can hold between two fingers) into the flowing water near the upper end of the trough and observe the movement of the sand particles.

You may see particles of sand bouncing along in the flowing water. This type of movement is called **saltation**. Both wind and water move sand in this way.

Answer the questions about the movement of sand.

After observing the motion of the sand, remove any sediment remaining in the trough. Empty the collecting pan and the sediments it contains into the class sediment bucket. Do not pour sediment into the sink—it will clog the drain.



Pebbles

Place four round and four flat pebbles in the upper end of the trough. Allow the water to begin flowing over them. Observe what happens and answer the questions about the movement of pebbles. After observing the movements of the pebbles, remove them from the trough. Empty the collecting pan into the class sediment bucket.

Clay

Put two pinches of powdered clay in a mixing cup of water and stir vigorously until the mixture appears cloudy. This clay-and-water mixture is called a **colloidal suspension**. Start the water flowing down the trough from one hole and pour the suspension of clay and water into the upper end of the stream. Observe what happens and answer the questions about the movement of clay. After observing the motion of the clay, remove any clay remaining in the trough. Empty the collecting pan into the class sediment bucket.

Salt solution

Use the eye dropper to add a small amount of salt solution to the upper end of the flowing stream of water. Observe what happens and answer the questions about the movement of solutions.

One way to tell whether or not a stream is carrying dissolved materials is to get a water sample and allow the water to evaporate. If salts are present in the water, they will **crystalize** as the water evaporates. Test for the presence of salt in the ion mixture as follows.

Place two drops of the ion mixture on a clean microscope slide. Set the slide in a warm place and allow the water to evaporate. Use a hand magnifying lens (or microscope, if one is available) to observe what remains after the water evaporates. Sketch or describe your observations in the space provided for Question 7.

Questions

Sand

1. Imagine millions of grains of sand bouncing along in the water of a stream. How might the sand change the streambed?

   Millions of sand particles bouncing along a streambed act like a grinder, smoothing out the streambed and any large rocks lying in it.

2. Would the grains of sand be changed by bouncing along? In what way?

   Yes, the sand grains themselves become smoother and rounder from rubbing against the streambed and each other.

Pebbles

3. Describe how the pebbles move down the trough. Do round pebbles move in the same way as flat pebbles? How are their movements different? Which do you think would move down the stream the fastest? Why?

   Round pebbles roll down the trough. Flat pebbles slide along. The round pebbles move faster and are less likely to catch on other materials in the streambed.

4. How do you think the shape of the pebbles might change if they were moving down a stream over long distances?

   As rocks slide and tumble over one another and because of abrasive sediments like sand, they tend to develop smooth surfaces and rounded edges. The smooth, rounded gravel found in fast-moving mountain streams is produced in this manner.

Clay

5. How is the colloidal suspension transported by the stream? How fast do colloids move compared to sand or pebbles?

   Particles in colloidal suspensions are carried along suspended in the moving water of a stream. They move at the same speed as the water, faster than sand or pebbles.

Salt solution

6. Can you see the salt solution being carried by the stream? How fast do dissolved materials move compared to sand, pebbles, or colloids? Describe how solutions are carried by streams.

   You cannot directly observe solutions carried by streams. Like colloids, solutions move at the same speed as the water. The material is carried by the water in a form that is invisible to the naked eye, but can be detected by various tests, such as the one suggested.

7. If you tested for salt in the solution, describe or sketch the results of your test.

   The sodium chloride (NaCl, or table salt) used to prepare the ion solution will form cubic crystals.

8. List four ways streams move sediments.
   Sediments are transported:
   - ***in solution (like the salt dissolved in the water)***
   - ***as a colloidal suspension (such as clay particles that are too small to see individually, but give the water an overall milky appearance)***
   - ***by saltation (the bouncing motion of sand particles)***
   - ***by rolling and sliding (like rocks and boulders in a real streams)***
9. Is a faster-moving stream able to carry more, less, or the same amount of sediments as a slower-moving stream?
   A faster-moving stream can carry *more* ***sediments than a slower stream.***
10. Is a faster-moving stream able to carry larger, smaller, or the same size sediments as a slower-moving stream.
    A faster-moving stream can carry *larger* ***sediments than a slower stream.***

Going further

1. Use the following procedures to investigate how the speed of the stream affects the sediment it can transport.
   - Measure out two equal quantities of mixed sediments (consisting of sand, soil, and small pebbles).
   - Set the stream trough at a “low” setting (about an inch above the table) so that it will have a slow rate of flow.
   - Place one of the sediment samples at the upper end of the stream trough and time how long it takes the water coming from the one-hole jug to carry the sediments to the bottom of the trough.
   - Reset the stream trough at a “high” setting (4 inches above the table), increasing the speed of the water flowing though it.
   - Place the second sediment sample at the upper end of the stream trough and time how long it takes the water coming from the one-hole jug to carry the sediments to the bottom of the trough.
   - Compare the times required to move the sediments for the “slow” and the “fast” streams.
2. Design an experiment to determine the speeds needed to carry specific-size sediments or sediments of different densities.

Name

Go with the flow!

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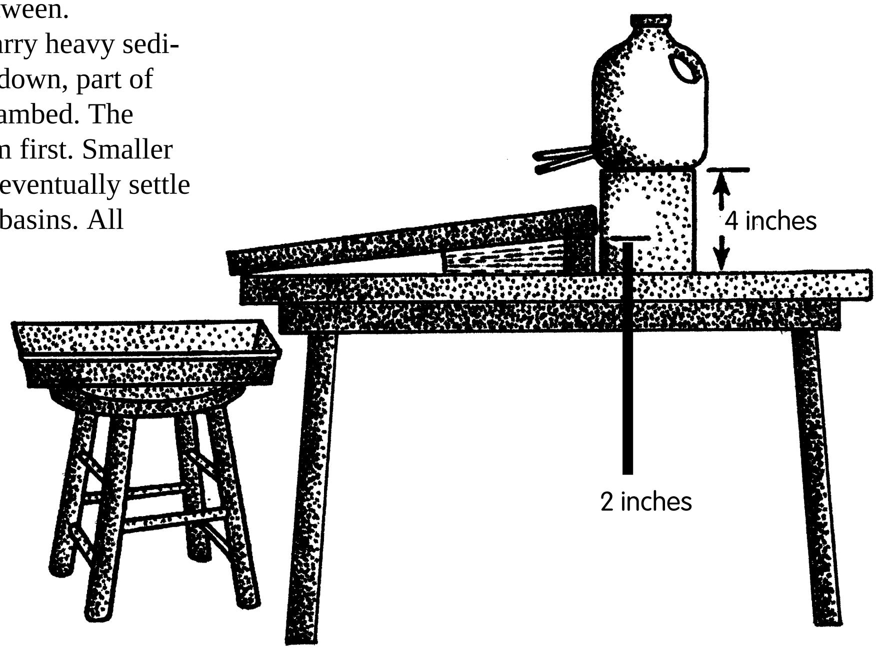

Adapted with permission from Special Publications, *Earth: The Water Planet* by Jack Gartrell, Jr., Jane Crowder, and Jeffrey Callister, Copyright © 1989 by the National Science Teachers Association, 1840 Wilson Boulevard, Arlington, VA 22201-3000

Vocabulary

collodial suspension
saltation
sediments
suspended sediments

Student sheet

level of the jug supports so that the base of the jug is about 4 inches above the table (1½ inches above the end of the trough). Place the pencils in the holes in the jug. Fill it with water and set it on the support.

Sand

Allow water to flow from the hole in the jug. Drop a pinch of sand (no more than you can hold between two fingers) into the flowing water near the upper end of the trough and observe the movement of the sand particles.

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Questions

Sand

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Clay

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10. Is a faster-moving stream able to carry larger, smaller, or the same size sediments as a slower-moving stream.

Water quantity

7.2

"Don't pray for the rain to stop. Pray for good luck fishing when the rivers flood."
— Wendell Berry

The quantity of water directly affects plants and animals that live in a stream and humans that use it. *Volume and velocity are key dimensions of water quantity.* These change with the season and are influenced by human actions, soil movement from erosion and landslides, and vegetation changes from fire, logging, grazing, disease and windstorms.

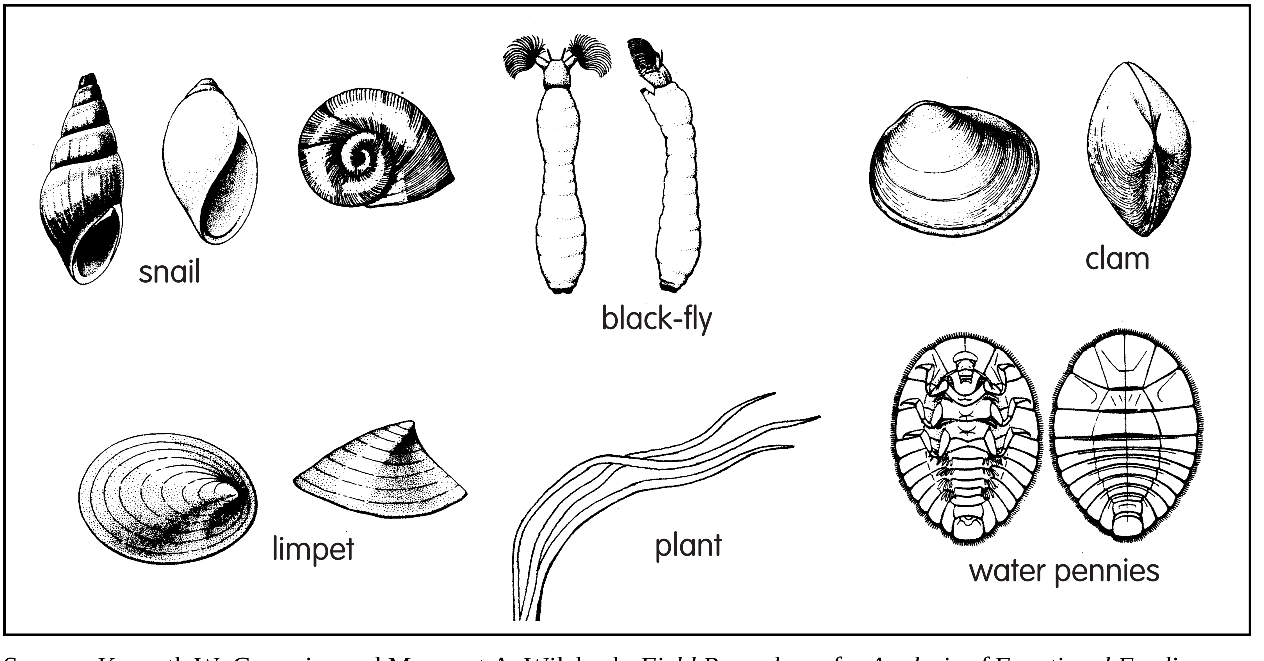
The volume of water affects composition of the streambed by moving and depositing sediments and debris. Fast-moving water carries more and larger material. The channel of a rapidly moving stream will have larger material, but a slowly moving stream will have a bed covered with mud and silt.

Velocity

Flow velocity is one of the main factors that determines the character of a stream. Velocity directly influences:

- dissolved oxygen (DO) concentration through aeration at the surface,
- water temperature through evaporation,
- composition of the streambed, and

Figure 9. Plant and Animal Adaptations to Water Velocity



Source: Kenneth W. Cummins and Margaret A. Wilzbach, *Field Procedures for Analysis of Functional Feeding Groups of Stream Macroinvertebrates,* 1985.

- amount of nutrients available to organisms.

Velocity is a measure of how fast water moves. Velocity is calculated in feet per second (velocity = ft/sec). The substrate also influences streamflow. A factor of 0.9 is used for smooth mud, silt or bedrock streambeds, and 0.8 for rubble, gravel or plant-covered streambeds. Streamflow (or discharge) is calculated in cubic feet per second (cfs). (Average width × average depth × velocity × bottom factor = streamflow in cfs.)

Volume and velocity are key dimensions of water quantity.

Adaptations to velocity

The rate at which a stream flows determines which plants and animals can live there. Plants adapted to fast water have strong, spreading roots for secure attachment. Their thin flexible stems offer little resistance to the current and have less chance of breaking. Algae adapted to fast flowing water have filaments that "stream" in the direction of the current.

Animals have a variety of adaptations. Clams and mussels burrow into the bottom avoiding the current. Blackfly larvae and limpets attach to rocks with sucker-like structures and use streamlined shapes to avoid being swept away. Water pennies have a streamlined, flattened shape. Snails adhere to the bottom with a broad foot. Fish and other organisms move to pockets of slower water.

Extensions

1. "We'll Form a Bucket Brigade," *Earth: The Water Planet*, pp. 85-89. Grades 4-8.
2. "Building A Model of A Stream," *Earth: The Water Planet*, pp. 35-38. Grades 4-8.
3. "What Factors Affect the Speed of A Stream?" *Earth: The Water Planet*, pp. 43-46. Grades 4-8.
4. "Calculating the Rate of Flow of A Stream," *Earth: The Water Planet*, pp. 39-42. Grades 4-8.

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A study in streamflows

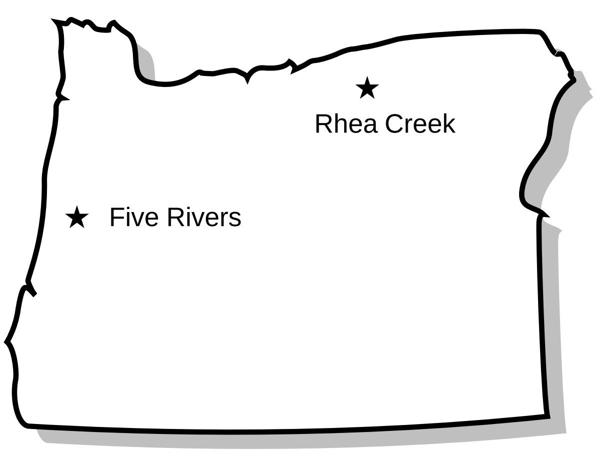
Activity Education Standards: *Note alignment with Oregon Academic Content Standards beginning on p. 483.*

Objectives

Students will (1) examine annual streamflow rates for two Oregon streams; (2) compare streamflows in an eastern Oregon stream and a western Oregon stream in terms of peak flows, critical periods, and related water quality aspects; (3) calculate the number of people who could be supported by average and minimum streamflows in these streams; and (4) predict how streamflow patterns can affect fish, wildlife, and human populations.

Method

Students will graph annual streamflow patterns for two Oregon streams—one representative of eastern Oregon and one representative of western Oregon—then compare and contrast the two. In addition, students will calculate and compare how many people could be supported by the discharge (streamflow) in these streams.



Activity adapted from *Investigating Your Environment—Water*, Pacific Northwest Region, 1993 and earlier versions.

For younger students

1. Read activity background information aloud to younger students or modify for your students' reading level.
2. Enlarge the graph on a copy machine or use a large piece of graph or chart paper. Modify questions to fit student vocabulary levels.
3. Part 2: Calculate streamflow usage and use as an example with students. Questions for Part 2 may require significant modification.

Materials

- copies of student sheets (pp. 223-230)

Background

Do you know . . .

The amount of water in a stream varies throughout a year. We can predict some of this variation because it is related to the **climate** (long-term weather patterns) of a region. Other variations are harder to predict, because they are caused by removal of watershed vegetation, associated with urban development, agricultural practices, and logging and grazing practices.

When the vegetation is removed, the soil cannot store and hold as much water. This means more water will run off the watershed, creating

Vocabulary

climate	erosion
cubic feet per second	sediment

higher peak flows. Higher flows carry more **sediment** and **erosion** of stream channels is greater. Less water storage in the watershed also means lower minimum flows during dry periods, leading to higher water temperatures and reduced oxygen.

People manage watersheds so the water in the watershed can be used to the best advantage for the resource and all other concerns. It is easy to imagine how many uses there are for a stream's water—human drinking water, irrigation for crops, hydroelectric power, water transportation, and the needs of aquatic and terrestrial life, to name a few. When decisions must be made about what uses will have priority over a year's time, it is necessary to predict peak and minimum flows.

Obviously, it is beneficial to all uses to store water in a healthy watershed. Disturbed watersheds cannot store as much water and much of the water goes to waste. Water management is tricky business!

In the Pacific Northwest, precipitation comes primarily in the form of rain or snow, and lowest streamflows generally occur in late summer. Also, rainfall tends to affect streamflow more quickly than snowfall. Streams with snow as a water source tend to experience peak flows later in the spring when the snow is melting.

Procedure

Now it's your turn . . .

Are streamflows west of the Cascade mountain range different from those east of the Cascades? How many people can be supported by water in our streams? In this exercise, you will look at streamflow data from Rhea Creek, in northeastern Oregon, and compare it with Five Rivers, a stream in the western Oregon Coast Range. Then, you will learn how to estimate the number of people who could potentially rely on those streams for their water.

Part 1

Five Rivers is a tributary of the Alsea River in the Coast Range west of the Cascades. Rhea Creek is a tributary of Willow Creek in the Blue Mountains east of the Cascades.

Streamflow (discharge) rates combine the two key dimensions of water quantity (volume and rate of flow) into one figure—cubic feet per

Streamflow Data

Rhea Creek, near Heppner, Oregon

Drainage area: 120 mi^2
Altitude: 2,320 feet at measuring station
Many irrigation diversions above measuring station.

Average discharge: 18.9 cfs
Highest recorded maximum discharge: 1,280 cfs, June 10, l969
Lowest recorded minimum discharge: no flow at times

Mean discharge (streamflow) in cubic feet per second (cfs)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep
5	10	21	37	48	63	35	18	19	6	2	2

Five Rivers, near Fisher, Oregon

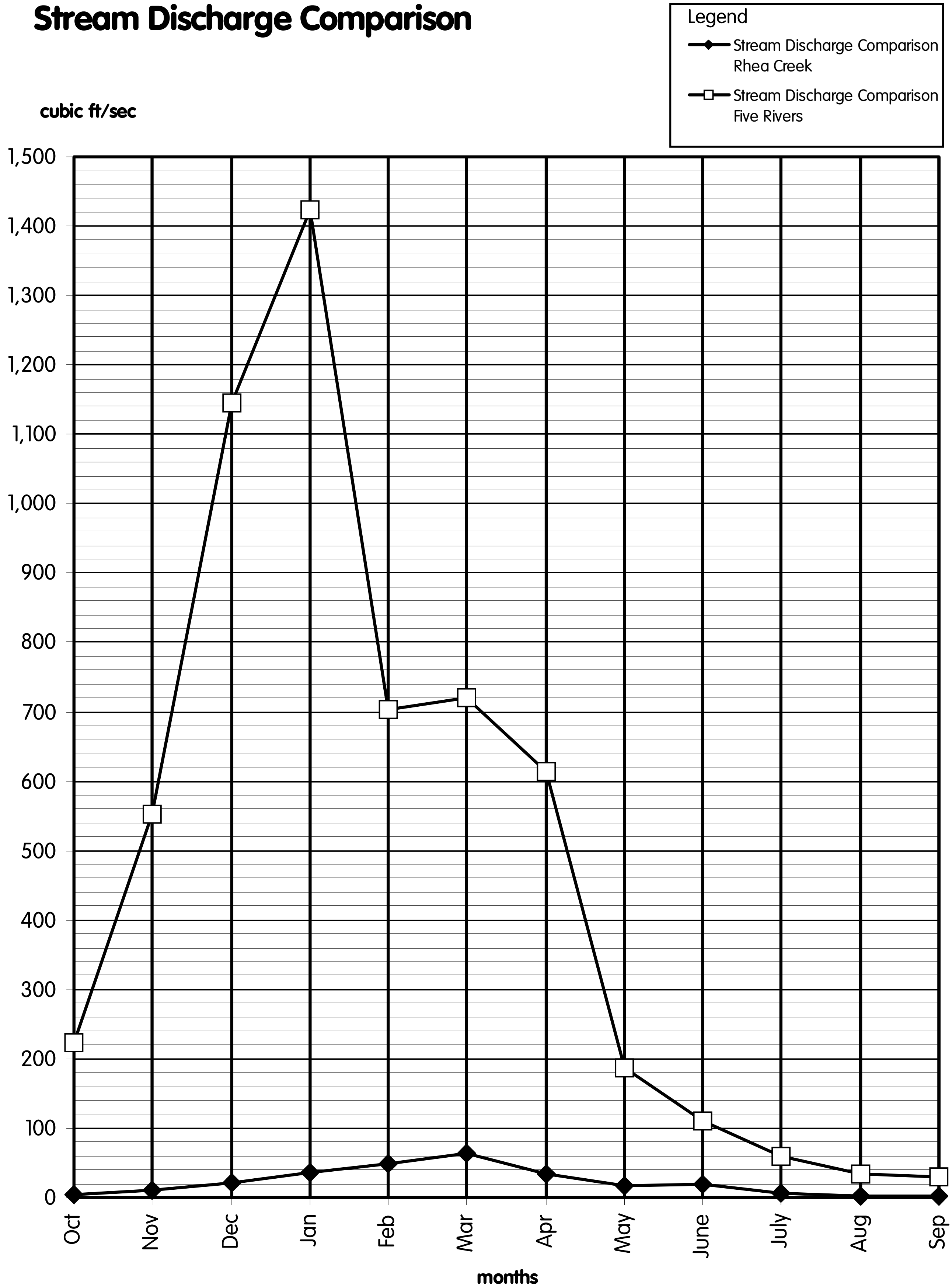
Drainage area: 114 mi^2
Altitude: 130 feet at measuring station
No regulation or diversion above measuring station

Average discharge = 551 cfs
Highest recorded maximum discharge: 17,200 cfs, Jan. 21, l972
Lowest recorded minimum discharge: 16 cfs, Oct. 1, l967

Mean discharge (streamflow) in cubic feet per second (cfs)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep
223	552	1146	1423	703	721	613	186	111	60	34	30

Stream Discharge Comparison



second (cfs). **One cubic foot per second is a block of water one foot high, one foot across, and one foot deep, passing by a given point every second.**

Streamflows (discharge rates in cubic feet per second) vary throughout the year and may influence activities and aquatic life associated with streams. Plot monthly streamflow on the graph provided, using two colored lines. Create a legend that shows the appropriate color for each stream. After the graph has been completed, answer the questions that follow.

Note: This information includes only one year of streamflow data for these two streams. Varying seasonal conditions may change streamflow patterns over a number of years.

Questions

1. What could explain the peak flow of Rhea Creek occurring two months later than the peak flow of Five Rivers?

   Rhea Creek's source is melting snow rather than seasonal rainfall.

2. During which month would the most gravel and sediment be carried downstream in Five Rivers?

   January

   In Rhea Creek?

   March

3. Could streamflow influence or modify the temperature of a stream? What other factors could modify stream temperature?

   Yes. Shading, stream depth and the temperature of water coming into the stream.

4. Could streamflow affect the amount of dissolved oxygen in the water? How?

   Yes. Low flows mean less turbulence to mix air and water.

5. In which month(s) would you predict Five Rivers would have the lowest dissolved oxygen level?

   July through September.

   In Rhea Creek?

   June through October.

   Why?

   High temperatures reduce the ability of the water to hold oxygen.

6. What would be the two most critical periods for fish survival in Five Rivers or Rhea Creek? Why would these time periods be so critical to survival of fish?

   Lowest streamflow and highest streamflow. Low streamflows mean higher temperatures and less DO. High streamflows mean high velocity water and more suspended sediments.

7. What could fish or other wildlife do to survive these periods?

   During low flows, they could congregate where there are pools or migrate to other sources of water. During high flows, fish could find cover along edges or behind boulders to avoid being swept downstream. Wildlife must have water to drink. During drier periods, when streamflows are lowest, they must congregate near a water source.

8. What is the fate of fish or other wildlife in an area if streamflows are too low during critical periods?

   If streamflows are too low, fish and wildlife are in greater competition for the water, and they might die if the water source will not support the population.

9. How would irrigation diversions on a stream affect the fish in that stream? What information would a biologist need to know in order to manage the stream?
It would lower the amount of water in the stream and affect the ability of the fish population to survive. A biologist would have to know how much water is being withdrawn and when it is being withdrawn. Unfortunately, the critical period for fish is also the period when irrigation is needed most.

Part 2

Streamflow information is needed to estimate the amount of water available for use in a watershed. Generally, one needs to consider the period of time when flows are the lowest, in order to make decisions based on the amount of water available. In the following activity you will calculate the amount of water available for human use based on average streamflows and compare it with the number of people that could be supported by the minimum streamflows. **Average streamflow** refers to the average discharge over the entire 12-month period shown in the data and is listed in the Streamflow Data table on page 216 describing each stream system. **Minimum average streamflow** refers to the lowest mean discharge for any one month during the 12-month period covered by the data.

10. Predict the number of people that could be supported by the average streamflow for Rhea Creek.
Answers will vary.

    Minimum average streamflow for Rhea Creek.
    Answers will vary.

    Minimum average streamflow for Five Rivers.
    Answers will vary.

11. Use the following formulas to compute how many people could live from the water in these streams.

Rhea Creek

18.9	×	7.48	=	**141.4**				
Average streamflow (cubic feet/second)		Gallons in 1 cu. ft. of water		Gallons of water/second				
141.4	×	60	=	**8,484**				
Gallons of water/second		Seconds in minute		Gallons of water/minute				
8,484	×	1440	=	**12,216,960**	/	200*	=	**61,084.8**
Gallons of water/minute		# Minutes/Day		Total gallons Water/Day		Amount of water one person uses per day (gallons)		Total # people who could live from water in this stream

Rhea Creek

2	×	7.48	=	**15**						
Minimum average streamflow (cubic feet/second)		Gallons in 1 cu. ft. of water		Gallons of water/second						
15	×	60	=	**900**						
Gallons of water/second		Seconds in minute		Gallons of water/minute						
900	×	1440	=	**1,296,000**	/	200*	=	**6,480**		
Gallons of water/minute		# Minutes/Day		Total gallons Water/Day		Amount of water one person uses per day (gallons)		Total # people who could live from water in this stream		

Five Rivers

30	×	7.48	=	**224.4**				
Minimum average streamflow (cubic feet/second)		Gallons in 1 cu. ft. of water		Gallons of water/second				
224.4	×	60	=	**13,464**				
Gallons of water/second		Seconds in minute		Gallons of water/minute				
13,464	×	1440	=	**19,388,160**	/	200*	=	**96,940.8**
Gallons of water/minute		# Minutes/Day		Total gallons Water/Day		Amount of water one person uses per day (gallons)		Total # people who could live from water in this stream

* The average person uses about 200 gallons of water a day for home use. This does not reflect each person's share of water used for industrial, public services, and commercial uses. (U.S. Office of Education figures.)

12. How did your predictions compare with the actual calculations for each of the situations above?
    Answers will vary.

13. In this activity, minimum average streamflows have only been considered with respect to the number of people that could be supported by these flows. If the minimum average streamflow required to support resident and anadromous (migratory) fish populations in the Five Rivers example was 20 cubic feet per second, then how many people would that exclude?

    20 × 7.48 = 149.6 gallons of water per second

    149.6 × 60 = 8,976 gallons of water per minute

    8,976 × 1,440 = 12,925,440 gallons of water per day

    12,925,440 ÷ 200 = 64,627.2 people.

14. If Five Rivers' flows were maintained for fish first and people second, how many people could be supported by the 30 cubic feet per second flow if 20 cubic feet per second of that amount were reserved for maintenance of the fish population? What does this example suggest about the conflicts for water usage?

    32,313.6 people. There are many demands on the available water supply and all must be carefully considered in management decisions affecting that water use.

15. Which of the following, average streamflow, maximum streamflow, or minimum streamflow, can be depended upon year-round?

    Minimum streamflow is the only amount that can be depended on year-round.

16. How can society change or affect the water quantity situation in a particular area?

    a. Human actions can destroy the natural functions of the watershed with poor management involving the practices of logging, agriculture, mining, road building, building construction, or livestock grazing.

    b. Human actions can restore the natural functions of the watershed through better management decisions affecting practices which have in the past harmed the watershed's ability to provide plentiful, pure water.

    c. Impoundments can be constructed to catch and store water during periods of high flows to be released during periods of low flow.

    Note: The pros and cons of these and other answers should be discussed to provide students with a fair treatment of the issues involved.

Going further

1. Design an experiment to measure the oxygen content of water at different temperatures and levels of agitation (or turbulence).
2. Make monthly streamflow measurements of a stream near your school (see Chapter 12 for the Streamflow Data Sheet). Compare your streamflow figures to those of Rhea Creek and Five Rivers.
3. Analyze historical streamflows for a river in your area and compare with present streamflows. Hypothesize reasons for differences, if any. Prepare a display to share the results of your research.

Name

A study in streamflows

Do you know . . .

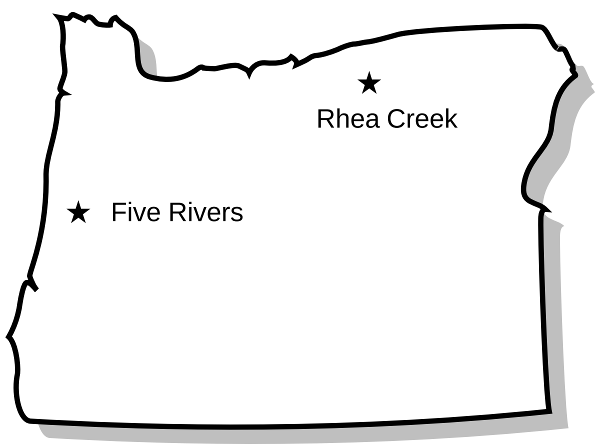
... that the amount of water in a stream varies throughout a year. We can predict some of this variation because it is related to the **climate** (long-term weather patterns) of a region. Other variations are harder to predict, because they are caused by removal of watershed vegetation, associated with urban development, agricultural practices, and logging and grazing practices.

When the vegetation is removed, the soil cannot store and hold as much water. This means more water will run off the watershed, creating higher peak flows. Higher flows carry more **sediment** and **erosion** of stream channels is greater. Less water storage in the watershed also means lower minimum flows during dry periods, leading to higher water temperatures and reduced oxygen.

People manage watersheds so the water in the watershed can be used to the best advantage for the resource and all other concerns. It is easy to imagine how many uses there are for a stream's water—human drinking water, irrigation for crops, hydroelectric power, water transportation, and the needs of aquatic and terrestrial life, to name a few. When decisions must be made about what uses will have priority over a year's time, it is necessary to predict peak and minimum flows.

Obviously, it is beneficial to all uses to store water in a healthy watershed. Disturbed watersheds cannot store as much water and much of the water goes to waste. Water management is tricky business!

In the Pacific Northwest, precipitation comes primarily in the form of rain or snow, and lowest streamflows generally occur in late summer. Also, rainfall tends to affect streamflow more quickly than snowfall. Streams with snow as a water source tend to experience peak flows later in the spring when the snow is melting.



Activity adapted from *Investigating Your Environment—Water,* Pacific Northwest Region, 1993 and earlier versions.

Vocabulary

climate
cubic feet per second
erosion
sediment

Student sheet

Now it's your turn . . .

Are streamflows west of the Cascade mountain range different from those east of the Cascades? How many people can be supported by water in our streams? In this exercise, you will look at streamflow data from Rhea Creek, in northeastern Oregon, and compare it with Five Rivers, a stream in the western Oregon Coast Range. Then, you will learn how to estimate the number of people who could potentially rely on those streams for their water.

Part 1

Five Rivers is a tributary of the Alsea River in the Coast Range west of the Cascades. Rhea Creek is a tributary of Willow Creek in the Blue Mountains east of the Cascades.

Streamflow (discharge) rates combine the two key dimensions of water quantity (volume and rate of flow) into one figure—cubic feet per second (cfs). **One cubic foot per second is a block of water one foot high, one foot across, and one foot deep, passing by a given point every second.**

Streamflows (discharge rates in cubic feet per second) vary throughout the year and may influence activities and aquatic life associated with streams. Plot monthly streamflow on the graph provided, using two colored lines. Create a legend which shows the appropriate color for each stream. After the graph has been completed, answer the questions which follow.

Note: This information includes only one year of streamflow data for these two streams. Varying seasonal conditions may change streamflow patterns over a number of years.

Streamflow Data

Rhea Creek, near Heppner, Oregon

Drainage area: 120 mi^2
Altitude: 2,320 feet at measuring station
Many irrigation diversions above measuring station.

Average discharge: 18.9 cfs
Highest recorded maximum discharge: 1,280 cfs, June 10, l969
Lowest recorded minimum discharge: no flow at times

Mean discharge (streamflow) in cubic feet per second (cfs)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep
5	10	21	37	48	63	35	18	19	6	2	2

Five Rivers, near Fisher, Oregon

Drainage area: 114 mi^2
Altitude: 130 feet at measuring station
No regulation or diversion above measuring station

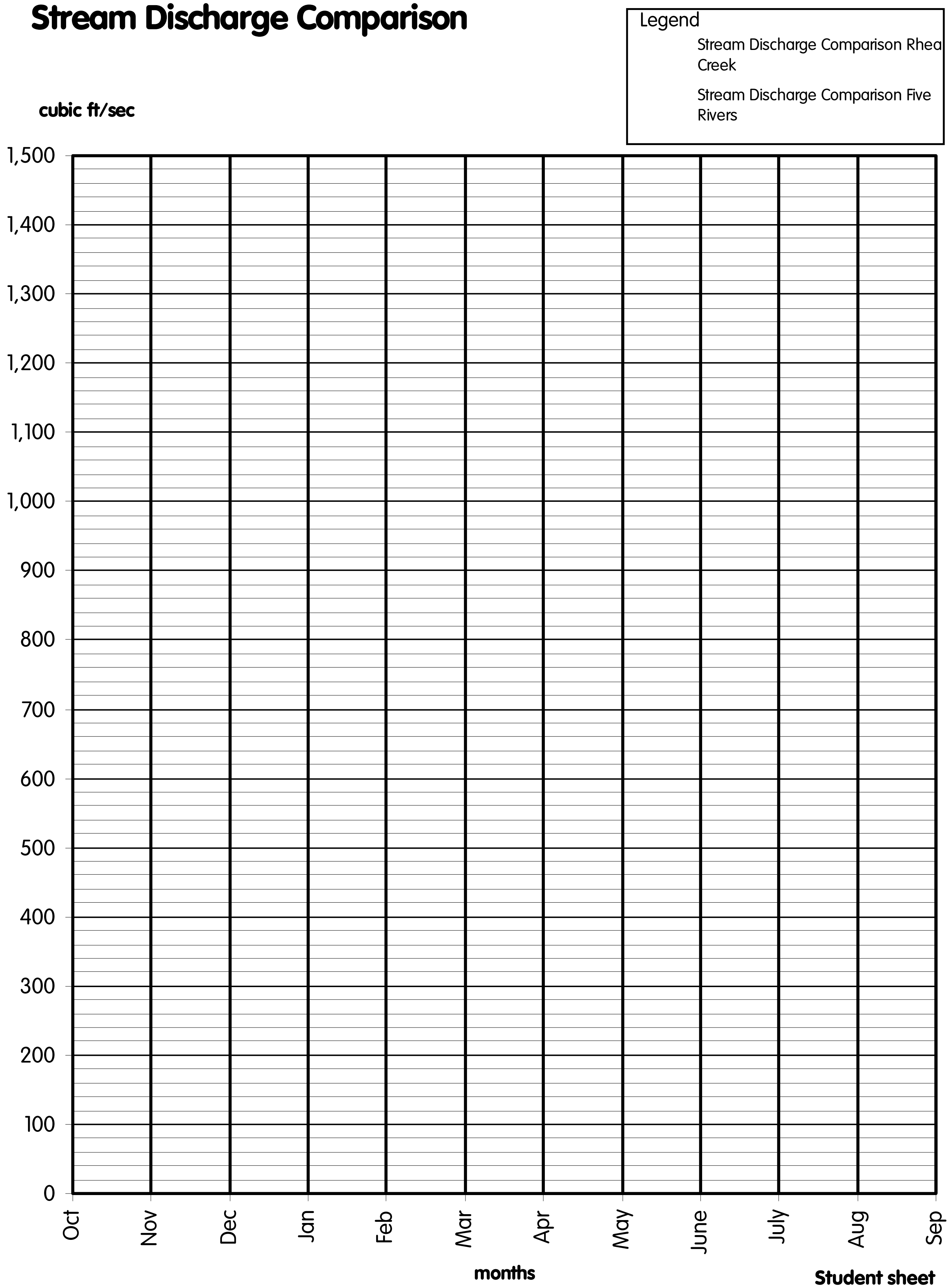
Average discharge = 551 cfs
Highest recorded maximum discharge: 17,200 cfs, Jan. 21, l972
Lowest recorded minimum discharge: 16 cfs, Oct. 1, l967

Mean discharge (streamflow) in cubic feet per second (cfs)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep
223	552	1146	1423	703	721	613	186	111	60	34	30

Student sheet

Stream Discharge Comparison



Student sheet

Questions

1. What could explain the peak flow of Rhea Creek occurring two months later than the peak flow of Five Rivers?

2. During which month would the most gravel and sediment be carried downstream in Five Rivers?

   In Rhea Creek?

3. Could streamflow influence or modify the temperature of a stream? What other factors could modify stream temperature?

4. Could streamflow affect the amount of dissolved oxygen in the water? How?

5. In which month(s) would you predict Five Rivers would have the lowest dissolved oxygen level?

   In Rhea Creek?

   Why?

6. What would be the two most critical periods for fish survival in Five Rivers or Rhea Creek? Why would these time periods be so critical to survival of fish?

7. What could fish or other wildlife do to survive these periods?

8. What is the fate of fish or other wildlife in an area if streamflows are too low during critical periods?

9. How would irrigation diversions on a stream affect the fish in that stream? What information would a biologist need to know in order to manage the stream?

Part 2

Streamflow information is needed to estimate the amount of water available for use in a watershed. Generally, one needs to consider the period of time when flows are the lowest, in order to make decisions based on the amount of water available. In the following activity you will calculate the amount of water available for human use based on average streamflows and compare it with the number of people that could be supported by the minimum streamflows. **Average streamflow** refers to the average discharge over the entire 12-month period shown in the data and is listed in the Streamflow Data table on page 224 describing each stream system. **Minimum average streamflow** refers to the lowest mean discharge for any one month during the 12-month period covered by the data.

10. Predict the number of people that could be supported by the average streamflow for Rhea Creek.

Minimum average streamflow for Rhea Creek.

Minimum average streamflow for Five Rivers.

11. Use the following formulas to compute how many people could live from the water in these streams.

Rhea Creek

____________	×	7.48	=	____________				
Average streamflow (cubic feet/second)		Gallons in 1 cu. ft. of water		Gallons of water/second				
____________	×	60	=	____________				
Gallons of water/second		Seconds in minute		Gallons of water/minute				
____________	×	1440	=	____________	/	200*	=	____________
Gallons of water/minute		# Minutes/Day		Total gallons Water/Day		Amount of water one person uses per day (gallons)		Total # people who could live from water in this stream

Student sheet

Rhea Creek

____________________	×	______7.48______	=	__________________				
Minimum average streamflow (cubic feet/second)		Gallons in 1 cu. ft. of water		Gallons of water/second				
____________________	×	_____60_____	=	__________________				
Gallons of water/second		Seconds in minute		Gallons of water/minute				
____________________	×	_1440_	=	____________	/	____200*___	=	________
Gallons of water/minute		# Minutes/Day		Total gallons Water/Day		Amount of water one person uses per day (gallons)		Total # people who could live from water in this stream

Five Rivers

____________________	×	______7.48______	=	__________________				
Minimum average streamflow (cubic feet/second)		Gallons in 1 cu. ft. of water		Gallons of water/second				
____________________	×	_____60_____	=	__________________				
Gallons of water/second		Seconds in minute		Gallons of water/minute				
____________________	×	__1440__	=	____________	/	____200*___	=	________
Gallons of water/minute		# Minutes/Day		Total gallons Water/Day		Amount of water one person uses per day (gallons)		Total # people who could live from water in this stream

* The average person uses about 200 gallons of water a day for home use. This does not reflect each person's share of water used for industrial, public services, and commercial uses. (U.S. Office of Education figures.)

12. How did your predictions compare with the actual calculations for each of the situations above?

Student sheet

13. In this activity, minimum average streamflows have only been considered with respect to the number of people that could be supported by these flows. If the minimum average streamflow required to support resident and anadromous (migratory) fish populations in the Five Rivers example was 20 cubic feet per second, then how many people would that exclude?

14. If Five Rivers flows were maintained for fish first and people second, how many people could be supported by the 30 cubic feet per second flow if 20 cubic feet per second of that amount were reserved for maintenance of the fish population? What does this example suggest about the conflicts for water usage?

15. Which of the following, average streamflow, maximum streamflow, or minimum streamflow, can be depended upon year-round?

16. How can society change or affect the water quantity situation in a particular area?

Streambed

7.3

"Regard now the sloping, mountainous rocks.
And the river that batters its way over stones…"
— Wallace Stevens

The bottom composition of a streambed determines the types of habitats and aquatic life found in a stream. Generally, the steeper the gradient and harder the rock layers, the faster and more narrow the stream will be. Gently sloping gradients and "S"-shaped curves characterize a slow moving stream. Different types of streams will have specific substrates, habitat types and aquatic organisms.

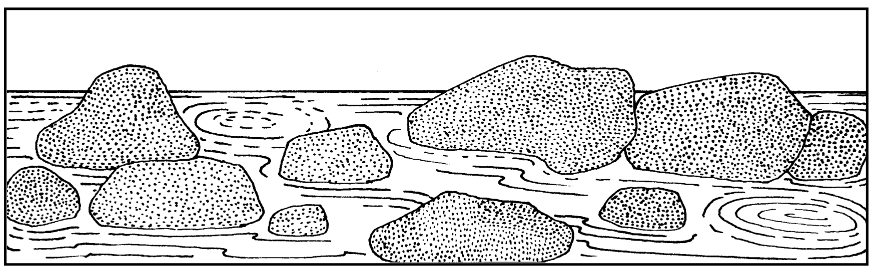
The **streambed** is the part of a stream over which water moves. **Substrate** is the mineral or inorganic material that forms a streambed.

Substrate types

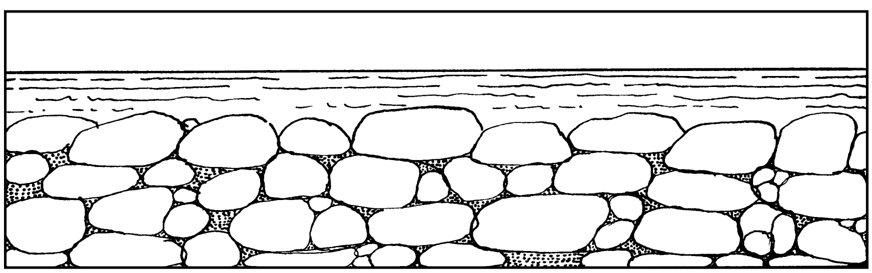
Boulders are 12 inches or more in size and are the largest substrate materials. Movement of water around boulders scours small pools in which fish rear and rest.

Rubble or **cobble** stabilizes the bottom of streams and provides habitat for fish rearing.

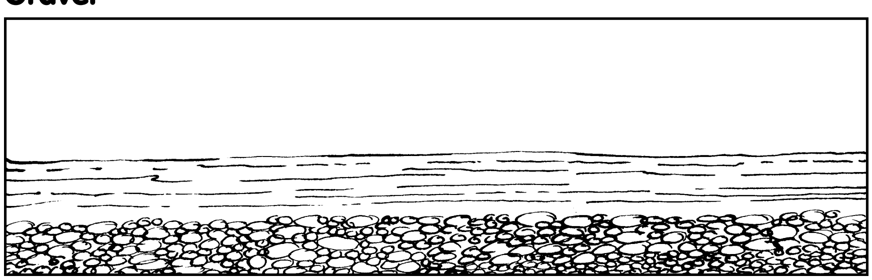
Boulders



Rubble or cobble



Gravel



Vocabulary

body
boulders
cobble
fine sediments
gravel
head
lateral habitats
pools
riffles
rubble
streambed
substrate
tailout

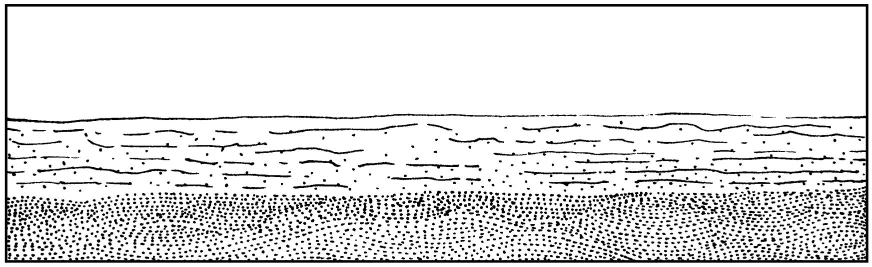
Most fish food is produced in cobbled areas. Cobble ranges from 3 to 12 inches.

Gravel is 0.2 to 3 inches in size, (somewhere between peas and oranges in size). It provides habitat for spawning, egg incubation, and homes for aquatic invertebrates. Gravel must remain clean and porous so circulating water can bring enough oxygen to embryonic fish. Different species of fish require different size, depth and volume of gravel for spawning. Bigger fish need a larger area.

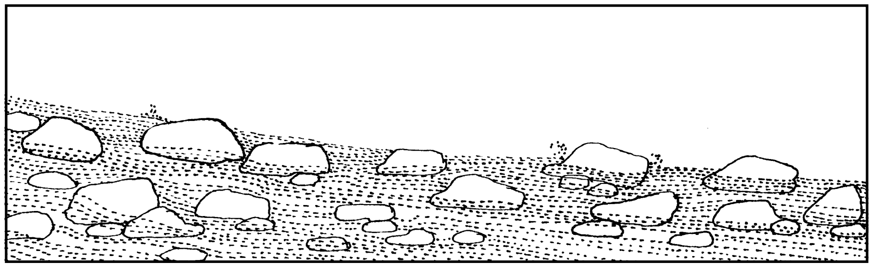
Fine sediments are less than 0.2 inch. "Large" fine particles can trap newly hatched fish in the redds and "small" fine particles decrease water percolation through spawning gravels. High sediment loads slow plant growth and reduce available food, oxygen and light.

The substrate types described above create certain configurations in a streambed. These configurations form specific habitat types. Stream width, depth, velocity, and flow also contribute to habitat diversity within a stream.

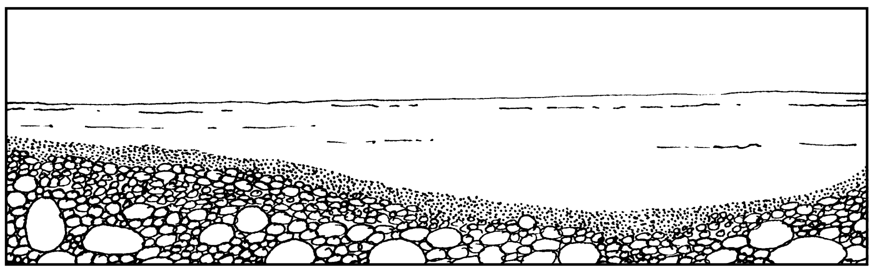
Fine sediments



Riffles



Pool



Fish wait in pools for drifting insects.

This diversity provides for specific needs of aquatic organisms, especially fish.

Stream habitats

Riffles are portions of a stream that are relatively shallow, fast and steep. They often have bedrock, cobbles, and sometimes boulders. In mountain streams, boulders and cobbles create rapids and cascades. As water rushes over these areas, the choppiness of the surface reflects the roughness of the bottom. Fish expend large amounts of energy to stay in riffle areas.

The sun shines through shallow riffle water and encourages algae to grow on the tops of rocks. The gravel and cobble bottom of a riffle provides nooks and crannies for insect larvae to live and feed. A rough cobble bottom slows water just above it, providing breaks, holding places and shelter for fish. Some organic material is scoured from the rocks and sent downstream to be used as food by aquatic organisms.

Pools are areas of deeper and slower waters often above and below riffles. Pools are important feeding and resting areas for fish. They are generally formed around stream bends or obstructions such as logs, root wads or boulders.

Pools contain three distinct areas: **head**, **body**, and **tailout**. Each part of a pool meets different fish needs. Turbulent water at the head collects food carried from upstream and provides cover and an area with a higher dissolved oxygen concentration.

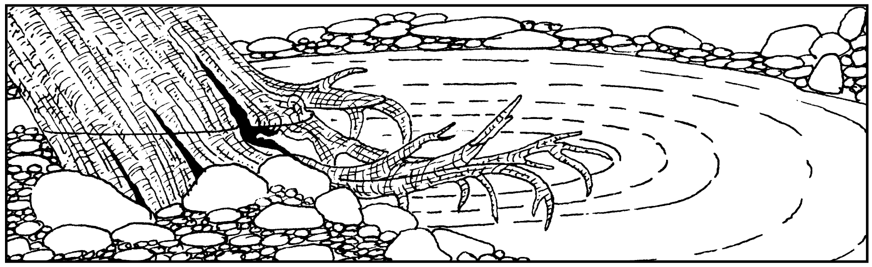
Slow water in the body of a pool indicates a reduced gradient. Organic material washes downstream, settles in pools, decomposes, and produces carbon dioxide and nutrients needed by plants in riffles. Drifting fine organic particles provide food for invertebrates. Fish wait in pools for drifting insects.

Gravel collects in pool tailouts. Fish use little energy to stay in this area and many wait here for food to pass by. Fish often use pool tailout areas with adequate flow as spawning beds.

The ratio of pools to riffles determines a stream's ability to provide suitable fish habitat. In general, a 1-to-1, pool-to-riffle ratio is optimum fish habitat.

Lateral habitats along the edges of streams are areas of quieter, shallow water. Boulders, root wads or logs can form small pools (pocket water or eddies). Fine sediments and gravels are found here. Accumulations of organic materials provide rich food sources for invertebrates. These areas provide important rearing habitat for young fish. Sculpins and crayfish wait for prey in pools near boulders or rootwads.

Lateral habitat



Illustrations in Chapter 7.3 adapted from original artwork by J. Nielsen, *Aquatic Habitat Inventory Glossary and Standard Methods*, American Fisheries Society, 1985.

Extensions

1. Create a model stream in an area of the schoolyard or use a stream table. Run water through the model stream. Observe the patterns of deposition and scour.

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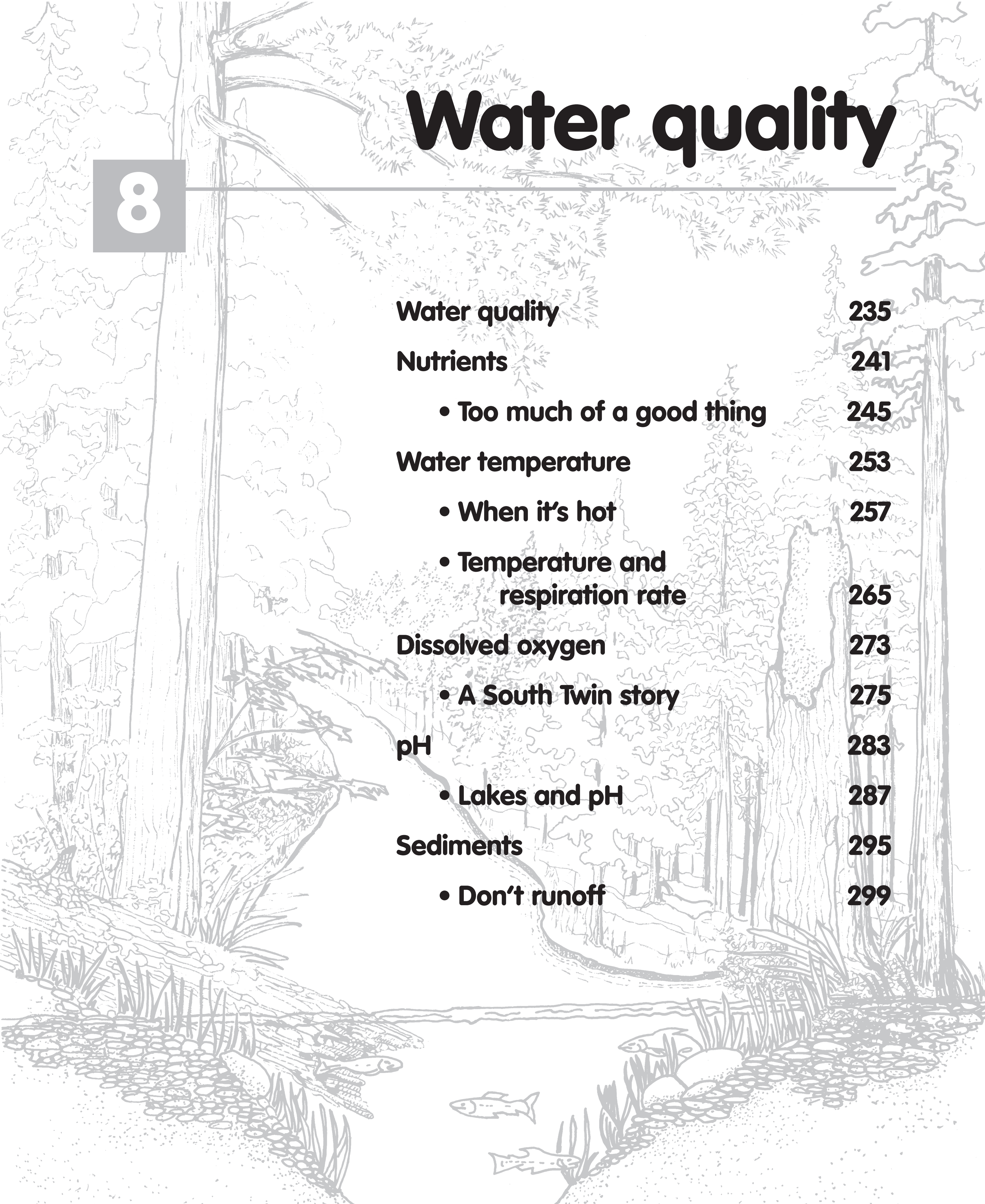
8

Water quality



Courtesy of Oregon Department of Forestry, Salem, Oregon (Graphics Unit)

8 Water quality

"Like swift water, an active mind never stagnates."
— Author unknown

Defining water quality depends on its intended use. A particular body of water might be clean enough for farm irrigation and yet too polluted for drinking water. Water could be clean enough for drinking water, and yet still be too warm for some aquatic organisms to live in it.

Natural conditions sometimes make water unsuitable for use. High levels of some inerals and salts are common in some areas, making water unfit for drinking. In other places the natural quality of the water has been degraded. We call this water polluted. Guidelines from the Environmental Protection Agency (EPA) for surface waters often refer to a goal of being "fishable and swimmable." While this does not provide precise values for various pollutants it does give a general goal. Water must be clean enough to allow aquatic life to live and not be a hazard to public health. Several types of water pollutants are discussed below.

Bacteria

Bacteria can come from improperly or incompletely treated sewage, failing septic systems, and livestock manure. High levels of bacteria indicate the presence of micro-organisms that can cause disease. Tests are often done to determine the concentrations of fecal coliform bacteria. Fecal coliform counts are used as an indicator of water quality.

Sediments

Sediments are small soil particles carried by surface runoff from logging, forestry, construction, mining, or agricultural sites. Sediments can carry nutrients and pesticides that degrade water quality. Sediments may settle to the bottom of streams, smothering aquatic life and fish spawning areas.

Toxics

Toxics can include pesticides, heavy metals, petroleum products from leaking underground storage tanks, solvents, and water runoff from hazardous waste disposal sites and landfills. The greatest sources of toxics are sewage and industrial wastewater. Toxics are also found in runoff from forests, farms and urban areas.

Nutrients

Nutrients, such as nitrogen and phosphorus, increase the growth of aquatic plants. When the plants die and decay they may make the water

Vocabulary

bacteria	toxics
beneficial uses	nutrients
Clean Water Act	dissolved oxygen
coliform	non-point source pollution
eutrophication	point source pollution
groundwater	pollution
surface water	
sediments	

unsuitable for other uses. Excess nutrients may be washed into streams and lakes from sewage and septic systems, livestock and pet wastes, and fertilizers.

Heat

Water temperature is critical to many kinds of aquatic life. Water temperature can be increased when warmer water, from industrial processes or irrigation returns, is added to streams. But the most important factor in raising water temperatures in Oregon streams and rivers is a lack of shade. Without a canopy of vegetation, solar radiation heats water in streams. Shade does not cool water. It helps prevent it from heating.

Dissolved oxygen

It is not dissolved oxygen, but the lack of it that results from pollution. Dissolved oxygen is essential for the survival of fish and aquatic life. The decay process—for organic materials washed into streams or the increased plant growth that goes along with the addition of extra nutrients—uses oxygen, making it unavailable for fish or other aquatic life.

Clean Water Act

The Clean Water Act includes federal water quality standards. The standards vary from stream to stream and are based on research data. These standards are set according to the natural, or background, conditions for each body of water. A stream fed by hot springs is not expected to have the same temperature as one fed solely by melting snow. The standards are also based on the **beneficial uses** for that particular body of water. The list of beneficial uses is defined by law and includes things as drinking water, recreation, preserving healthy conditions for aquatic life, fisheries, aesthetics, and irrigation. When there are competing beneficial uses in a river or stream, the Department of Environmental Quality (DEQ) is required to protect the beneficial uses that are most sensitive.

When a particular body of water is identified as below the water quality standards for its beneficial uses, **point sources of pollution**—those that come from an identifiable source such as a pipe—are controlled first. These sources of pollution are the easiest and generally least expensive to find and control. If controlling point sources is not enough to achieve water quality standards, then **non-point sources of pollution**, those that come from wide areas, such as soil eroded from uplands, are included in efforts to clean up the water. (See Table 2.)

Section 303(d) of the Clean Water Act requires that bodies of water that cannot achieve the standards by controlling point source pollution alone are placed on a special list—the 303(d) list—and additional measures must be taken to help them achieve the standards. Although the Clean Water Act is a federal law, individual states have responsibility for determining which bodies of water should be on the 303(d) list. In Oregon, the Department of Environmental Quality (DEQ) is responsible for this list. It is compiled using the best scientific and technical information available. In the past several years many more lakes and segments of streams and rivers have been added to the list. Recent additions do not mean that water quality in Oregon is getting worse, but instead reflects more information and knowledge about waters in the state. Currently there are 1,067 streams and rivers, 32 lakes and 1,168 stream segments on the list.

Groundwater

When we think of water pollution we most often connect it with rivers, streams, lakes, and other bodies of surface water. Groundwater can also suffer from pollution. Groundwater is a precious resource. Each day in Oregon 700 million gallons of groundwater are used. The drinking water supply for almost 77% of Oregonians comes, at least partially, from groundwater. Groundwater supplies some or all of the drinking water to 3,100 public water systems.

Groundwater is easily contaminated by pollutants. Pollutants dissolved in water can percolate through the soil and become part of groundwater. Groundwater contamination is often caused by leaking landfills, failing septic systems, runoff from animal feed yards, leaking underground storage tanks, and the improper use of fertilizers and pesticides. Nitrates are the most common form of groundwater pollution. Nitrates come from fertilizers and human and animal wastes. Drinking water contaminated with high levels of nitrates can be harmful to humans and livestock. Contaminated groundwater is very difficult, sometimes impossible, to clean up. As of March 1993, DEQ had identified 1,359 groundwater contamination sites in Oregon.

Sources of pollutants

Generally we associate water pollution with pollutants that come from a pipe, such as discharges from factories and sewage treatment plants. Point source pollutants include heavy metals, toxic chemicals, heated water, sewage, radioactive materials and other pollutants from industrial or municipal sources. Often, point source pollutants are the most dangerous. But they are not the only pollutants.

In terms of the volume of pollutants the largest source is non-point source pollution in the form of surface water runoff. Rainwater and melting snow pick up and carry soil, garbage, and various toxics as they wash over streets, roofs, lawns, constructions sites, logging sites, and farm fields. It is estimated that non-point sources are responsible for half or more of all nitrogen, coliform bacteria, iron, phosphorus, oil, zinc, lead, chromium, and copper that enter the surface waters of the United States. Sediments from non-point sources alone are responsible for an estimated $6 billion in damage per year. Even though many non-point source pollutants are less toxic than some industrial wastes, they still damage fish and wildlife and their habitats, degrade drinking water supplies, promote eutrophication, and damage the aesthetics and the recreation potential of Oregon's waters.

Non-point source pollution carried with surface water runoff is hard to detect and control because it does not come from a single source. It is hidden in many everyday activities. Non-point source pollutants come from farm fields, pastures, backyards, parks, streets, roads, mines, and construction sites. Anything on the surface of the land can be carried with surface runoff to gutters, storm drains, or ditches and then on to streams and rivers. Some common sources of non-point source pollutants include:

- household chemicals and soaps from driveways, roofs, and yards;
- fertilizers and pesticides from farm fields, yards, parks, golf courses, and landscaped areas;
- oil, anti-freeze, and other toxic materials from streets and roads;
- eroded soil from farm fields, logging areas, and construction sites;
- failing septic tanks; and
- manure from livestock and pets.

Controlling water pollution

It is easier and cheaper to prevent pollution than it is to clean it up. It is illegal to discharge pollutants into Oregon waters without a permit from DEQ. Some pollution, such as treated effluent from sewage treatment plants, is allowed when a stream is able to process it without degrading its quality. DEQ has responsibility for seeing that pollution problems are addressed. This agency works with other agencies to ensure that the job of controlling pollution, both point and non-point, progresses. Agencies responsible for forestry, urban areas, and agriculture all play a part in controlling pollution. Individual cities are responsible for overseeing their municipal wastes.

The Oregon Department of Forestry is responsible for designing and enforcing measures in the Oregon Forest Practices Act to prevent and control non-point source pollution from forest lands. Responsibility for non-point source pollution from rural and agricultural lands rests with the Oregon Department of Agriculture. Other state agencies involved in various aspects

continued, p. 238

Table 2. Some Non-point Source Pollutants, Their Sources, and Water Quality Impacts

Pollutant	Sources	Water Quality and Related Impacts
Sediment	Agriculture—crops and grazing Forestry Urban runoff Construction Mining	• decreases water clarity and light transmission through water, which: —causes a decrease in aquatic plant production —obscures sources of food, habitats, refuges, and nesting sites of fish —interferes with fish behaviors which rely on sight, such as mating activities • adversely affects respiration of fish by clogging gills • fills gravel spaces in stream bottoms, smothering fish eggs and juveniles • inhibits feeding and respiration of macroinvertebrates, an important component of fish diets • decreases dissolved oxygen concentration • acts as a substrate for organic pollutants, including pesticides • decreases recreational, commercial and aesthetic values of streams • decreases quality of drinking water
Pesticides Herbicides	Agriculture Forestry Urban runoff	• kill aquatic organisms that are not targets • adversely affect reproduction, growth, respiration, and development in aquatic organisms • reduce food supply and destroy habitat of aquatic species • accumulate in tissues of plants, macroinvertebrates and fish • some are carcinogenic (cause cancer), mutagenic (induce changes in genetic material –(DNA), and/or teratogenic (cause birth defects) • create health hazards for humans consuming contaminated fish or drinking water lower organisms' resistance and increase susceptibility to diseases and environmental stress • decreases photosynthesis in aquatic plants • reduces recreational and commercial activities
Polycholorinated biphenyls (PCBs)	Urban runoff Landfills	• accumulate in tissues of plants, macroinvertebrates and fish • toxic to aquatic life • adhere to sediments; persist in environment longer than most chlorinated compounds
Polycyclic aromatic hydrocarbons	Urban runoff	• accumulate in tissues of plants, macroinvertebrates and fish • when digested, create substances which are carcinogenic (cancer-causing) • toxic to aquatic life • toxicity is affected by salinity; estuaries with low salinities may be the most biologically sensitive
(PAHs) Petroleum	Urban runoff	• water soluble components can be toxic to aquatic life • portions may adhere to organic matter and be deposited in sediment • may adversely affect biological functions
hydrocarbons Pathogens and fecal	Agriculture Forestry Urban runoff	• create human health hazard • increase costs of treating drinking water • reduce recreational value

Pollutant	Sources	Water Quality and Related Impacts
bacteria Nutrients (phosphorous,	Agriculture Forestry Urban runoff Construction	• overstimulate growth of algae and aquatic plants, which later, through their decay, cause: —reduced oxygen levels that adversely affects fish and other aquatic organisms —turbid conditions that eliminate habitat and food sources for aquatic organisms —reduced recreational opportunities —reduced water quality and increased costs of treatment —a decline in sensitive fish species and an overabundance of nutrient-tolerant fish species, decreasing overall diversity of the fish community —premature aging of streams, lakes and estuaries • high concentrations of nitrates can cause health problems in infants
nitrogen)	Urban runoff Industrial runoff Mining Automobile use	• adversely affect reproduction rates and life spans of aquatic organisms • adversely disrupt food chain in aquatic environments • accumulate in bottom sediments, posing risks to bottom feeding organisms • accumulate in tissues of plants, macroinvertebrates, and fish • reduce water quality
Metals	Mining Industrial runoff	• lower pH (increase acidity) in streams which stresses aquatic life and leaches toxic metals out of sediment and rocks. • High acidity and concentrations of heavy metals can be fatal to aquatic organisms, may eliminate entire aquatic communities
Sulfates	Mining and ore processing Nuclear power plant fuel and wastes Commercial/industry	• release radioactive substances into streams • some are toxic, carcinogenic (cancer causing) and mutagenic (induce change in genetic material-DNA) • some break down into "daughter" products, such as radium and lead, which are toxic and carcinogenic to aquatic organisms • some persist in the environment for thousands of years and continue to emit radiation • accumulate in tissues, bones and organs where they can continue to emit radiation
Radionuclides Salts	Agriculture Mining Urban runoff	• eliminate salt intolerant species, decreasing diversity • can fluctuate in concentration, adversely affecting both tolerant and intolerant species • impact stream habitats and plants which are food sources for macroinvertebrates • reduce crop yield • decrease quality of drinking water • reduce recreation values through high salinity levels and high evaporation rates

Table provided courtesy of the Adopt-A-Stream Foundation from the *Streamkeeper's Field Guide*, of controlling water pollution in Oregon include the Division of State Lands, the Department of Geology and Mineral Industries, the Department of Transportation, and the Water Resources Department.

State agencies are not the only ones with control over pollutants and water quality. The actions of local governments, businesses, and private individuals all have an effect on water quality in Oregon. An effort to control water pollution through cooperative efforts, called the Healthy Streams Partnership, was instituted by Oregon Governor John Kitzhaber and approved and funded by the Oregon Legislature in 1997. This partnership includes representatives from agriculture, forestry, environmental groups, local governments, state agencies, and the governor's office. Its goal is to restore water quality in Oregon's rivers, streams, lakes, and estuaries so they can support salmon and other beneficial uses.

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Nutrients

8.1

"Slime is the agony of water."
— Jean-Paul Sartre

The uplands, riparian corridors and streams of a watershed are all connected to each other. None is separate or distinct from the others. Each is an integral part of the ecosystems in a watershed. When water passes through the uplands and riparian corridors it picks up and carries materials to the stream. Some may be carried intact, such as small pieces of soil or organic material. But water is also an effective solvent, so some materials are dissolved and carried in solution. Even under the most pristine conditions, water in streams carries a complex mix of chemicals, many of which are nutrients necessary to support aquatic life. In small concentrations many of these nutrients are beneficial. But if concentrations are high, then the stream may be considered polluted.

Two nutrients that often create water quality problems are **nitrogen (N)** and **phosphorus (P)**. Much as a weed is a plant in the wrong place, nitrogen and phosphorus, as pollutants, are nutrients in the wrong place. Both are essential for life and occur naturally in all living cells and in every ecosystem. The problem they pose for water quality is not their presence, but how much is present.

Nitrogen and phosphorus are the two elements most critical to the growth of plants. While increased plant growth might seem desirable, in aquatic environments the effects of that growth can be far from desirable. Slightly increased water fertility can have beneficial effects on fisheries, but most aquatic ecosystems evolved with low nutrient levels. A shift to higher nutrient levels causes aquatic plants, in general, and algae, in particular, to reproduce and grow at high rates. These rapid growth conditions can have widespread effects on aquatic systems. An increase of surface plants reduces light penetration, which in turn reduces or eliminates plant growth at greater depths. This, combined with competition for other essential needs and the relatively short life span of many of the individual plants, produces a large amount of dead organic material. Decaying plants increase the **biochemical oxygen demand (BOD)** in water, reducing the amount of oxygen available for fish and other aquatic life.

This demand for oxygen, along with the rotting vegetation, can create bad tastes in drinking water, even after it passes through water purification systems, and foul smells in water used for recreation or drinking. During periods of high **photosynthesis** the withdrawal of carbon dioxide for plant respiration may cause the water to become more alkaline. The change in **pH** and loss of oxygen from increased BOD can result in the death of other aquatic organisms or a change in the species composition of the aquatic community. This process, known as **eutrophication**, may affect the potential uses of water. Eutrophic waters may be unsuitable for boating, fishing,

Vocabulary

- alkaline
- biochemical oxygen demand (BOD)
- eutrophication
- nitrates
- nitrogen (N)
- pH
- phosphorus (P)
- photosynthesis

swimming, drinking, irrigation, or other beneficial uses.

Nitrogen

In most undisturbed watersheds, upland areas tend to generate nitrogen, particularly nitrogen compounds called **nitrates**. Nitrogen makes up a large part of our atmosphere, and some bacteria and plants have the ability to fix nitrogen in their tissues. Small amounts of nitrogen may also come from the weathering of rocks. Much nitrogen from the uplands—carried in organic material or dissolved in rainwater—moves through the watershed to **riparian areas**. A riparian area tends to accumulate excess nitrogen in its lush vegetation and rich soils, denitrifies it over time, and releases it back to its gaseous form in the atmosphere.

Human activities in the watershed can affect the amount of nitrogen in the system, sometimes increasing nitrate concentrations to levels higher than the land portion of the ecosystem can effectively process. Septic tanks, livestock wastes, and runoff from intensively fertilized lawns, gardens, and golf courses are all potentially rich sources of nitrogen that can increase nitrate-N concentrations in water. When groundwater used for drinking water becomes enriched with nitrogen it can cause health problems for humans and livestock. In humans, nitrate levels above 10 mg/l can cause methemoglobinemia, or "blue baby syndrome," which robs the blood cells of their ability to carry oxygen. This potentially fatal condition is generally only found in infants under six months of age. However both adult and young cows and sheep, baby pigs, and chickens can also suffer from the same condition.

Human activities in the watershed can also increase nitrate-N concentrations in surface waters, and these high concentrations can stimulate the growth of algae and other aquatic plants. Some fish are also directly affected by nitrate-N concentrations above 4.2 mg/l. But nitrogen in aquatic ecosystems—even in relatively high concentrations—may have relatively little effect on plant growth unless phosphorus is also present. When phosphorus is present, as little as 0.30 mg/l of nitrogen in the form of nitrates may cause algal blooms.

Phosphorus

Unlike nitrogen, phosphorus does not occur as a gas in its biogeochemical cycle. This means that virtually all phosphorus in aquatic environments was carried there by water. Unless it is physically removed, accumulated phosphorus is stored in the system and available for repeated aquatic growth cycles. Phosphorus is the single most limiting factor for aquatic plant growth. Other nutrients may play a role in eutrophication, but phosphorus is the nutrient most easily controlled through management. In general, relatively undisturbed lakes and streams have levels of phosphorus too low (below 0.7 mg/l) for the rapid algal growth characteristic of eutrophication.

Sources of phosphorus in a watershed may include rock, and the soils created by weathering actions on those rocks. Most ecosystems evolved with these relatively low levels of phosphorus. Accumulations above historic background levels are mainly from human activities. Soil, in the form of erosion sediments, can be a rich source of phosphorus for aquatic ecosystems. Even soils with relatively low levels of phosphorus can be rich by aquatic standards. This means any human activity that increases soil erosion has the potential to increase phosphorus concentrations in surface waters. Industrial discharges, fertilizers, phosphorus detergents, organic materials—including animal wastes, sewage, leaves and lawn clippings—are all rich sources of phosphorus.

Soil disturbance and fertilization occurring as part of agricultural and forest practices can influence the amount of phosphorus in surface waters, but urban runoff is also an important source. A study in Seattle, Washington, found phosphorus concentrations in storm-water runoff as high as 200 times the accepted background level for streams. In part, this is because urban and suburban lawns and gardens are often heavily fertilized, and organic materials such as leaves and lawn clippings are often carried to streams with surface runoff that enters storm drains. Most storm drain systems dump directly into streams without passing through a riparian area. A healthy riparian corridor could filter and delay phosphorus-rich materials so they could be used by other terrestrial plants.

Controlling nutrient pollution

The easiest and most effective way to control water pollution from nutrients is to prevent nutrients from entering streams. Nutrients may be carried with soil sediments, organic material, or carried in solution as surface runoff or through the soil to groundwater. To prevent nutrients from reaching surface or ground water:

- keep pet wastes, leaves, lawn clippings, and debris out of street gutters and storm drains;
- apply only as much fertilizer as plants need, and only when they need it;
- control soil erosion in urban areas by planting ground cover and stabilizing erosion-prone areas;
- use proper logging and erosion control practices on forest lands;
- use proper construction, maintenance, and closure of farm and logging roads;
- manage animal waste to minimize contamination of surface water and groundwater;
- reduce soil erosion on farms by using sound conservation; and
- manage grazing on pasture and rangeland to maintain a healthy stand of plants covering the soil.

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Too much of a good thing

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

Objectives

The student will (1) observe, (2) record, and (3) analyze the effects of nutrients on aquatic plants.

Method

Students grow aquatic plants in nutrient solutions to observe the effects of nutrients on aquatic plant growth.

For younger students

1. Consult extension activities at the end of each chapter to address the needs of younger students.
2. Read activity background information aloud to younger students or modify for your students' reading level.

Materials

- copies of student sheets (pp. 249-252)
- water containers (2-liter used plastic drink bottles)
- ammonium nitrate fertilizer
- TSP (trisodium phosphate)
- aquatic plants such as Elodea
- paper towels
- scale or balance

For each team:

- four 2.0 liter soda bottles
- deionized water (preferred)
- measuring spoons
- aquatic plants
- ammonium nitrate fertilizer
- TSP
- funnel for filling bottles
- scale or balance (may be shared between teams)

Note to the teacher

Deionized water is not only distilled, but demineralized. If it is not readily available, distilled water can be used.

The nutrient content of commercial fertilizer or plant food is generally shown by a series of three numbers, for example 10-10-20. This shows, in order, the relative amounts of nitrogen, phosphorus, and potash. For this experiment you need a fertilizer with only nitrogen, for example 10-0-0.

This lends itself well to an independent study project. Two weeks may not be enough time for changes to occur. Take this into consideration when planning the activity.

Students may need to experiment with the amounts of nitrogen and phosphorous to notice growth changes.

Background

Do you know . . .

Most aquatic life developed in environments with low levels of nutrients. When nutrients are available in amounts greater than this natural background level, plants may grow very rapidly. In lakes and streams, this rapid growth can cause

Vocabulary

alkaline	nitrogen (N)
biochemical oxygen demand (BOD)	pH
eutrophication	phosphorus (P)
nitrates	photosynthesis

serious problems. Plants may grow so fast and in such abundance they shade out the plants below them. Without light the shaded plants die and begin to decay. The decay process requires oxygen, sometimes removing so much from the water that other aquatic organisms cannot live. The decaying plants may also make the water smell and taste bad, making it unsuitable for drinking or swimming.

Nitrogen and phosphorus are vital for the growth of aquatic plants. Much as a weed is a plant in the wrong place, nitrogen and phosphorus as pollutants are nutrients in the wrong place. Both are essential for life and occur naturally in all living cells and in every ecosystem. The problem they pose for water quality is not their presence, but how much is present.

Nitrogen is naturally found in watersheds. Our atmosphere contains more nitrogen gas than any other substance. Large amounts of nitrogen are also tied up in plant and animal tissues. Some bacteria and plants also have the ability to "fix" nitrogen from the air and incorporate it into their tissues. Human activities in the watershed can affect the amount of nitrogen in the system. Septic tanks, livestock wastes, and runoff from heavily fertilized lawns, gardens and golf courses are all potentially rich sources of additional nitrogen.

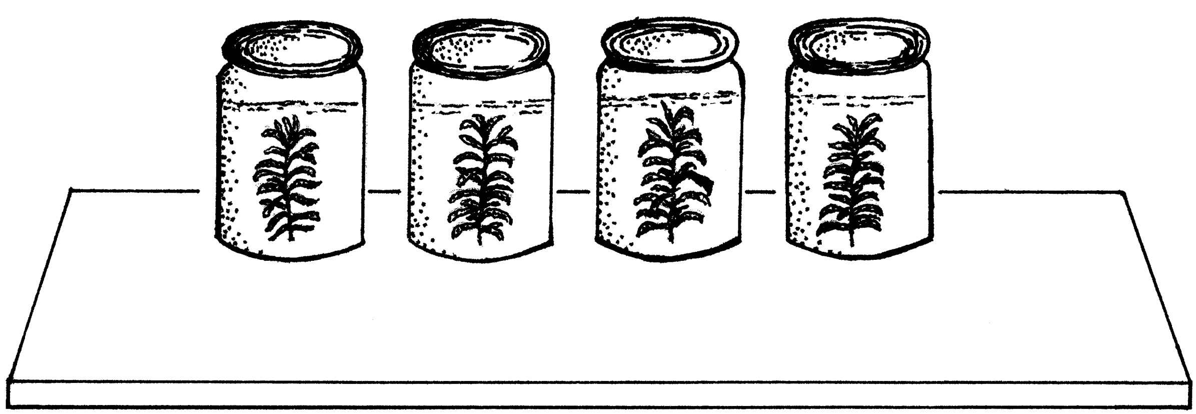
Phosphorus is a normal component of most rocks. As a result, phosphorus is commonly attached to soil particles created from the weathering of those rocks. This means that any human activity that increases soil erosion has the potential to increase phosphorus concentrations in surface water. Industrial discharges, fertilizers, detergents high in phosphates, organic materials—including animal wastes, sewage, leaves, and lawn clippings—are also rich sources of phosphorus.

Procedure

Now it's your turn . . .

How do nitrogen and phosphorus affect plant growth in an aquatic environment? Do they work better together or separately? Set up the following investigation to test your ideas.

1. Label each container with the date, the name of your team, plus:
   a. label the first container "control,"
   b. label the second container "nitrogen,"
   c. label the third container "phosphorus," and
   d. label the fourth container "nitrogen and phosphorus."
2. Add nutrients to the containers as follows:
   a. do not add any nutrients to "control"
   b. add one-quarter teaspoon ammonium nitrate fertilizer to "nitrogen"
   c. add one-eighth teaspoon TSP to "phosphorus"
   d. add one-quarter teaspoon ammonium nitrate fertilizer *and* one-eighth teaspoon TSP to "nitrogen and phosphorus"
3. Add one liter of deionized water to each of the four containers. Screw the caps on and



	Control	Nitrogen	Phosphorus	Nitrogen and Phosphorus
Final weight of plants				
Original weight of plants				
Weight gained (subtract original weight from final weight)				

shake the bottles until the fertilizers dissolve. Then add one more liter of deionized water to each botttle.

4. Take four samples (strands) of *Elodea* and blot gently with paper towels. Remove any snails you find. To add an equal weight of plants to each container, weigh the shortest strand. Carefully snip off pieces of each of the remaining samples until all are as close as possible to the same weight as the first. Record the weight of each sample on the chart and place it in the correct water container.
5. Place all samples where they get plenty of light, but not exposed to direct sunlight. Let the samples grow for two weeks. At the end of two weeks:
   a. Remove the plant from the “control” container. Blot gently with a paper towel. Weigh the sample and record the weight on the chart.
   b. Remove the plant from the “nitrogen” container. Blot gently with a paper towel. Weigh the sample and record the weight on the chart.
   c. Remove the plant from the “phosphorus” container. Blot gently with a paper towel. Weigh the sample and record the weight on the chart.
   d. Remove the plant from the “nitrogen and phosphorus” container. Blot gently with a paper towel. Weigh the sample and record the weight on the chart.
6. Complete the chart by subtracting the original weight from the final weight to get weight gained.

Questions

1. Which container had the greatest increase in plant growth? Based on your results, was a single nutrient or a combination of nutrients most effective in increasing growth? If a single nutrient, which one?
   Answers will vary, but the expected result would be greatest growth from the combination of nitrogen and phosphorus.
2. Why is it important to remove any snails from the strands of plant material used in your experiment?
   Snails feed on aquatic plants as well as microorganisms living on the plant material. If the snails consumed a significant amount of the plant material, it could affect the results. The weight of the snails, although small, and their waste could also affect the results. It is always better to remove as many variables as possible when conducting an experiment.

3. Besides nutrients, what environmental factors might affect the growth of aquatic plants in your experiment and in nature?

   Factors identified might include light, temperature, other nutrients, the effects of grazing by aquatic herbivores (snails), competition with other plants, and others.

4. How might the rapid growth of aquatic plants affect the rest of the aquatic ecosystem?

   Plants with the most rapid growth rate can more effectively compete for nutrient resources. As a result, other plants may decline or disappear. As plants die, dissolved oxygen is used in the decay processes. Oxygen levels may become so low other aquatic organisms, such as fish, can no longer live.

5. If excess nutrient levels cause aquatic plants to grow unchecked, eventually creating water quality problems, what are some ways to control the amount of nutrients in water? How can we remove nutrients from water?

   Answers will vary. Removing nutrients from water may require water treatment, such as in a sewage treatment plant. Removing plants will also remove the nutrients in their tissues, although as a practical matter this method is expensive and may not remove enough nutrients to be effective. Preventing nutrients from entering water is the most effective and economical means of controlling nutrients.

6. How can we prevent nutrients from entering water?

   Preventing nutrients from entering water is the most effective and economical means of controlling nutrients. Answers should include various methods to control non-point source pollution.

Going further

1. Add a fifth treatment using tap water. How does plant growth in tap water alone compare to deionized water alone? Is it likely your tap water contains nutrients?
2. Use different amounts of nutrients. Is there a threshhold level where accelerated plant growth begins or when growth ceases to occur?
3. Add other combinations of plant nutrients. Which has the greatest effect on aquatic plant growth?
4. Add a similar set of treatments using terrestrial plants, such as beans or tomatoes, grown hydroponically in sand with nutrient solutions. Do terrestrial plants show the same response to nutrients as aquatic plants?
5. To demonstrate eutrophication, let a container with rapid growth continue to grow until the plants begin to die and decay. Measure and discuss the effects this has on water quality.

Name

Too much of a good thing

Do you know . . .

Most aquatic life developed in environments with low levels of nutrients. When nutrients are available in amounts greater than this natural background level, plants may grow very rapidly. In lakes and streams, this rapid growth can cause serious problems. Plants may grow so fast and in such abundance they shade out the plants below them. Without light the shaded plants die and begin to decay. The decay process requires oxygen, sometimes removing so much from the water that other aquatic organisms cannot live. The decaying plants may also make the water smell and taste bad, making it unsuitable for drinking or swimming.

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Vocabulary

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biochemical oxygen demand (BOD)	pH
eutrophication	phosphorus (P)
nitrates	photosynthesis

Student sheet

Then add one more liter of deionized water to each botttle.

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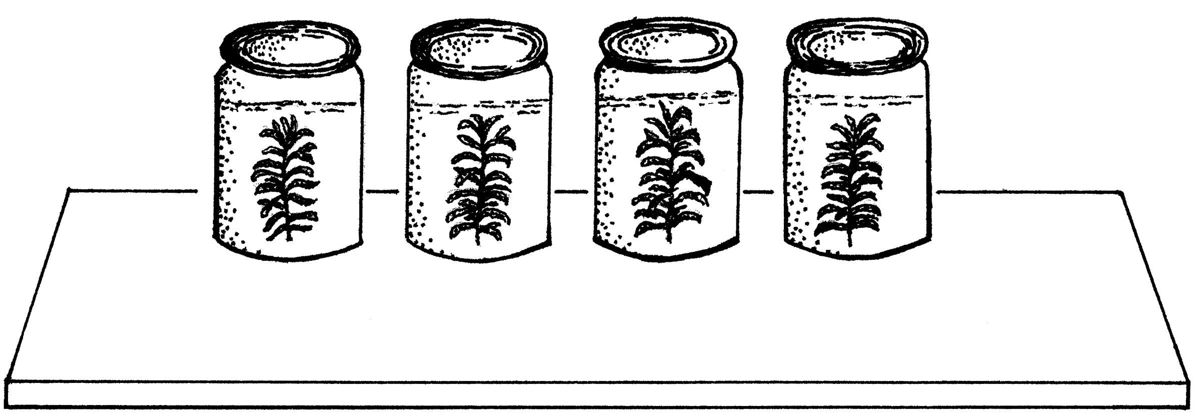
6. Complete the chart by subtracting the original weight from the final weight to get weight gained.

	Control	Nitrogen	Phosphorus	Nitrogen and Phosphorus
Final weight of plants				
Original weight of plants				
Weight gained (subtract original weight from final weight)				



Student sheet

Questions

1. Which container had the greatest increase in plant growth? Based on your results, was a single nutrient or a combination of nutrients most effective in increasing growth? If a single nutrient, which one?

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3. Besides nutrients, what environmental factors might affect the growth of aquatic plants in your experiment and in nature?

4. How might the rapid growth of aquatic plants affect the rest of the aquatic ecosystem?

5. If excess nutrient levels cause aquatic plants to grow unchecked, eventually creating water quality problems, what are some ways to control the amount of nutrients in water? How can we remove nutrients from water?

6. How can we prevent nutrients from entering water?

Water temperature

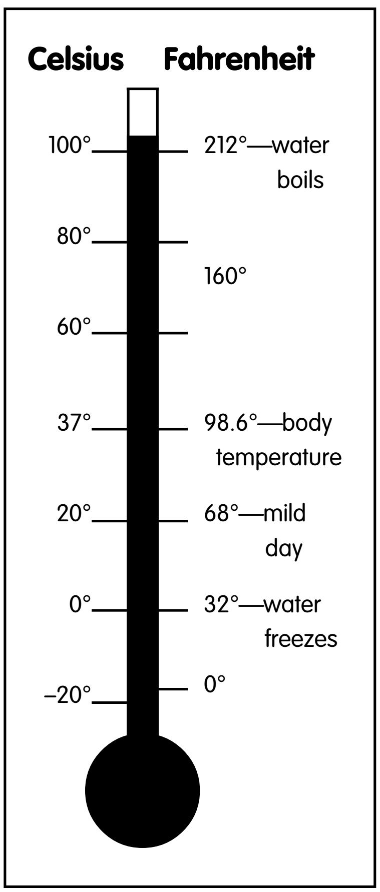
8.2

"Worsewick Hot Springs was nothing fancy . . . . There were dozens of dead fish floating in our bath."
— Richard Brautigan

Water temperature is one of the most important factors for survival of aquatic life. Most aquatic organisms become the temperature of the water that surrounds them. Their **metabolic rates** are controlled by water temperature. This metabolic activity is most efficient within a limited range of temperatures. If temperatures are too high or too low, productivity can decrease or metabolic function cease. The organism can die. These extremes, or lethal limits, vary for different species.

Lethal limits

Within the lethal limits there is an ideal range of temperatures. In this range, an organism is more efficient, and the species has a greater chance of success. Various species of fish have adjusted to upper and lower levels of an optimum temperature range. Spawning, hatching and rearing temperature ranges vary from species to species.



Vocabulary

metabolic rates
riparian
streamflow

In this way, temperature determines the character and composition of a stream community.

In the Pacific Northwest, most streams have had populations of salmon and trout, which prefer temperatures between 40.5°F and 65.5°F. In the summer, when temperatures are highest and water flows lowest, juvenile fish live in the pools of smaller streams. Pools offer deeper, cooler, oxygen-rich water and increased protection from predators. Because of low water flows, fish can be confined to a limited area. A temperature rise in a rearing pool can kill fish by exceeding their lethal temperature limits.

Plant cover's role

With the exceptions of hot springs and thermal pollution, solar radiation is the cause of increased water temperatures. Shade from **riparian** vegetation plays a major role in keeping streams cool. During midsummer, adequate shade will keep a stream 7.5°F to 12.5°F cooler than one exposed to direct sunlight.

One example of the effects of vegetation in keeping water cool is what happened on Cedar Creek, a tributary of Steamboat Creek in Oregon's Umpqua Basin. The site was clearcut in 1969. A 25-year temperature study followed the clearcut. Immediately after the clearcut the 14 warmest daily temperature measurements averaged 78°F. By 1995, after trees had more than 20 years to regrow, the temperature on the warmest 14 days was between 64°F and 65°F.

Water temperature is one of the most important factors for suvival of aquatic life.

Even the shade from floating debris in water will help keep temperatures low. If there is enough debris, temperatures can be 3°F to 8°F cooler than if there was no shade. Once water has warmed, it does not cool rapidly, even if it flows into a shady stretch.

It is important to recognize that water temperatures change from day to night and that cool-water areas exist in a stream.

Warmer temperatures encourage the growth of life forms that adversely affect fish and human health. Pathogens such as bacteria, as well as several parasitic organisms, thrive in warmer waters.

Air temperature, surface area

As water in a stream mixes with air through exposure and turbulence at the surface, water is influenced by the air temperature. This mixing action can also increase the evaporation rate.

The greater the surface area of a body of water, the greater its exposure to both solar radiation and air. Because of its increased surface area a wide, shallow stream will heat more rapidly than a deep, narrow stream.

Streambed, streamflow, orientation and sediments

Color and composition of a streambed also affect how rapidly stream temperature rises. A dark bedrock channel will gain and pass to the stream more solar radiation than a lighter-colored channel. Similarly, solid rock absorbs more heat than gravel.

The streamflow, or volume of water in a stream, influences temperature. The larger a body of water, the slower it will heat. Rivers and large streams have more constant temperatures than smaller streams.

The direction a stream flows also affects how much solar radiation it will collect. Because of the angle of the sun's rays, southerly flowing streams receive more direct sunlight than streams flowing north. Eastward or westward flowing streams receive shading from adjacent ridges, trees and riparian vegetation.

Sediments suspended in water can absorb, block or reflect some of the sun's energy depending on their color and position in the water. Particles on or near the surface can have a beneficial influence through reflection, but those with a dark color increase the total energy absorbed from the sun.

Table 3. Temperature Ranges (approx.) Preferred by Certain Organisms

Temperature (Fahrenheit)	Examples of life
Greater than 68° (warm)	Redside shiner, crappie, bluegill, carp, catfish, caddisfly, dragon fly, and much plant life
Middle range (55°-68°)	Brown trout, rainbow trout, stonefly, mayfly, caddisfly, water beetles, sculpins, and some plant life
Low range (cold, less than 55°)	Brook trout, sculpins, caddisfly, stonefly, mayfly, and some plant life

Adapted from Claire Dyckman and Stan Garrod, eds., *Small Streams and Salmonids,* p. 73.

Effects of thermal pollution

Thermal pollution occurs when heated water is discharged into cooler streams or rivers. This heated water generally has been used to cool power plants or industrial processes and can be as much as 20ºF warmer than the water into which it is discharged. This increase in temperature can have drastic effects on downstream aquatic ecosystems.

Extensions

1. "Water Canaries," *Aquatic Project WILD*, pp. 38-42. Grades 4-12.
2. "Deadly Waters," *Aquatic Project WILD*, pp. 146-150. Grades 3-12.

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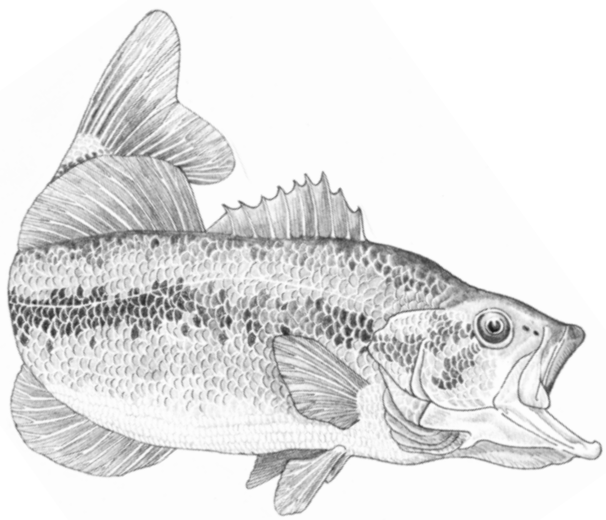
When it's hot . . .

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

Objectives

The student will (1) analyze temperature tolerance data of various fish species, (2) graph and compare temperature tolerance information for several fish species, and (3) respond to questions analyzing information presented on the graph.



Method

The student will graph, compare, and analyze the temperature tolerance data presented in the table.

For younger students

1. Consult extension activities at the end of each chapter to address the needs of younger students.
2. Read activity background information aloud to younger students or modify for your students' reading level.
3. Use as a demonstration activity, rephrase some questions or answer questions as part of a group discussion.

Acitivity adapted from: Daniel Stoker, et al., *A Guide to the Study of Freshwater Ecology,* 1972, p. 159.

Materials

- copies of student sheets (pp. 261-264).

Background

Do you know . . .

Some fish can live in warm water while other fish require colder water. By experimenting with different kinds of fish, and raising the water temperature of the water a little bit at a time, biologists have learned a lot about how fish respond to changes in temperature in their environment.

One way to measure temperatures a fish can tolerate or live through is called the 24-hour tolerance limit median (24-hour TLm). Why do biologists need to know this? What does it mean? Let's look at an example.

A biologist collects several largemouth bass, all about the same size. They are put into a tank and held for 24 hours. The temperature of the water in the tank is slowly raised. At a certain point the water will become so warm that one-half (or 50%) of the fish will not be able to tolerate the temperature and will die. If that temperature was 84°F, we can say the 24-hour TLm is 84°F.

If the temperature continued to rise, a point would be reached where half the fish would die in only 12 hours. This temperature is called the 12-hour TLm.

The table on the next page lists some of the fish species found in streams and rivers. Because their TLm values are close to the same, we can assume these different kinds of fish could, but may not, live together in one body of water.

Procedure

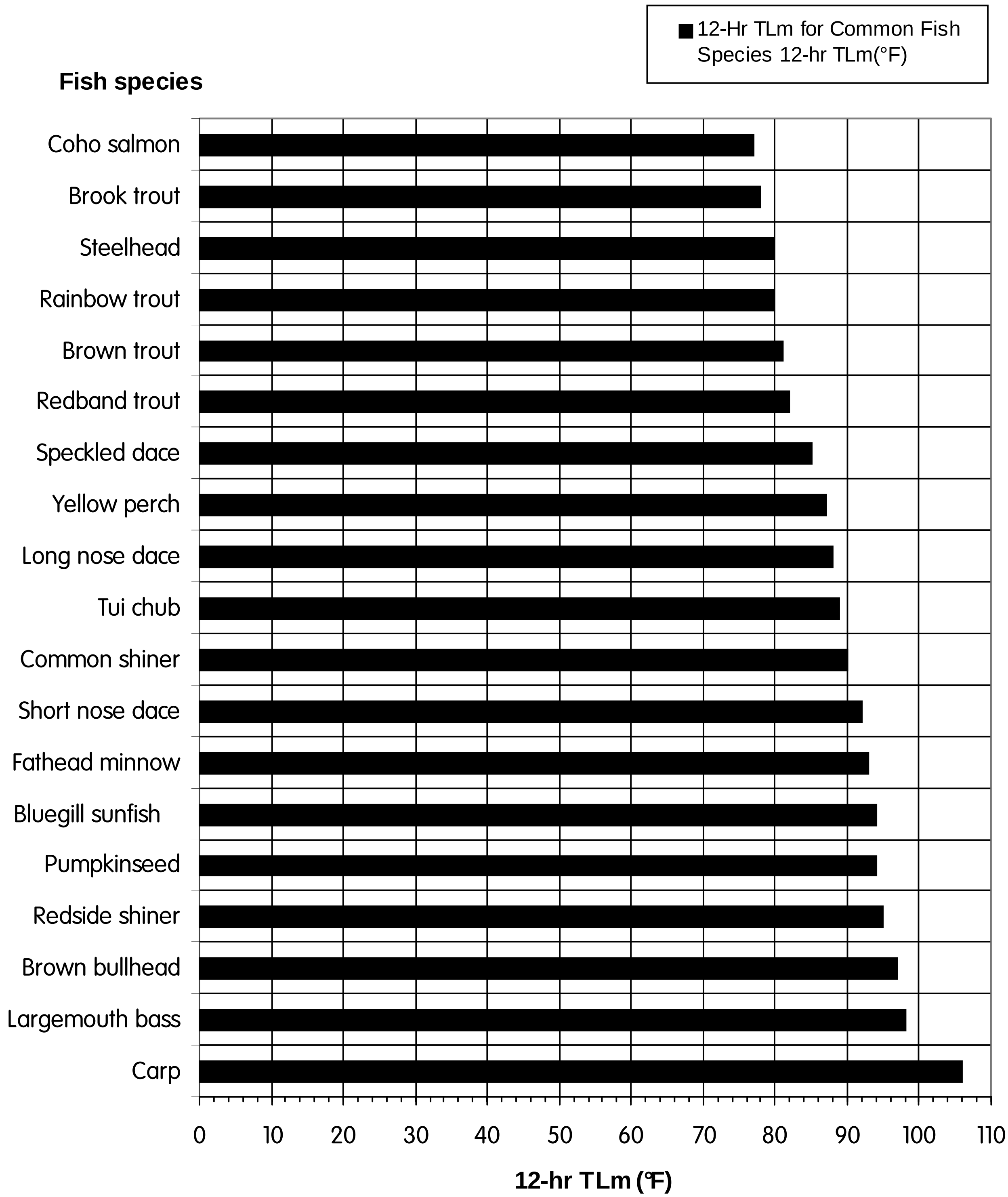
Now it's your turn . . .

Look at the data in the table below. It is sometimes easier to compare this kind of information when seen in a different form. Using the one provided, create a bar graph showing the 12-hour TLm for each species on the table. Working from **top to bottom** on the vertical axis, start with the lowest temperature (77°F for cutthroat and coho salmon) and plot the values in order from **lowest to highest temperature**. Carp (106°F) should be the last fish listed at the bottom of the vertical axis.

Answer the questions that follow.

Common name	12-hr. TLm (°f)	Common name	12-hr. TLm (°f)	Common name	12-hr. TLm (°f)
Common shiner	90	Brook trout	78	Pumpkinseed	94
Long nose dace	88	Carp	106	Redband trout	82
Steelhead	80	Rainbow trout	80	Largemouth bass	98
Bluegill sunfish	94	Speckled dace	85	Coho salmon	77
Brown bullhead	97	Brown trout	81	Yellow perch	87
Redside shiner	95	Cutthroat trout	77	Fathead minnow	93
Tui chub	89	Short nose dace	92		

12-Hr TLm for Common Fish Species 12-hr TLm (°F)



Questions

Suppose an industry pumped very hot waste water into a river, raising the water temperature by many degrees.

1. Which would be the first five fish species to die from the increased water temperatures (thermal pollution)?
   Cutthroat trout, coho salmon, brook trout, steelhead, rainbow trout, and brown trout.
2. Which five species would be most tolerant or able to survive the higher temperatures?
   Largemouth bass, carp, brown bullhead, redside shiner, pumpkinseed, and bluegill sunfish.
3. Looking at the graph, how would you classify these fish species according to their ability to tolerate temperature changes? Explain.
   Fish can be classified as warm water fish and cool water fish. Those with a shorter bar are less tolerant of warm water, and those with longer bars are more tolerant.
4. Compare the salmon and trout with the other species listed. Based on what is shown on the graph, what specific habitat requirements could be indicated for salmon and trout by the information portrayed?
   Answers will vary, but they should include information about cooler and deeper water, shaded streams, and cover.
5. Compare the salmon and trout with each other. Which species would be most tolerant of warmer waters? Which would be least tolerant?
   Redband trout are most tolerant of warmer water. Cutthroat and brook trout are least tolerant.
6. Which of the other species is most tolerant of warmer waters? What would this tell you about their habitat needs?
   Carp are most tolerant and would survive in a wider range of conditions.

Going further

1. Design an experiment to test which factors most affect water temperature (soil temperature, air temperature, shading, substrate types, or others) at a specific site in your watershed. Can this information be applied to other watersheds or even other areas within your own watershed? Why or why not? Prepare a report summarizing your findings and share with the class.
2. Contact your local department of fish and wildlife, watershed council, or department of environmental quality office. Volunteer to assist with temperature monitoring on streams in your area. Ask local experts to show you how the data is collected, analyzed and presented. Prepare a report and share this information with the class.

Name

When it's hot . . .

Do you know . . .

Some fish can live in warm water while other fish require colder water. By experimenting with different kinds of fish, and raising the water temperature of the water a little bit at a time, biologists have learned a lot about how fish respond to changes in temperature in their environment.

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Answer the questions that follow.

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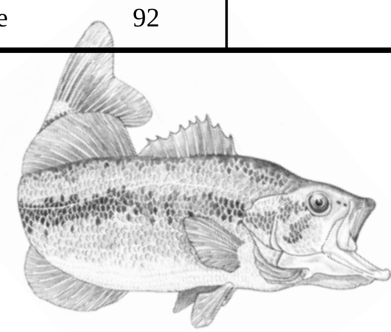
Acitivity adapted from: Daniel Stoker, et al., *A Guide to the Study of Freshwater Ecology*, 1972, p. 159.



Student sheet

12-Hr TLm for Common Fish Species 12-hr TLm (°F)

Student sheet

Questions

Suppose an industry pumped very hot waste water into a river, raising the water temperature by many degrees.

1. Which would be the first five fish species to die from the increased water temperatures (thermal pollution)?

2. Which five species would be most tolerant or able to survive the higher temperatures?

3. Looking at the graph, how would you classify these fish species according to their ability to tolerate temperature changes? Explain.

4. Compare the salmon and trout with the other species listed. Based on what is shown on the graph, what specific habitat requirements could be indicated for salmon and trout by the information portrayed?

5. Compare the salmon and trout with each other. Which species would be most tolerant of warmer waters? Which would be least tolerant?

6. Which of the other species is most tolerant of warmer waters? What would this tell you about their habitat needs?

Temperature and respiration rate

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

Objectives

The student will demonstrate (1) the inverse relationship between water temperature and dissolved oxygen levels, and (2) its effect on the respiration rates of fish.

Method

Fish respiration rates can be estimated by counting the number of gill plate (opercula) beats per minute at different water temperatures.

For younger students

1. Consult extension activities at the end of each chapter to address the needs of younger students.
2. Read activity background information aloud to younger students or modify for your students' reading level.
3. It is necessary for you to gather supplies and closely monitor student work with this activity. Simply questions. Students must know how to read a thermometer.

Materials

- copies of student sheets (pp. 269-272)
- fahrenheit/celsius conversion formulas (Chapter 14.2)
- an aerated aquarium at room temperature with enough fish to supply all teams; all fish should be of similar size; goldfish are hardy and inexpensive

For each team

- fish
- dip net
- thermometer
- ice
- warm water (without chlorine)
- watch or clock with second hand
- small container (less than one-half full of water)
- large container (at least 2" in diameter larger than the small container)

Background

Do you know . . .

Aquatic life must deal with a very different set of environmental conditions than terrestrial (land) life. For example, temperatures on land can move quickly from hot to very cold while water temperatures usually are slow to change. Water has the ability to absorb weather extremes and other environmental factors, so water temperature remains within a narrow range.

Water temperatures have an effect on the amount of dissolved oxygen (DO) available to fish. As water warms, it cannot hold as much DO. In contrast, air temperature has little effect on the amount of oxygen in the air we breathe.

A fish must pump water across its gills to meet its oxygen needs. If DO in the water is low, the gills must move faster to get enough oxygen for the fish to survive. We can count these gill movements to estimate the DO requirements of fish.

Note to teacher

Refer to the dissolved oxygen saturation charts in the next chapter to encourage students to make the connection between water temperature and the dissolved oxygen content of the water.

Procedure

Now it's your turn . . .

Divide into teams of three students each. Each team member will have a specific job as outlined below.

1. **Gill beat counter**
   Count and record the number of gill beats/ minute every time the water changes by 5°F.
2. **Time counter**
   Tell the gill plate counter when to start and end (one-minute counting intervals).
3. **Temperature guardian**
   Announce the temperature changes by approximately 5°F intervals (but no more than 10°F intervals). It is not essential to be exact. Make sure the water changes happen slowly to avoid harming the fish.

Place the fish in a small container with water as close to the aquarium's temperature as possible. Water in the small container must be either spring water or treated to remove the chlorine. ***These two steps are very important to avoid shocking or killing the fish.*** Each team's container should have the same amount of water to control the variables and increase accuracy in later comparisons of results.

Now you are ready to begin changing the water temperature. As the temperature changes, make a total of six observations, recording the results in the chart at right.

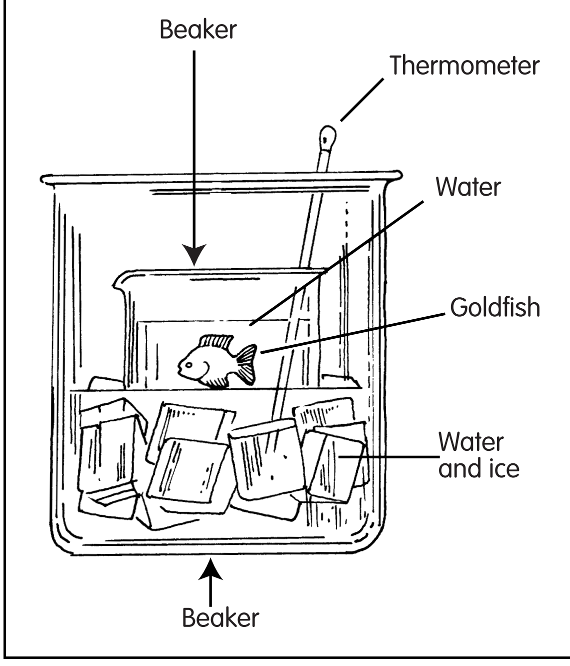
Temperature guardian

Add ice or cold water to the large container. When the water temperature of the large container is well below room temperature (**but no lower than 55°F**), place the small container with the fish into the larger one (see drawing). Once the fish has calmed down, measure the water temperature in the small container. All other water temperature measurements should be taken from the small container. **Do not allow the temperature of the small container to drop below 55°F.**

After the count has been completed at the 55°F reading, change the water temperature (**slowly, remember!**) by adding warm water near the outside of the outer container. **Do not add ice or warm water to the smaller container with the fish.** At each 5°F interval, signal the time and gill beat counters to do their counts.

Do not allow the temperature of the smaller container to exceed 80°F.

Observation No.	Temperature	Gill beats/minute
1		
2		
3		
4		
5		
6		



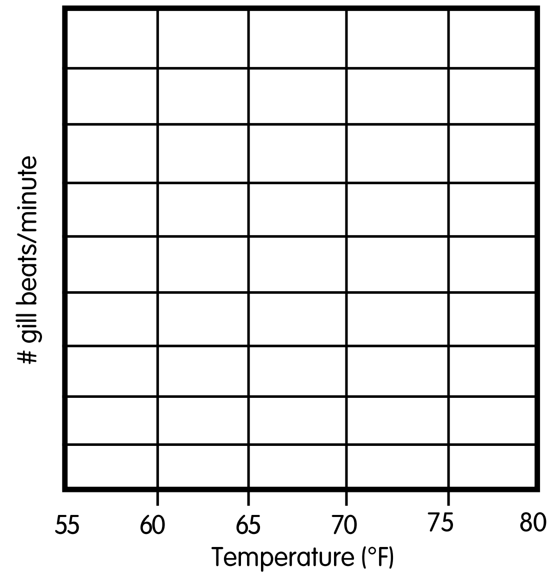
Gill beat and time counters

Once the Temperature Guardian has indicated the starting temperature, begin your counts. Count for one minute and record the results.

Make your counts at 5°F intervals.

If the fish is to be returned to the aquarium, the temperature of the water in the fish's container and the aquarium should be within 5°F of each other. Remove the fish from the jar with a dip net. Do not dump water from the beaker into the aquarium.

Transfer your results to the graph at right. Compare your results with those of another team by recording their measurements on your graph in another color.



Questions

1. The amount of oxygen water can hold is directly related to the temperature of the water (the higher the temperature, the less oxygen it can hold). The amount of oxygen water can hold is also related to the pressure (the higher the pressure, the more oxygen the water can hold). How might the combined effects of temperature and pressure affect the number of gill beats?

   If the temperature of the water is cool and the pressure is high, water has the greatest potential to hold oxygen. If the temperature is cooler, but the pressure is low, the water could not hold as much oxygen as would be expected. The amount of oxygen available in the water would affect the number of times the gills would have to open and close to meet the oxygen needs of the fish.

2. What could account for unexpected results in the data? For example, why would the number of gill cover beats be lower than expected at a certain temperature when the trend appeared to show a larger number of beats as the temperature increased?

   Person doing the counts may have counted incorrectly, or other variables such as pressure or fish using up available oxygen may be influencing the results.

3. List several factors that would affect the amount of sunlight reaching a stream and the effect each factor would have on the temperature of the stream, thus affecting its aquatic life.

   Many answers are possible. Acceptable answers might refer to the amount of shading from the riparian area; instream structure or debris; the amount of surface area of the stream; the color and composition of the streambed; the volume of water in a stream; the direction the stream is flowing; the amount and kind of sediments suspended in the water; or the human activities occurring in the riparian area that might be affecting any of the above. A correct answer should refer to how the above factors would affect the water's temperature and subsequently the fish and other aquatic life present in the stream.

4. How might seasonal temperature changes affect fish?

   Warmer air temperatures during the summer would generally create warmer water conditions with lower oxygen levels. Those fish with high oxygen needs would have more difficulty obtaining the necessary oxygen from the water. These fish would possibly move to cooler water areas. During cold weather, the formation of ice in some streams would require movement of fish to open water areas.

5. How could the presence of fish affect the amount of oxygen in the water?

   Fish are depleting the available oxygen in the water through the respiration process. This introduces another variable to be considered in the experiment. The usage of oxygen by the fish and the amount of oxygen available in the water as a function of the temperature and pressure could both be influencing the number of gill beats.

Going further

1. Following the end of the experiment, place food coloring near the mouth of the fish with a dropping pipette. Observe the flow of water as shown by the dye. Describe what you see. Discuss the implications of this discovery if the water in which the fish lives is polluted or full of sediment.
2. Repeat the experiment using other species of fish (some warm water species and some cold water species). Compare the results. Based on your results, discuss why different species are found in completely different environments or different parts of the same stream.
3. Design an experiment to test factors other than temperature which may affect the dissolved oxygen content of water.
4. Contact your local department of fish and wildlife, watershed council, or department of environmental quality office. Volunteer to assist with temperature monitoring on streams in your area. Ask local experts to show you how the data is collected, analyzed and presented. Prepare a report and share this information with the class.

Name

Temperature and respiration rate

Do you know . . .

Aquatic life must deal with a very different set of environmental conditions than terrestrial (land) life. For example, temperatures on land can move quickly from hot to very cold while water temperatures usually are slow to change. Water has the ability to absorb weather extremes and other environmental factors, so water temperature remains within a narrow range.

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Observation No.	Temperature	Gill beats/minute
1		
2		
3		
4		
5		
6		

Student sheet

Temperature guardian

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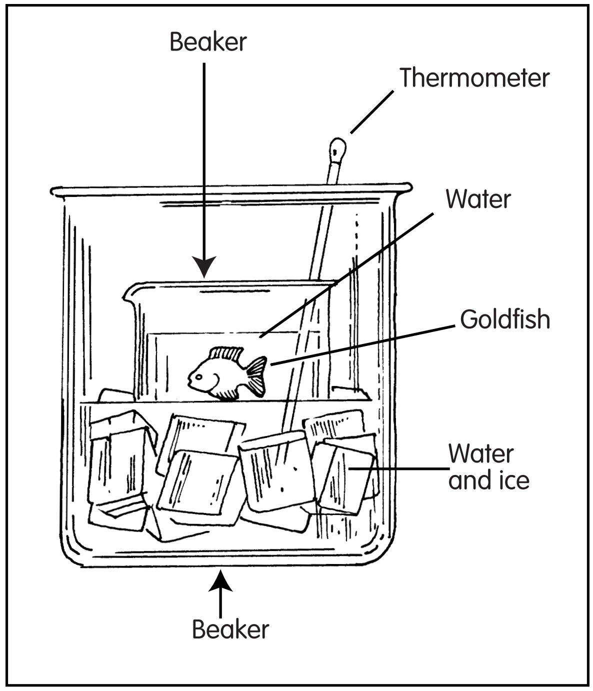
Do not allow the temperature of the smaller container to exceed 80°F.



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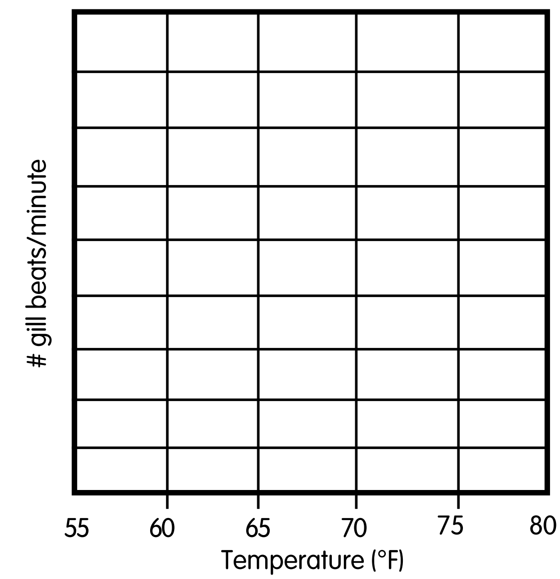
Transfer your results to the graph provided. Compare your results with those of another team by recording their measurements on your graph in another color.



Questions

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2. What could account for unexpected results in the data? For example, why would the number of gill cover beats be lower than expected at a certain temperature when the trend appeared to show a larger number of beats as the temperature increased?

3. List several factors that would affect the amount of sunlight reaching a stream and the effect each factor would have on the temperature of the stream, thus affecting its aquatic life.

4. How might seasonal temperature changes affect fish?

5. How could the presence of fish affect the amount of oxygen in the water?

Dissolved oxygen

8.3

"And the boiling voice of the waters…"
— Thomas Hardy

Oxygen is as essential to life in water as it is to life on land. Oxygen availability determines whether an aquatic organism will survive and affects its growth and development. The amount of oxygen found in water is called the **dissolved oxygen concentration (DO)** and is measured in milligrams per liter of water (mg/l) or an equivalent unit, parts per million of oxygen to water (ppm).

DO levels are affected by:

- altitude,
- water agitation,
- water temperature,
- types and numbers of plants,
- light penetration, and
- amounts of dissolved or suspended solids.

As water low in oxygen comes into contact with air, it absorbs oxygen from the atmosphere. The turbulence of running water and the mixing of air and water in waterfalls and rapids add significant amounts of oxygen to water.

Effects of temperature on DO

Temperature directly affects the amount of oxygen in water—the colder the water, the more oxygen it can hold. Bodies of water with little shading can experience a drop in DO during periods of warm weather.

Thermal pollution, the discharge of warm water used to cool power plants or industrial processes, can reduce DO levels. The area immediately downstream from the entry of warm water can be altered drastically. Thermal pollution generally occurs in larger streams. However, dilution will temper these effects as warm water mixes with colder water downstream.

Temperature alterations are occasionally used to increase fish productivity, such as at a hatchery.

Temperature directly affects the amount of oxygen in water.

At higher altitude (elevation), the dissolved oxygen saturation point is lower than under the same conditions at lower altitude. Shown below are maximum amounts, or saturation levels, of dissolved oxygen (in ppm) in fresh water at sea level for different temperatures:

DO ppm	5	6	7	8	9	10	11	12	13	14	15
Temp°F	117	92	90	77	68	59	50	45	39	36	32

When aeration is high, DO levels can temporarily be higher than the saturation level. This extra oxygen is not stored in the water.

Vocabulary

biochemical oxygen demand (BOD)
dissolved oxygen concentration (D)
salmonid

Photosynthesis, oxidation and decomposition

Oxygen can also be added to water as a result of plant photosynthesis. During the day, plants can produce oxygen faster than it can be used by aquatic animals. This surplus is temporarily available throughout the night for plant and animal respiration. Depending on individual stream conditions, high daytime DO levels and low nighttime DO levels can occur.

Photosynthesis can be inhibited by sediments. Suspended sediments make water look murky or cloudy and block or reflect much of the sunlight that would otherwise be available for photosynthesis. Sediments can also settle onto the leaves of plants, further blocking their efficiency as oxygen producers.

Most DO problems occur when temperatures are at their highest and streamflows at their lowest.

The chemical oxidation and decomposition of dissolved, suspended and deposited sediments remove oxygen from the water. The amount of oxygen needed for these processes is called **biochemical oxygen demand (BOD)** and is oxygen that is unavailable for aquatic life. If the quantity of these sediments is large, remaining oxygen can be insufficient to support many forms of aquatic life.

Most DO problems in Oregon streams occur when temperatures are at their highest and streamflows at their lowest. Salmon and trout are especially at risk during this time. Fry are often limited to small spawning streams during these "pinch periods" and DO is critical to their development. While a juvenile **salmonid** can withstand 1-2 ppm of DO for short periods, its growth rate drops sharply below 5 ppm, especially if the temperature is high.

Fish die-offs in shallow, warm ponds are a fairly common occurrence during the summer. During a long period of warm sunshine, algae grow profusely. A summer storm can result in several days of cloudy weather. The reduced sunlight can cause a massive die-off of the algal bloom. As dead algae decompose, available oxygen is depleted. The amount of DO drops to lethal levels, causing a subsequent die-off of fish and other aquatic organisms.

Maintaining productive DO levels

To maintain productive DO levels in a stream, shade should be provided to keep water temperatures cool. The presence of instream structures ensures mixing of water and air. Materials that can increase BOD, such as manure from feedlots or untreated municipal waste, should not be introduced.

Extensions

1. "Water Canaries," *Aquatic Project WILD*, pp. 38-42. Grades 4-12.
2. "The Glass Menagerie," *Aquatic Project WILD*, pp. 130-133. Grades 7-12.
3. "Deadly Waters," *Aquatic Project WILD*, pp. 146-150. Grades 3-12.

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A South Twin story

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

Objectives

The student will (1) graph DO and temperature changes for various depths of South Twin Lake, and (2) describe the relationship between temperature and dissolved oxygen in water.

Method

The student will graph and analyze the relationship between temperature and DO information and how it relates to aquatic life.

For younger students

1. Consult extension activities at the end of each chapter to address the needs of younger students.
2. Read activity background information aloud to younger students or modify for your students' reading level.
3. Students need the experience with the activity "Temperature and Respiration Rate" (pp. 265-268) before proceeding with this activity. Students must know how to read a thermometer. Prior graphic experience is helpful. Simply questions.

Materials

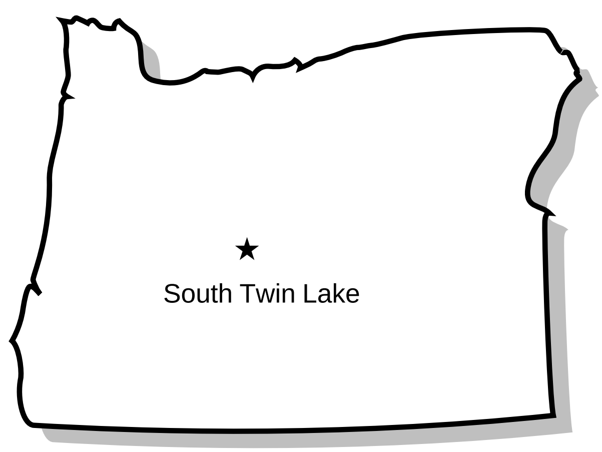
- colored pencils or markers
- rulers
- copies of student sheets (pp. 279-282)

Background

Do you know . . .

Oxygen is as important to life in water as it is to life on land. Aquatic life needs a minimum amount of oxygen to survive, grow and develop. The oxygen found in water is called the **dissolved oxygen concentration (DO)** and is measured in milligrams per liter of water (mg/l) or parts per million of water (ppm). The two measurements are equal.

DO levels can be changed by water movement, water temperature and the growth of aquatic plants. The *amount* of oxygen put into the water by these plants can also be changed by water temperature, the amount of light (cloudy vs. sunny days), and water depth (plants can only photosynthesize at depths to which light can penetrate). Clearness of the water can affect oxygen levels, too. Muddy water will block the sunlight needed by plants to make food and produce oxygen.



Vocabulary

dissolved oxygen concentration (DO)

Water temperature directly affects the amount of oxygen water can hold. The colder the water, the more oxygen it can hold. The chart belows shows how much dissolved oxygen (in ppm) fresh water (at sea level) can hold at different temperatures.

DO ppm	5	6	7	8	9	10	11	12	13	14	15
Temp°F	117	92	90	77	68	59	50	45	39	36	32

The saturation level is the maximum amount of DO that water can hold. This saturation level can be temporarily exceeded when many plants are growing in the water, or if the water is very turbulent (tumbling water caused by rocks). This extra oxygen is not stored in the water.

Most DO problems in Oregon streams occur between April and October. During this time, temperatures are at their highest levels and streamflows are at their lowest. Fish, especially salmon and trout, have problems surviving during this time. Fry are often found only in small spawning streams during these "pinch periods," and DO is necessary for their development. Even though a young fish can survive 1-2 ppm of DO for short periods, their growth rate drops sharply below 5 ppm, especially if the temperature is high.

Procedure

Now it's your turn . . .

How does temperature affect the amount of DO in a body of water? To answer this question, you will graph temperature and dissolved oxygen data gathered from South Twin Lake in the Oregon Cascades. Make the graph as instructed, then answer the questions about the relationship of dissolved oxygen (DO) and temperature.

The information in the table at right is from a 1982 survey of South Twin Lake near Bend, Oregon. Fish found in the lake include rainbow trout, chub, brown trout, brook trout, and kokanee (land-locked sockeye salmon). Aquatic plants found in the lake include water milfoil and algae.

South Twin Lake, July 1982

Depth (ft.)	DO (ppm)	Temp (°F)	O_2 Saturation (ppm)
0	—	—	
2	15	70	
4	15	69	
6	15	68	9
8	16	68	
10	16	68	
12	16	68	
14	16	68	
16	16	68	
18	16	67	
20	16	66	
22	17	64	
24	17	63	
26	17	61	
28	18	59	10
30	18	57	
32	13	55	
34	12	54	
36	8	52	
38	5	51	
40	2	50	11

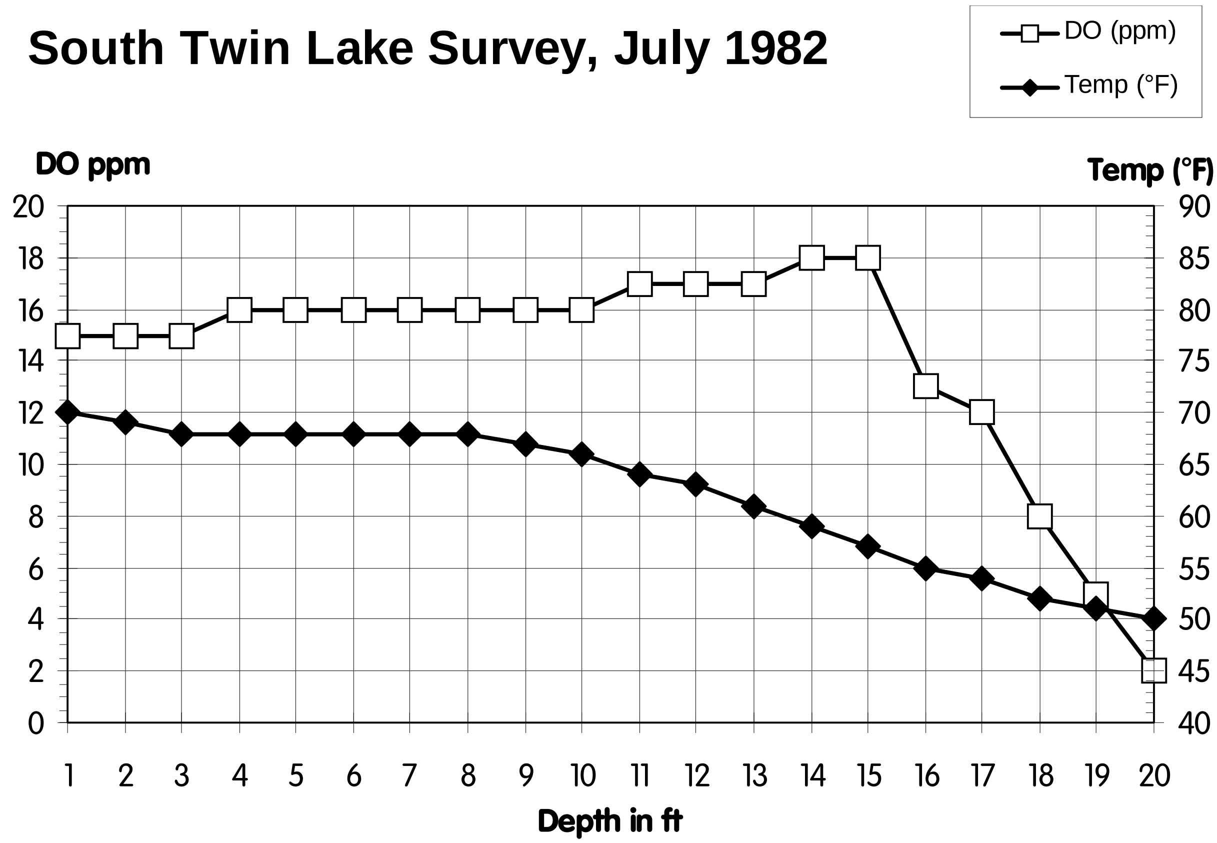
Graph

Plot depth versus dissolved oxygen (DO) and temperature on the following graph.

Going further

1. Design an experiment to test oxygen production by plants under different light and temperature conditions. Produce a display to summarize your results.
2. Contact your local department of fish and wildlife, watershed council, or department of environmental quality office. Volunteer to assist with temperature monitoring on streams in your area. Ask local experts to show you how the data is collected, analyzed and presented. Prepare a report and share this information with the class.

South Twin Lake Survey, July 1982



Questions

1. At what depths would you expect to find the greatest number of salmon or trout? Why?
   Between 22 feet and 30 feet. (Students may need to refer to water temperature background information on page 253 to make a better determination.) Salmon and trout prefer temperatures between 40°F and 65°F, and water can hold the greatest amount of oxygen at these temperatures.

2. List as many reasons as you can why more dissolved oxygen is present in the water between the depths of 20 and 30 feet?
   Cold water at these depths holds more oxygen, and enough light is present for food and oxygen production by plants.

3. According to the graph, what effect does temperature appear to have on dissolved oxygen saturation?
   Cold water holds more oxygen, except at depths below 30 feet.

4. At depths less than 36 feet, the DO level is higher than saturation level. Why?
   At less shallow depths, light penetration allows more oxygen production by photosynthetic plants. (Students may need additional information to answer this question.)

5. Why does the DO level drop between 30 feet and 40 feet?
   Available light is limited, reducing photosynthesis and the amount of oxygen produced by that process.

Name

A South Twin story

Do you know . . .

Oxygen is as important to life in water as it is to life on land. Aquatic life needs a minimum amount of oxygen to survive, grow and develop. The oxygen found in water is called the **dissolved oxygen concentration (DO)** and is measured in milligrams per liter of water (mg/l) or parts per million of water (ppm). The two measurements are equal.

DO levels can be changed by water movement, water temperature and the growth of aquatic plants. The *amount* of oxygen put into the water by these plants can also be changed by water temperature, the amount of light (cloudy vs. sunny days), and water depth (plants can only photosynthesize at depths to which light can penetrate). Clearness of the water can affect oxygen levels, too. Muddy water will block the sunlight needed by plants to make food and produce oxygen.

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DO ppm	5	6	7	8	9	10	11	12	13	14	15
Temp°F	117	92	90	77	68	59	50	45	39	36	32

The saturation level is the maximum amount of DO that water can hold. This saturation level can be temporarily exceeded when many plants are growing in the water, or if the water is very turbulent (tumbling water caused by rocks). This extra oxygen is not stored in the water.

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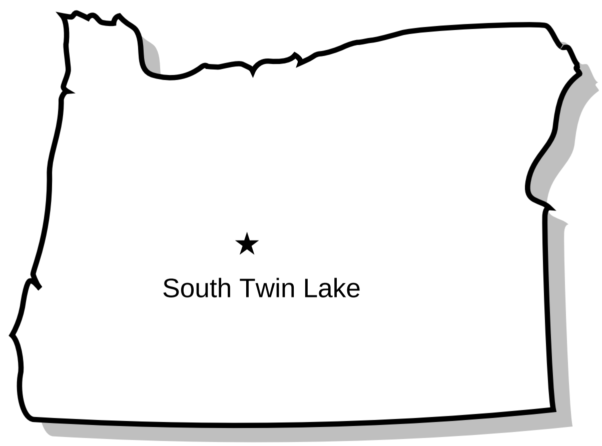


Vocabulary

dissolved oxygen concentration (DO)

Student sheet

Now it's your turn . . .

How does temperature affect the amount of DO in a body of water? To answer this question, you will graph temperature and dissolved oxygen data gathered from South Twin Lake in the Oregon Cascades. Make the graph as instructed, then answer the questions about the relationship of dissolved oxygen (DO) and temperature.

The information in the table at right is from a 1982 survey of South Twin Lake near Bend, Oregon. Fish found in the lake include rainbow trout, chub, brown trout, brook trout, and kokanee (land-locked sockeye salmon). Aquatic plants found in the lake include water milfoil and algae.

Graph

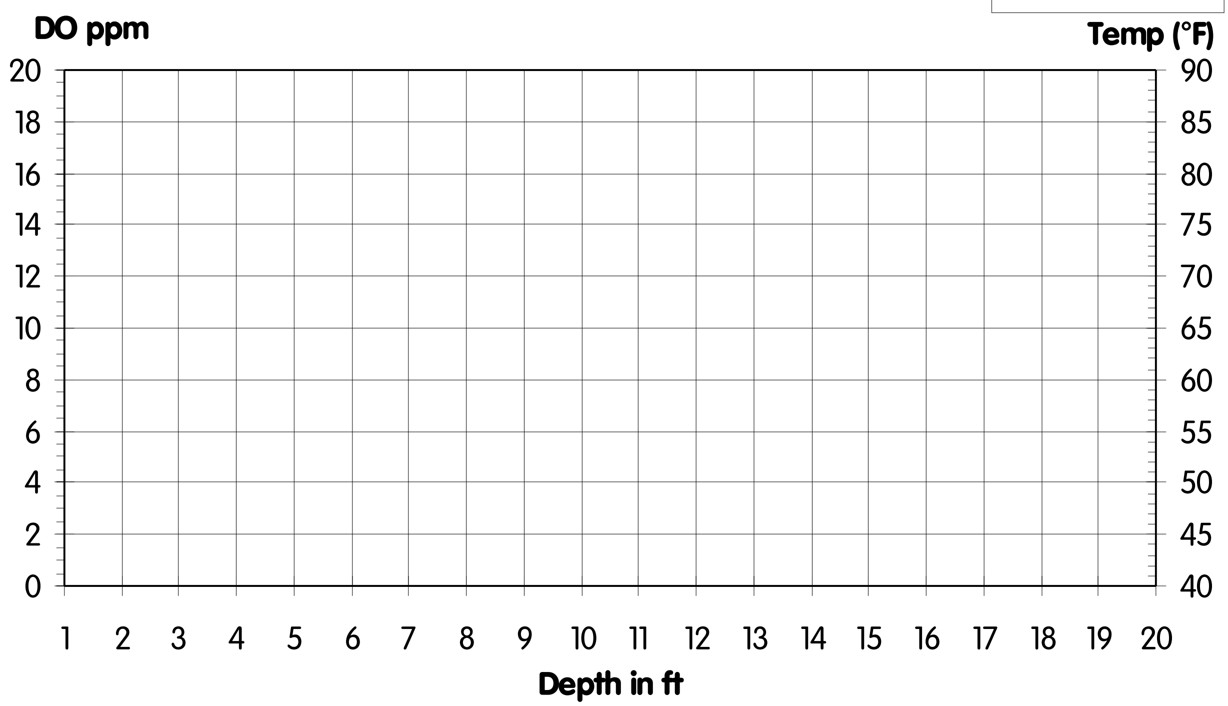
Plot depth versus dissolved oxygen (DO) and temperature on the following graph.

South Twin Lake, July 1982

Depth (ft.)	DO (ppm)	Temp (°F)	O_2 Saturation (ppm)
0	—	—	
2	15	70	
4	15	69	
6	15	68	9
8	16	68	
10	16	68	
12	16	68	
14	16	68	
16	16	68	
18	16	67	
20	16	66	
22	17	64	
24	17	63	
26	17	61	
28	18	59	10
30	18	57	
32	13	55	
34	12	54	
36	8	52	
38	5	51	
40	2	50	11

South Twin Lake Survey, July 1982

DO (ppm)
Temp (°F)



Student sheet

Questions

1. At what depths would you expect to find the greatest number of salmon or trout? Why?

2. List as many reasons as you can why more dissolved oxygen is present in the water between the depths of 20 and 30 feet?

3. According to the graph, what effect does temperature appear to have on dissolved oxygen saturation?

4. At depths less than 36 feet, the DO level is higher than saturation level.Why?

5. Why does the DO level drop between 30 feet and 40 feet?

pH

8.4

"There was, at this time, a small alkaline water hole at the desert's edge.… No one but crows would drink there."
— Barry Holstun Lopez

The concentration of hydrogen ions in a solution is called **pH** and determines whether a solution is acid or alkaline. A pH value shows the intensity of acid or alkaline conditions. In general, acidity is a measure of a substance's ability to neutralize bases, and alkalinity is a measure of a substance's ability to neutralize acids.

The pH scale ranges from 1 (acid) to 14 (alkaline or basic) with 7 as neutral. The scale is logarithmic so a change of one pH unit means a tenfold change in acid or alkaline concentration. A change from 7 to 6 represents 10 times the concentration, 7 to 5, 100 times, and so on.

Most organisms have a narrow pH range in which they can live (Figure 10). While some fish can tolerate a range of 5 to 9, others cannot tolerate a change of even one pH unit. Because of this narrow range of tolerance, pH limits where many organisms can live and the composition of a community.

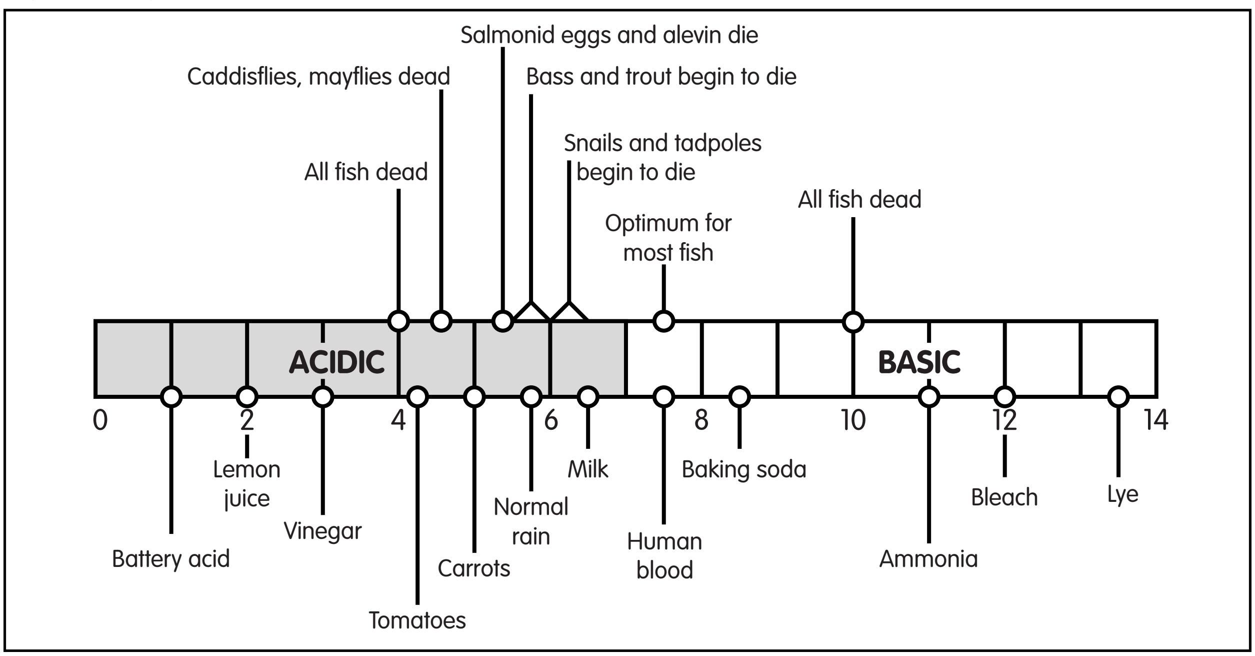
Although pure distilled water has a pH of about 7, any minerals dissolved in water can change the pH. These minerals can be dissolved from a streambed, the soil in a watershed, sediments washed into a stream, or the atmosphere.

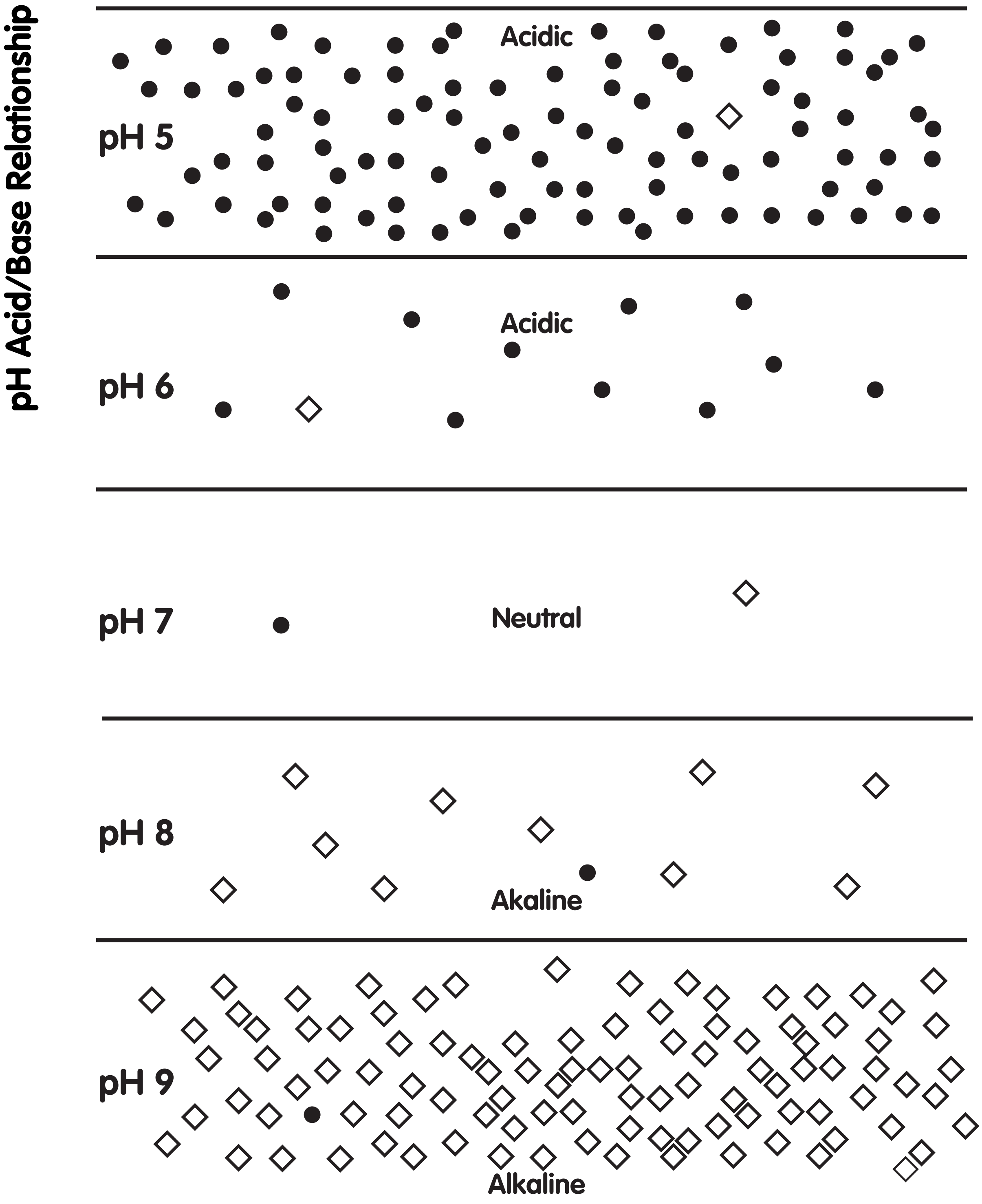
In eastern Oregon, where many soils have a high alkaline content, pH levels of some water bodies can rise above 10. Forest soils tend to

Vocabulary

pH

Figure 10. pH Scale





Each pH increment changes the pH factor 10 times

Adapted from materials prepared by Stephanie Gunckel, Andrew Talabere, and Art McEldowney and used with permission.

be slightly acid and many lakes or streams in forested regions of Oregon can approach a pH of 6.

The age of a lake can also influence pH. Young lakes are often basic. As organic materials build up, decomposition forms organic acids and releases carbon dioxide. Carbon dioxide mixed with water forms carbonic acid, making the lake more acidic.

Rainfall measuring just under 2.0 fell on Wheeling, WV, in 1978.

When rain falls through the atmosphere, the gases it contacts come into solution. As rain absorbs carbon dioxide it becomes slightly acidic, but reaches a natural lower limit of pH 5.6.

Air pollution, primarily from automobile exhaust and fossil fuel burning, has increased concentrations of sulfur and nitrogen oxides in the air. These fall with rain as weak sulfuric and nitric acids causing an "acid rain." Currently in portions of the eastern United States, the mean pH for rainfall is 4.3, approximately ten times more acidic than normal. Rainfall measuring just under pH 2.0 fell on Wheeling, West Virginia, in 1978. This was approximately 5,000 times the acidity of normal rainfall and is the most acidic rainfall on record.

Increased acidity has caused pH to exceed lethal levels for fish in many lakes. A U.S. government study estimated that 55 percent of the lakes and 42 percent of stream miles in the eastern United States are currently being subjected to acidic deposition, which will eventually lead to their deterioration. In addition, acid build-up in soils can have detrimental effects on forests and crops, and hinders natural nutrient recycling processes.

Because rain can fall a considerable distance from a pollution source, acid rain is a regional and global problem.

Factors that determine the pH of a body of water can be far removed from a particular site, making it difficult to directly manage the pH. Because pH is a limiting factor, it is important to have a measurement to determine which organisms can survive and prosper. This measurement also serves as a baseline measurement and can assist in the monitoring of future changes.

Note: Use the graphic on p. 284 as an overhead transparency to demonstrate the concept that each pH increment changes the pH by a factor of 10.

Extensions

1. "Deadly Skies," *Aquatic Project WILD*, pp. 142-145. Grades 1-12.
2. "Water Canaries," *Aquatic Project WILD*, pp. 38-42. Grades 4-12.
3. "Deadly Waters," *Aquatic Project WILD*, pp. 146-150. Grades 3-12.
4. "How the Soil Affects Acid Rain," *Earth: The Water Planet*, pp. 73-78. Grades 4-8.
5. "Acid Rain—How Acid Is It?" *Groundwater: A Vital Resource*, pp. 31-34. Grades 7-12.
6. "Does Acid Rain Affect Groundwater?" *Groundwater: A Vital Resource*, pp. 39. Grades 8-12.
7. "Making Acid Rain," *Groundwater: A Vital Resource*, pp. 40-41. Grades 4-8.
8. Take comparably aged leaves from several different tree species. Set up separate containers for each species with 16 oz. of water each. Measure the pH.

   Strip the leaves from the stems and soak 1 oz. of the leaf material in the water overnight. Test the pH the next day. Note the differences in pH from naturally occurring materials in the leaves.

   Discuss how plant materials falling into a stream can change the water quality for stream organisms. A good choice of species includes Douglas-fir, alder, willow and oak. (Contributed by Mary Roberts, 1989.)

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Lakes and pH

__Activity Education Standards:__ Note alignment with Oregon Academic Content Standards beginning on p. 483.

Objectives

The student will (1) compare the pH differences of two lakes, and (2) answer questions analyzing the reasons for and effects of those differences.

Method

The student will compare and analyze the pH differences of two Oregon lakes.

For younger students

1. Consult extension activities at the end of each chapter to address the needs of younger students.
2. Read activity background information aloud to younger students or modify for your students' reading level.
3. Provide sufficient background information about pH using common products students recognize (baking soda, vinegar, coke, lemon juice, etc.).

Materials

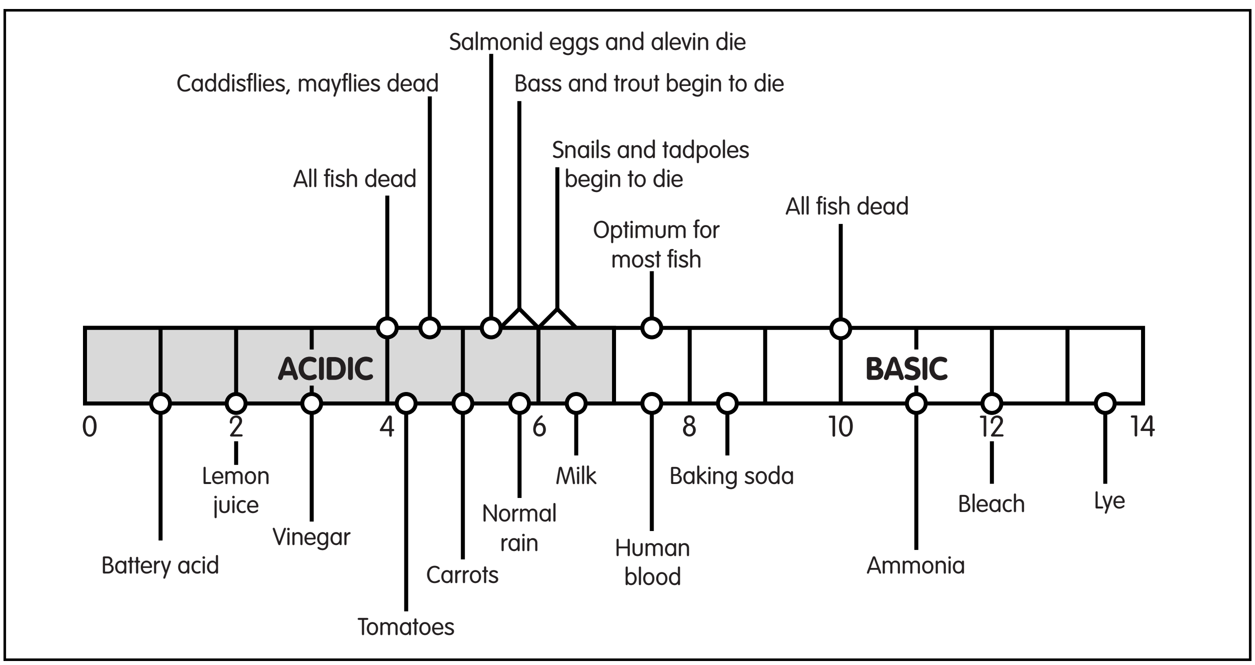
- copies of student sheets (pp. 291-294)

Background

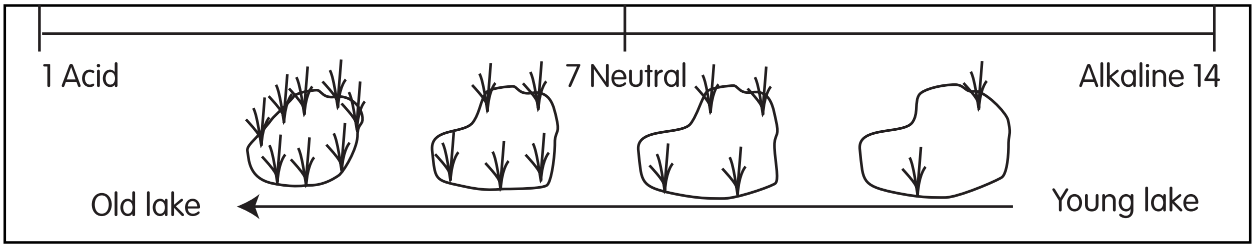
Do you know . . .

Water has an important chemical nature. We measure this chemical nature with a pH scale. If you look at the pH scale below, you will see this watery environment can be very acid (0 on the pH

pH Scale



pH Scale



scale) or very alkaline (14 on the pH scale) or anywhere in between. We meet these extremes every day in our foods—vinegar is very acid and baking soda or antacid pills are very alkaline. Pure distilled water has a neutral pH of about 7.

Each increase in value away from the neutral point of 7 is 10 times greater than the previous value. Small changes in the acidity or alkalinity of water can have big impacts on aquatic life, most of which require a pH level ranging from 6.0 to 8.5. Even if fish could survive changes in pH, insects on which they feed and aquatic plants cannot. The food chain can collapse if the pH goes beyond these narrow boundaries.

Acid rain results when water vapor in the air becomes acidified through chemical reactions with pollution coming from refineries and factories, coal- or oil-fired power plants, and cars. It falls to earth as acid rain. Acidified water can be very harmful to living organisms.

Soils also have a chemical nature. When soils are mixed with water, the pH may change. In eastern Oregon, where soils are high in alkali content, the pH of many lakes and streams can be greater than 10—or very alkaline. Forested soils are usually slightly acidic. Their influence creates a pH near 6 in the streams and lakes near them. Natural rainfall has a pH of 5.7.

Some areas of the country have a major problem with acid rain while in other areas the threat is not as great. The degree to which acid rainfall affects a watershed depends on the system's natural "buffering capacity." In areas with alkaline soils, natural runoff is enough to keep the water from becoming too acidic. In forested areas, soils have far less ability to buffer the effects of acid rain.

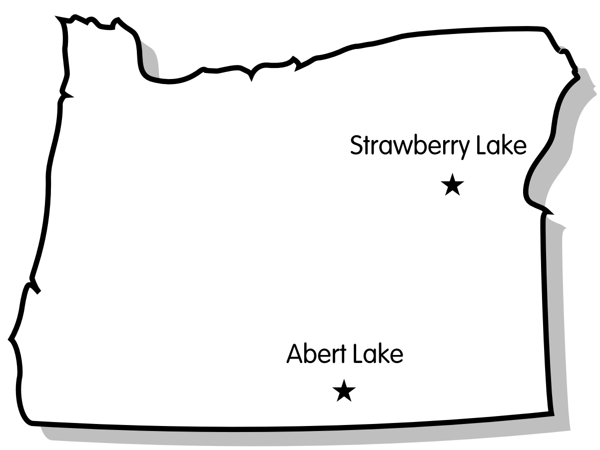
The age of a lake influences the pH of the water in the lake. The drawing above illustrates how this happens.

As trees and other plants grow, die and decompose, they release carbon dioxide (CO_2) into the water. This succession forms carbonic acid and makes the lake more acidic as time passes.

Procedure

Now it's your turn . . .

Does Oregon have acidic or alkaline lakes? In this exercise you will study the descriptions of two Oregon lakes. Compare the factors that may influence their pH and answer the questions that follow.



Description

Strawberry Lake is found in the Strawberry Mountains of eastern Oregon. Forest covers more than 75% of its steeply sloped watershed. A survey of Strawberry Lake found the following information:

	Depth	Dissolved Oxygen	Temp	pH
Maximum	27 ft.	8.4 ppm	64.8°F	6.5
Average	9 ft.			

Abert Lake has no outlet, and is found in an arid, highly mineralized area of southeastern Oregon. Forest covers 30 percent of its moderately sloped watershed. A survey of Abert Lake found the following information:

	Depth	Dissolved Oxygen	Temp	pH
Maximum	11 ft.	9.5 ppm	65.3°F	10.1
Average	7 ft.			

Notes to the teacher

An apparent discrepancy exists between depth, temperature and dissolved oxygen between the two lakes. This discrepancy could be a result of specific conditions on the day measurements were taken or sampling error. The discrepancy does not affect the questions in this activity but may be used to generate discussion with the students.

Questions

1. Why is the pH different in the two lakes?
   The alkaline soils in the Abert Lake drainage account for its high pH, while the forested drainage of Strawberry Lake contributes organic material to make it more acidic.
2. Which lake could support the most life? Why?
   Strawberry Lake. More species are tolerant of its pH range.
3. If both lakes dried up, which lake bed would likely have the best chemical environment to become colonized by plants? Why?
   Strawberry Lake. Fewer plant species are tolerant of alkaline soils.
4. If acid rain becomes a problem in Oregon, predict what could happen to Strawberry Lake.
   Because Strawberry Lake is already near the lower limit for many fish, an increase in acidity would make it uninhabitable for most species.
5. What could happen to Abert Lake?
   If the increase in acidity is great (bringing it closer to neutral), Abert Lake could support a greater number of species.

Going further

1. Collect water samples from several sites in your local community or watershed. Test their pH. Hypothesize about the quality of each of the collection sites with respect to suitable aquatic habitat for living organisms. Research whether or not the pH levels in these areas have changed over the past several years. Prepare a report to summarize your findings and present the results to the class.
2. See "Deadly Skies," *Aquatic Project Wild*, pp. 142-145.
3. Design an experiment to test how soil types affect acid rain. See "How The Soil Affects Acid Rain," *Earth: The Water Planet*, pp. 73-78. Prepare a report to summarize your findings and present the results to the class.
4. Design an experiment to test the effect naturally occurring materials in leaves and twigs have on the pH of water during autumn when large amounts of organic material fall into the water. A good choice of species to compare includes Douglas fir, alder, willow, and oak. Prepare a report summarizing your findings and present it to the class.
5. Contact your local department of environmental quality office. Volunteer to assist with water quality monitoring on streams in your area. Ask local experts to show you how the data is collected, analyzed and presented. Prepare a report and share this information with the class.

Name

Lakes and pH

Do you know . . .

Water has an important chemical nature. We measure this chemical nature with a pH scale. If you look at the pH scale below, you will see this watery environment can be very acid (0 on the pH scale) or very alkaline (14 on the pH scale) or anywhere in between. We meet these extremes every day in our foods—vinegar is very acid and baking soda or antacid pills are very alkaline. Pure distilled water has a neutral pH of about 7.

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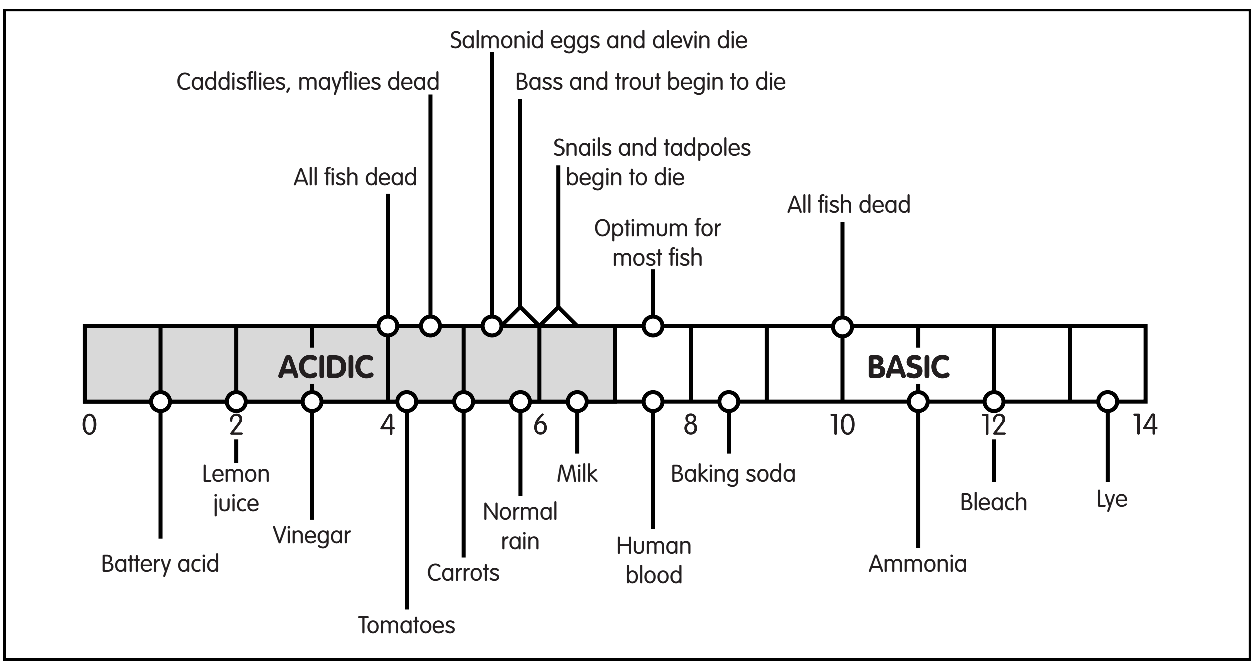
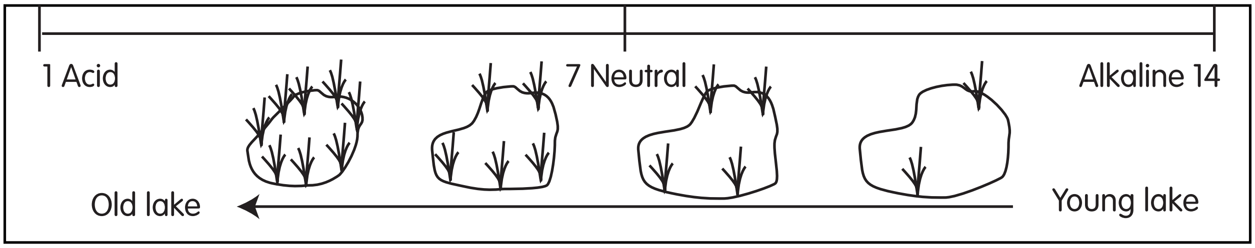
Some areas of the country have a major problem with acid rain while in other areas the threat is not as great. The degree to which acid rainfall affects a watershed depends on the system's natural "buffering capacity." In areas with alkaline soils, natural runoff is enough to keep the water from becoming too acidic. In forested areas, soils have far less ability to buffer the effects of acid rain.

pH Scale



Student sheet

pH Scale

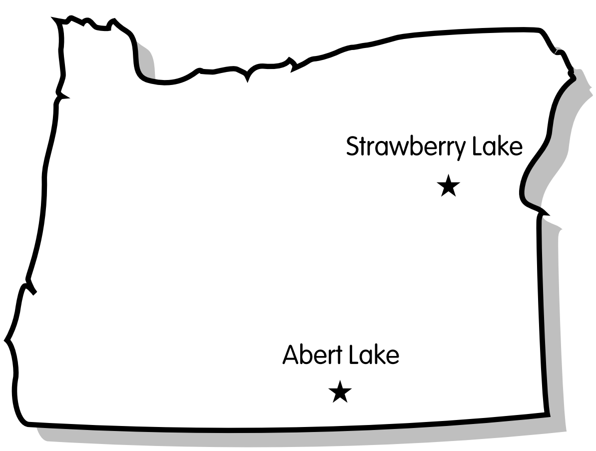


The age of a lake influences the pH of the water in the lake. The drawing below illustrates how this happens.

As trees and other plants grow, die and decompose, they release carbon dioxide (CO_2) into the water. This succession forms carbonic acid and makes the lake more acidic as time passes.

Now it's your turn . . .

Does Oregon have acidic or alkaline lakes? In this exercise you will study the descriptions of two Oregon lakes. Compare the factors that may influence their pH and answer the questions that follow.



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	Depth	Dissolved Oxygen	Temp	pH
Maximum	11 ft.	9.5 ppm	65.3°F	10.1
Average	7 ft.			

Questions

1. Why is the pH different in the two lakes?

2. Which lake could support the most life? Why?

3. If both lakes dried up, which lake bed would likely have the best chemical environment to become colonized by plants? Why?

4. If acid rain becomes a problem in Oregon, predict what could happen to Strawberry Lake.

5/ What could happen to Abert Lake?

Sediments

8.5

"Mud, mud, glorious mud, mud, mud, mud."
— Outdoor School song

As long as there has been water, it has carried solid particles called **sediments**. Sediments occur naturally as products of weathering and erosion. Wind, water or frost action on rock surfaces result in gradual breakdown of large, solid rock pieces to finest sand. Nutrients necessary to life are transported as sediments, using rivers and streams as pipelines.

Ecosystems depend on sediments for their health, but excessive amounts are harmful. Erosion and sediment transport are natural phenomena that can improve as well as degrade habitats within a watershed. Water erodes gravel banks to provide a continuing source of gravel for a stream, shifts gravel bars, and forms or deepens pools, all of which benefit spawning and rearing fish. However, erosion of fine-textured soils such as clays, silts, and fine sand can reduce habitat quality by compacting gravel or lowering water quality.

Sediment types

There are several types of sediments. **Bedload sediments** are too heavy to be constantly suspended. They are rolled and bounced along the bottom of a stream. The size of a particle of bedload sediment will vary with the volume and speed of the water. Spawning gravel is often transported as bedload sediment during high winter streamflow. Periodic fluctuations in the amount of sediment and bedload being transported naturally occur.

Suspended sediments are those carried in suspension. Rapidly flowing water can carry more suspended sediments than slow-moving water.

A gradient of deposition exists and is determined by streamflow velocity and volume and sediment size. Heavier sediments settle out first, followed by successively lighter materials. As velocity decreases, as from the center of the stream out toward its edges, or in slow water areas, the finest sediments settle to the bottom, no longer suspended by the action of water.

Total suspended sediment (TSS) is a measure of how much sediment a stream is carrying.

Nutrients necessary to life are transported as sediments, using rivers and streams as pipelines.

Suspended sediments can give water a murky or cloudy appearance by reducing light penetration. **Turbidity** is the term used to describe and measure the degree to which light is blocked.

Vocabulary

- bedload sediments
- sediments
- suspended sediments
- total dissolved solids (TSD)
- total suspended sediment
- turbidity

Helpful and harmful sediments

Sediments dissolved in water can be beneficial or harmful to the aquatic community. Some are nutrients essential to life. Others can be minerals or salts that change water pH or are poisonous to life. The measure of solids dissolved in water is called **total dissolved solids** (**TDS**). TDS levels higher than 500 ppm make water unfit for consumption.

In western Oregon, 200 communities get at least a part of their water supply from municipal watersheds. Currently, because of its high quality, little treatment is needed to make most of this water fit for domestic use.

Manufacturing of high-quality paper products and beer depend on availability of clear, clean water. High concentrations of sediments make water unfit for these processes without expensive filtering.

Sediments are the nations primary water pollutant, even though industrial and municipal wastes receive more attention.

Suspended sediments can block or reflect sunlight before it reaches aquatic plants. Heavier sediments can cover leaves, inhibiting photosynthesis, or even bury plants.

Sediments affect insect life in a body of water. Large amounts of sediments can smother some species. A change in the bottom material and the type, number, and health of plants changes the habitat, and, therefore, the species composition of the insect community.

Today, even though industrial and municipal wastes receive more attention, sediments are the nation's primary water pollutant. Erosion is the source of most sediments. Agriculture is responsible for more erosion than any other single activity, but road construction and use, timber harvest, forest fires and other sources contribute. Heavy concentrations of sediments increase the cost of municipal water treatment, can be harmful or fatal to aquatic life, and are indicators of excessive erosion.

Fish are also adversely affected by high sediment levels. Very high concentrations of suspended sediments can irritate and actually clog gill filaments, causing fish to suffocate.

Bedload sediments deposited in the channel change the composition of gravel beds used for spawning. This can reduce the amount of oxygen available to the eggs by blocking water circulation, trap fry in the gravel, or reduce the amount of suitable spawning habitat. Changes in plant and insect composition can also reduce amount and types of food needed during different stages of development.

Importance of vegetation

Excessive sedimentation and the problems it causes can be controlled by reducing erosion. Surface runoff is the primary cause of erosion and can be prevented with adequate plant cover during periods of runoff. Plants and the organic material they add to soil lessen the force of falling rain, add structure to the soil, and increase the soil's ability to absorb and hold water. When surface runoff does take place, leaves and stems of plants trap much debris and sediment that would otherwise be carried into streams.

As a stream meanders across a floodplain, it moves sediments and deepens its channel. Riparian vegetation is especially important in the control of these sediments. Plants along streams help prevent bank erosion.

Death of a stream

If these plants are lost, a devastating chain of events can begin. The banks become eroded, undercut, and frequently collapse, destroying more plants and exposing more soil to weathering and erosion. Sedimentation increases. Heavy flows scour the channel, moving even greater quantities of sediments. The stream channel continues to downcut, interfering with the re-deposition of sediments. This lowers the water table and decreases water retention in the area around the stream. Decreased water retention in the area around a stream means higher flows that will accelerate erosion.

During the summer months, a wide, shallow stream, shaded only by its deep cutbanks, will be warm and have limited quantities of dissolved oxygen. At this point, it is no longer a productive or healthy stream. Control of excessive sedimentation and the health of streams depend on vegetation, especially in riparian areas.

Extensions

1. "Where Does Water Go After School?" *Aquatic Project WILD*, pp. 82-85. Grades 6-12.
2. "Deadly Waters," *Aquatic Project WILD*, pp. 146-150. Grades 3-12.
3. "The Invisible Load," *Groundwater: A Vital Resource*, pp. 28-28. Grades 8-12.
4. "How Raindrops Erode The Soil," *Earth: The Water Planet*, pp. 63-68. Grades 4-8.
5. "How Can Farmers Reduce Erosion Caused by Rain?" *Earth: The Water Planet*, pp. 69-72. Grades 4-8.
6. The following demonstration shows the effects of raindrop impact on various soil surfaces:
   - Obtain several dowels and wrap a piece of filter paper around each one, securing it with a rubber band.
   - Choose several sites (for example, bare soil, sod-covered soil, or soil covered with forest litter).
   - At each site, make a hole in the ground sufficient to hold the dowel upright with its filter paper covering above the soil's surface.
   - Use a sprinkling can to simulate rainfall or allow the dowels to remain at the sites during a storm.
   - Raindrop impact and splash will deposit sediment and organic material on the filter paper.
   - Collect the dowels.
   - Carefully remove the filter paper.
   - Dry and weigh the paper to compare the sites.
   - Take note of what sticks to the filter paper.
   - Discuss the implications of the results as they relate to riparian area health and sedimentation.

(Contributed by Bruce Anderson, 1988.)

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Don't runoff

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

Objectives

The student will (1) demonstrate how sediments enter a stream and (2) describe the effect of sediments on stream dynamics, plants and animals.

Method

The student will use sod-covered soil and bare soil samples to demonstrate how ground cover reduces erosion.

For younger students

1. Consult extension activities at the end of each chapter to address the needs of younger students.
2. Read activity background information aloud to younger students or modify for your students' reading level.
3. Teacher should set up activity prior to student use, or use as a demonstration activity. Simply the questions.

Materials

- copies of student sheets (pp. 303-306)
- 2 boxes about 12" wide, 24" long, and 2" to 4" deep. A plastic tray used for starting plants makes a good box. The boxes should be water tight. At one end, cut a "V" notch about half the depth of the tray. Fit a spout (of tin or other material) at the notch to draw running water off into a container.
- 2 sprinkling cans, or make your own with two, 1-gallon plastic milk jugs. (With a hot straight pin, melt the same number of holes in each jug in an area near the top and opposite of the handles. Melt an eighth-inch hole in the jug at the top of the handle.)
- Soil to fill each container. Make sure the soil for both containers is gathered from the same spot. The soil need not be completely dry, but avoid waterlogged soil.
- Piece of sod from a pasture, lawn, or fence row, cut to fit one of the boxes (trim grass to one inch in height). Grass clippings or other mulch to cover the soil in one container could also be used.
- 2, ½-gallon or larger, wide-mouth glass jars
- 2 sticks of wood about 1 inch thick
- ½ gallon of water for each sprinkler (1 gallon total)
- 2 stools (to support jars collecting runoff water)

Source: U.S. Department of Agriculture, Soil Conservation Service, *Soil and Water Conservation Activities for Scouts,* PA-978, 1977.

Background

Do you know . . .

Ground cover (grass, herbs, shrubs, etc.) actually protects the soil from a real pounding. Raindrops that hit bare soil break it down and reduce the amount of water it can absorb (store). Unprotected soil can also be easily washed into a stream. This is why plants are so important to soil, riparian areas and watersheds.

The soil in a healthy area would contain large amounts of decomposed organic matter (**humus**). Humus can absorb lots of water—like a sponge. Water is also held in the pores between the soil particles. The make-up of a soil determines how much water it can absorb.

Healthy soils can absorb most

Vocabulary

humus

rain and snowmelt until saturated (full of water). This means water seeps into streams more slowly, reducing erosion and sediments. It also means flooding is less likely, because most of the water is stored in the soil.

Plants benefit, too. Plants can use the stored water over a longer time period, increasing their growth rates. Plant roots open up channels allowing water to enter the soil easily. Plant stems and leaves also slow water, greatly reducing erosion and sediments in streams. Streams run clear in a healthy system.

A riparian area with little or no cover is exposed to the force of raindrops. Raindrops soften binding material that holds soil particles together, breaking them into fine particles. The impact of the drops splashes the fine particles into the air. These fine particles collect on the soil surface and fill the spaces between the larger soil particles. The result is a "seal" over the surface that prevents much of the rain from entering the soil. The water has no choice but to run off quickly, carrying sediments that end up in the stream. River systems with poor soils in the riparian area and uplands experience high sediment loads and heavy flooding.

Sediments that end up in a stream can harm aquatic plants and animals. Muddy or murky water blocks sunlight, which plants need to make food. Sediments also settle on plant leaves, further reducing their ability to produce food and oxygen. Extremely heavy sediment loads can even bury plants.

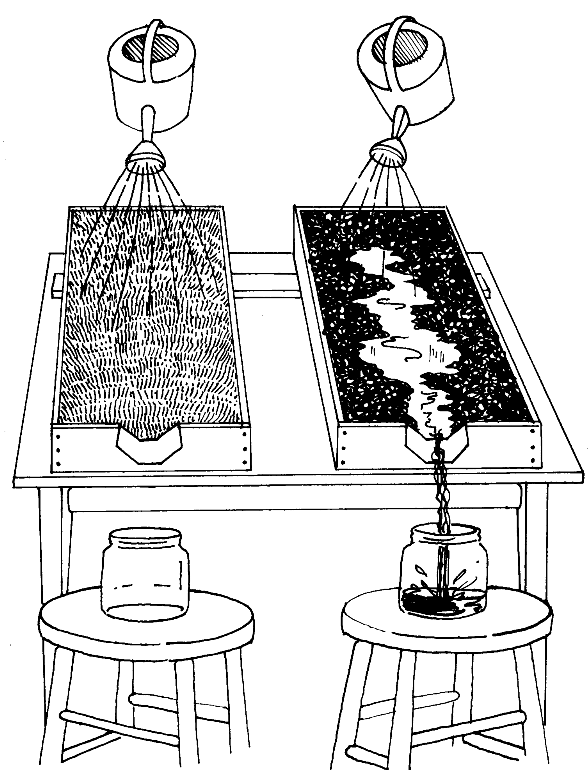
Large amounts of sediments suspended in the water can clog a fish's gills, causing it to suffocate. Sediments sift into spaces among the gravel. This can reduce oxygen flow to developing fish eggs, trap fry in the spawning gravel, and make aquatic insect habitat unsuitable.

Procedure

Now it's your turn . . .

Will vegetation protect the soil's surface from erosion? In this investigation you will demonstrate how ground cover affects erosion by comparing the effects of falling water on vegetated and nonvegetated soils.

1. Prepare two boxes as directed by your teacher. Refer to the diagram at right.
2. Set both boxes on a table so the spouts extend over the edge. Place sticks under the opposite end to give the boxes slope. Both boxes should have the same slope.
3. Fill both trays with soil from the same place—no grass, just soil. The idea is to have the same kind of soil in both boxes.
4. Place the empty jars on stools placed beneath the spouts of the boxes.
5. Cover the soil in one tray with sod (or grass clippings).
6. Fill two sprinkling jugs with ½ gallon of water each. Holding each jug about one foot above the boxes, sprinkle water onto the soil at the upper end of both boxes. It is important to pour the water from the same height and at the same steady rate.
7. Collect water in both jars for five minutes. If necessary, adjust the collection time for the soil and slope you are using.
8. Compare the amounts and clarity of water in each jar.



Questions

1. Describe the water in the runoff jars from each box. Is the same amount of runoff found in each jar? Why or why not?
   There should be less water from the tray with grass clippings or sod. The mulch has held the soil and slowed the water velocity allowing greater infiltration.
2. Why is it important to use the same amount of water and pour it from the same height and at the same rate when conducting this activity? What would happen if the height at which the water was being poured was increased? How would this have affected the runoff rate?
   To keep the runoff rates even. Increasing the height from which the water is poured will increase "splash" erosion and water velocity. This will increase the amount of soil carried away and the speed of runoff.
3. What conclusion can be drawn about the influence of vegetation on the amount of sedimentation in a stream?
   Vegetation reduces the amount of sediments carried to a stream.
4. How important is vegetation to stream quality?
   Very important. A healthy riparian area acts as a filter to keep the water clean.
5. How might excessive sedimentation in streams affect aquatic plants?
   Excessive sedimentation makes water murky. This reduces light for photosynthesis. Silt may also smother or bury plants.
6. How might excessive sedimentation in streams affect aquatic animals, especially fish?
   Fish eggs and aquatic insects may be buried or smothered. Silty water may also make it harder for aquatic animals to filter water for breathing. Reduced insect populations make it harder for fish to get enough to eat.
7. What does the accumulation of excessive sediments in a stream indicate about the water flow of a stream?
   For small sediments to settle out, water velocity must be slow.
8. How does organic material affect water retention in riparian areas?
   Organic material adds structure and helps hold the soil. It also creates spaces in the soil so that the soil can act as a giant sponge.
9. Specifically, how does vegetation protect the soil's surface?
   Vegetation breaks the force of raindrops and reduces "splash" erosion. Roots help hold the soil surface.
10. How could removing streamside vegetation influence sedimentation?
    It would increase erosion and reduce the amount of debris trapped and collected by the riparian vegetation.
11. How might roadbuilding, building construction, livestock grazing, and farming influence stream sedimentation?
    All create soil disturbance, exposing bare soils to the effects of water and wind, contributing a source of sediments to an adjacent stream system.

12. What preventive measures might be taken to reduce the effects of sedimentation created by the disturbances mentioned in the two previous questions?
Many specific answer are possible. A correct answer should include the retention of vegetation along streambanks to trap sediments transported from upland areas.

Going further

1. See "How Can Farmer's Reduce Erosion Caused By Rain?" *Earth: The Water Planet*, pp. 69-72.
2. Design an experiment to demonstrate the effects of "splash erosion" caused by raindrops falling on different soils and vegetative cover. See "How Raindrops Erode The Soil," *Earth The Water Planet*, pp. 63-68. Suggest ideas for reducing the effects of splash erosion. Prepare a display to present your findings.

Name

Don't runoff

Do you know . . .

Ground cover (grass, herbs, shrubs, etc.) actually protects the soil from a real pounding. Raindrops that hit bare soil break it down and reduce the amount of water it can absorb (store). Unprotected soil can also be easily washed into a stream. This is why plants are so important to soil, riparian areas and watersheds.

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Healthy soils can absorb most rain and snowmelt until saturated (full of water). This means water seeps into streams more slowly, reducing erosion and sediments. It also means flooding is less likely, because most of the water is stored in the soil.

Plants benefit, too. Plants can use the stored water over a longer time period, increasing their growth rates. Plant roots open up channels allowing water to enter the soil easily. Plant stems and leaves also slow water, greatly reducing erosion and sediments in streams. Streams run clear in a healthy system.

A riparian area with little or no cover is exposed to the force of raindrops. Raindrops soften binding material that holds soil particles together, breaking them into fine particles. The impact of the drops splashes the fine particles into the air. These fine particles collect on the soil surface and fill the spaces between the larger soil particles. The result is a "seal" over the surface that prevents much of the rain from entering the soil. The water has no choice but to run off quickly, carrying sediments that end up in the stream. River systems with poor soils in the riparian area and uplands experience high sediment loads and heavy flooding.

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Source: U.S. Department of Agriculture, Soil Conservation Service, *Soil and Water Conservation Activities for Scouts,* PA-978, 1977.

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Vocabulary

humus

Student sheet

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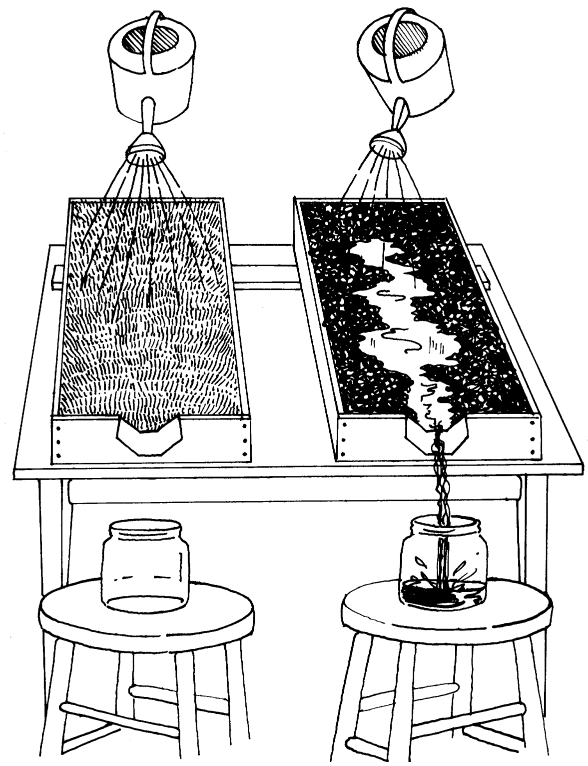

Questions

1. Describe the water in the runoff jars from each box. Is the same amount of runoff found in each jar? Why or why not?

2. Why is it important to use the same amount of water and pour it from the same height and at the same rate when conducting this activity? What would happen if the height at which the water was being poured was increased? How would this have affected the runoff rate?

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4. How important is vegetation to stream quality?

5. How might excessive sedimentation in streams affect aquatic plants?

6. How might excessive sedimentation in streams affect aquatic animals, especially fish?

7. What does the accumulation of excessive sediments in a stream indicate about the water flow of a stream?

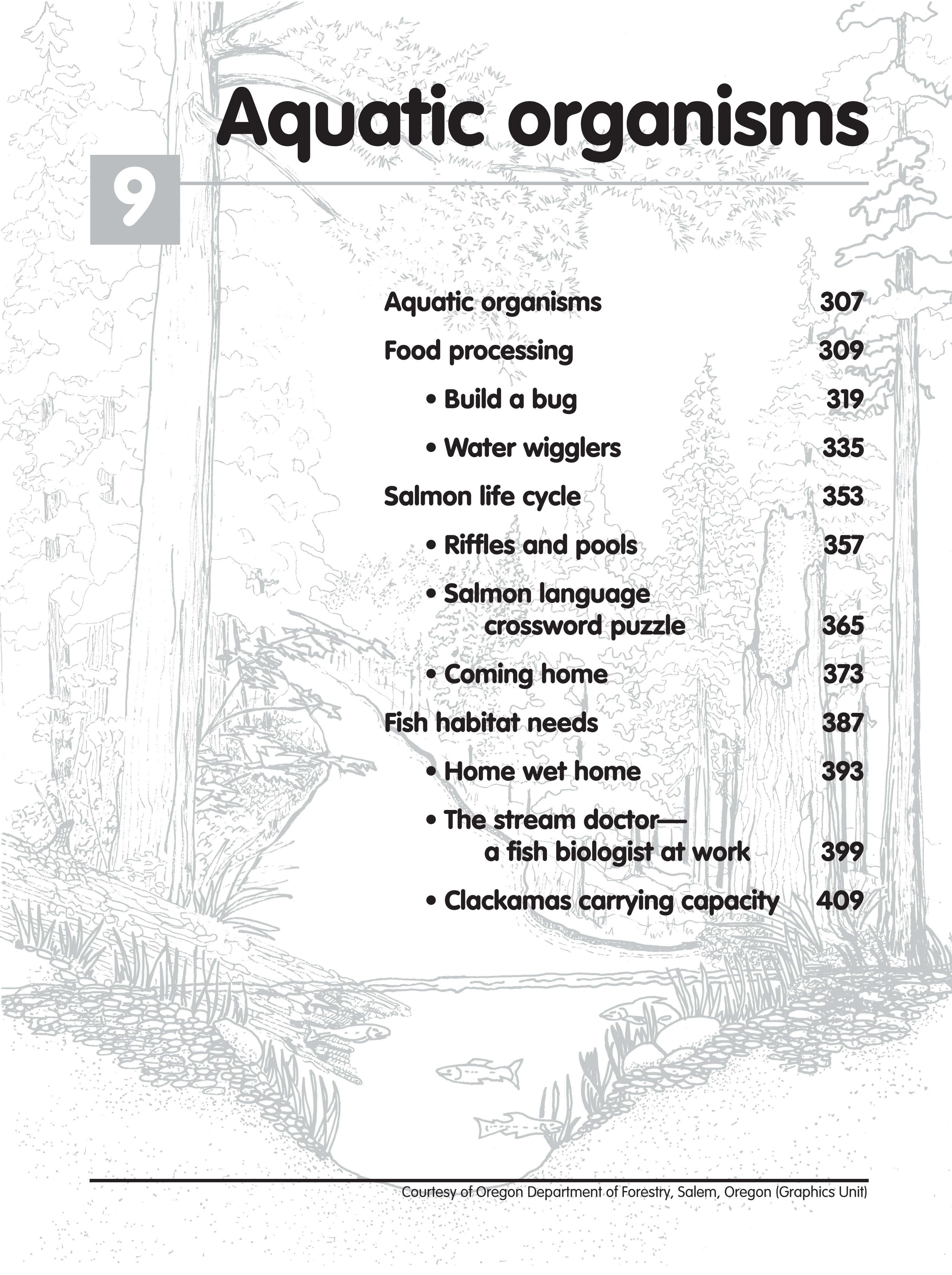
8. How does organic material affect water retention in riparian areas?

9. Specifically, how does vegetation protect the soil's surface?

10. How could removing streamside vegetation influence sedimentation?

11. How might roadbuilding, building construction, livestock grazing, and farming influence stream sedimentation?

12. What preventive measures might be taken to reduce the effects of sedimentation created by the disturbances mentioned in the two previous questions?



9 Aquatic organisms

Courtesy of Oregon Department of Forestry, Salem, Oregon (Graphics Unit)

Aquatic organisms

9

“Is ditch water dull? Naturalists with microscopes have told me that it teems with quiet fun.”
— G.K. Chesterton

A healthy stream is a highly diversified ecosystem. Its complex food chain ranges from microscopic diatoms and algae to large fish, birds and mammals. The diversity of species, particularly aquatic organisms, and their numbers are important to any stream study for two reasons:

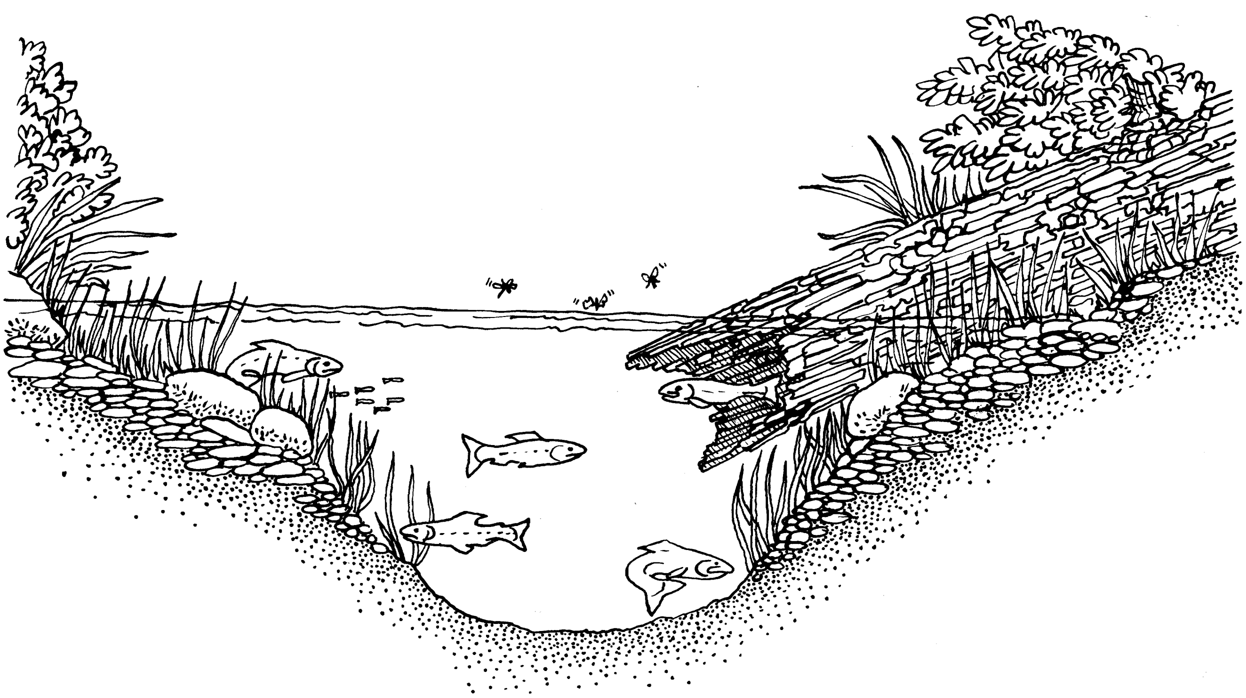
- as indicators of water quality in the stream and
- as parts of various food chains, including fish.

A wide variety of organisms inhabit water. The size and diversity of a population depend on the quality of available water. Fish occupy an important position in the aquatic food chain and obtain their food supply from several sources.

The amount of food available in a stream is determined by the physical and biological conditions of the area. When producers are plentiful, consumers also flourish. Diatoms coating a rock feed primary consumers such as mayflies. They, in turn, feed higher-order consumers like stoneflies and fish.

Overhanging vegetation supplies a variety of terrestrial insects to the menu.

Vocabulary
benthic
hyporheic
plankton



Many aquatic insects use streamside vegetation during emergence and adult stages of their life cycle.

Some aquatic insects leave their positions among boulders and gravel in riffles and are carried downstream short distances before reattaching to the stream bottom. When insects are moving in a water column, as drift or during emergence, they are most vulnerable to being eaten.

Benthic (bottom dwelling) organisms are found on stones or in mud or vegetation. Because a streambed serves as a place for attachment, most organisms in a fast-moving stream will be benthic.

Organisms in fast water have many specialized methods for obtaining food. To gather food in a water column, they grasp it quickly or filter it from the water while remaining stationary. Others gather food on the bottom.

Plankton can be producers or consumers and float or swim freely throughout a stream. Few organisms can live in rapid sections of streams without being swept downstream by the current. Consequently, plankton are abundant in slower waters of large streams and rivers.

Stream ecologists have found a complex community of small animals living in the ground water below the stream channel and sometimes for miles on each side. Many types of small blind shrimp, primitive worms, bacteria, algae, and various kinds of immature insects live most, if not all, of their lives in a maze of channels in this underground and under-river ecosystem. These organisms contribute to the health and productivity of the river by supporting the aquatic food chain that extends to and beyond the water's surface.

The diversity of species, particularly aquatic organisms and their numbers, are important to any stream.

Evidence suggests that **hyporheic** (from Greek for "below" and "flow") exchange is significant in large streams, like the Santiam River of Oregon's Willamette Valley. Some scientists feel the stability of many streams may depend largely on these hyporheic zones, which exchange water and materials with the river channel. The hyporheic zone may extend 15 feet to 30 feet below the river bottom and two miles to either side of the river.

The knowledge of hyporheic zones, and the organisms found there, challenges traditional views of how rivers work. It may have an effect on river system assessments. It could also mean that measures to protect streams from pollution or alteration may need expansion to include wider areas along the watercourses.

9.1 Food processing

"And in the water winding weeds move round."
—Wallace Stevens

In autumn, forest floors are piled high with leaves. But in spring, the Earth's load is lightened; the leafy carpet has worn thin and seems to disappear with the melting snow. Where have the leaves gone? Those that stay where they fall are decomposed, for the most part, by soil invertebrates and microbes. But many of the "disappearing leaves" are carried down hill slopes into small, heavily canopied forest streams.

Most leaves and other organic materials blown by the wind, washed from the surrounding landscape, or fallen directly from overhanging limbs into watercourses do not get very far. They are trapped by rocks, logs and branches close to where they entered the water. They become part of the food or energy base of the stream.

Some of this material settles out in pools and backwaters. Leaves that get buried will decompose anaerobically. Because **anaerobic** processes are much slower than **aerobic** ones, buried leaves remain intact longer. These leaves can be recognized by their black color. Eventually the buried leaves are re-exposed, and decomposition continues aerobically, much as if they had never been buried.

This section is adapted from "Turning Over a Wet Leaf," by Rosanna Mattingly, and used with permission from *The Science Teacher*, September 1985.

Functional feeding groups

What or who is responsible for all this aerobic decomposition? Leaf litter can be broken down and decomposed slowly by abrasion and microbial action, but streams also harbor invertebrates that help decompose leaves and other organic materials under a variety of conditions. A rich, diverse population of aquatic insects is keyed to the varied quality of this food base.

What is important is not so much what, but how the animals eat.

Although most of us have seen our share of crayfish and snails, other aquatic invertebrates, a bit smaller and often a bit quicker, can easily elude us. The aquatic invertebrates we are interested in here are inconspicuous aquatic insect larvae and nymphs (immature forms). It is hard to distinguish one species from another at this

Vocabulary

aerobic	gatherers
anaerobic	predators
collectors	scrapers
filters	shredders

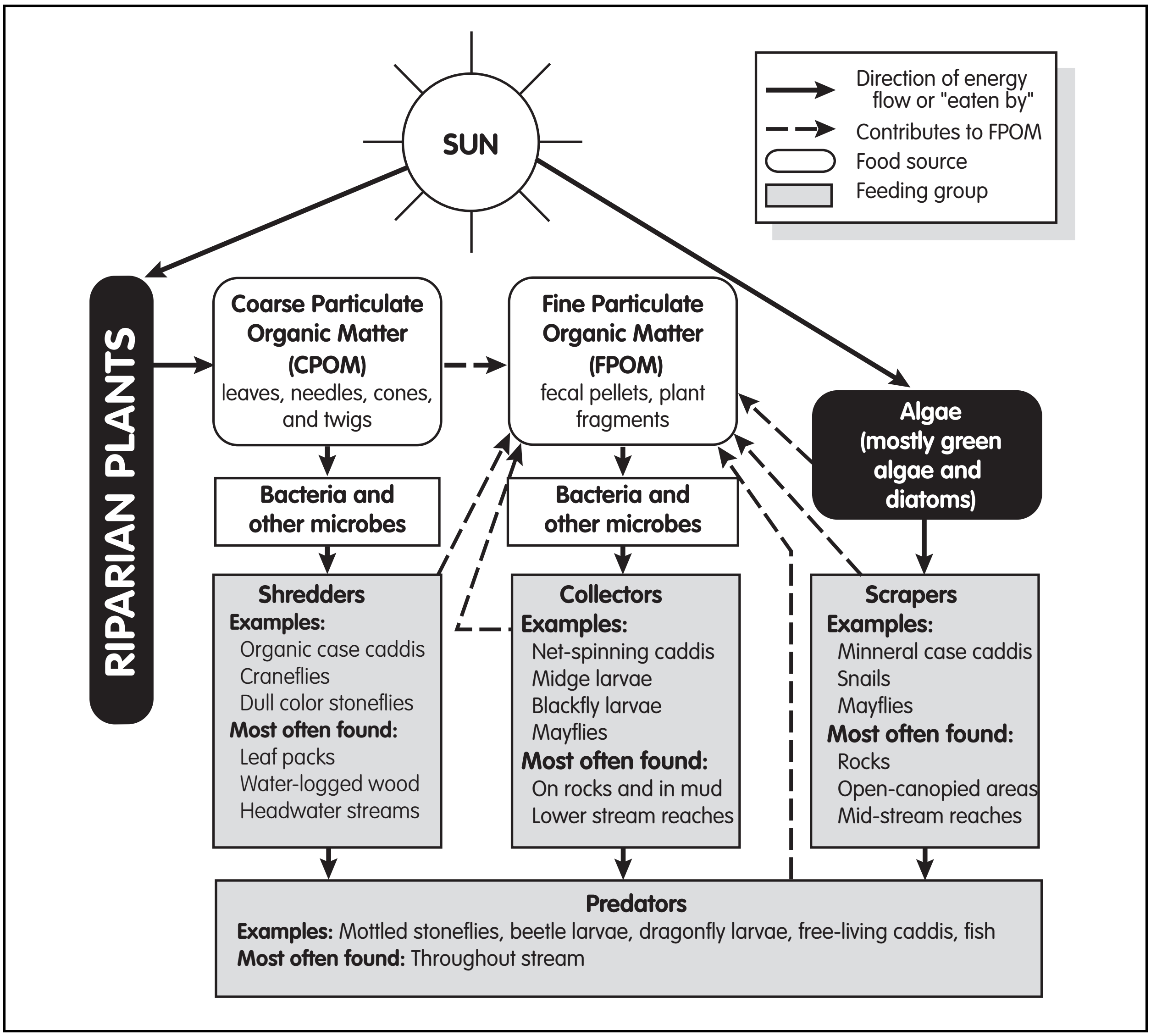
immature stage, and the nymphs' names are based, in general, on their adult characteristics. So, rather than identify these animals individually, we can group them according to the mode of feeding for which each animal is adapted. What is important is not so much what, but how the animals eat, hence the distinct functional feeding groups.

Shredders

Some aquatic invertebrates feed on leaves or other organic material—such as wood, needles and fruits—by biting into them or by cutting or boring through them. These insects are called **shredders**. Shredders generally reduce whole leaves to masses of small particles, but they often leave the midrib and veins intact. Thus, they "skeletonize" the leaves. Many shredders prefer leaves that have been partially decomposed by microbes; with microbial decomposition, leaves become tender and digestible.

In the Pacific Northwest, litter from many soft-leaved shrubs is quickly colonized by microbes. This microbe conditioning makes leaves

Figure 11. Food Processing in Streams



Adapted from: Ken Cummins, "From Headwater Streams to Rivers," *American Biology Teacher*, May 1977, p. 307.

into palatable, nourishing invertebrate meals before most other leaves are ready. Though they are somewhat slower to decompose than herbaceous leaves, alder leaves are also a favorite. Other types of leaves must remain in a stream longer before they become soft enough for the animals to eat, so shredders end up with a "time-release" menu.

Collectors are often more abundant than shredders in low-gradient streams.

By chewing on leaves, shredders expose leaf surfaces and edges to further attack by microbes. Shredders also biochemically alter organic substrates as the material passes through their digestive tracts. So, shredders excrete material usually composed of particles that are smaller and of a different quality than what they ate.

Many stonefly and caddisfly larvae are shredders. Caddisflies are especially intriguing because many use the same leaf bits and other organic fragments they eat to construct the cases in which they live.

Collectors

Collectors are animals that feed on particles of organic material less than 1 millimeter in diameter. These particles may not be very wide, but they are a mouthful for most collectors. One major food source for collectors is fecal pellets of other stream organisms. One group of collectors, called **filterers,** uses nets or mucus-coated fans to filter these small particles from the water. Others, **gatherers**, eat particles deposited or growing on the bottom of a stream channel.

Collectors eat algae, fragments of plants and animals, dissolved organic matter that has come together (flocculated) to form a particle, bacteria, and inorganic particles such as sand, in addition to the feces of shredders and other animals. Some filterers and gatherers feed, at least for short periods, on particles of little or no nutritional value. Apparently, some appear to pay no attention to what they are eating.

Filter feeders include blackfly larvae—elongate animals that are bulbous near the bottom end where they attach themselves to stream substrates. Blackfly larvae have fans with which they strain particles from the water column. These fans are coated with a sticky substance that catches small particles that would otherwise pass through their fans.

Freshwater clams feed in a similar manner by passing food over mucous-covered gills that filter out small food particles. Some free-living caddisflies spin nets of various mesh sizes and thereby selectively collect particles of certain sizes. Mayfly nymphs and beetle and fly larvae are particularly abundant gathering collectors.

In streams, organic materials are produced, received, stored and decomposed.

Collectors are often more abundant than shredders in low-gradient streams where fine particles are not washed away so rapidly. These streams provide pools and other areas where particles can settle out of the water. Fairly large numbers of collectors live all year long, unlike shredders, which are abundant during the fall in most streams.

Scrapers

Scrapers (sometimes called grazers) harvest algae and other materials from rocks and stream surfaces. Diatoms and other algae associated with these surfaces (*periphyton*) are generally most abundant in spring before leaves develop on overhanging tree limbs and block the sun. Periphyton also flourish in wide streams where the canopy does not stretch across the width. Algae will thrive again in autumn, in part because more light and nutrients reach a stream after leaves fall. Predictably, the abundance of scrapers follows the same pattern.

Scrapers include certain mayfly larvae, some of which are flat. Their flatness lets them stay close to rock surfaces to avoid being swept away by swift currents. Some scrapers have suction disks on their abdomens. With these disks the insects can attach to surfaces and feed in rapidly flowing water where diatoms and other algae grow. Some scraper caddisflies construct their cases with small stones that afford the animals additional protection from the current.

Snails also harvest algae. They use feeding structures called radulae to rasp food from stone surfaces and to rasp at leaf surfaces.

Predators

Those invertebrates and other aquatic organisms, such as fish, that capture live members of other functional groups can be classified as **predators**. Predators may be among the first animals spotted in a sample collected from a stream because many of these animals, particularly predacious stoneflies, are comparatively active and conspicuously patterned or colored.

Crane fly larvae and odonates (dragonflies and damselflies) differ from stoneflies as predators because they are more non-descript and relatively inactive. Odonates often sit still and hidden (some bury themselves in sediment with only their eyes protruding) with their hinged, retractile mouthparts aimed at unsuspecting prey.

Predators can be subdivided into **piercers**, which suck the body fluids of their prey, or **engulfers**, which ingest their prey whole.

Diversity and adaptability

In streams, organic materials are produced, received, stored and decomposed. A large flood one year can introduce material from a floodplain. A fairly mild discharge another year can promote storage. Even nearby streams sometimes differ remarkably in gradient and riparian vegetation. The kinds and amounts of invertebrates vary along with each stream's characteristics. But the similarity between the types of invertebrates the world over is striking.

The similarity between the types of invertebrates the world over is striking.

Dividing stream invertebrates into shredders, collectors, scrapers and predators is artificial, because some of these immature forms fit into more than one category. For example, scrapers may eat a lot of detritus while they graze algae. However, they may not grow as well or may pupate at a smaller size in areas where relatively less algae is available. Collectors may eat algae, bacteria, animals and sand. Some collectors also shred leaves, and some shredders can survive on fine particles when leaves are not available. But these distinctions are valuable. By looking at the feeding habits of these young invertebrates, you can begin to sort out different roles these animals play in the ecology of watersheds.

River continuum

Each year, large amounts of organic material fall into the headwaters of forested streams. Of this material, only 20% to 35% is flushed downstream. The remaining organic input is retained in the system and used by stream organisms. It can be processed by bacterial and fungal metabolic action, physical abrasion or consumed by insects. However it is processed, the debris is broken into smaller pieces, which increases the surface area of debris particles and subjects them to further degradation by microbial action.

In this way, small first- and second-order streams send partially prepared food into larger streams. Processing continues as small debris moves downstream through the system. A stream is a continuum that transports progressively smaller food materials.

The river continuum concept models running water systems. It describes biological communities in a stream that change in a somewhat predictable pattern from headwaters to the mouth. This pattern is influenced by:

- structure and gradient of the channel,
- bank stability,
- sediment loads,
- riparian habitats and cover,
- light penetration, and
- temperature.

Predictions work particularly well for forested mountain streams. As might be expected, with a model of this type, there are several exceptions to the pattern outlined in Figure 12 (p. 315). But the concept shows what might be expected in a stream system. If a factor does show up differently, it should act as a red flag, encouraging any researcher to question why it does not match the concept.

Adapted from Ken Cummins, *The Ecology of Running Waters: Theory and Practice*, pp. 287-290; and Jerry F. Franklin et al., *Ecological Characteristics of Old-Growth Douglas-fir Forests*, 1981, pp. 8-11.

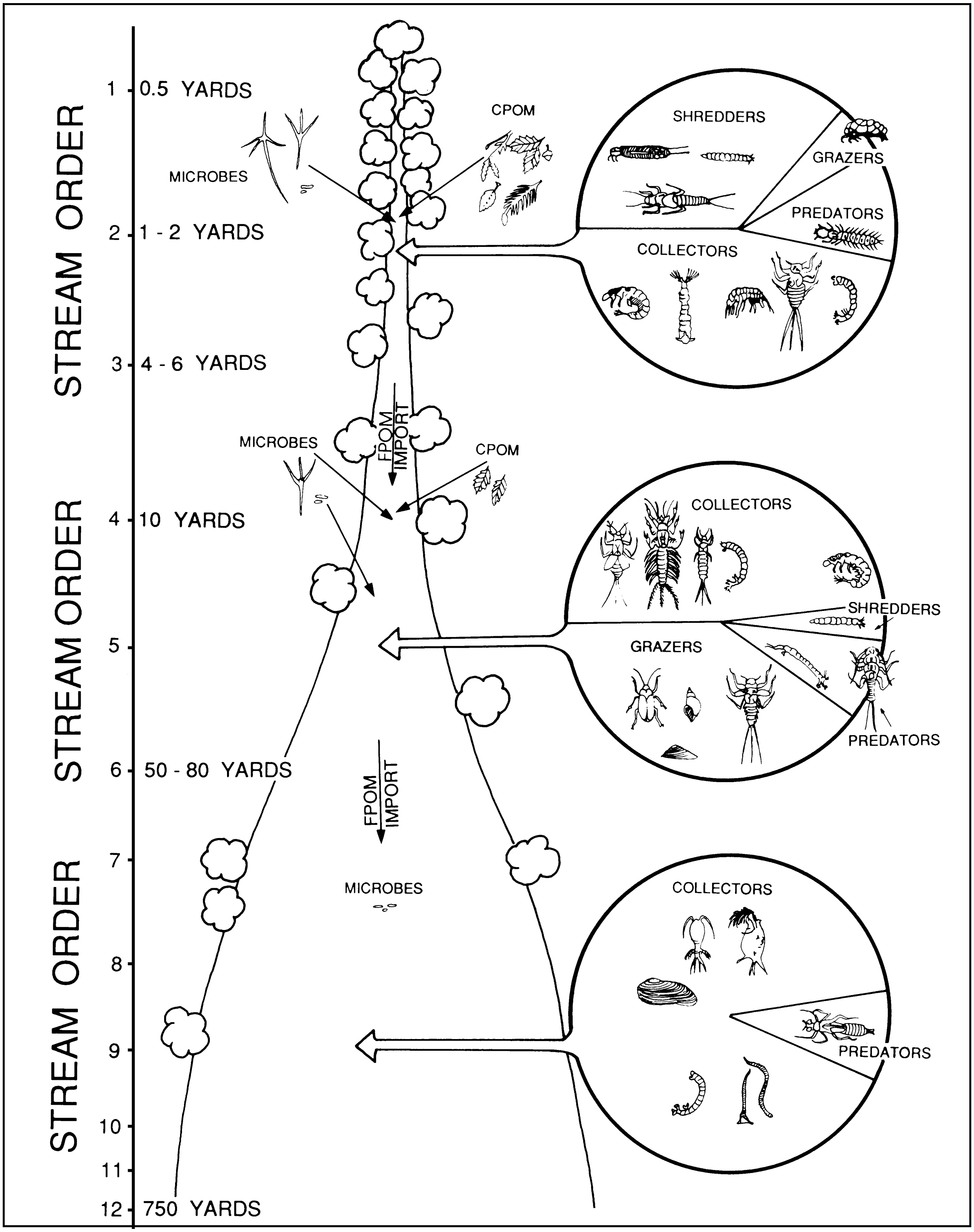
Figure 12. The River Continuum

A diagram of the river continuum theory is shown at right. The forests at the headwaters (first- to third-order streams, see page 35) have less influence as a stream gets larger. With less input from the riparian habitat, the energy base relies more on algae that is produced from the opening of the canopy and on processed materials brought in from intermediate or midreach (third- to fifth-order) streams. As the kind of organic material changes, there is a decrease in the number of shredders and an increased number of collectors and scrapers (grazers).

The diversity of species that live in the midreaches of a stream system is greater than either upstream or downstream. The reason for this is not completely understood, but researchers have pointed out that midreach water temperatures can change more than those of headwaters or larger rivers. The variety of organic substrates and physical components found in midreach streams can also have an effect.

Turbidity increases in the lower reaches (sixth- and higher-order streams) due to the greater loads of fine sediments from tributaries and downstream movement of processed particulate matter. Collectors dominate these reaches, and the diversity of other organisms decreases. Increased turbidity reduces light penetration and thereby reduces the efficiency and photosynthetic production of algae in larger streams. Large plankton communities are important in these areas. In summary, as the size of a stream changes, there is a shift in dominant organisms and the role they play.

Figure 12. The River Continuum



Source: Ken Cummins, "From Headwater Streams to Rivers," *The American Biology Teacher,* May 1977, p. 306.

Figure 13. Headwaters

The **headwaters**—or source—of a watershed are usually first- to third-order streams. These small streams constitute nearly 85% of the total length of running water in our country. Forested headwater streams receive significant organic debris from surrounding riparian habitat that heavily shades streams. As a result, small streams are generally **heterotrophic**, deriving most of their energy base from coarse organic input, rather than from aquatic plants. These streams are characterized by high gradients, low light and a fairly constant temperature. Understory vegetation is limited by heavy shading. An abundance of shredder invertebrate organisms are found because of large amounts of **coarse particulate organic matter** (**CPOM**) falling into the stream. These streams are narrow, generally only 1½ feet to 20 feet in width.

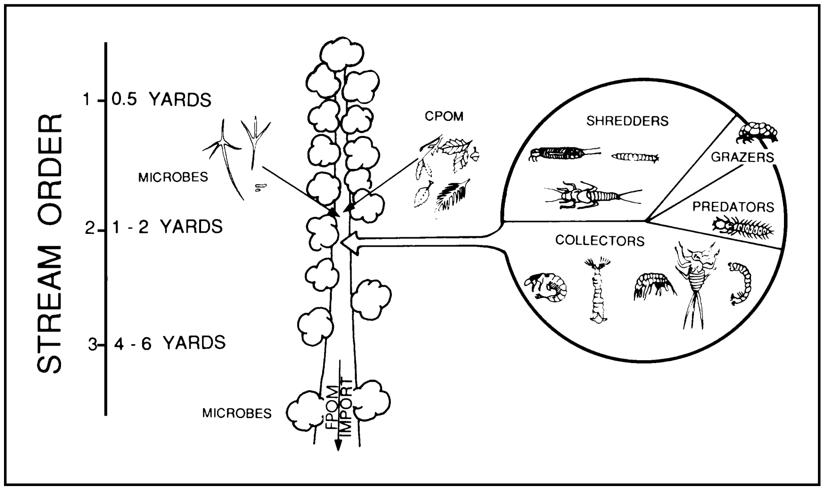


Figure 14. Midreaches

Midreaches are composed of third- to fifth-order streams. This size usually distinguishes streams from rivers. These streams are wider than headwater streams, often more than 30 feet. As a result, the riparian canopy does not cover the stream. Floodplain widths also increase.

Because the canopy is more open, more deciduous riparian vegetation is present and more sunlight reaches the water's surface. This allows an increase in primary photosynthetic production by algae and rooted plants. A shift from consumers to producers as the primary energy base of the stream occurs.

There is also a shift from coarse debris to **fine particulate organic matter** (**FPOM**) as the network of incoming headwater streams concentrates nutrients and partially processed particulate matter from upstream reaches. Less coarse debris and more fine matter means a change from shredders to collectors in the invertebrate population of the stream. Greater biological diversity is found in these reaches than in either upstream or downstream areas.

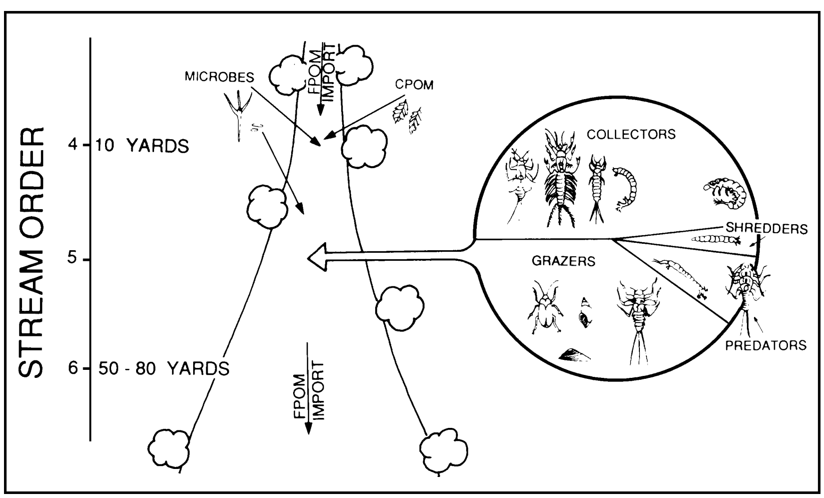
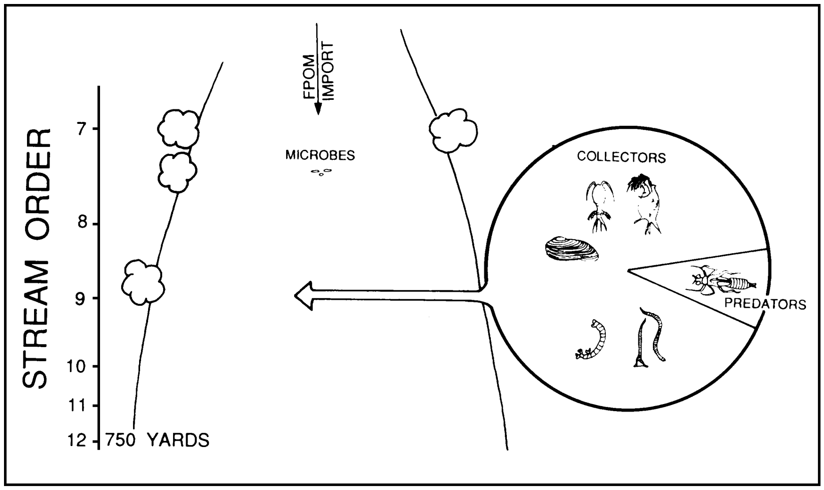


Figure 15. Large Rivers

Large rivers are sixth- to twelfth-order streams. Incoming particulates and fine sediments from upstream reaches increase turbidity in these streams. Murky water means less light penetration and a corresponding drop in productivity by algae and other aquatic plants. The energy base of a stream again shifts to consumers, relying on input from upstream waters.

Because of the prevalence of fine sediments, collectors are the dominant invertebrate life. Plankton and bottom-feeding fish are also common. There is little shading or daily temperature fluctuation in large rivers. The biological diversity is less than in the midreaches.

Few of these large rivers remain unaltered by human impoundments or pollution.



Extensions

1. "Are You Me?" *Aquatic Project WILD,* pp. 13-18.
2. "Blue Ribbon Niche," *Aquatic Project WILD*, pp. 65-68.
3. "Water Canaries," *Aquatic Project WILD*, pp. 35-39.

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Build a "bug"

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

Objectives

Students will (1) learn vocabulary associated with aquatic insects, including head, thorax, abdomen, anterior, posterior, lateral, and ventral, gills; (2) accurately use linear metric measurement; (3) and work in small groups and as a team to create a product.

Method

Students work in small teams to build an aquatic insect model out of simple materials.

For younger students

1. Change all measurements to standard English units and increase the size of the units to make it easier for smaller fingers to measure and cut out the pieces of their insect.
2. Provide a simplified drawing of an aquatic insect for students to reference while creating their own insect.
3. Collect a few large living specimens of aquatic insects, like large stoneflies or dragon flies. Place the insect in a clear glass bowl and set it on an overhead projector. Project the insect on the screen or wall and ask students to draw the specimen as they see it. Then, using a pointer, locate body parts and identify their locations (dorsal, ventral, lateral, anterior, posterior). Label the insect as part of a group discussion.

This activity is adapted from the original activity, "The Kneebone is Connected to the Legbone," by Carolyn Hensley Johnson, Yamhill-Carlton (Oregon) Union High School, and is used with permission.

Materials

Per group of three students
- set of three insect body part instructions on pp. 323-238 (one set per team: Insect A (stonefly) or Insect B (mayfly))
- small metric rulers (3)
- clear tape or glue stick
- color markers or colored pencils
- large paper sheets (easel pad sheets)
- scissors (3)
- aquatic insect drawing
- pencil (3)
- copies of student sheets (pp. 331-334)

Notes to the teacher

Although inaccurate, "bug" is a term often used to refer to any insect. Take time to instruct students that not all insects are bugs. Bugs are only those insects that belong to the Order Hemiptera, which means "half-winged." Common examples would include water striders and stink bugs. The

Vocabulary

abdomen	mandible
antenna	maxillae
anterior	mesothorax
caudal	metathorax
centerline	ocelli
cerci	posterior
compound eye	proportional
dorsal	prothorax
gills	thorax
lateral	ventral
macroinvertebrates	wing pads

insects constructed in this activity are not true "bugs." Stoneflies belong to the Order Plecoptera and mayflies belong to the Order Ephemeroptera.

The length of class time required to complete this activity varies widely with grade level, but count on at least 60 minutes. Each student in the group of three works on a different part of the insect. Measurement, interpretation, and following instructions are important aspects of this experience. In classrooms where use of the metric system is not an objective, you could convert the metric measurement to the nearest eighth, quarter, or full inch.

Make up enough sets of the insect cards so half of the groups receive instructions for Insect A and half receive instructions for Insect B. For durability, print the insect cards on card stock and laminate. Teams of three students receive one set of insect cards—either Insect A (a stonefly) or Insect B (a mayfly). Each set has instructions to construct a head, thorax and abdomen, with each on a separate page. Each student in the team receives one page of the instructions. The team can decide who will draw which part. When all segments are completed, the team glues or tapes them together to form an entire insect. Encourage students to decorate their insects with camouflage colors, or the bright colors of some predators.

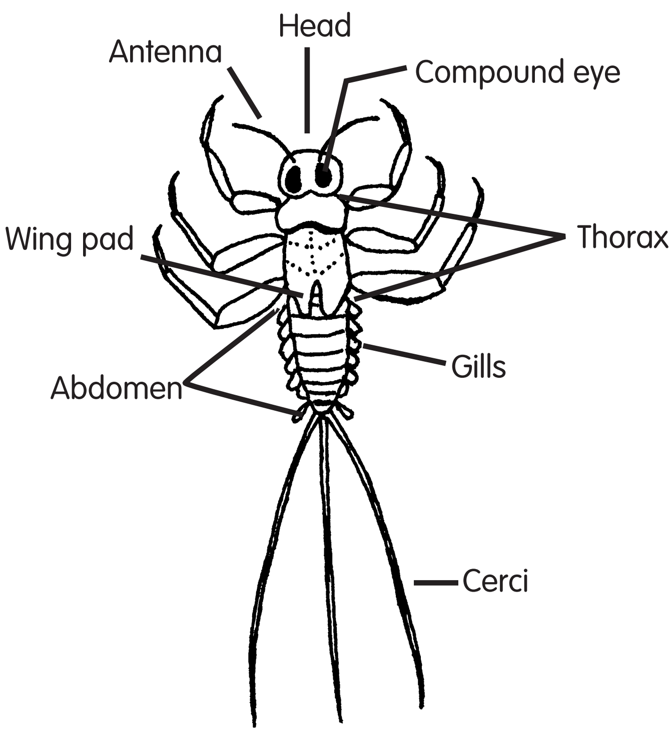
Once the teams have completed their insects, post them on the wall or window. Using the key on page 336, have each team determine the group to which their insect belongs. Then have each group present their insect, noting what group it belongs to and why.

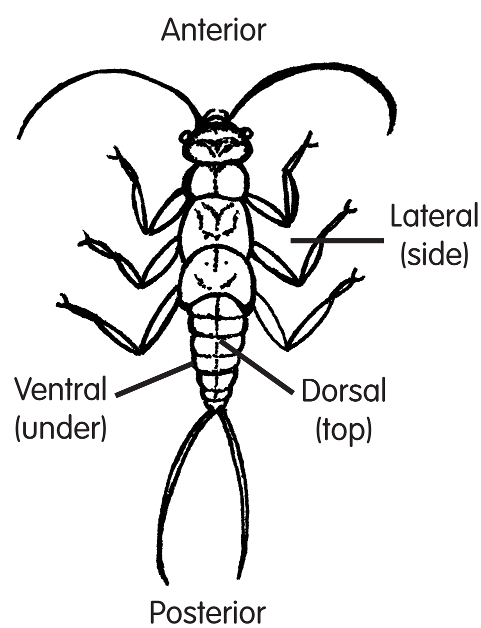
Refer students to the vocabulary list to help them orient to the insect body parts. Some students may require a labeled diagram of an aquatic insect to ensure a more successful experience. One of the key objectives of this exercise is to translate and follow directions. The teacher may choose to not show the labeled diagrams so student work is clearly the result of interpretations rather than a copy of the accompanying diagrams.

Background

Do you know…

A study of streams would not be complete without a survey of the **macroinvertebrates** in the





stream. A large portion of those macroinvertebrates are insects—aquatic insects. These creatures live much of their lives in aquatic environments as larva before they emerge as adults to mate and lay eggs. Some aquatic insects live their entire lives in a stream or lake. This is a good thing for fish, because aquatic insects and other macroinvertebrates are important menu items for fish.

A survey of the aquatic insects in a stream can tell you much about the condition of the stream. Some species of aquatic insects have very low tolerances for polluted water or high temperatures, so if they are missing from the stream, you know there might be a water quality problem.

Aquatic insects are easy to identify if you know a few things about their body parts. Even a simple key will require you to know the difference between the head, thorax and abdomen of an insect before you can classify it into a group, like a stonefly, mayfly, or caddisfly.

Procedure

Now, it's your turn…

Not all insects are "bugs," but because so many people use the term "bug" it is an easy habit to get into when talking about insects that live either on land or in water. One way to really get to know a stream is to look at the aquatic insect populations in that stream.

It can be really hard to identify aquatic insects without a basic knowledge of their body parts. The best way to learn about aquatic insect parts is to "build" an entire aquatic insect.

Get into groups of three. Each member of the group will build one of the major body parts of either a mayfly or a stonefly, two common aquatic insect types, (Stoneflies or mayflies are not true "bugs" even though they may be called that from time to time.) When the body parts are completed, attach them together to form a complete insect. If all of you have measured carefully, the head, thorax and abdomen should fit together to make your aquatic insect look **proportional.**

Insect terminology

abdomen: the posterior body part

antenna: sensory structures located on the head; usually segmented

anterior: situated before or in the front; front end of a bilaterally symmetrical organism

caudal: tail; situated in or directed to the hind part of the body

centerline: imaginary line in the apparent center of the insect dorsal side running the length of its body

cerci: a pair of small, sensory appendages at the posterior end of some insects (cercus-singular)

compound eye: an eye made up of many separate visual units

dorsal: back or upper side of an organism that has bilateral symmetry

gill: filamentous respiratory structure in an aquatic animal

lateral: situated on or coming from the side

mesothorax: the middle segment of the thorax

metathorax: the posterior segment of the thorax

ocelli: simple, light-sensitive eyes

posterior: situated behind; back end of a bilaterally symmetrical organism

prothorax: the anterior segment of the thorax

thorax: the body part located between the head and the abdomen

ventral: lower side of an organism that has bilateral symmetry

wing pads: areas on the thorax of many aquatic forms from which wings will develop in the adult insect

- Each team will receive a set of three cards labeled “Insect A” or “Insect B.” The cards give detailed instructions for drawing the shape and size of the head, thorax, and abdomen of your insect.
- Pick up a large sheet of paper, a marker, a ruler, clear tape or a glue stick, scissors and a drawing of a generalized insect body for each team member.
- Draw your body part, then cut it out and put it together. You may want to color it prior to assembly, or after. Use the vocabulary list to help you with your drawing.
- When finished, put the parts together to form one insect. Be sure to put the parts together in the correct order. Label the parts, including the head, thorax and abdomen.
- Using the simple insect identification key on page 336, determine what kind of insect you created.

Insect A: Head

Using the following description, draw the head portion of Insect A. Be accurate in your measurements so the head will fit with the parts built by other team members.

- The head of this aquatic insect is shaped somewhat like a flattened, shortened pear, the narrow end being the most **anterior** on the insect.
- The head is 7.2 cm in length, and 8.4 cm in width at its widest point.
- Two **compound eyes**, one located on each side (laterally) and at the widest lateral point on the head, are 2.0 cm in diameter.
- The three **ocelli**, or eye spots, are located as the points of a triangle, with the top point (ocelli) located 1.2 cm from the front of the head along the center line. The two other points of the triangle (ocelli) are located 2.8 cm from the anterior (front) of the head, each 0.8 cm from the center line.
- The **antennae** are long segmented, pointed structures, each a total of 24 cm in length. Each segment is approximately 4 mm in length. The antennae taper toward the ends from a base width of 5 mm. They are attached to the dorsal side of the head anterior to the compound eyes and 2.8 cm from the center line of the head.

After completing the head, label the parts.

The compound eyes, light-sensitive ocelli, and the antennae allow the insect to monitor its environment. The food gathering structures are located ventrally and are unseen in your model. These include the mandibles and maxillae. The **mandibles** are used for chewing or crushing food or may be modified for piercing or scraping. The **maxillae** are used for tearing or manipulating food, or they may be highly modified. These modifications allow certain groups of aquatic insects to move through coarse sediments and cling to exposed surfaces in rapidly flowing streams.

Insect A: Thorax

Using the following description, draw the thorax portion of Insect A. Be accurate in your measurements so the thorax will fit with the parts built by other team members.

- The mid region of the body, or **thorax**, bears the jointed legs and the wings. It is divided into three segments. The first segment bears the forelegs, the second segment bears the mid legs and fore wings, and the third segment the hind legs and hind wings (if wings are present). The jointed legs have five segments each.
- The first (most anterior) segment of the thorax is called the **prothorax**, and is shaped like a pillow. It is 10.8 cm wide and 8.0 cm long. The forelegs, composed of five segments, are 16.0 cm in length and are attached to the ventral (underside) side of the prothorax. They taper in width from 5.0 cm at the base to a point at the end. Branched filamentous gills are also attached to the ventral side of the prothorax, and appear as hair-like projections. (Make these by cutting strips of paper like the fringe.)
- The second segment of the thorax is called the **mesothorax**. It is somewhat square and 8.0 cm on a side. The forewing pads, which are shaped like lopped rabbit ears, are attached laterally to the mesothorax. These wing pads are 12.0 cm in length and 3.2 cm at the widest point. (In the finished insect, these **wing pads** will overlap the hind wings pads on the third thorax segment.) The mid leg is attached to the ventral surface and is 14.0 cm in length. They taper in width from 4.0 cm at the base to a point at the end. Filamentous gills are also attached to the ventral side of the mesothorax. Again, they appear as hair-like projections.
- The third segment of the thorax is called the **metathorax**. It is rectangular in shape, 6.8 cm long and 8.0 cm wide. The hind wing pads are 10.8 cm in length and 4.8 cm at the widest point, and are shaped like the forewing pads. The hind leg is attached to the ventral surface and is 16.0 cm in length. They taper in width from 5.0 cm at the base to a point at the end. Filamentous gills are also attached to the ventral side of the metathorax. They appear as hair-like projections.

After completing the thorax, label the parts.

Insect A: Abdomen

Using the following description, draw the **abdomen** portion of Insect A. Be accurate in your measurements so the abdomen will fit with the parts built by other team members.

- There are 11 abdominal segments, although in most adults, fusion of the last two makes them difficult to distinguish. Filamentous gills may be located on some segments of the abdomen. The end of the abdomen bears two cerci.
- The abdomen consists of 11 segments, with the first 10 rectangular is shape. They become progressively narrower toward the **posterior** end. Draw each segment using the following measurements:
- The 11th segment is shaped like a funnel, with the narrow part the most posterior. It is 6.8 cm long along the central line and 3.6 cm at the anterior end.
- Two segmented **cerci** (tails) are attached to the lateral portions of the 11th segment. They are 18.0 cm long with each segment 4.0 cm in length. Each cerci is about 4 mm at the base and tapers to 1 mm.

After completing the abdomen, label the parts.

Segment	Length	Width
1	2.4 cm	7.2 cm
2	2.4 cm	7.0 cm
3	2.4 cm	7.0 cm
4	2.4 cm	6.8 cm
5	2.4 cm	6.8 cm
6	2.4 cm	6.4 cm
7	2.4 cm	6.0 cm
8	2.4 cm	5.6 cm
9	2.4 cm	5.2 cm
10	2.4 cm	4.4 cm

Insect B: Head

Using the following description, draw the head portion of Insect B. Be careful in your measurements so the head will fit with the parts built by other team members.

- The head of this aquatic insect is shaped somewhat like a rounded rectangle, wider than it is long. The **anterior** surface has a convex curve. It is 4.5 cm long and 8.0 cm wide.
- The two compound eyes are moderately large and are situated **laterally** and **dorsally** on the head. They are shaped like rounded gumdrops and are 3.0 cm in diameter.
- The three **ocelli**, or eye spots, are located in a line running laterally 1.6 cm from the head's anterior. One is on the center line, and the other two are 1.2 cm on either side of the center line.
- The **antennae** are long, segmented, pointed structures, each a total of 12.8 cm long. Each segment is approximately 4 mm long and from 5 mm to 3 mm wide. They are attached to the dorsal side of the head anterior to the compound eyes and 2.8 cm from the center line of the head.

After completing the head, label the parts.

Sensory structures are located on the dorsal side of the head and the food gathering structures are located ventrally. The compound eyes, light sensitive ocelli (simple eyes), and the antennae allow the insects to monitor their environment. The feeding apparatus is composed of the mandibles and maxillae. The mandibles are used for chewing or crushing the food or may be modified for piercing (piercing herbivores or predators) or scraping (scraping herbivores that graze on attached algae.). The maxillae are variously used for tearing and manipulating food, or they may be highly modified. These modifications allow certain groups of aquatic insects to move through coarse sediments and cling to exposed surfaces in rapidly flowing streams.

Insect B: Thorax

Using the following description, draw the thorax portion of Insect B. Be careful with your measurements so the thorax will fit with the parts built by other team members.

- The mid region of the body is called the **thorax**. It bears the jointed legs and the wings, and is divided into three segments: the prothorax, the mesothorax and the metathorax.
- The first segment is called the **prothorax**. It is shaped like a pillow and is 16.4 cm wide and 4.4 cm long. The forelegs, composed of five segments, are 16.0 cm long and are attached to the ventral side of the prothorax. They taper in width from 3 cm at the base to a point at the end.
- The second segment of the thorax is called the **mesothorax**. It is rectangular in shape and is 10.4 cm long and 13.2 cm wide. The mid leg has five segments, is attached to the ventral surface, and is 19.2 cm in length. They taper in width from 3 cm at the base to a point at the end. The forewing pads, shaped like lopped rabbit ears, are attached laterally to the mesothorax. These **wing pads** are 12.0 cm in length and 4.8 cm at the widest point. (In the finished insect, these wing pads overlap the hind wing pads.)
- The third segment is called the **metathorax**. It is rectangular in shape, 3.2 cm long and 12.8 cm wide. The hind leg is attached to the ventral surface and is 22.8 cm long. They taper in width from 2.5 cm at the base to a point at the end. The hind wing pads are 4.0 cm long and 2.8 cm at the widest point, attached posteriorly to the hind legs.

After completing the thorax, label the parts.

Insect B: Abdomen

Using the following description, draw the abdomen portion of Insect B. Be careful in your measurements so the **abdomen** will fit with the parts built by other team members.

- There are 10 abdominal segments. **Gills** are located on segments one through seven, and are plate-like in structure. The end of the abdomen bears three caudal filaments.
- The 10 segments of the abdomen are rectangular in shape. Draw each segment using the following measurements:
- Two gills are attached to the dorsal and lateral side of segments one through seven. Each gill is 4.8 cm long and 2.4 cm at the widest point. They are shaped somewhat like a ping pong paddle.
- Three caudal filaments are present, composed of two segmented **cerci** (tails) and a terminal filament. The two cerci are attached to the lateral portions of the 10th segment. They are 25.0 cm long and segmented, with each segment 5 cm in length. The terminal filament is attached between the two cerci and is 27.0 cm long with similar segmentation. The cerci and terminal filament is about 4 mm at the base and tapers to 1 mm.

After completing the abdomen, label the parts.

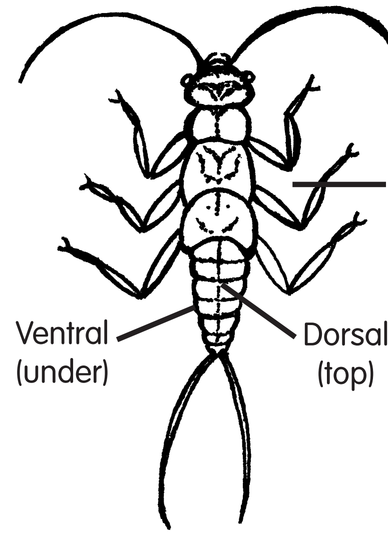
Segment	Length	Width
1	2.8 cm	10.4 cm
2	2.8 cm	10.4 cm
3	2.4 cm	10.8 cm
4	2.4 cm	12.0 cm
5	2.4 cm	12.0 cm
6	2.4 cm	12.0 cm
7	2.4 cm	11.2 cm
8	3.2 cm	10.0 cm
9	3.2 cm	6.8 cm
10	2.0 cm	4.0 cm

Questions

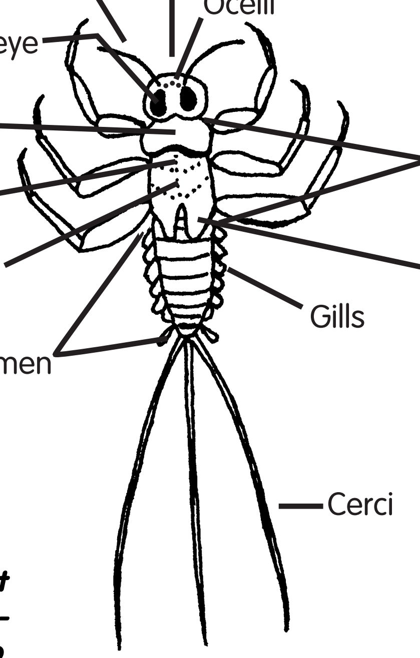
1. To what group of aquatic insects does your insect model belong?

   Answers will vary, but should be either stonefly (Insect A) or mayfly (Insect B).

2. Label the following locations on the insect drawing to the right: anterior, posterior, dorsal, ventral, lateral.



3. Label the following body parts on the insect drawing below right: head, thorax, abdomen, cerci, compound eye, ocelli, gill, prothorax, mesothorax, metathorax, wing pads.



4. Which of the two aquatic insect groups in this activity (stoneflies or mayflies) has gills on the thorax? Which has gills on the abdomen?

   Most stoneflies have thoracic gills and mayflies have abdominal gills.

5. What have you learned about reading and interpreting instructions in this activity? How might what you have learned apply to data collection?

   Even though two or more groups have the same set of instructions, their interpretations of those instructions may be very different. This could also apply to data collected with the same sets of instructions. That is why it is very important that data collection instructions are very clear and understandable and that quality control measures are in place to reduce interpretation errors.

Going further

1. Now that students are familiar with insect body terminology, ask them to key out real aquatic insects using the key on page 336. Drawings or photos of aquatic insects would also work well.
2. Ask student teams to prepare a short natural history of their insect group or others and present it to the class.
3. Have students build an insect as before, using only a drawing or photo of an aquatic insect from a different group such as caddis flies, but on the same size scale as the one they just built.

Name

Build a "bug"

Do you know…

A study of streams would not be complete without a survey of the **macroinvertebrates** in the stream. A large portion of those macroinvertebrates are insects—aquatic insects. These creatures live much of their lives in aquatic environments as larva before they emerge as adults to mate and lay eggs. Some aquatic insects live their entire lives in a stream or lake. This is a good thing for fish, because aquatic insects and other macroinvertebrates are important menu items for fish.

A survey of the aquatic insects in a stream can tell you much about the condition of the stream. Some species of aquatic insects have very low tolerances for polluted water or high temperatures, so if they are missing from the stream, you know there might be a water quality problem.

Aquatic insects are easy to identify if you know a few things about their body parts. Even a simple key will require you to know the difference between the head, thorax and abdomen of an insect before you can classify it into a group, like a stonefly, mayfly, or caddisfly.

This activity is adapted from the original activity "The Kneebone is Connected to the Legbone," by Carolyn Hensley Johnson, Yamhill-Carlton (Oregon) Union High School, and is used with permission.

Now, it's your turn…

Not all insects are "bugs," but because so many people use the term "bug" it is an easy habit to get into when talking about insects that live either on land or in water. One way to really get to know a stream is to look at the aquatic insect populations in that stream.

It can be really hard to identify aquatic insects without a basic knowledge of their body parts. The best way to learn about aquatic insect parts is to "build" an entire aquatic insect.

Get into groups of three. Each member of the group will build one of the major body parts of either a mayfly or a stonefly, two common aquatic insect types, (Stoneflies or mayflies are not true "bugs" even though they may be called that from time to time.) When the body parts are completed, attach them together to form a complete insect. If all of you have measured carefully, the head, thorax and abdomen should fit together to make your aquatic insect look **proportional.**

- Each team will receive a set of three cards labeled "Insect A" or "Insect B." The cards give detailed instructions for draw-

Vocabulary

abdomen	mandible
antenna	maxillae
anterior	mesothorax
caudal	metathorax
centerline	ocelli
cerci	posterior
compound eye	proportional
dorsal	prothorax
gills	thorax
lateral	ventral
macroinvertebrates	wing pads

ing the shape and size of the head, thorax, and abdomen of your insect.

- Pick up a large sheet of paper, a marker, a ruler, clear tape or a glue stick, scissors and a drawing of a generalized insect body for each team member.
- Draw your body part, then cut it out and put it together. You may want to color it prior to assembly, or after. Use the vocabulary list to help you with your drawing.
- When finished, put the parts together to form one insect. Be sure to put the parts together in the correct order. Label the parts, including the head, thorax and abdomen.
- Using the simple insect identification key provided by your teacher, determine what kind of insect you created.

Insect terminology

abdomen: the posterior body part

antenna: sensory structures located on the head; usually segmented

anterior: situated before or in the front; front end of a bilaterally symmetrical organism

caudal: tail; situated in or directed to the hind part of the body

centerline: imaginary line in the apparent center of the insect dorsal side running the length of its body

cerci: a pair of small, sensory appendages at the posterior end of some insects (cercus-singular)

compound eye: an eye made up of many separate visual units

dorsal: back or upper side of an organism that has bilateral symmetry

gill: filamentous respiratory structure in an aquatic animal

lateral: situated on or coming from the side

mesothorax: the middle segment of the thorax

metathorax: the posterior segment of the thorax

ocelli: simple, light-sensitive eyes

posterior: situated behind; back end of a bilaterally symmetrical organism

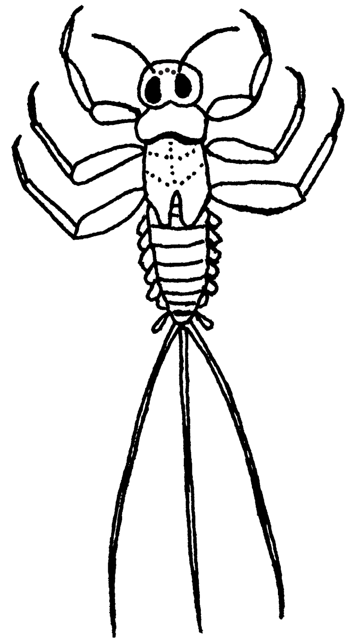
prothorax: the anterior segment of the thorax

thorax: the body part located between the head and the abdomen

ventral: lower side of an organism that has bilateral symmetry

wing pads: areas on the thorax of many aquatic forms from which wings will develop in the adult insect

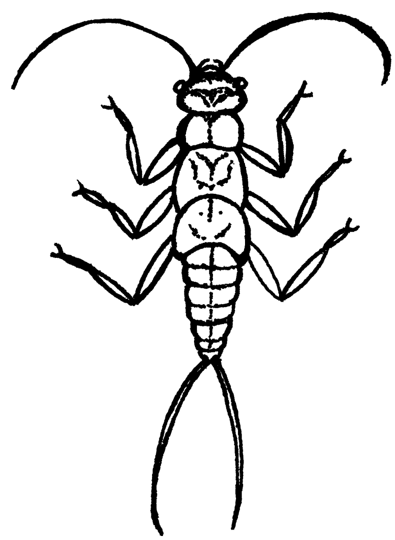
Questions



1. To what group of aquatic insects does your insect model belong?

2. Label the following locations on the insect drawing to the right: anterior, posterior, dorsal, ventral, lateral.

3. Label the following body parts on the insect drawing below right: head, thorax, abdomen, cerci, compound eye, ocelli, gill, prothorax, mesothorax, metathorax, wing pads.



4. Which of the two aquatic insect groups in this activity (stoneflies or mayflies) has gills on the thorax? Which has gills on the abdomen?

5. What have you learned about reading and interpreting instructions in this activity? How might what you have learned apply to data collection?

Water wigglers

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

Objectives

The student will (1) examine different instream microhabitats; (2) sort, count and record invertebrates from each microhabitat into functional feeding groups—shredders, collectors, scrapers, and predators; (3) calculate the percentage of each functional feeding group compared with the total number of insects observed by habitat type; and (4) analyze the data in accordance with stream type and general expectations for diversity based on background information.

Method

Students collect material from microhabitats within a determined reach of stream. Invertebrates are taken from these samples and sorted into feeding groups. A count is kept of each feeding group on the data sheet and the percentage of each group/habitat is calculated.

For younger students

1. Consult extension activities at the end of each chapter to address the needs of younger students.
2. Read activity background information aloud to younger students or modify for your students' reading level.
3. Vocabulary background is necessary. Some practice identification with different insect types would develop some familiarity with insects Consider creating a student user guide as a knowledge base. Modify questions. If unable to travel to a body of water, you can collect and bring samples to the classroom for exploration.

Materials

- D-frame nets for collecting
- white enamel pans, photo developing trays, or other suitable light-colored shallow pans for general sorting
- 1-mm sieves (can be made from window screening)
- ice cube trays or other suitable containers for specific sorting
- forceps, probes, eye droppers, and small artist's paint brushes for picking up invertebrates
- razor blade or vegetable brush for scraping or scrubbing rocks
- copies of student sheets (pp. 345-352)
- identification guides

Notes to teacher

1. A diversity of different species distributed throughout the functional feeding groups, as opposed to an abundance of individuals in any one functional feeding group, is significant. For example, many different kinds of invertebrates versus a large number of one kind of species speaks for the diversity of organisms and the ability of the habitat to support that diversity (i.e., four different species of mayflies exhibit more diversity than four individuals of one species of mayfly).

2. Use *Field Procedures for Analysis of Functional Feeding Groups of Stream Macroinvertebrates* by Kenneth W. Cummins and

Vocabulary

coarse organic matter	predators
collectors	rocks
fine organic matter	scrapers
large wood	shredders

Margaret A. Wilzbach for keying organisms into functional feeding groups.

3. Should the data on the table show one particular organism or habitat type to be considerably out of line for expected ratios, be prepared to explain to students that occasionally, patchy distribution or inappropriate sample size may weight the data one way or the other. If it is too far off, it probably should be dropped from the data base with careful explanation.

4. Consider seasonality in assessing and observing aquatic invertebrate communities. Certain parts of the life cycle of some invertebrates may be missed. For example, at different times of the year scrapers would be most abundant during the summer when algae production is highest. Some have several generations per year. The life histories of these invertebrates are adapted to food availability. Whatever food resources are available influences which invertebrates will be found. Autumn is the best time for the greatest diversity of organisms for this activity.

5. Remember that functional feeding groups do not necessarily follow trophic levels. These categorizations simply describe how the organism gets its food.

6. If there are some aquatic insects you cannot identify in the field or if you want to do further sorting in the classroom, preserve the insects in a 70% ethyl alcohol solution (seven parts ethyl alcohol to three parts water) in a plastic or glass container with a screw-on cap. You can also create a reference collection of aquatic insects in this manner, using small vials to hold different insect types.

Aquatic Insect Guide

Builds a portable "house" or case to live in	**Caddisfly**
If case is made of material that was once living (wood, leaves, etc.)	**Shredder**
If case is made of mineral material (rocks, sand grains)	**Scraper**
Has two tails, without abdominal gills	**Stonefly**
If dark and uniformly colored	**Shredder**
If large and brightly colored and/or mottled	**Predator**
Has three tails (sometimes two), with abdominal gills	**Mayfly**
If flat, sometimes egg-shaped	**Scraper**
If cigar-shaped	**Gathering Collector**
Worm-like, without true legs	**Flies**
If <1 cm long, 1 pair stubby "legs," head well developed	**Gathering Collector (Midge)**
If >1.5 cm long, head reduced, often found in leaf litter	**Shredder (Cranefly)**
Antennae modified as tiny fans	**Filtering Collector (Blackfly)**
Free-living, 3 pairs of legs	**Odonates/Beetles**
If large, with gills at end of abdomen	**Predator (Damselfly, Dragonfly)**
If no gills, usually tough outer covering, jaws often easy to see	**Beetles**
Dark brown; tough outer covering	**Gathering Collector (Riffle Beetle)**
Color varied; abdomen soft-bodied	**Predator (Beetle)**

Adapted from: Bill Hastie, "What Wiggles in Winter Water," *Oregon Wildlife*, December 1983, p. 15.

Background

Do you know . . .

Gazing into the cold water of a small stream in winter reveals little animal activity. The stream, like the woods around it, seems lifeless. But take a closer look. Skeletons of leaves with only the main ribs remaining provide evidence of animal activity. What happened to these leaves?

The leaves are eaten by aquatic invertebrates, especially insects, that spend most of their lives in water. They change their form, grow wings and emerge from water only during spring or summer when they mate.

During late fall and winter, small streams in wooded areas are menageries of aquatic insects. This is because most of the leaves and wood (containing energy for the insects) fall into the stream during this time. At other seasons of the year, you would probably find a different assemblage of animals.

If you were to gather a handful of leaf litter or a rock from the stream or kick up some bottom material from under rocks and let the current carry the material into a fine mesh net, you probably will collect a wide range of insects you probably had not known were present. These insects can be placed into groups according to how they feed (**functional feeding groups**) as explained below:

Shredders: Feed on leaves or wood that falls into streams and eat the softer plant material, leaving the leaf skeleton.

Collectors: Feed on fine material in streams. Some filter the water for their food (filtering collectors), while others burrow in the stream bottom, feeding as they go (gathering collectors).

Scrapers: Feed by scraping the surface of rocks and logs, removing algae.

Predators: Feed on insects and other invertebrate animals.

Use the guide (p. 336) to help you discover what kind of insects live in your stream. Remember, this is only a general guide; it will help you identify most insects to a particular group. Ask your instructor for other references.

Procedure

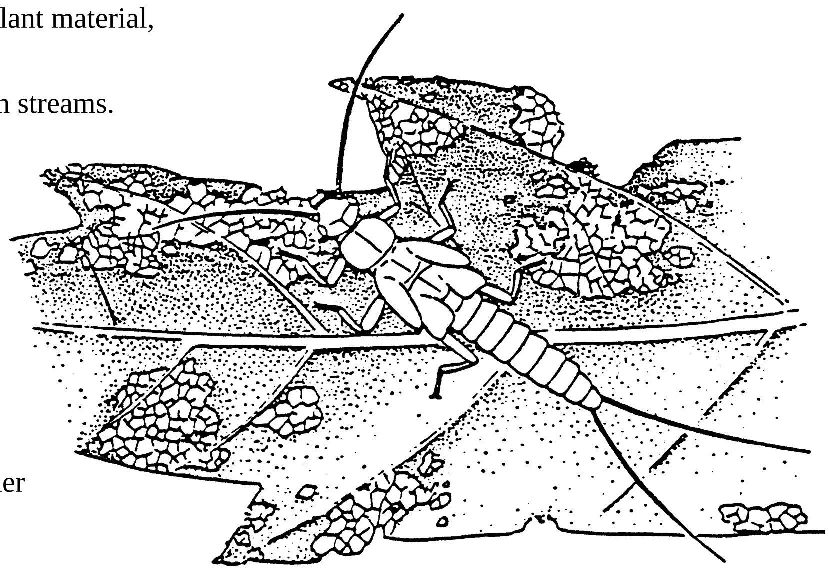
Now it's your turn . . .

If you have a cough, a fever, or a stomach ache, your mother usually figures that you are sick. After she determines that you're not faking it and trying to take a vacation from school, she usually lets you stay home for the day. The cough, fever, or stomach ache are indicators that something is wrong in your body.

Streams get sick, too. Poor land use practices and pollution in a stream's watershed (the area the stream drains) can lead to a stream health problem. How do biologists know when the stream starts to get sick? What are the indicators of poor stream health?

A stream that does not support as many fish as it once did is one indication. But even before changes in fish populations are noticed, biologists can tell if a stream is healthy or not by looking at the aquatic insects in the stream.

A stream with a diversity (many different kinds) of insects living in it is usually considered



healthy. But much can be learned about the stream by also looking at the kinds of insects living there. In general, insects can be placed in three groups.

- Some insects cannot tolerate pollution so good numbers of these insects indicate good water quality. Caddisflies, stoneflies, and mayflies are examples of insects in this group.
- Other insects can live in a wide range of water conditions and to some degree can tolerate both good and poor water quality. Examples in this group are dragonflies, damselflies, beetles, and craneflies.
- Some insects can live in polluted water and good numbers of these insects indicate poor water quality. Midges and black flies are two examples in this group.

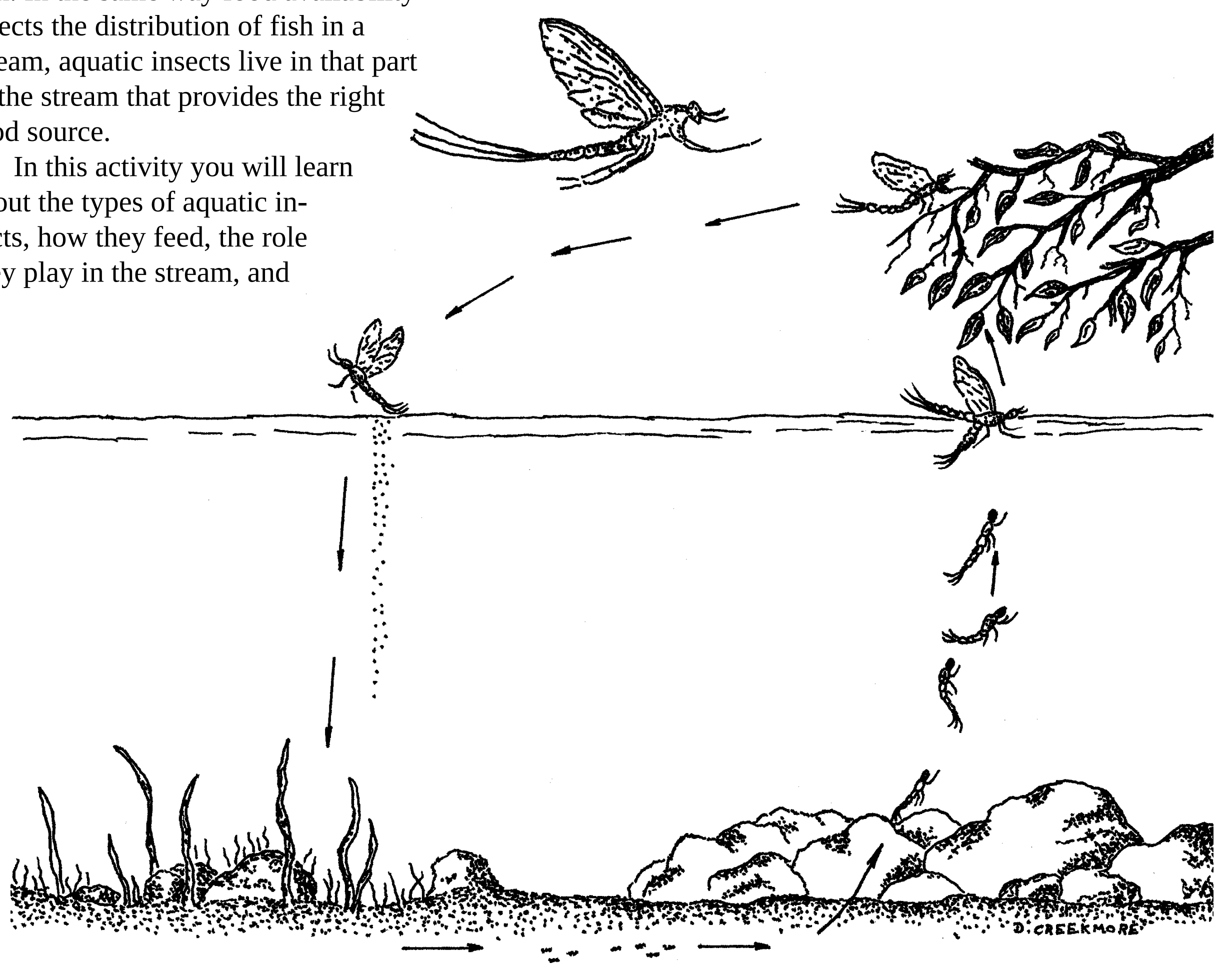
Aquatic insects are a major food source for fish. In the same way food availability affects the distribution of fish in a stream, aquatic insects live in that part of the stream that provides the right food source.

In this activity you will learn about the types of aquatic insects, how they feed, the role they play in the stream, and what they can tell us about stream health.

1. When you arrive at the stream, look for different habitats where fish and insects live. Examples are **pools** where the water is deep and the surface is fairly quiet, **riffles** where the water is shallow and ripples over the rocks, and **backwaters** at the stream's edge that are shallow and quiet. These habitats are identified primarily by characteristics of water flow. The size of rocks in the stream, the amount of leaf or fine woody litter, and large woody debris (branches or logs) also help determine the distribution and abundance of invertebrates.

2. Use the following procedures to collect a sample from each of the habitat types—riffles, pools, and backwaters.

   a. To avoid disturbing the sample area, approach the habitat type from the down-



stream end. Place the D-frame aquatic sampling net or other sampling device firmly on the bottom, perpendicular to the flow at the lower end of your sampling site.

b. Collect a sample from a one square foot area immediately upstream from the net opening. Pick up any rocks that are more than 2 inches in diameter and while holding them underwater in front of the net, gently rub, scrape, or brush their surfaces so the water will carry any dislodged organisms into the net. Place "cleaned" rocks outside of the sample area.

c. If present include coarse organic matter (primarily leaf, needle, and fine wood litter) and pieces of water-logged branches and wood in your sample.

d. After larger rocks and debris have been rubbed and set aside, stir up the bottom of the one foot square sample area to a depth of at least 1 inches to 2 inches, allowing the current to carry particles and organisms into the net.

e. Collect at least three samples per habitat type (riffles, pools, backwaters) to get an average count per habitat.

3. Wash each sample into a 1-millimeter sieve. Then, wash the material from the sieve into a shallow white pan. Add just enough stream water to cover the sample.

4. Use tape and a waterproof marker to label the sections of the sorting (ice cube) tray. Use labels like mayflies, stoneflies, caddisflies, beetle larvae, dragonflies, and others appropriate for the area you are sampling. You may need to consider subdividing some of the groups, for example, stony case caddisflies and organic case caddisflies. Fill the labeled ice cube tray with stream water. Using forceps, plastic spoons, eyedroppers, or small brushes gather the insects and place them in the appropriately labeled cube

5. Use a dichotomous key to separate invertebrates into functional feeding groups: shredders, scrapers, filtering collectors, gathering collectors, and predators. (See page 336) or consult other similar guides.)

6. Count the kinds of invertebrates and the numbers of each kind for each functional feeding group. Enter these numbers on the data sheet. Calculate the percentage of each group/habitat from the numbers.

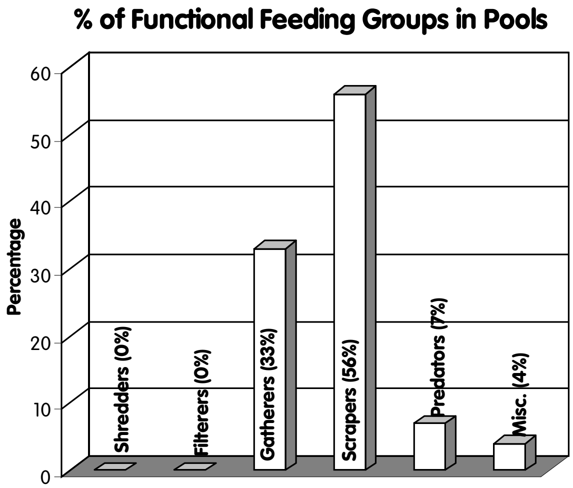
   To gain a better idea of the variety of organisms, list invertebrates within each functional feeding group by "kind." Riffle beetles and mayflies are different kinds. If you can tell two different types within a "kind" (e.g., two different caddisflies), but do not know the specific names, simply list them as "caddisfly A" or "caddisfly B."

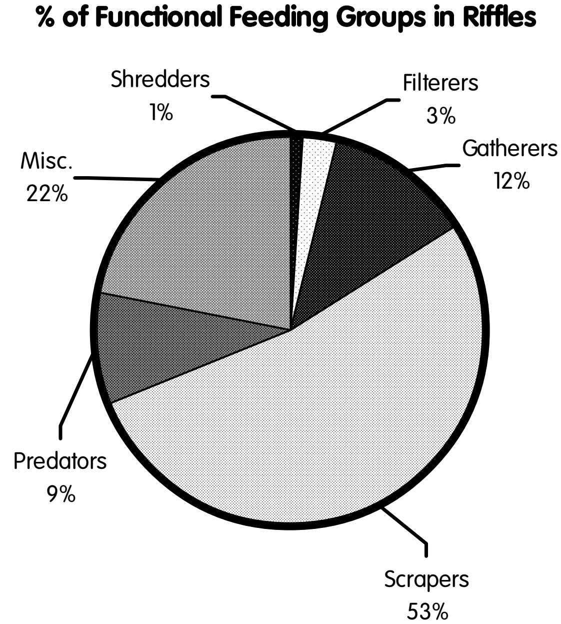
7. If possible, estimate the kinds and types of substrates where you sample and record on the data sheet *before* you collect the sample. An aquascope, or clear plastic mounted on the bottom end of a 5 gallong bucket or a long styrofoam box, will help cut surface water turbulence. Refer to the sizes listed on the chart for rock categories. Use the following categories for organic material:

   - Coarse organic matter (primarily leaf needle and fine wood litter >1 mm in diameter)
   - Fine organic matter (<1 mm to 0.45 mm)
   - Large wood (logs, stumps, branches)

   For each sampling site list substrates as percentages (e.g., 25% sand, 50% cobble, 25% coarse organic matter). The total of all substrate types should equal 100%.

Example Bar and Pie Graphs





Analysis

The analysis compares samples, either as habitat types within a small stretch of stream (a reach), as different reaches along one stream, or even as samples from different streams.

a. After sorting has been completed, calculate the percentage of each functional feeding group to the total. Total = number of shredders + filtering collectors + gathering collectors + scrapers + predators.

Example:

Habitat 1—Backwaters
# of shredders = 10
Total invertebrates = 20

$$\frac{\text{Shredders}}{\text{Total}} \times 100 = \text{ \% shredders}$$

$$\frac{10}{20} \times 100 = 50\% \text{ shredders}$$

b. Draw a bar or pie graph (see examples below) showing percentages for each functional feeding group for the each habitat type).

c. Compare these graphs for all of your study all habitat types: riffles, pools, and backwaters. Consider whether the proportion of each functional feeding group fits what you might expect in each habitat. For example, when a lot of leaf litter is present, many shredders could be expected. In a sunny spot with an abundance of algae, more scrapers should be found.

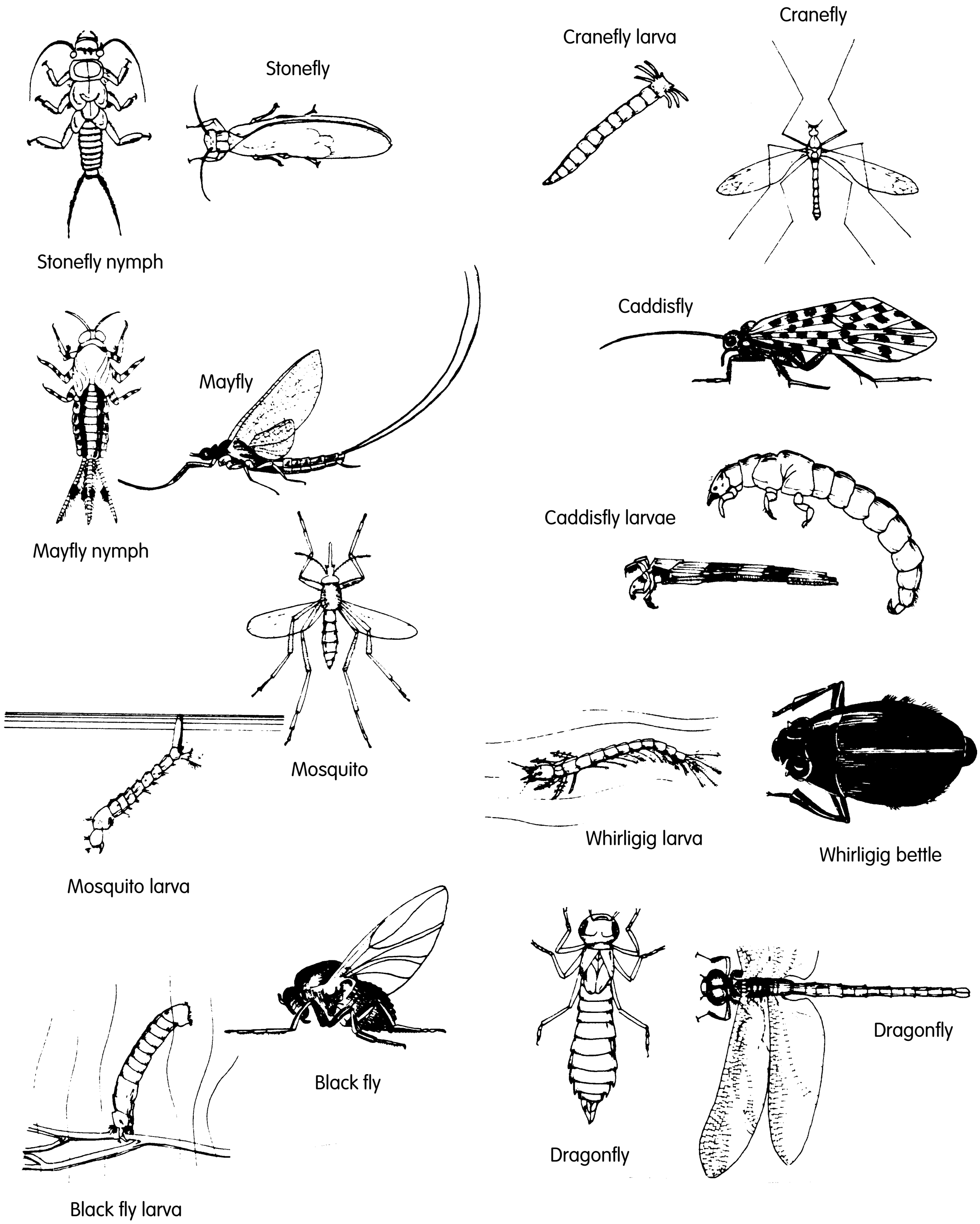
Team members ______________________

Date ______________________
Stream ______________________
Site ______________________

Data sheet for feeding groups

Numbers of organisms/functional feeding group

		Habitat type:		Habitat type:		Habitat type:	
		Kinds	Numbers	Kinds	Numbers	Kinds	Numbers
Shredders							
Filtering collectors							
Gathering collectors							
Scrapers							
Predators							
Miscellaneous							
Substrate (% composition)	Boulders (>12")						
	Cobble (3"-12")						
	Gravel (0.2"–3")						
	Sand } <0.2"						
	Silt } <0.2"						
	Clay } <0.2"						
	Organic material						
Notes							



Source: 1987 Western Regional Environmental Education Council

Questions

1. Would a riffle habitat aquatic insect sample containing 1,000 blackfly larvae (filtering collector) show a greater diversity than one containing several species representative of all four functional feeding groups (shredders, grazers, collectors, and predators)? Why or why not?

   No. Diversity means how many different **kinds** ***of things. One kind is not diverse. A habitat that can support a large variety of organisms has a greater potential for diversity than a habitat that supports large numbers of the same kind of organism.***

2. What kind of stream habitat conditions could contribute to low aquatic insect diversity?

   Lack of proper substrate, high sedimentation, little input of organic debris that serves as food for some aquatic insects, low water quality, high water temperature, low light conditions for algal growth that supports scrapers, plus others.

3. What kind of stream habitat conditions contribute to a high aquatic insect diversity?

   Basically, habitat complexity. Optimal conditions include a variety of substrates, various flow conditions, cool water temperatures, little sedimentation, well-oxygenated water, a variety of organic debris and plants, plus others.

4. Which functional feeding group would you expect to be predominant in a small stream with a nearly closed canopy of deciduous trees? Why?

   Shredders, because their primary role is to process the organic debris that falls into a stream.

5. A slow-moving, shallow stream with a muddy bottom would best support which functional feeding group? Why?

   Collectors, especially gathering collectors that burrow in the stream bottom and feed on fine material.

6. Describe a stream situation that would illustrate prime habitat for the greatest diversity of aquatic insects.

   Answers will vary, but should include components of the answer to question 3.

Going further

1. Use specific microhabitats such as coarse organic matter, fine organic matter, rocks, and large woody debris, or any other prevalent stream component to do the same functional group analysis. Use a uniform sample size for each habitat. This is a good approach for characterization of the whole stream.

2. Take a class walk to map out relative proportions of the stream occupied by each of the different habitat types. Using numbers derived from the "Water Wigglers" activity, calculate the relative abundance of invertebrates in a measured reach of stream.

3. In warmer months, allow students to snorkel to observe fish populations for an interesting and informative experience. Snorkeling may be used as an alternative to electrofishing to determine fish densities. **Snorkeling should not be done without proper supervision.**

4. To assess processing of coarse particulate matter, use a study of leaf packs. One or more types of leaves of dominant trees or shrubs from the riparian area should be collected just prior to autumn leaf fall and air

dried for at least a week.

Package the leaves into 5- to 10-gram packs, keeping track of beginning weights. When ready to do the activity, soak until softened, assemble and fasten loosely with heavy monofilament line or a large safety pin. Label each pack with a separate number. Place leaf packs in the stream facing into the current to simulate the natural accumulation of leaves on the upstream surface of obstructions such as logs and rocks.

At warmer temperatures, the packs should be evaluated about once each week and about once a month at colder temperatures. Estimates of the percentage of leaf remaining and observations of the type of feeding activity that has occurred should be part of an evaluation. After observation, remove the remaining leaf packs and allow them to dry. Re-weigh and calculate the rate of processing.

Compare processing times for different types of leaves and relate this information to food processing in headwater streams (Peterson and Cummins, 1974).

5. "Using Stream Fish to Demonstrate Predator-Prey Relationships and Food Selection," *The American Biology Teacher*, Volume 49, No. 2, February, 1987, pp. 104-106

6. Make collections from streams that appear to be similar and dissimilar in size, gradient, riparian vegetation, or from the same stream at different seasons. Note trends and differences in types of animals present. Have students suggest reasons for these differences.

7. Ask students to hunt for the largest and smallest aquatic insects in their samples. Take this opportunity to discuss adaptations of each functional feeding group for the kinds of food they eat or lifestyle they lead.

8. See "Blue Ribbon Niche," *Aquatic Project Wild*, pp. 72-75.

9. Contact your local department of fish and wildlife, watershed council, or department of environmental quality office. Volunteer to assist with macroinvertebrate sampling on streams in your area. Ask local experts to show you how the data is collected, analyzed, and presented. Prepare a report and share this information with the class.

Name

Water wigglers

Do you know . . .

Gazing into the cold water of a small stream in winter reveals little animal activity. The stream, like the woods around it, seems lifeless. But take a closer look. Skeletons of leaves with only the main ribs remaining provide evidence of animal activity. What happened to these leaves?

The leaves are eaten by aquatic invertebrates, especially insects, that spend most of their lives in water. They change their form, grow wings and emerge from water only during spring or summer when they mate.

During late fall and winter, small streams in wooded areas are menageries of aquatic insects. This is because most of the leaves and wood (containing energy for the insects) fall into the stream during this time. At other seasons of the year, you would probably find a different assemblage of animals.

If you were to gather a handful of leaf litter or a rock from the stream or kick up some bottom material from under rocks and let the current carry the material into a fine mesh net, you prob-

Vocabulary

coarse organic matter	predators
collectors	rocks
fine organic matter	scrapers
large wood	shredders

Aquatic Insect Guide

Builds a portable "house" or case to live in	**Caddisfly**
If case is made of material that was once living (wood, leaves, etc.)	**Shredder**
If case is made of mineral material (rocks, sand grains)	**Scraper**
Has two tails, without abdominal gills	**Stonefly**
If dark and uniformly colored	**Shredder**
If large and brightly colored and/or mottled	**Predator**
Has three tails (sometimes two), with abdominal gills	**Mayfly**
If flat, sometimes egg-shaped	**Scraper**
If cigar-shaped	**Gathering Collector**
Worm-like, without true legs	**Flies**
If <1 cm long, 1 pair stubby "legs," head well developed	**Gathering Collector (Midge)**
If >1.5 cm long, head reduced, often found in leaf litter	**Shredder (Cranefly)**
Antennae modified as tiny fans	**Filtering Collector (Blackfly)**
Free-living, 3 pairs of legs	**Odonates/Beetles**
If large, with gills at end of abdomen	**Predator (Damselfly, Dragonfly)**
If no gills, usually tough outer covering, jaws often easy to see	**Beetles**
Dark brown; tough outer covering	**Gathering Collector (Riffle Beetle)**
Color varied; abdomen soft-bodied	**Predator (Beetle)**

Adapted from: Bill Hastie, "What Wiggles in Winter Water," *Oregon Wildlife,* December 1983, p. 15.

Student sheet

ably will collect a wide range of insects you probably had not known were present. These insects can be placed into groups according to how they feed (**functional feeding groups**) as explained below:

Shredders: Feed on leaves or wood that falls into streams and eat the softer plant material, leaving the leaf skeleton.

Collectors: Feed on fine material in streams. Some filter the water for their food (filtering collectors), while others burrow in the stream bottom, feeding as they go (gathering collectors).

Scrapers: Feed by scraping the surface of rocks and logs, removing algae.

Predators: Feed on insects and other invertebrate animals.

Use the guide (p. 345) to help you discover what kind of insects live in your stream. Remember, this is only a general guide; it will help you identify most insects to a particular group. Ask your instructor for other references.

Now it's your turn . . .

If you have a cough, a fever, or a stomach ache, your mother usually figures that you are sick. After she determines that you're not faking it and trying to take a vacation from school, she usually lets you stay home for the day. The cough, fever, or stomach ache are indicators that something is wrong in your body.

Streams get sick, too. Poor land use practices and pollution in a stream's watershed (the area the stream drains) can lead to a stream health problem. How do biologists know when the stream starts to get sick? What are the indicators of poor stream health?

A stream that does not support as many fish as it once did is one indication. But even before changes in fish populations are noticed, biologists can tell if a stream is healthy or not by looking at the aquatic insects in the stream.

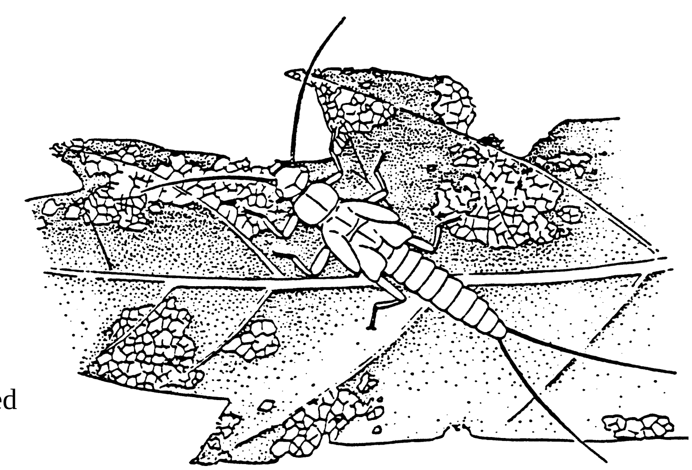
A stream with a diversity (many different kinds) of insects living in it is usually considered healthy. But much can be learned about the stream by also looking at the kinds of insects living there. In general, insects can be placed in three groups.

- Some insects cannot tolerate pollution so good numbers of these insects indicate good water quality. Caddisflies, stoneflies, and mayflies are examples of insects in this group.
- Other insects can live in a wide range of water conditions and to some degree can tolerate both good and poor water quality. Examples in this group are dragonflies, damselflies, beetles, and craneflies.
- Some insects can live in polluted water and good numbers of these insects indicate poor water quality. Midges and black flies are two examples in this group.

Aquatic insects are a major food source for fish. In the same way food availability affects the distribution of fish in a stream, aquatic insects live in that part of the stream that provides the right food source.

In this activity you will learn about the types of aquatic insects, how they feed, the role they play in the stream, and what they can tell us about stream health.

1. When you arrive at the stream, look for different habitats where fish and insects live. Examples are **pools** where the water is deep and the surface is fairly quiet, **riffles** where the water is shallow and ripples over the rocks, and **backwaters** at the stream's edge that are shallow and quiet. These habitats are identified primarily by characteristics of



Student sheet

water flow. The size of rocks in the stream, the amount of leaf or fine woody litter, and large woody debris (branches or logs) also help determine the distribution and abundance of invertebrates.

2. Use the following procedures to collect a sample from each of the habitat types—riffles, pools, and backwaters.
   a. To avoid disturbing the sample area, approach the habitat type from the downstream end. Place the D-frame aquatic sampling net or other sampling device firmly on the bottom, perpendicular to the flow at the lower end of your sampling site.
   b. Collect a sample from a one square foot area immediately upstream from the net opening. Pick up any rocks that are more than 2 inches in diameter and while holding them underwater in front of the net, gently rub, scrape, or brush their surfaces so the water will carry any dislodged organisms into the net. Place "cleaned" rocks outside of the sample area.
   c. If present include coarse organic matter (primarily leaf, needle, and fine wood litter) and pieces of water-logged branches and wood in your sample.
   d. After larger rocks and debris have been rubbed and set aside, stir up the bottom of the one foot square sample area to a depth of at least 1 inches to 2 inches, allowing the current to carry particles and organisms into the net.
   e. Collect at least three samples per habitat type (riffles, pools, backwaters) to get an average count per habitat.

3. Wash each sample into a shallow white pan. Add just enough stream water to cover the sample.

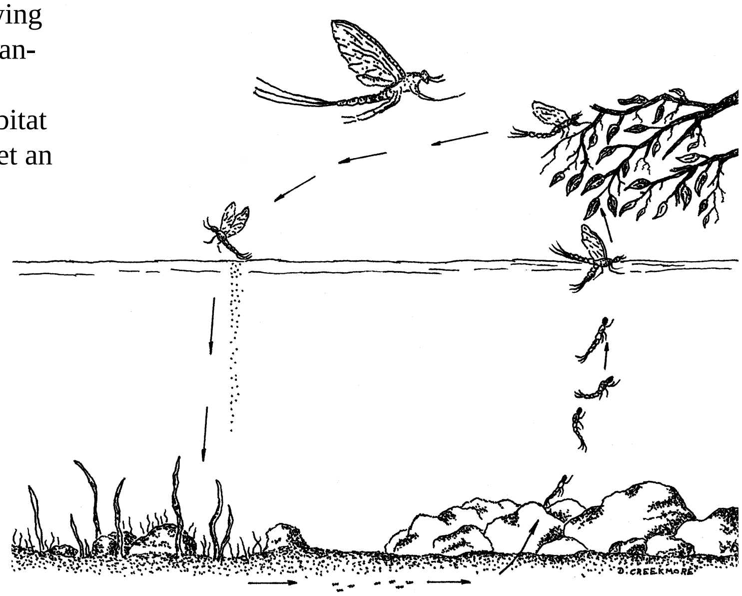
4. Use tape and a waterproof marker to label the sections of the sorting (ice cube) tray. Use labels like mayflies, stoneflies, caddisflies, beetle larvae, dragonflies, and others appropriate for the area you are sampling. You may need to consider subdividing some of the groups, for example, stony case caddisflies and organic case caddisflies. Fill the labeled ice cube tray with stream water. Using forceps, plastic spoons, eyedroppers, or small brushes gather the insects and place them in the appropriately labeled cube

5. Use a dichotomous key to separate invertebrates into functional feeding groups: shredders, scrapers, filtering collectors, gathering collectors, and predators. (See page 345 or consult other similar guides.)

6. Count the kinds of invertebrates and the numbers of each kind for each functional feeding group. Enter these numbers on the data sheet. Calculate the percentage of each group/habitat from the numbers.

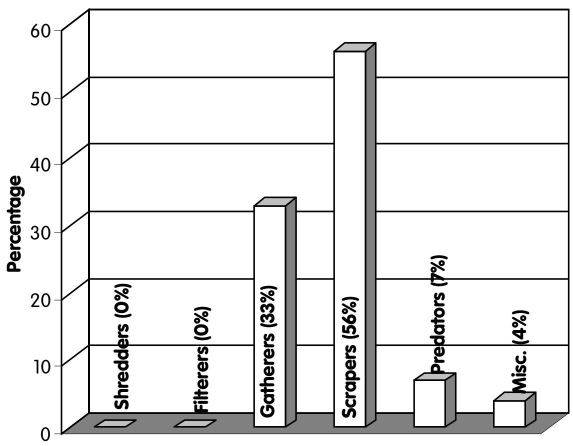
   To gain a better idea of the variety of organisms, list invertebrates within each functional feeding group by "kind." Riffle beetles and mayflies are different kinds. If you can tell two different types within a "kind" (e.g., two different caddisflies), but do not know the specific names, simply list them as "caddisfly A" or "caddisfly B."

7. If possible, estimate the kinds and types of substrates where you sample and record on the data sheet *before* you collect the sample. An aquascope, or clear plastic mounted at the end of a long 5 gallon bucket or a styrofoam box, will help cut surface water turbulence.

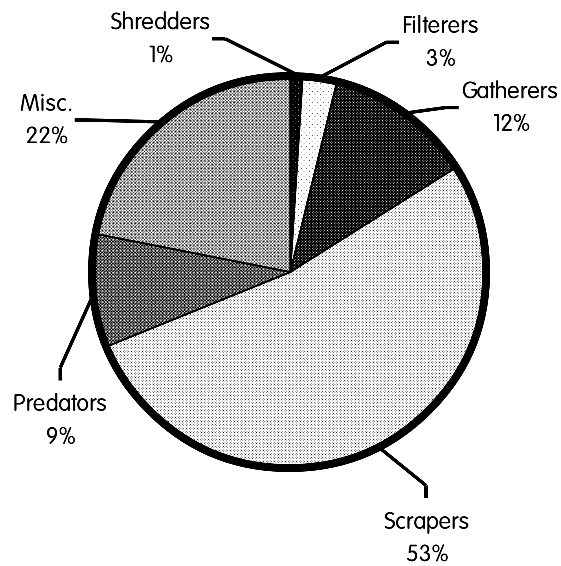


Example Bar and Pie Graphs

% of Functional Feeding Groups in Pools



% of Functional Feeding Groups in Riffles



Refer to the sizes listed on the chart for rock categories. Use the following categories for organic material:

- Coarse organic matter (primarily leaf needle and fine wood litter >1 mm in diameter)
- Fine organic matter (<1 mm to 0.45 mm)
- Large wood (logs, stumps, branches)

For each sampling site list substrates as percentages (e.g., 25% sand, 50% cobble, 25% coarse organic matter). The total of all substrate types should equal 100%.

Analysis

The analysis compares samples, either as habitat types within a small stretch of stream (a reach), as different reaches along one stream, or even as samples from different streams.

a. After sorting has been completed, calculate the percentage of each functional feeding group to the total. Total = number of shredders + filtering collectors + gathering collectors + scrapers + predators.

Example:

Habitat 1—Backwaters
# of shredders = 10
Total invertebrates = 20

$$\frac{\text{Shredders}}{\text{Total}} \times 100 = \text{ \% shredders}$$

$$\frac{10}{20} \times 100 = 50\% \text{ shredders}$$

b. Draw a bar or pie graph (see examples below) showing percentages for each functional feeding group for the each habitat type).

c. Compare these graphs for all of your study all habitat types: riffles, pools, and backwaters. Consider whether the proportion of each functional feeding group fits what you might expect in each habitat. For example, when a lot of leaf litter is present, many shredders could be expected. In a sunny spot with an abundance of algae, more scrapers should be found.

Team members ______________________________

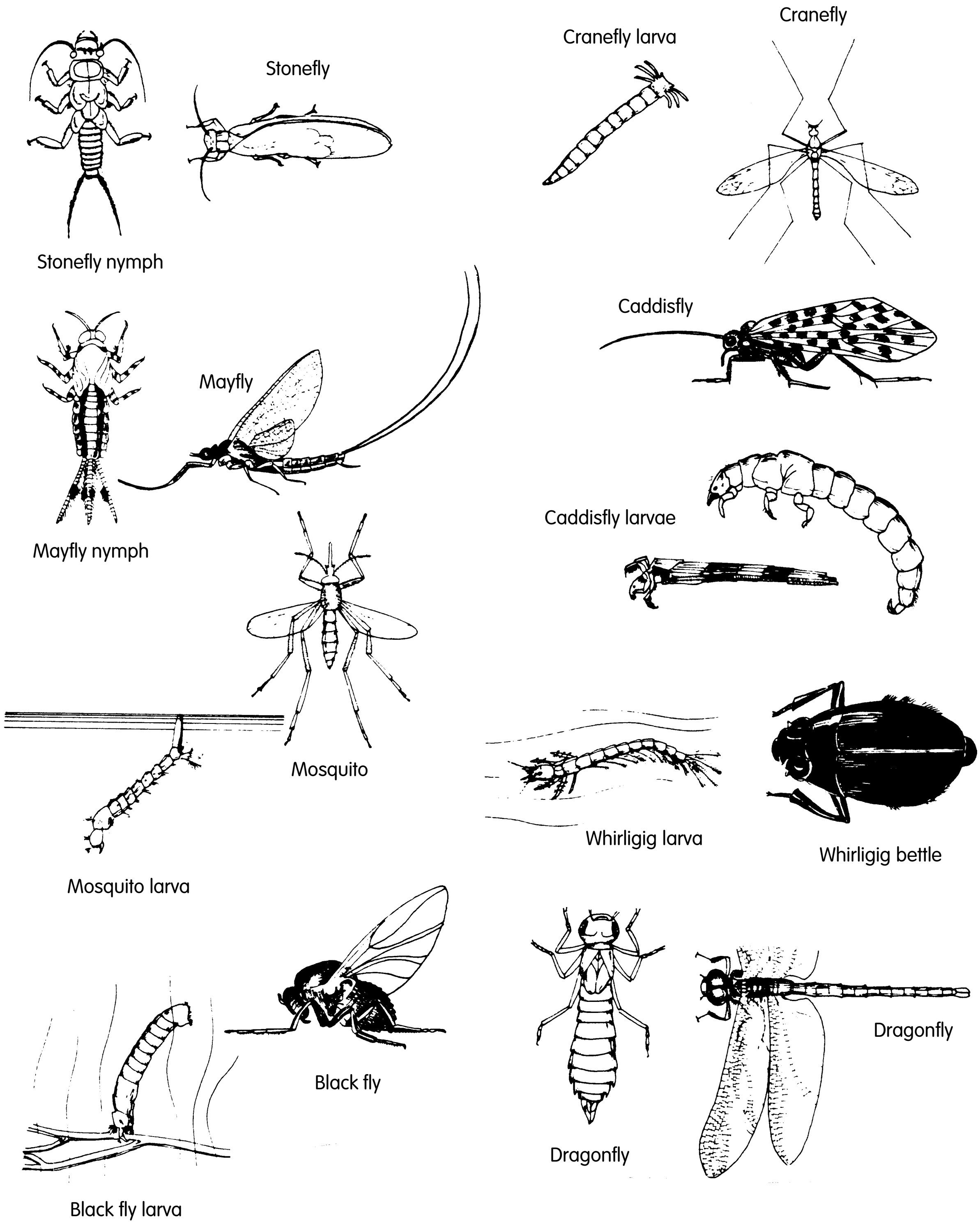
Date ______________________
Stream ______________________
Site ______________________

Data sheet for feeding groups

Numbers of organisms/functional feeding group

		Habitat type:		Habitat type:		Habitat type:	
		Kinds	Numbers	Kinds	Numbers	Kinds	Numbers
Shredders							
Filtering collectors							
Gathering collectors							
Scrapers							
Predators							
Miscellaneous							
Substrate (% composition)	Boulders (>12")						
	Cobble (3"-12")						
	Gravel (0.2"–3")						
	Sand } <0.2"						
	Silt } <0.2"						
	Clay } <0.2"						
	Organic material						
Notes							

Student sheet



Source: 1987 Western Regional Environmental Education Council

Student sheet

Questions

1. Would a riffle habitat aquatic insect sample containing 1,000 blackfly larvae (filtering collector) show a greater diversity than one containing several species representative of all four functional feeding groups (shredders, grazers, collectors, and predators)? Why or why not?

2. What kind of stream habitat conditions could contribute to low aquatic insect diversity?

3. What kind of stream habitat conditions contribute to a high aquatic insect diversity?

4. Which functional feeding group would you expect to be predominant in a small stream with a nearly closed canopy of deciduous trees? Why?

5. A slow-moving, shallow stream with a muddy bottom would best support which functional feeding group? Why?

6. Describe a stream situation that would illustrate prime habitat for the greatest diversity of aquatic insect .

9.2 Salmon life cycle

"... the fish is as clever as any creature could be in its position."
— Richard Jeffries

Eggs

The life cycle of a salmon or other **anadromous** fish begins when **eggs** are deposited and fertilized in the gravel of a stream. Successful reproduction depends on an adequate supply of gravel with low sediment content. The gravel protects eggs during incubation.

About one month after being deposited (although this varies, depending upon water temperature), eyes begin to show. During incubation, water flow (to deliver oxygen and carry away waste products) and temperature (40ºF to 65ºF) must be suitable. **Salmonids** are cold-water fish and generally cannot tolerate temperatures above 68ºF. The greatest mortality in a salmon's life cycle occurs during the egg-to-fry stage.

Alevins

In late winter or spring, the eggs hatch. Young fish, called **alevins**, rapidly grow under the gravel for one to three months. An alevin is a fragile creature with huge eyes and a large yolk sac protruding from its belly. The orange sac contains a completely balanced diet that lasts for several months. The **vitelline vein** runs through the center of the sac and picks up oxygen from water.

Fish at this stage are protected from most predators and other hazards by remaining under the gravel. A flow of water is critical to alevin survival. Porous gravel provides a stable streambed and allows good percolation of oxygen-rich water.

Fry

Alevins absorb their yolk sacs and emerge from the gravel as **fry** in late spring and summer. About an inch long, they are easy prey for larger fish. Chinook, sockeye, coho salmon and steelhead may spend a year or more in streams or lakes, while chum salmon begin to migrate directly to the sea.

The greatest mortality in a salmon's life cycle occurs during the egg-to-fry stage.

Fry feed on plankton and small insects. At this stage, streamside cover is needed for protection from predators and temperature extremes and as a source of food.

Vocabulary

alevins	redd
anadromous	salmonids
eggs	smoltification
fry	smolts
milt	spawn
parr marks	vitelline vein

Fish habitat needs

9.3

"The falling waters led me, the foodful waters fed me."
— Ralph Waldo Emerson

Though the physical characteristics of a stream largely determine its ability to pro duce fish, survival of each new hatch is dependent upon many environmental factors. A relatively stable, pollutant-free water flow is important for a productive stream.

Anadromous salmonids use a variety of streams. Although each species has its own specific habitat requirements, some generalizations can be made.

Spawning habitat

Successful spawning and development from egg to fry require:

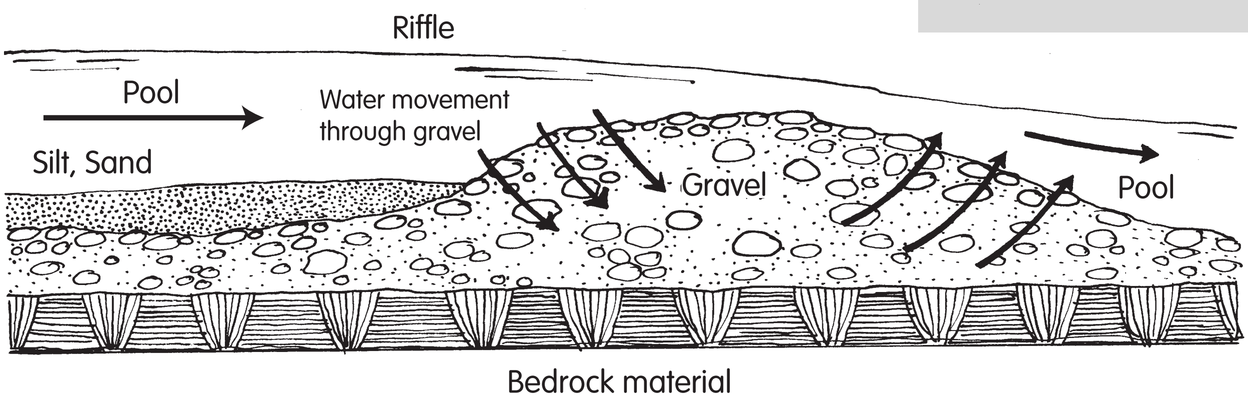
- absence of barriers to upstream migration of adults,
- spawning areas with sediment-free substrate and adequate water flows,
- a balance of pools to riffles that provides spawning areas and nearby escape cover, and
- a constant flow of cool, well-oxygenated water through the spawning gravel.

Anadromous fish must be able to move upstream to spawning areas. Log jams and other barriers can prevent this from happening. Fish can injure themselves trying to jump barriers or become weak and exhausted, reducing chances for successful spawning.

In ideal spawning habitat, cool, well-oxygenated water flows freely through sediment-free gravel areas. The cleanest gravel is usually found at the tailout, or downstream end, of a pool. Heavy flooding can disturb spawning beds in unstable channels.

Vocabulary

carrying capacity



Adapted from: Province of British Columbia, Ministry of Environment, *Stream Enhancement Guide*, Vancouver, B.C., 1980.

Rearing habitat

Young fry are vulnerable to predators, as they leave the gravel to seek food. High stream velocities can carry fry far downstream or strand them in floodplain pools. To enhance the survival of fry, pools for rearing, temperature regulation and cover should be close to each other. Productive juvenile rearing habitat requires:

- low to moderate slope and velocity;
- a balance of pool and riffle habitat;
- a variety of substrate types to provide hiding cover for juvenile fish and places for aquatic insects to live;
- undercut banks, stable natural debris such as fallen trees, and overhanging vegetation to provide cooling shade and protection for juvenile fish, and leaf litter for aquatic insect production; and
- sufficient nutrients to promote growth of naturally occurring plants and other organisms beneficial to the stream.

As young salmonids grow, they seek progressively higher velocities, often moving from the edge of a stream to midstream to take advantage of increased insect drift. Facing upstream or into the current allows a fish to conserve energy while watching for food drifting downstream.

Facing upstream or into the current allows a fish to conserve energy while watching for food drifting downstream.

In winter, all species seek areas of lower water velocity. This helps conserve energy while food and growing conditions are poorer, enabling fish to better cope with winter extremes.

Habitat preferences

Though basic requirements are the same, salmonid species differ in the types of habitat they use. For example, juvenile coho choose pool areas of moderate velocity in summer. They prefer eddies or backwaters near an undercut bank, root wad or log. In winter, they are found in slow, deep pools or side channel areas, seeking cover under rocks, logs and debris.

During winter, spring chinook salmon use riparian edges where vegetation has grown into a stream, providing cover and shelter. Streambanks must be covered with vegetation to provide this feature. Degraded streambanks do not provide suitable winter habitat for young fish. Rearing densities can increase dramatically where good streambank recovery has occurred.

Rearing densities can increase dramatically where good streambank recovery has occurred.

Juvenile steelhead spend from one to three years in fresh water, and their habitat needs must be considered throughout that time. In the first summer after hatching, young steelhead stay in relatively shallow, cobble-bottomed areas at the tail of a pool or shallow riffle. In winter, they hide under large boulders in shallow riffle areas.

Older steelhead juveniles prefer the heads of pools and riffles with large boulder substrate and woody cover in the summer. The turbulence created by this substrate is also important cover in these areas. During winter, older steelhead juveniles are found in pools, near streamside cover and under debris, logs or boulders.

Cutthroat habitat requirements are similar to those of steelhead, and although chinook juveniles tend to rear in large streams, their requirements parallel those of coho.

Table 4. Salmonids and Physical Stream Characteristics

Physical stream characteristics useful in differentiating habitat preferences of salmonids.

Habitat preference	Species: Coho	Chinook	Steelhead	Cutthroat
% pools	50-80	50-100	< 50	40-60
% gradient	<3	< 2	>1-5	1-20
Stream order	2-5	≥ 5	2-5	> 2
Maximum temperature	<65°F 18°C	< 68°F 20°C	< 73°F 23°C	< 65°F 18°C

Physical stream characteristics useful in evaluating stream quality preferences for salmonids.

Characteristics	Coho	Chinook	Steelhead	Cutthroat
Cover	woody structure	pool depth	boulders & wood	wood, volume, boulders
Channel profile	flat	moderately flat	steep	undercut banks
Riparian	Presence of riparian vegetation important for all species. Vegetation type (fir, alder) and age of vegetation determine quality.			

Limiting factors

Limiting factors must be considered for all phases of a salmonid's life cycle. The quantity and quality of riffle areas and spawning gravels in a stream limit spawning production. The quantity and quality of juvenile nursery areas or pools is a limiting factor for rearing juvenile salmonids and producing smolts ready for migration to the ocean.

When spawning habitat is limited, excessive numbers of adults on the spawning beds dislodge previously deposited eggs. If too many juveniles exist in rearing areas, competition for food and space force some to move into less suitable areas. These areas may have limited food and shelter from predators.

These limiting factors establish the salmonid **carrying capacity** of a stream. Within the limits of the available habitat, salmonid populations fluctuate from year to year because of varying environmental factors.

Limiting factors establish the salmonid carrying capacity of a stream.

Streamflow, for example, causes wide variations in survival and production of coastal salmonid populations. Extended low flows may keep adults from moving into streams, drain their limited energy reserves and affect upstream distribution and spawning success. High winter flows can destroy eggs and alevins by scouring spawning beds or depositing sediments. Low stream flows during winter incubation periods can cause exposure and freezing of spawning beds. Low summer flows often allow stream temperatures to increase, which reduces rearing areas for juveniles.

Stream temperatures may also affect survival indirectly. Abnormally high temperature conditions during migration have contributed to outbreaks of disease among adults, causing them to die before spawning. High winter temperatures increase the rate of development from egg to fry, and may cause fry to emerge from the gravel before the spring increase in food supplies.

A critical issue in eastern Oregon is the buildup of heavy ice (anchor ice) in streams. **Anchor ice** can trap fish in pockets where they freeze and die. Healthy riparian systems and stable streambanks help reduce heavy anchor ice and winter mortality of juvenile fish.

Recommended habitat conditions

As a stream is surveyed and analyzed, consider the habitat needs and stream quality references of the several salmonid species listed in Table 4 to ensure the best possible management of the resource.

Following is a list of other conditions that may improve the quality of fish habitat in streams. This list was prepared by the Riparian Habitat Subcommittee of the Oregon and Washington Interagency Wildlife Committee. Included is an explanation of how each contributes to salmonid health and survival.

Between 60% and 100% of a stream surface should be shaded from June to September during the hours of 10:00 A.M. to 4:00 P.M.

- Solar radiation is greatest during this season and time of day. Streamside vegetation provides shade to help keep water temperatures from becoming lethal during hot summer months. Streambank vegetation is also important habitat for terrestrial insects and is the main nutrient source for aquatic insects. These are both important sources of fish food. Shade is most important on small streams (less than 50 feet wide). Water depth and turbulence help compensate for the lack of shade on large streams.

Stream banks should have 80% or more of their total linear distance in a stable condition.

- Stable, well-vegetated streambanks help maintain stream channel integrity. They provide cover for fish and reduce temperature increases from solar radiation. In winter, they keep water temperatures slightly warmer, reducing ice buildup and decreasing winter mortality of juvenile fish. Sediments from streambanks are reduced, protecting the water quality of the entire system. Vegetation reduces bank erosion and helps hold the soil in place. Sediments are trapped and mature grasses and forbs form a strong sod.

No more than 15% of stream substrate should be covered by inorganic sediment.

- Aquatic insects, developing salmonid eggs and recently hatched fry still in the gravel depend on a continuous supply of cool, oxygen-rich water for survival. Large amounts of fine sediments clog the spaces between gravels. This prevents water from percolating through and causes fish and insect mortality. If pools are filled with sediments, rearing and hiding habitat is reduced or eliminated.

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Home wet home . . .

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

Objectives

The student will (1) recognize the habitat components necessary for salmonids in a stream, and (2) analyze and describe how each stream structure contributes to salmonid habitat needs.

Method

Students read background material, observe and analyze the stream diagram, and describe how each item noted develops or provides salmonid habitat.

For younger students

1. Consult extension activities at the end of each chapter to address the needs of younger students.
2. Read activity background information aloud to younger students or modify for your students' reading level.
3. This activity builds on knowledge from prior activities. Constructing a model stream where students can manipulate structures would be more effective for younger students.

Materials

- copies of student sheets (pp. 397-398)

Notes to the teacher

Because a number of fish species in Oregon are classified as threatened or endangered under the Endangered Species Act, fish restoration activities are closely monitored. Consult the *Oregon Aquatic Habitat Restoration and Enhancement Guide* for more specific information. You can get it from the Oregon (formerly Governor's) Watershed Enhancement Board (phone: 503-378-3589).

Background

Do you know . . .

Salmon and trout (salmonids) are important to anglers. Salmonids are also important to biologists because their presence helps indicate the health of the stream in which they live. Salmonids are one of the first organisms to be affected if their watery home starts to change or if their habitat is unsuitable. Biologists refer to sensitive animals like salmonids as "indicator" species.

Although a healthy natural habitat is preferred, fish biologists have developed many ways to improve degraded stream habitat to enhance fish survival. In some cases, biologists can produce a fishery where none was previously found.

The ecological requirements of salmonids are:

- cool, clear, well-oxygenated water,
- sections of gravel bottom for spawning,
- occasional pools for feeding and resting,

Vocabulary

boulder cluster	rip rap
cover logs	rock weir
cover tree	rock wing deflector
gravel bar	root wad
log sill	shade plantings
pool	streamside vegetation

- adequate food (aquatic and terrestrial insects, the latter usually falling from streamside vegetation), and
- cover for protection from predators.

Procedure

Now it's your turn . . .

How do you make a house a home? A house is just walls, a floor and a roof. But to make it a home, you have to arrange the furniture and hang the pictures. Structures like chairs, sofas, tables, beds, and your favorite wall hangings make the house more comfortable and livable.

Fish also need homes. A stream without structures like rocks, plants, logs, boulders, and gravel is just a "house." But with those structures in the stream and arranged just so, fish can live there comfortably.

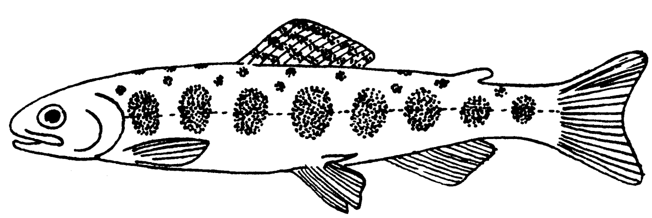
In a healthy stream, nature creates fish "homes" with all the right furnishings. But many streams today are not healthy and have lost their ability to serve as good homes for fish. So, fish biologists often build structures in and around streams to help restore fish habitat so that more fish can live there. They create pools, riffles, curves, and bends and grow plants along the stream. They also try to make the new changes look as natural as possible.

Following is a drawing of a stream that biologists have been working on. They have created each of the lettered structures. Can you tell how each structure helps fish live there? For instance, Item A—streamside vegetation—provides shade to keep the water cool and creates food (leaves) for insects that live in the water, which are in turn eaten by the fish.

Test your knowledge about fish habitat. Describe how each features serves as fish habitat in the space provided on the student answer sheet.

Going further

1. Repeat the "Temperature and Respiration Rate" experiment (pp. 265-268) using other species of fish (some warm water species and some cold water species). Compare the results. Based on your results, discuss why different species are found in completely different environments or in different parts of the same stream.
2. Design an experiment to measure the rate of flow in riffles and pools (and other habitat types including glides, rapids, and cascades.) Research the different types of fish habitat, including all kinds of slow-water and fast-water habitats. Consult with a fish habitat biologist to learn how each of the habitat types provides for the needs of fish. Prepare a report or display of your findings and present to the class.
3. Investigate the types of restoration work that are appropriate along a stream that has been severely damaged by flooding, heavy erosion, or other events. Explore the possibility of a work team from your school assisting others in the community to complete restoration work on a stream. Research who has responsibility for coordinating work projects of this type and the requirements necessary to proceed.
4. Have students build a stream table (model stream) to test different structures to control streamflow and erosion.



A. streamside vegetation

Provides cover in addition to shade for temperature regulation. In autumn, leaves drop into stream and eventually provide food for invertebrates that are eaten by fish.

B. rock weir

Slows the water, traps gravel for spawning, and creates pools.

C. root wad

Provides shade, cover, and resting areas, and produces spot scouring.

D. cover logs

Provides shade, cover, and resting areas, and produces spot scouring.

E. rip rap (rocks or vegetative)

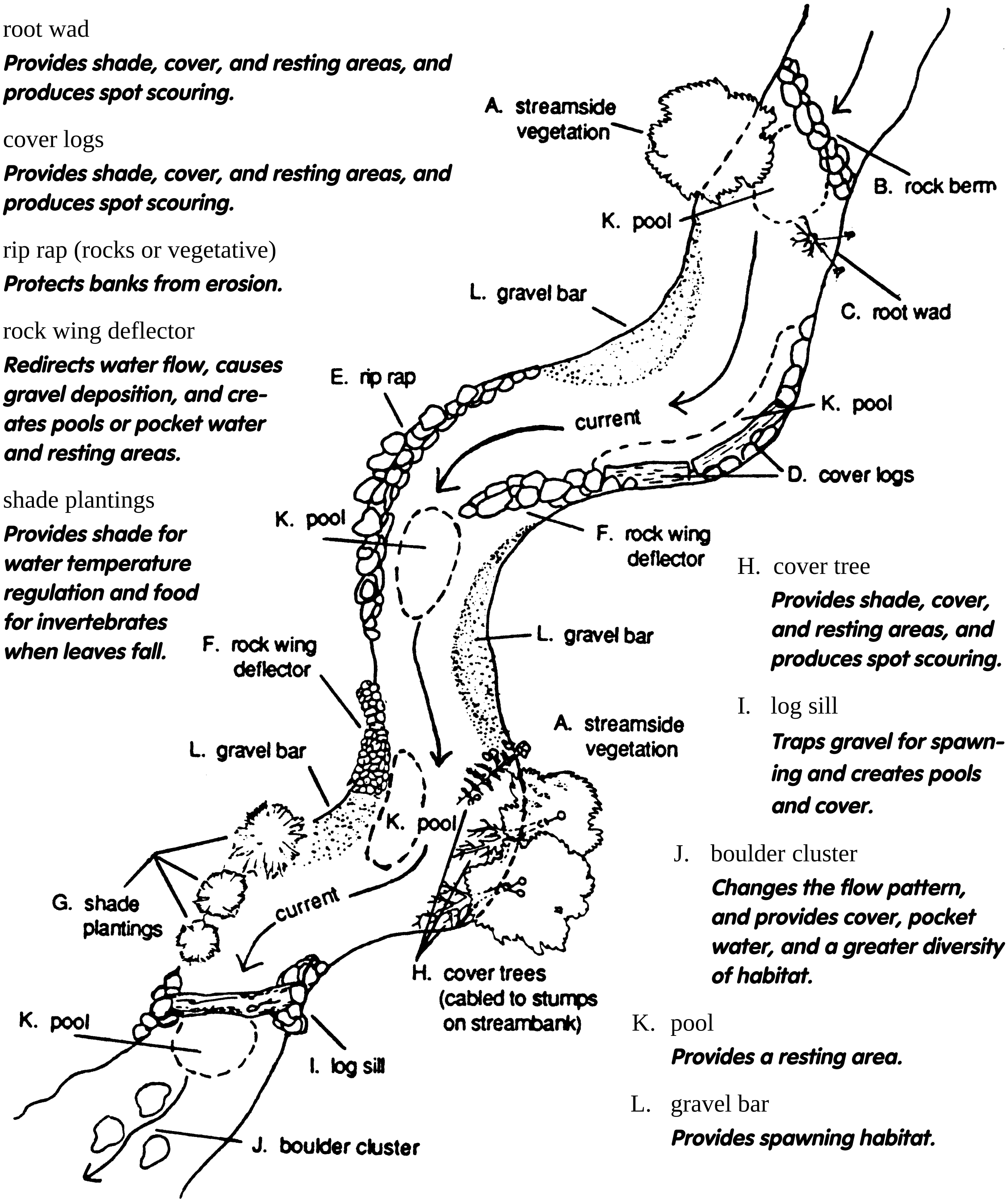
Protects banks from erosion.

F. rock wing deflector

Redirects water flow, causes gravel deposition, and creates pools or pocket water and resting areas.

G. shade plantings

Provides shade for water temperature regulation and food for invertebrates when leaves fall.



H. cover tree

Provides shade, cover, and resting areas, and produces spot scouring.

I. log sill

Traps gravel for spawning and creates pools and cover.

J. boulder cluster

Changes the flow pattern, and provides cover, pocket water, and a greater diversity of habitat.

K. pool

Provides a resting area.

L. gravel bar

Provides spawning habitat.

Name

Home wet home . . .

Do you know . . .

Salmon and trout (salmonids) are important to anglers. Salmonids are also important to biologists because their presence helps indicate the health of the stream in which they live. Salmonids are one of the first organisms to be affected if their watery home starts to change or if their habitat is unsuitable. Biologists refer to sensitive animals like salmonids as "indicator" species.

Because salmonids are so significant, fish biologists have developed many ways to improve stream habitat to enhance fish survival. In some cases, biologists can produce a fishery where none was previously found.

The ecological requirements of salmonids are:

- cool, clear, well-oxygenated water,
- sections of gravel bottom for spawning,
- occasional pools for feeding and resting,
- adequate food (aquatic and terrestrial insects, the latter usually falling from streamside vegetation), and
- cover for protection from predators.

Now it's your turn . . .

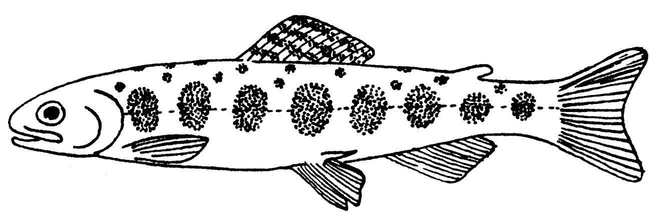
How do you make a house a home? A house is just walls, a floor and a roof. But to make it a home, you have to arrange the furniture and hang the pictures. Structures like chairs, sofas, tables, beds, and your favorite wall hangings make the house more comfortable and livable.

Fish also need homes. A stream without structures like rocks, plants, logs, boulders, and gravel is just a "house." But with those structures in the stream and arranged just so, fish can live there comfortably.

In a healthy stream, nature creates fish "homes" with all the right furnishings. But many streams today are not healthy and have lost their ability to serve as good homes for fish. So, fish biologists often build structures in and around streams to help restore fish habitat so that more fish can live there. They create pools, riffles, curves, and bends and grow plants along the stream. They also try to make the new changes look as natural as possible.

Following is a drawing of a stream that biologists have been working on. They have created each of the lettered structures. Can you tell how each structure helps fish live there? For instance, Item A—streamside vegetation—provides shade to keep the water cool and creates food (leaves) for insects that live in the water, which are in turn eaten by the fish.

Test your knowledge about fish habitat. Describe how each features serves as fish habitat in the space provided on the student answer sheet.



Vocabulary

boulder cluster	rip rap
cover logs	rock weir
cover tree	rock wing deflector
gravel bar	root wad
log sill	shade plantings
pool	streamside vegetation

Student sheet

A. streamside vegetation

B. rock weir

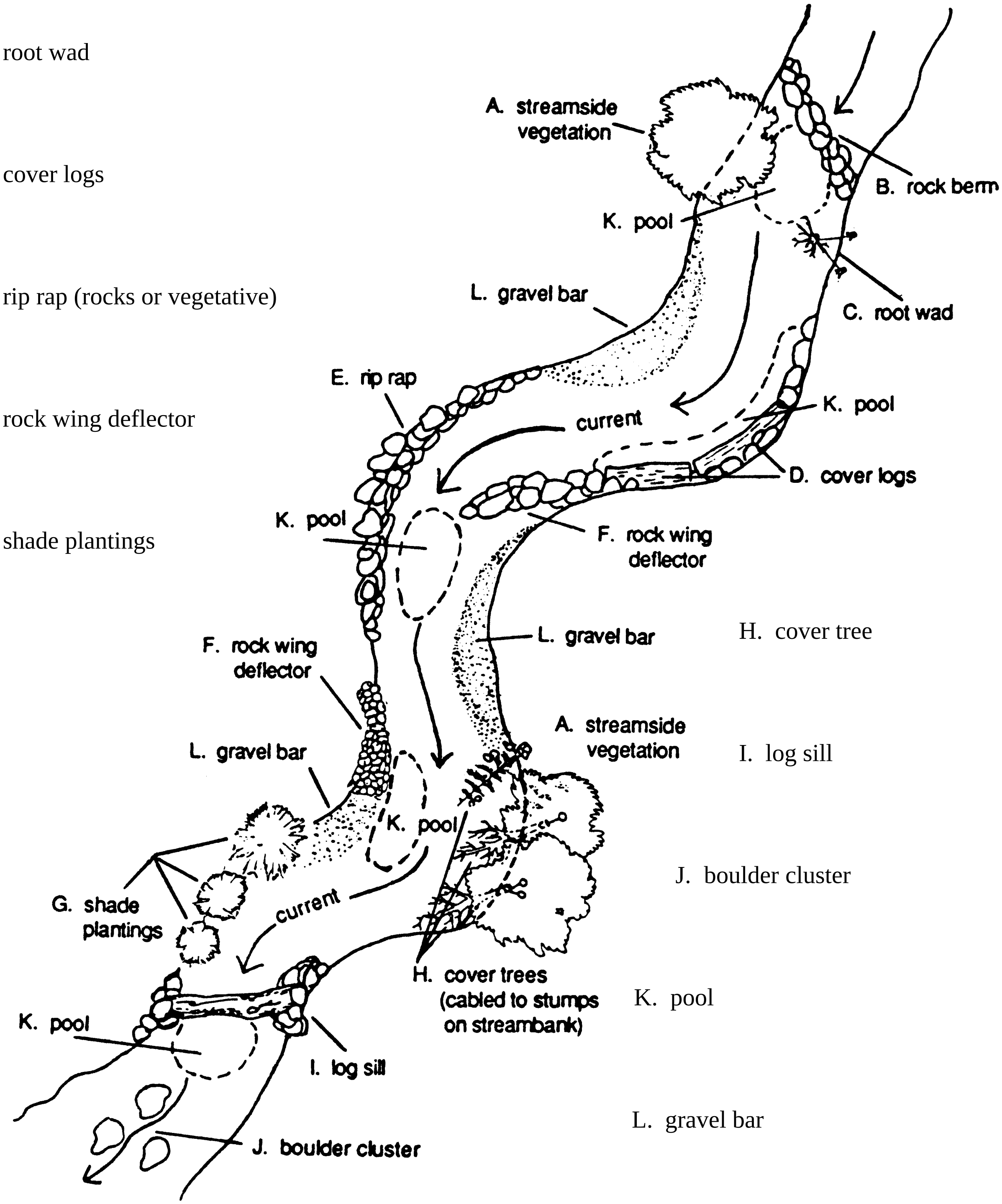
C. root wad

D. cover logs

E. rip rap (rocks or vegetative)

F. rock wing deflector

G. shade plantings



H. cover tree

I. log sill

J. boulder cluster

K. pool

L. gravel bar

Student sheet

The stream doctor—a fish biologist at work

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

Objectives

Students will (1) calculate the average number of redds per mile for the John Day River system; (2) graph and compare the spawning densities of chinook salmon in the mainstem, North Fork, and Middle Fork of the John Day River before and after riparian habitat improvement work; and (3) describe what influence stream habitat improvement work can have on fish numbers.

Method

Students graph spawning ground survey data for chinook salmon in the John Day Basin. The students then make comparisons and draw conclusions as to the effects of habitat improvement on these particular streams.

For younger students

1. Consult extension activities at the end of each chapter to address the needs of younger students.
2. Read activity background information aloud to younger students or modify for your students' reading level.
3. To make the complex graph easier to read for younger students, use clear overlays or a larger chart paper and break the graphing procedure into steps. Simply questions.

Vocabulary

redds
spawning

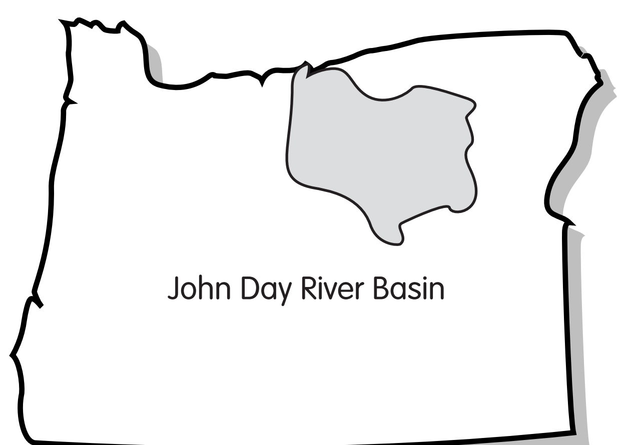
Materials

- copies of student sheets (pp.405-408)

Notes to the teacher

Following are graph interpretation comments provided by the John Day Basin fish biologist.

> The Middle Fork John Day River and John Day River are the most graphic in terms of recovery, which just happens to coincide with the amount of habitat work that has been done. Most of the habitat work on the Middle Fork is the result of better livestock management on U.S. Forest Service lands, a Nature Conservancy Preserve, and riparian fencing on a private ranch. Almost all the habitat work on the John Day River has been on private land. A typical project may consist of riparian fencing, removal of push-up irrigation dams, more efficient irrigation systems, converting from flood irrigation to gated pipe or sprinkler), or elimination of irrigation return water (installing drain pipe under the field and routing it directly to the river). Where return water has



Adapted from Jim Gladson, "The Stream Doctor," *Oregon Wildlife,* July 1983.

been eliminated, we have seen an 11ºF temperature change (inflow prior to the project was 11ºF warmer than after completion). At least one ranch has seen a doubling of hay production by converting to gated pipe from flood irrigation. Thus restoration activity not only benefits the fish, but benefits the landowner.

Background

Do you know . . .

Protection and improvement of riparian habitat in the John Day River Basin are serious subjects. Years of livestock grazing to the water's edge and poor land-use practices left bare and broken-down banks on many John Day streams. Without cooling shade, the waters warmed in the direct sun. Without the binding root systems of growing plants, banks collapsed and loaded the streams with silt.

The soil is the "money" and vegetation acts as the "security system."

By the late 1960s, streams that had once produced good runs of wild salmon and steelhead were in poor shape. Very few of these fish were able to survive in the warm, murky water. Other fish, such as squawfish, chiselmouth and shiners, could adjust to the change. These fish, not valued by anglers, began to take over the habitat. This invasion of non-game fish became so serious the North Fork of the John Day River had to be poisoned to remove them.

Errol Claire, a fish biologist with the Oregon Department of Fish and Wildlife in John Day and a pioneer in riparian restoration, saw the natural system breaking down and knew something had to be done. He set up a program to make the riparian habitat on the South Fork John Day River and its tributary, Murderer's Creek, healthy again. In 1982, the Bonneville Power Administration (BPA) also began several projects to help pay for riparian habitat restoration in the John Day system. The success of these efforts is evaluated as adult fish return to their home streams.

To improve riparian habitat, work must begin with the streambanks themselves. In fact, you can literally think of them as "banks." The soil is the "money" and vegetation acts as the "security system." In a natural system, the soil "money" is deposited a little at a time, and the vegetation "security system" guards it. The bank is rich. If we take away the security system (vegetation), then the natural system changes. Wind, rain and other eroding forces make withdrawals from the soil "bank" without replacing the soil "money." The bank becomes poor and useless. Practices, like *unmanaged* livestock grazing and others, that allow vegetation removal to the stream's edge, are like "robbing the bank."

Through riparian restoration projects, miles of streambanks have been fenced to keep cattle away from fragile banks and allow vegetation to re-grow. Rotating cattle grazing schedules has permitted some riparian areas to recover. Willows have been planted to protect and keep the banks from collapsing into the water. Riprap, rock and cut junipers have also been placed in streams to reduce bank erosion.

Miles of water that had poor spawning or rearing habitat have also been improved. Placement of boulders and logs in the stream has made the habitat more attractive to fish, especially salmon and trout. Pollution sources, like abandoned mines, have been identified and controlled. Clearing log jams and placing fish ladders have helped in areas with poor fish passage.

Fish populations are making a comeback in restored areas. Researchers have found more salmonids in cool, clear streams that have healthy riparian vegetation than in warmer, silty water with no protective riparian vegetation.

Procedure

Now it's your turn . . .

The information in the table on this page is valuable to biologists because it shows trends in the numbers of chinook salmon spawning in the John Day River and its tributaries over an extended period of time. In this exercise you will graph and compare the spawning densities of chinook salmon from three streams.

When fish lay eggs it is called **spawning**. Nests, or **redds**, prepared by the female are circular holes dug in the gravel in the stream bottom. The male drives away all other fish from his selected mate and fertilizes the eggs as the female deposits them.

When water conditions are low and clear, the redds are visible from the streambank. To discover how many salmon are spawning in a drainage basin, fish biologists count the number of redds, or fish nests, per mile on certain streams (called index streams) in the area. Difficult viewing conditions, like high, murky water, can make fish counts seem lower than normal. For example, in 1972, the count of redds per mile on the John Day River was low because of heavy rains.

Look at the information presented in the table on this page. It represents a portion of a nearly 40-year study of 116 total miles of index streams in the John Day Basin. Begin by:

- Calculating the average number of redds per mile for each stream. Record the average in the box provided at the end of the table.
- On the graph on page 403, starting with the John Day River, create a line graph by plotting the number of redds per mile for each of the 32 years of data. Repeat the process for the Middle Fork and the North Fork and the average.
- **Use a different color for each of the three lines.**
- **Be sure to mark the legend with the color representing each line.**

Chinook Salmon Spawning Density, John Day District, 1967-1998

Year	John Day River	Middle Fork John Day River	North Fork John Day River
1967	7.4	1.7	5.5
1968	0.7	0.4	8.8
1969	9.3	4.8	20.5
1970	8.3	7.6	16.8
1971	7.0	4.1	11.8
1972	**3.9	5.1	10.5
1973	8.9	4.3	19.4
1974	2.5	8.1	7.2
1975	7.1	8.9	11.7
1976	4.6	6.6	6.2
1977	4.9	5.8	16.4
1978	4.5	10.7	5.9
1979	5.2	11.8	11.1
1980	1.2	5.8	4.3
1981	3.9	2.6	7.7
1982	3.8	6.2	5.5
1983	10.2	5.1	4.2
1984	5.6	6.7	3.5
1985	8.9	4.0	6.1
1986	12.2	6.3	14.3
1987	19.0	28.3	20.8
1988	6.3	20.1	13.6
1989	12.7	9.4	10.9
1990	9.5	3.9	14.3
1991	4.7	2.9	6.4
1992	10.9	9.0	18.8
1993	10.4	12.9	21.1
1994	13.0	7.8	11.2
1995	2.2	1.3	1.5
1996	17.5	11.3	16.2
1997	9.6	13.6	10.9
1998	8.3	6.6	5.6
Average	**8.6**	**8.9**	**10.2**

** Count low due to rain and increased river flow that delayed survey and caused poor counting conditions.

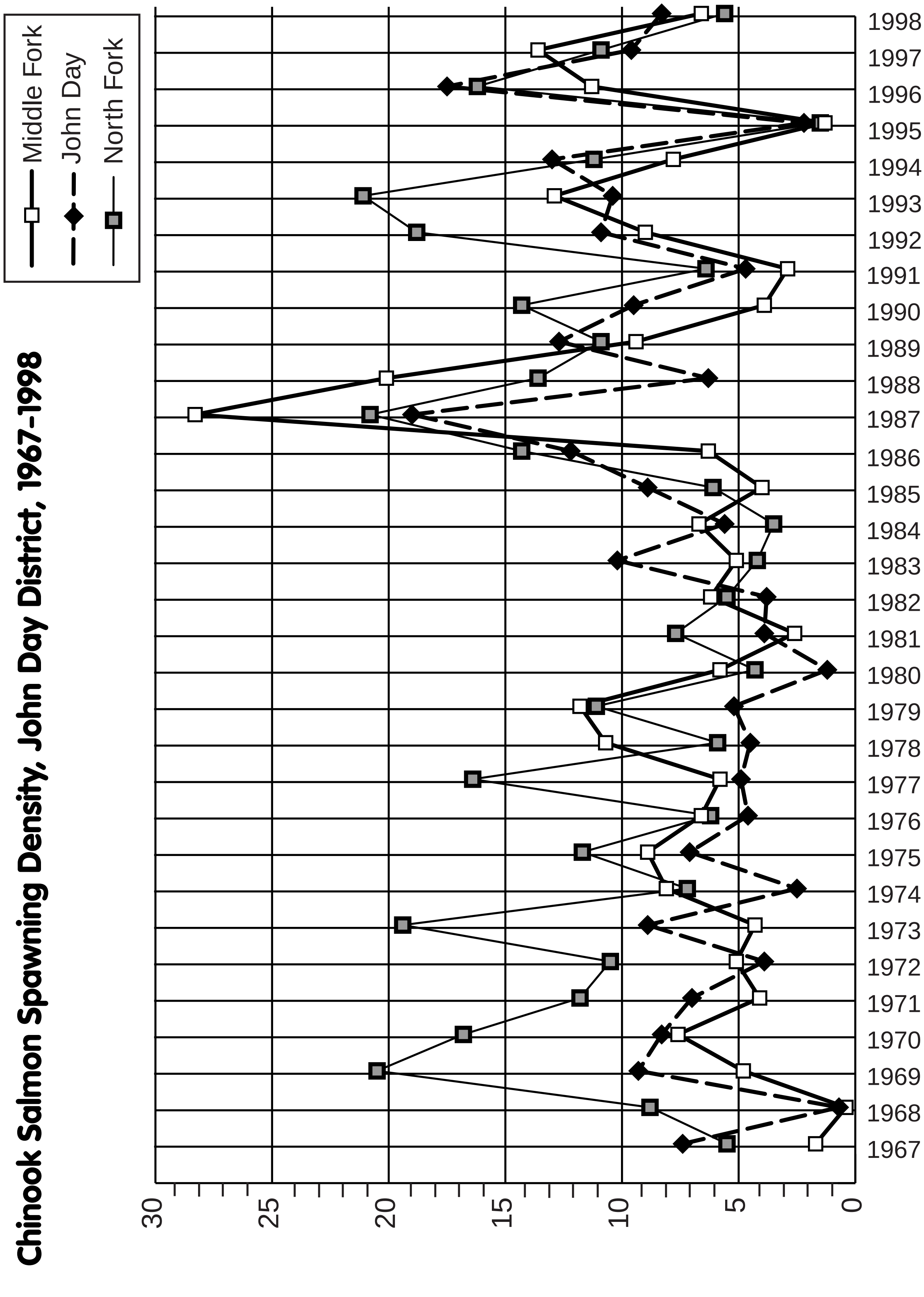
Questions

1. Look carefully at the overall picture of how John Day Basin spawning fish populations have changed throughout the years. Do the peaks and valleys for each stream's line parallel each other? Describe the general trends and comparisons you see on the graph.
   Lines basically parallel each other. Seems unstable.
2. Describe any change in the pattern for the years 1977 to 1989. What has happened since 1990?
   Still unstable, but generally lower average than previous decade; 1986-89 shows slight upward trend. From 1990 to 1993, upward trend then a marked drop in 1995.
3. Which tream had the lowest average redds per mile?
   Mainstem John Day River.
4. Referring to the introductory information, what human activity may have helped increase the number of redds per mile on the North Fork John Day in the late 1960s?
   Removal of competition from non-game fish by poisoning.
5. Looking at the overall trends on the graph, do you notice any changes after 1984? Describe what you see. Why do you think this is happening?
   Yes. More consistent increases in the number of redds per mile on all but the Middle Fork. The new habitat restoration work has been in place long enough to show fish population responses.
6. List as many ways as you can to describe how stream habitat restoration efforts can help increase fish populations?
   Answers will vary, but should include improvement of spawning and rearing habitat, protection of eroding streambanks, riparian area protection, etc.
7. What are the things a "stream doctor" must know to be effective in restoring a stream?
   Answers will vary, but could include kinds of fish currently and historically present in the stream, habitat requirements of the fish in the stream, streamflow pattern of the stream, location of irrigation diversions, key erosion points and the reason for them, locations of barriers to fish migration, etc.

Going further

1. Contact your local department of fish and wildlife. Invite a fisheries biologist to review the data from this activity with you and make his or her own analysis. Does it differ significantly from your own? If so, how?
2. Contact your local department of fish and wildlife. Volunteer to assist with fish spawning surveys on streams in your area. Ask the local fisheries biologist to show you how the data is analyzed and presented. Prepare a report and share this information with the class.
3. Have students build a stream table (model stream) to test different structures to control streamflow and erosion.

Chinook Salmon Spawning Density, John Day District, 1967-1998



Name

The stream doctor—a fish biologist at work

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Vocabulary

redds
spawning

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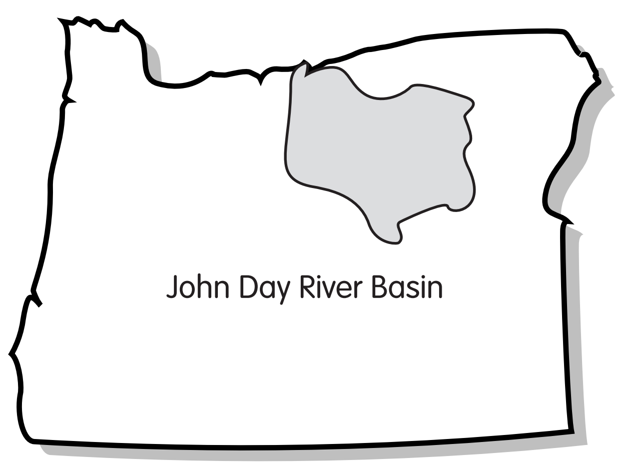

Adapted from Jim Gladson, "The Stream Doctor," *Oregon Wildlife*, July 1983.

Student sheet

Placement of boulders and logs in the stream has made the habitat more attractive to fish, especially salmon and trout. Pollution sources, like abandoned mines, have been identified and controlled. Clearing log jams and placing fish ladders have helped in areas with poor fish passage.

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1978	4.5	10.7	5.9
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1983	10.2	5.1	4.2
1984	5.6	6.7	3.5
1985	8.9	4.0	6.1
1986	12.2	6.3	14.3
1987	19.0	28.3	20.8
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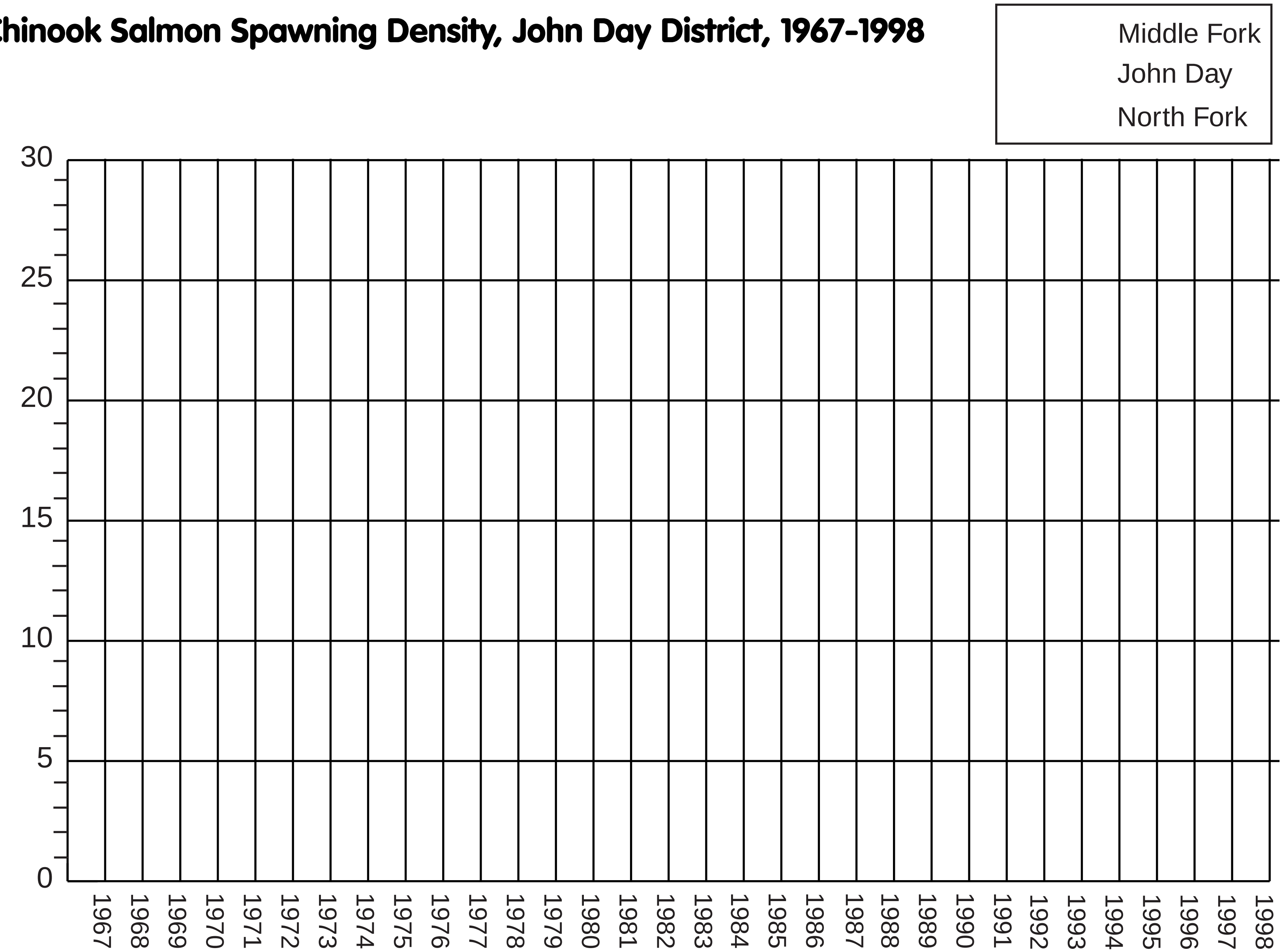
1997	9.6	13.6	10.9
1998	8.3	6.6	5.6
Average			

** Count low due to rain and increased river flow that delayed survey and caused poor counting conditions.

Student sheet

Chinook Salmon Spawning Density, John Day District, 1967–1998



Student sheet

Questions

1. Look carefully at the overall picture of how John Day Basin spawning fish populations have changed throughout the years. Do the peaks and valleys for each stream's line parallel each other? Describe the general trends and comparisons you see on the graph.

2. Describe any change in the pattern for the years 1977 to 1989. What has happened since 1990?

3. Which team had the lowest average redds per mile?

4. Referring to the introductory information, what human activity may have helped increase the number of redds per mile on the North Fork John Day in the late 1960s?

5. Looking at the overall trends on the graph, do you notice any changes after 1984? Describe what you see. Why do you think this is happening?

6. List as many ways as you can to describe how stream habitat restoration efforts can help increase fish populations?

7. What are the things a "stream doctor" must know to be effective in restoring a stream?

Student sheet

Clackamas carrying capacity

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

Objectives

The student will (1) calculate the estimated number of steelhead smolts per mile that could survive to migrate to the ocean, (2) calculate how many smolts could be produced by the available habitat within the entire 135 miles of the Clackamas Basin, (3) calculate how many adults are needed to fill the habitat to capacity and determine the potential production of a pair of adult steelhead, (4) compare the calculated figures obtained with the actual numbers counted by researchers, and (5) suggest reasons why the calculated carrying capacity does not match the actual numbers.

Method

Students will complete a series of calculations to determine the rearing potential of the stream, compare these figures to actual counts determined by fish biologists, and draw comparisons between the two numbers.

For younger students

1. Consult extension activities at the end of each chapter to address the needs of younger students.
2. Read activity background information aloud to younger students or modify for your students' reading level.
3. Use "carrying capacity" extension activity to help younger students grasp this concept.

Vocabulary

carrying capacity

Materials

- copies of student sheets (pp. 413-418)

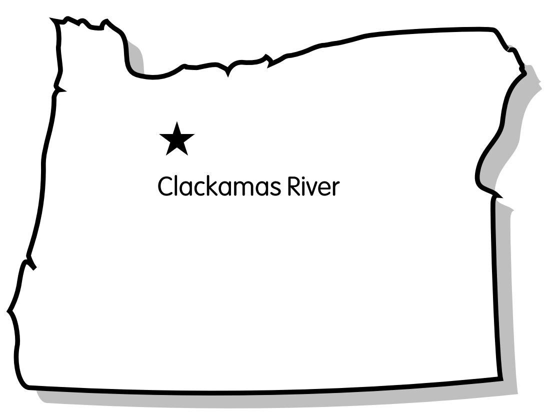
Background

Do you know . . .

Carrying capacity is the number of animals a habitat can support throughout the year without harm to either the organisms or the habitat. Factors like food, water, cover, and space limit the number of fish or other animals any specific habitat, like a stream, can support.

Carrying capacity is generally highest during the summer months when food supplies are at their peak and lowest during the winter months when food is in short supply. Carrying capacity in streams is affected by low streamflows and high water temperatures in late summer.

Fish and most other populations tend to expand to numbers their habitat (food, water, cover, and space) can support. This is true even though disease, competition, predation, parasitism, and reproductive capabilities all play a part in keeping populations down.



Activity developed by Nancy MacHugh, Oregon Department of Fish and Wildlife.

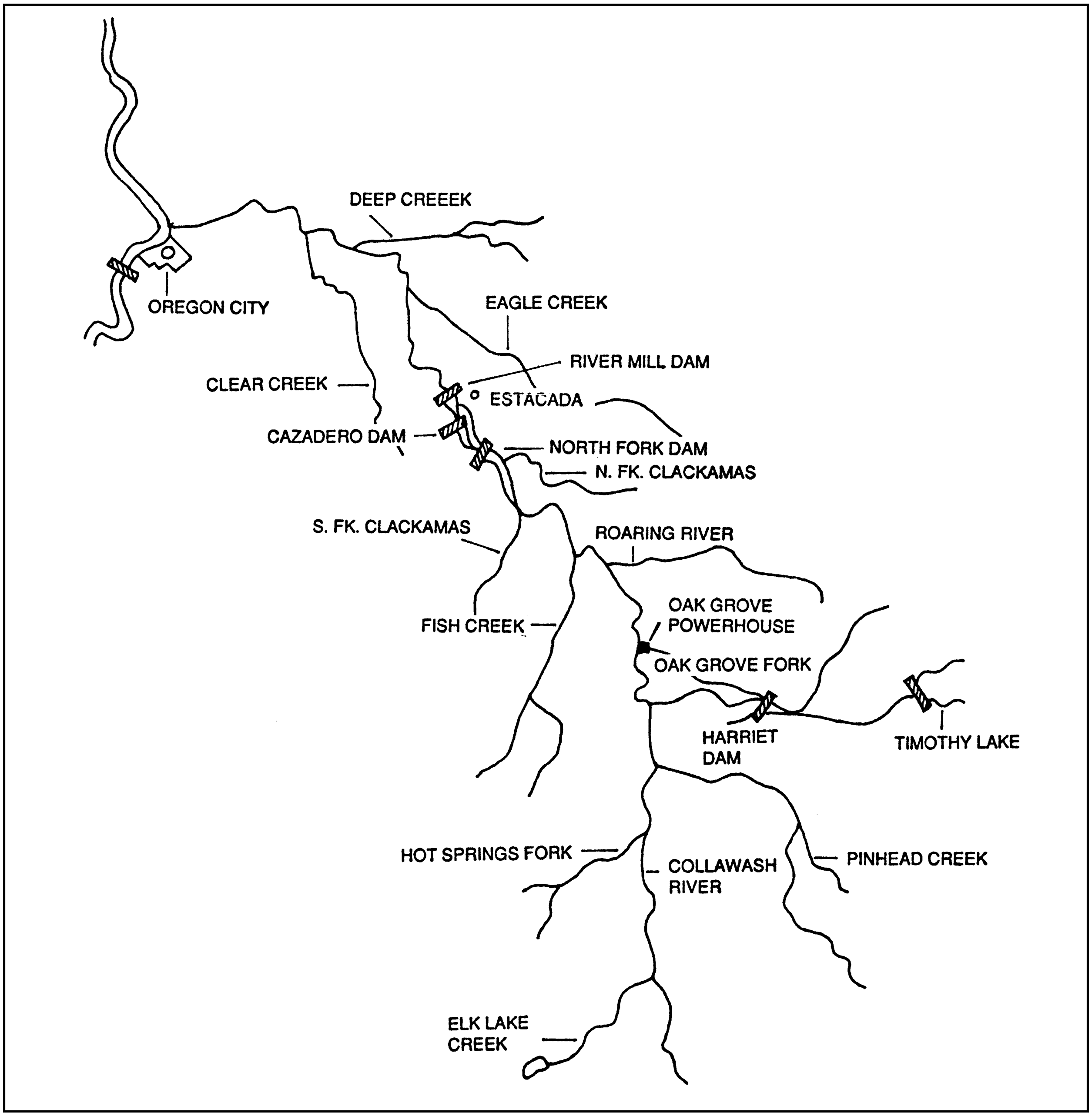
Biologists inventory fish populations throughout the year to find out how the fish are doing. For example, biologists regularly survey a few sections of the upper Clackamas River (above the North Fork Dam) and count young winter steelhead in selected tributaries and sections of the mainstem Clackamas River. Their calculations reveal an average of 1,776 yearling and older steelhead per mile of stream surveyed.

Procedure

Now it's your turn . . .

What is the carrying capacity of these surveyed sections of the Clackamas River? In this activity you will calculate the estimated carrying capacity for this stream section and compare it to actual fish counts.

Clackamas River System



Questions

1. Wild winter steelhead spend two to three years in freshwater habitats before migrating to the ocean. How many ocean-going smolts per mile would be produced and supported, based on the average listed in the introductory information, if 50% of the juveniles observed survived to migrate to the ocean?

   888 smolts per mile (50% of 1,776 yearling or older steelhead per mile of survey)

2. Surveys also showed 135 miles of the upper Clackamas Basin were used by steelhead. If all sections of the river produced steelhead at the same rate as the small number of sections surveyed, how many smolts could be expected to be produced by the entire 135 miles of stream?

   119,880 smolts (135 × 1,776)

3. Using the table at the right, calculate the average number of adult winter steelhead spawning per year in the upper watershed of the Clackamas River for the period 1957-1984.

   1,806 adult steelhead (add counts for 1957-1984 and divide by number of years)

4. If 50% of the adults spawning in Question 3 above are females, how many females are present?

   903 females (50% of 1,806)

5. If each female places 4,500 eggs in a redd (fish nest), how many eggs would this represent?

   4,063,500 eggs (903 × 4,500)

6. If only one of every 100 eggs survives to smolt age, how many smolts would be expected to survive to migrate to the ocean? (The greatest mortality in a steelhead's life cycle occurs during the egg-to-fry stages. Poor gravel conditions, inadequate oxygen, predators, and temperature extremes all take their toll on the eggs and fry.)

   40,635 smolts (4,063,000 ÷ 100)

7. A count of smolts is taken as they migrate downstream through the North Fork Dam fishway. What is the average number of smolts surviving to migrate to the ocean per year (produced by the 1957-1984 adults in the questions above) based on these fishway counts? Use the 1959-1986 downstream migrant counts from the table at left. (*Do not use the 1976 figure when calculating the average.* A large release of smolts from a hatchery source was made in 1976. Using this figure in calculation of the average would create unrealistic expectations from the data.)

North Fork Clackamas Downstream Migrants, Wild Steelhead Smolts

Year	Count
1959	36,336
1960	38,888
1961	17,694
1962	22,531
1963	24,806
1964	30,727
1965	13,858
1966	11,035
1968	31,386
1968	35,758
1969	29,187
1970	31,457
1971	19,111
1972	15,476
1973	21,403
1974	27,306
1975	28,024
1976	*105,577*
1977	33,792
1978	77,828
1979	41,334
1980	48,231
1981	43,558
1982	44,544
1983	31,615
1984	40,647
1985	35,152
1986	50,355

Adult Winter Steelhead Counts at PGE's North Fork Dam

Year	Count
1957	1,648
1958	566
1959	1,148
1960	2,204
1961	4,360
1962	2,257
1963	1,883
1964	1,552
1965	1,290
1966	682
1968	790
1968	2,316
1969	2,809
1970	4,349
1971	2,634
1972	1,897
1973	671
1974	1,526
1975	1,182
1976	1,527
1977	1,987
1978	1,511
1979	2,065
1980	2,697
1981	1,446
1982	1,099
1983	1,238
1984	1,225

35,272 smolts (add counts for 1959-1986, excluding 1976 and divide by number of years)

8. In Question 2 you calculated the potential number of smolts (or carrying capacity for production). What percent of those smolts does your estimate in Question 6 represent?

   33.9% (40,635 ÷ 119,880 × 100)

   What percent does the actual fishway count in Question 7 represent?

   29.4% (35,272 ÷ 119,880 × 100)

9. Assuming the smolt estimate from stream surveys is reasonably accurate, does your answer to Question 8 suggest steelhead production is at capacity?

   No, there is room for more production. If survival to smolt, smolt-to-adult survival, or numbers of adult steelhead returning past fishermen can be increased, more steelhead smolts could be produced.

10. If survival from egg to smolt stays at 1 in 100, how many adult steelhead would need to spawn in the Clackamas to achieve the actual carrying capacity of the 135 miles of habitat?

    5,328 adults (119,880 × 100 = 11,988,000 eggs, 11,988,000 ÷ 4,500 eggs/female = 2,664 females × 2 = 5,328 adults)

11. If, as part of a habitat enhancement project, an additional quarter mile of spawning gravel was placed in areas of the Clackamas that were previously lacking adequate spawning gravel, would the carrying capacity of this section of the river be increased? Why or why not?

    Increased amounts of good quality spawning gravel would provide more habitat for spawning to occur. If more fish were able to spawn, and if rearing areas for the young fish were available, the carrying capacity of the stream could be increased. However, additional spawning gravel does not guarantee higher carrying capacity if sufficient good quality rearing areas are not available. The available habitat has a specific carrying capacity and will only support a certain number of juveniles.

Going further

1. Identify several factors in your local watershed that could affect the survival of salmon or other fish species. Hypothesize how these factors could change survival rates and calculate those change in survival over several generations.

2. Contact your local department of fish and wildlife. Volunteer to assist with fish population surveys on streams in your area. Ask the local fisheries biologist to show you how the data is collected, analyzed and presented. Prepare a report and share this information with the class.

Name ____________

Clackamas carrying capacity

Do you know . . .

Carrying capacity is the number of animals a habitat can support throughout the year without harm to either the organisms or the habitat. Factors like food, water, cover, and space limit the number of fish or other animals any specific habitat, like a stream, can support.

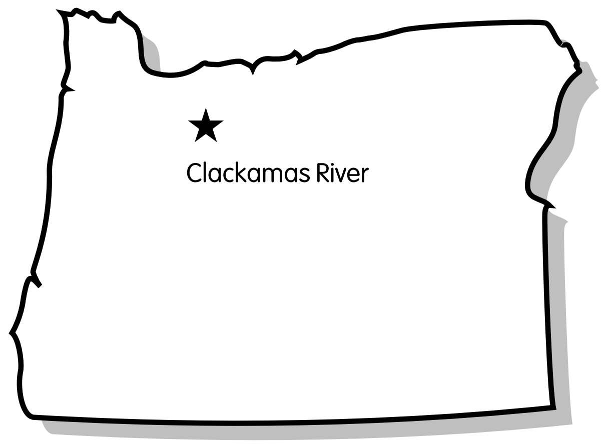
Carrying capacity is generally highest during the summer months when food supplies are at their peak and lowest during the winter months when food is in short supply. Carrying capacity in streams is affected by low streamflows and high water temperatures in late summer.

Fish and most other populations tend to expand to numbers their habitat (food, water, cover, and space) can support. This is true even though disease, competition, predation, parasitism, and reproductive capabilities all play a part in keeping populations down.

Biologists inventory fish populations throughout the year to find out how the fish are doing. For example, biologists regularly survey a few sections of the upper Clackamas River (above the North Fork Dam) and count young winter steelhead in selected tributaries and sections of the mainstem Clackamas River. Their calculations reveal an average of 1,776 yearling and older steelhead per mile of stream surveyed.

Now it's your turn . . .

What is the carrying capacity of these surveyed sections of the Clackamas River? In this activity you will calculate the estimated carrying capacity for this stream section and compare it to actual fish counts.



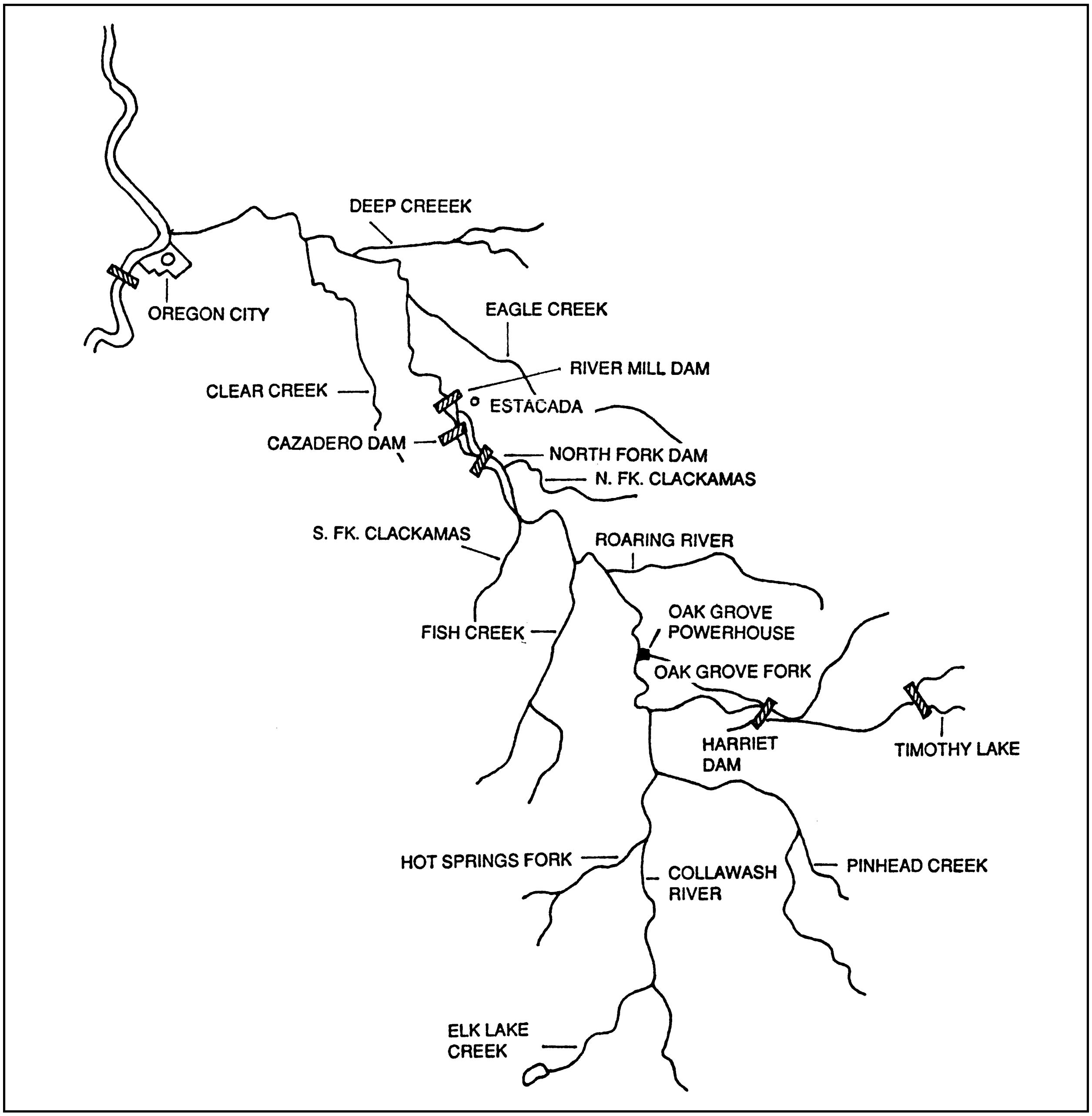
Vocabulary

carrying capacity

Activity developed by Nancy MacHugh, Oregon Department of Fish and Wildlife.

Student sheet

Clackamas River System



Student sheet

Questions

1. Wild winter steelhead spend two to three years in freshwater habitats before migrating to the ocean. How many ocean-going smolts per mile would be produced and supported, based on the average listed in the introductory information, if 50% of the juveniles observed survived to migrate to the ocean?

2. Surveys also showed 135 miles of the upper Clackamas Basin were used by steelhead. If all sections of the river produced steelhead at the same rate as the small number of sections surveyed, how many smolts could be expected to be produced by the entire 135 miles of stream?

3. Using the table at the right, calculate the average number of adult winter steelhead spawning per year in the upper watershed of the Clackamas River for the period 1957-1984.

4. If 50% of the adults spawning in Question 3 above are females, how many females are present?

5. If each female places 4,500 eggs in a redd (fish nest), how many eggs would this represent?

Adult Winter Steelhead Counts at PGE's North Fork Dam

Year	Count
1957	1,648
1958	566
1959	1,148
1960	2,204
1961	4,360
1962	2,257
1963	1,883
1964	1,552
1965	1,290
1966	682
1968	790
1968	2,316
1969	2,809
1970	4,349
1971	2,634
1972	1,897
1973	671
1974	1,526
1975	1,182
1976	1,527
1977	1,987
1978	1,511
1979	2,065
1980	2,697
1981	1,446
1982	1,099
1983	1,238
1984	1,225

6. If only one of every 100 eggs survives to smolt age, how many smolts would be expected to survive to migrate to the ocean? (The greatest mortality in a steelhead's life cycle occurs during the egg-to-fry stages. Poor gravel conditions, inadequate oxygen, predators, and temperature extremes all take their toll on the eggs and fry.)

7. A count of smolts is taken as they migrate downstream through the North Fork Dam fishway. What is the average number of smolts surviving to migrate to the ocean per year (produced by the 1957-1984 adults in the questions above) based on these fishway counts? Use the 1959-1986 downstream migrant counts from the table above right. (*Do not use the 1976 figure when calculating the average.* A large release of smolts from a hatchery source was made in 1976. Using this figure in calculation of the average would create unrealistic expectations from the data.)

8. In Question 2 you calculated the potential number of smolts (or carrying capacity for production. What percent of those smolts does your estimate in Question 6 represent?

What percent does the actual fishway count in Question 7 represent?

North Fork Clackamas Downstream Migrants, Wild Steelhead Smolts

Year	Count
1959	36,336
1960	38,888
1961	17,694
1962	22,531
1963	24,806
1964	30,727
1965	13,858
1966	11,035
1968	31,386
1968	35,758
1969	29,187
1970	31,457
1971	19,111
1972	15,476
1973	21,403
1974	27,306
1975	28,024
1976	*105,577*
1977	33,792
1978	77,828
1979	41,334
1980	48,231
1981	43,558
1982	44,544
1983	31,615
1984	40,647
1985	35,152
1986	50,355

9. Assuming the smolt estimate from stream surveys is reasonably accurate, does your answer to Question 8 suggest steelhead production is at capacity?

10. If survival from egg to smolt stays at 1 in 100, how many adult steelhead would need to spawn in the Clackamas to achieve the actual carrying capacity of the 135 miles of habitat?

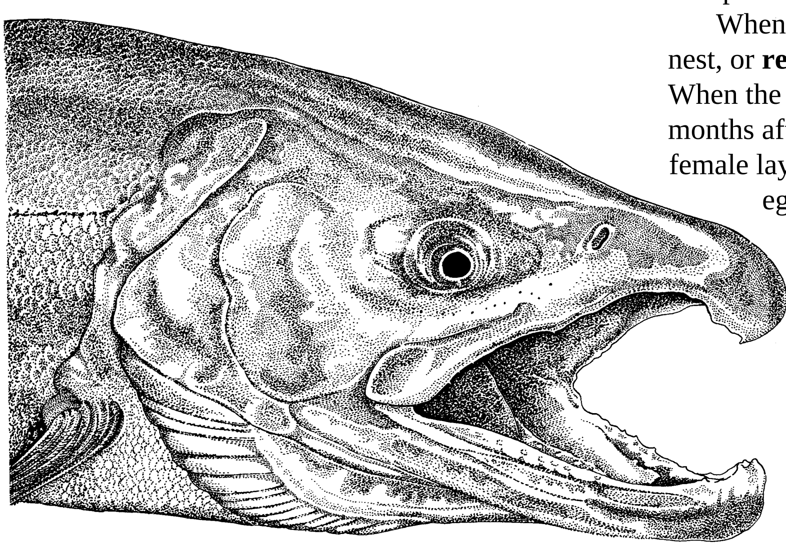
11. If, as part of a habitat enhancement project, an additional quarter mile of spawning gravel was placed in areas of the Clackamas that were previously lacking adequate spawning gravel, would the carrying capacity of this section of the river be increased? Why or why not?

Smolts

After spending time in freshwater, the 4- to 6-inch fish, known as **smolts**, head to the sea with fall or spring freshets. **Smoltification** requires physiological changes enabling the fish to survive the drastic change from fresh to salt water. In addition, the **parr marks** disappear as the smolt becomes silvery and more distinctly counter-shaded (dark above, light below) to survive ocean conditions. Water flow is again a critical factor during downstream smolt migration.

High flows mean higher survival rates. On some streams, dams alter the natural flows of river systems as they store spring runoff. Decreased flows can increase the amount of time it takes smolts to reach the ocean and affect their ability to adjust to salt water conditions. A delay can increase their susceptibility to predators and disease. Smolts are also lost as a result of passing into unscreened irrigation ditches, becoming stranded in a field. Smolts can also be injured or killed as they pass through hydroelectric facilities or fail to find passageways at dams.

Anadromous salmonids spend varied amounts of time in the sea, up to five years, depending on the species. While in the ocean, usually near the Gulf of Alaska, salmon grow rapidly by feeding on the rich, available food supply. Plankton makes up their first food source. As the fish grow, shrimp, anchovies and herring make up the majority of their diet.



Sharks, marine mammals and other predators take a portion of the maturing salmon as food. Commercial and sports fisheries also harvest fish.

Adult salmon

Usually in early summer of their maturing year, salmon begin to head back to their home streams. While their exact method of navigation is not fully understood, researchers believe salmonids navigate by electromagnetic signals, the moon and stars, the smell of their home stream, or a combination of these factors. Salmon stop feeding when they enter fresh water and live on stored body fats for the rest of the trip.

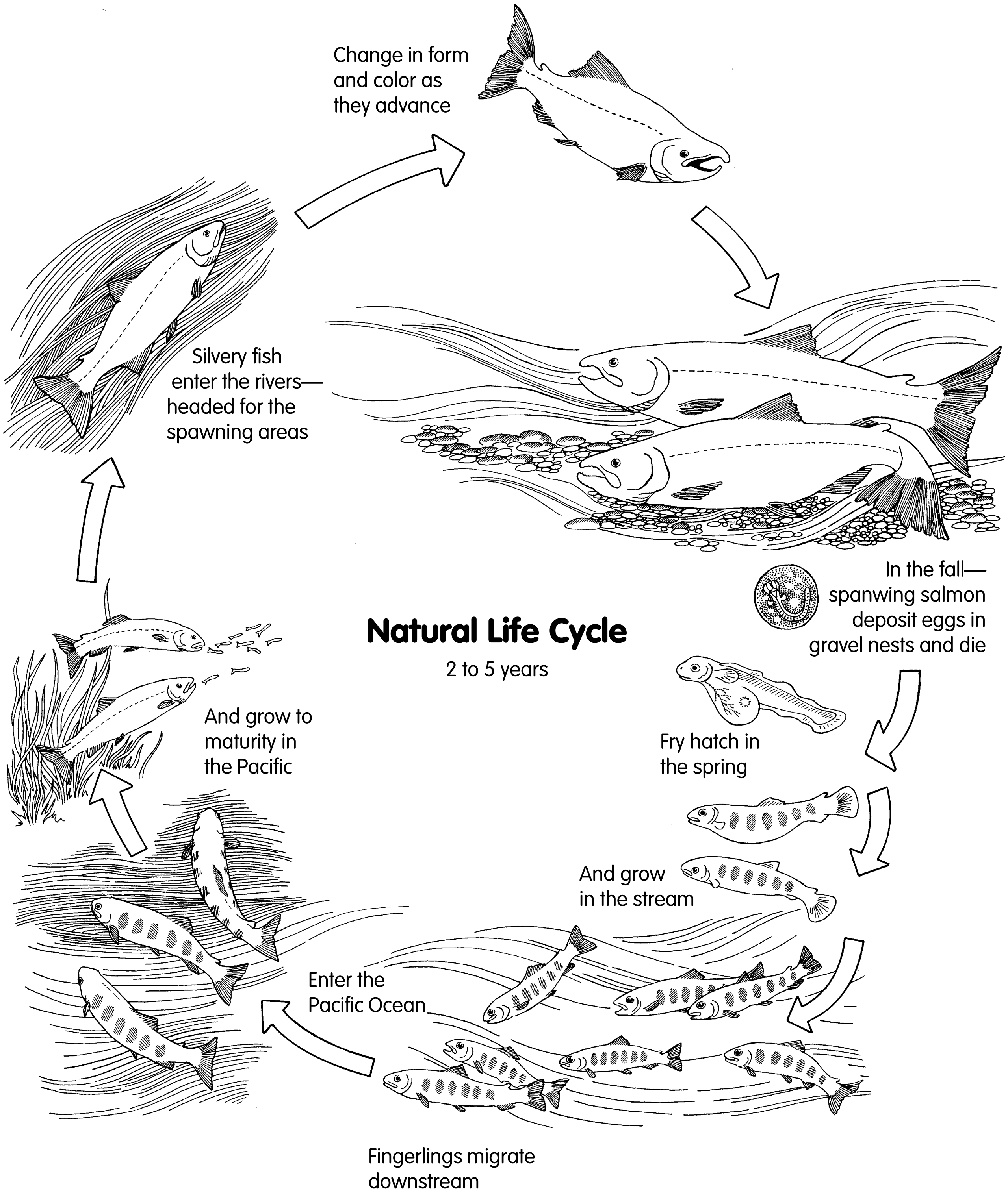
Anglers, natural predators, and other hazards continue to reduce salmon numbers on their way to the spawning beds of their home stream.

Hydroelectric dams block passage upriver. Most dams now have fish passages, but finding them uses part of the salmon's limited energy supply. Log jams, landslides or other obstructions occasionally restrict passage. Waterfalls, road culverts and velocity barriers also create migration problems for salmon.

When flows are too low for upstream movement, water temperatures can become quite warm in the holding pools and cause conditions promoting disease outbreaks. Restricted flows can hold salmon for too long, reducing their chances for successful spawning when they finally reach the spawning beds.

When ready to **spawn**, the female digs a nest, or **redd**, up to 16 inches deep in the gravel. When the nest is ready, which can be weeks or months after they reach the gravel beds, the female lays her eggs. She deposits 3,000 to 8,000 eggs in the redd. The male fertilizes the eggs by covering them with **milt**, a milky substance that contains sperm. The female covers the eggs with gravel to complete the spawning process.

After spawning, the adult salmon's life is finished. Within a short time it dies, and the carcass drifts downstream, decaying and contributing its



Length of life cycle varies with species and consitions nutrients to the stream from which it originally arose. Not all steelhead die after spawning, but because of their weakened condition, the percentage of adults that live to return to spawn again is very small.

Extensions

1. "Hooks and Ladders," *Aquatic Project WILD*, pp. 76-81. Grades 3-9.
2. *Discovering Salmon: A Learning and Activity Book*, Nancy Field and Sally Machlis, Dog-eared Publications, P.O. Box 814, Corvallis, OR 97339, 1984. Grades K-6.
3. "Sniffin' Salmon," *Water, Water Everywhere Curriculum Project*, Newport OR: OSU Hatfield Marine Science Center. Grades 3-9.
4. "Comings and Goings of Coho" *Water, Water Everywhere Curriculum Project*, Newport OR: OSU Hatfield Marine Science Center. Grades 3-9.
5. "Where Have All the Salmon Gone?" *Aquatic Project WILD*, pp. 110-113. Grades 6-12.

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Riffles and pools

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

Objectives

The student will analyze and describe how riffles and pools meet the needs of salmon and trout.

Method

Students will apply concepts learned about habitat needs of salmonids during their life cycle by completing a work sheet analyzing riffles and pools.

For younger students

1. Consult extension activities at the end of each chapter to address the needs of younger students.
2. Read activity background information aloud to younger students or modify for your students' reading level.
3. Requires some vocabulary building.

Materials

- copies of student sheets (pp. 361-364)

Background

Do you know . . .

All Pacific salmon are **anadromous**. They begin their lives in freshwater, migrate to the ocean, and return to freshwater to spawn and die. Salmon are important to Oregon's commercial and recreational fisheries.

The salmon life cycle begins when eggs are deposited and fertilized in the gravel of cool, clean rivers and streams. Until they hatch, the cold (40ºF to 65ºF) water flowing through the gravel delivers oxygen and carries away wastes. The gravel itself protects the eggs from predators.

In late winter or spring, the eggs hatch. The young fish, called **alevins**, are less than one inch long. They still depend on cold, well-oxygenated water for their survival and stay in the gravel for shelter. During this time they are fed from a **yolk sac** that protrudes from their bellies. As the yolk sacs are used up, the fish, now called **fry**, emerge from the gravel in late spring or summer, approximately one to three months after hatching.

The fry of some species head directly for the sea, but others might stay in freshwater for a few months to a few years. Fry depend on streamside vegetation and the turbulent water at the beginning of pools for cover. Aquatic invertebrates provide most of the food for salmon fry.

When they are ready to migrate to the sea, they go through **smoltification**, a physiological change, and are known as **smolts**. Smolting prepares them for life in saltwater. Once in the sea they spend up to five years, depending upon the species, feeding and growing before they are ready to return to fresh water.

Salmon return to spawn in the same stream where they hatched. No one knows for certain how they find their way back to the same stream,

Adapted from *Clean Water, Streams and Fish,* Borton, et al., pp. 123-125, 136-137.

Vocabulary

alevins	milt
anadromous	redd
yolk sac	smoltification
fry	smolts

although one theory is that they can smell or actually taste the water chemistry of their home stream. When they enter fresh water, salmon stop feeding. Their journey upriver is made on the energy stored while living in the ocean.

Salmon spawning beds are generally found in the shallow headwaters of a stream and other suitable areas in the mainstems of streams. Weeks or months after they have reached the gravel beds, the female digs a nest, or **redd**. Here she deposits up to 5,000 eggs. The male fertilizes the eggs by covering them with **milt**, a milky substance that contains the sperm. The female finishes the spawning process by covering the eggs with gravel. After spawning, the salmon's life is finished. Within a short time, it dies and the carcass drifts downstream, decaying and contributing its nutrients to the stream from which it originally came.

Note: Trout, with the exception of steelhead and some cutthroat, are not anadromous. However, they are closely related to salmon and have needs similar to those of salmon during their time in fresh water.

Procedure

Now it's your turn . . .

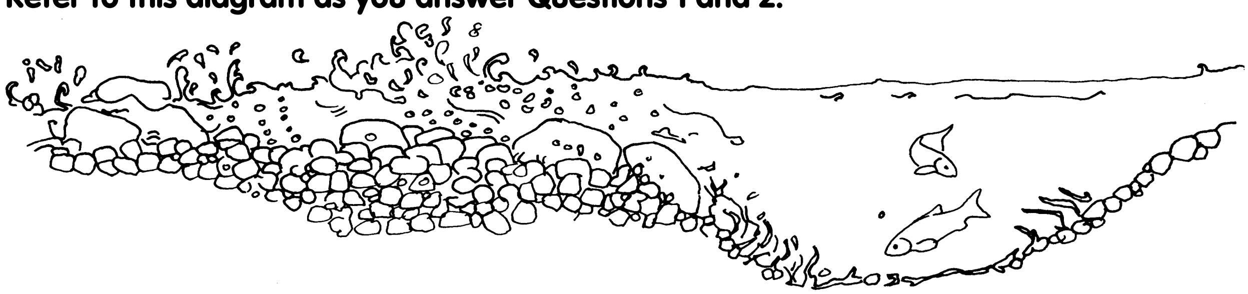
Think about the last time you were at a stream. Let's review some of the things you might have observed or remember about good fish habitat.

- What is dissolved oxygen? Why is it important to streams and fish?
- What are pools? What are riffles? What kind of habitat do they provide for fish? Since salmonids spawn in gravel, and gravel is usually found in riffles, riffles are often called "spawning habitat." The amount of good quality gravel and riffles in a stream determine the number of salmonids that can spawn. The areas of a stream that provide places to eat, rest, and hide are called "rearing habitat."
- Stonefly and other aquatic insect larvae live on, around, and under rocks in the bottom of a stream. Some are shredders, feeding on decomposing leaves. Others are scrapers, grazing on algae growing on the rocks. Still others are predators that eat other invertebrates. To move to new rocks these aquatic insects detach themselves and drift downstream. Because they are carried by the current, most are found where the current is strongest. Salmonid fry eat these larvae (or floating sandwiches) as they drift past.

Look carefully at the drawings. Answer the questions based on your own experience and the introductory information in this exercise.

Questions

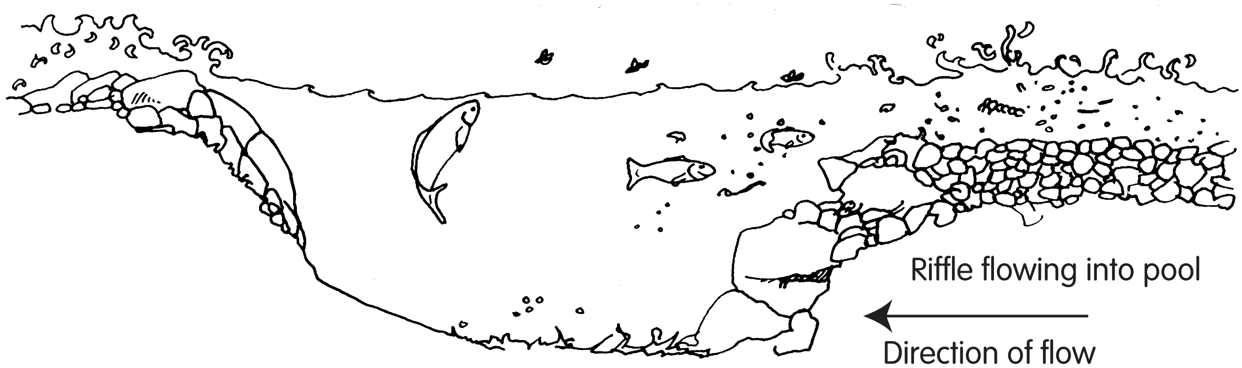
Refer to this diagram as you answer Questions 1 and 2.



1. Will the dissolved oxygen concentration be higher at the bottom of the pools or in the riffles?
   Generally, riffles should have more dissolved oxygen than pools, as a result of air and water mixing in the more turbulent water of the riffles.

2. Which would give more shelter or protection to salmonid eggs, pools or riffles? Why?
   Riffles. The gravel usually found in the riffles would protect the eggs. Pools are more likely to have collections of fine sediments rather than gravels.

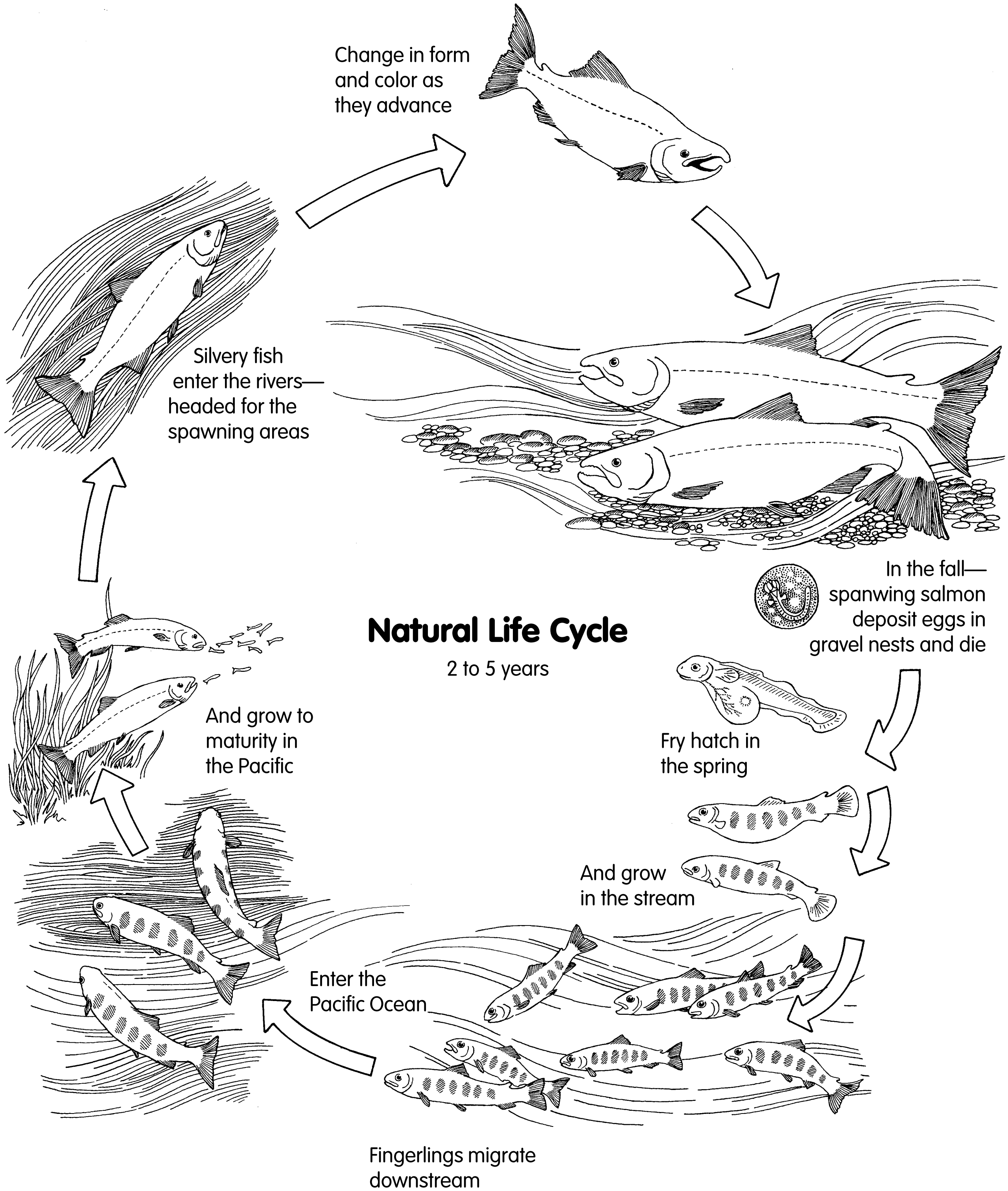
Refer to this diagram as you answer Questions 3 through 5.



3. What happens to aquatic insect larvae as the current enters a pool and slows down?
   They settle to the bottom or are eaten by predators (other insects or fish).
4. Where would be the best place for salmonid fry to wait for lunch? Why?
   At the head of a pool or tail of a riffle. To be first in line for drifting insects.
5. Where would salmonid fry use the most energy catching food? Why?
   In the riffles. It is harder to maintain position in the faster water of a riffle.
6. Chum fry only spend as much time in the stream as it takes to get to the ocean (one day to three weeks). Coho salmon juveniles live for a year in the stream before heading to the ocean. Steelhead and sea-run cutthroat juveniles live up to three years in the stream before heading to the ocean. If a stream has good spawning habitat but not much rearing habitat, will it be more likely to support chum or coho salmon fry? Why?
   Chum. Because chum salmon fry immediately begin moving toward the sea; they do not need extensive rearing habitat in the stream.
7. If a stream has both spawning and rearing habitat, which salmonid species might it support? Why?
   Both. Coho salmon fry could live there because of the availability of rearing habitat.

Going further

1. Design an experiment to compare oxygen content of agitated and still water. Based on your results, hypothesize what the value of one might be over the other.
2. Design an experiment to measure the rate of flow in riffles and pools (and other habitats including glides, rapids, and cascades). Research the different types of fish habitat, including all kinds of slow and fast water habitats. Consult with a fish habitat biologist to learn how each of the habitat types provides for the needs of fish. Prepare a report or display of your findings and present to the class.
3. Contact your local department of fish and wildlife or watershed council. Volunteer to assist with fish habitat surveys on streams in your area. Ask local experts to train you in data collection methods and data analysis. Consider recruiting other volunteers to assist with the project. Prepare a report and share this information with the class.



Length of life cycle varies with species and consitions

Name

Riffles and pools

Do you know . . .

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The salmon life cycle begins when eggs are deposited and fertilized in the gravel of cool, clean rivers and streams. Until they hatch, the cold (40ºF to 65ºF) water flowing through the gravel delivers oxygen and carries away wastes. The gravel itself protects the eggs from predators.

In late winter or spring, the eggs hatch. The young fish, called **alevins**, are less than one inch long. They still depend on cold, well-oxygenated water for their survival and stay in the gravel for shelter. During this time they are fed from a **yolk sac** that protrudes from their bellies. As the yolk sacs are used up, the fish, now called **fry**, emerge from the gravel in late spring or summer, approximately one to three months after hatching.

The fry of some species head directly for the sea, but others might stay in freshwater for a few months to a few years. Fry depend on streamside vegetation and the turbulent water at the beginning of pools for cover. Aquatic invertebrates provide most of the food for salmon fry.

When they are ready to migrate to the sea, they go through **smoltification**, a physiological change, and are known as **smolts**. Smolting prepares them for life in saltwater. Once in the sea they spend up to five years, depending upon the species, feeding and growing before they are ready to return to fresh water.

Salmon return to spawn in the same stream where they hatched. No one knows for certain how they find their way back to the same stream, although one theory is that they can smell or actually taste the water chemistry of their home stream. When they enter fresh water, salmon stop feeding. Their journey upriver is made on the energy stored while living in the ocean.

Salmon spawning beds are generally found in the shallow headwaters of a stream and other suitable areas in the mainstems of streams. Weeks or months after they have reached the gravel beds, the female digs a nest, or **redd**. Here she deposits up to 5,000 eggs. The male fertilizes the eggs by covering them with **milt**, a milky substance that contains the sperm. The female finishes the spawning process by covering the eggs with gravel. After spawning, the salmon's life is finished. Within a short time, it dies and the carcass drifts downstream, decaying and contributing its nutrients to the stream from which it originally came.

Note: Trout, with the exception of steelhead and some cutthroat, are not anadromous. However, they are closely related to salmon and have needs similar to those of salmon during their time in fresh water.

Adapted from *Clean Water, Streams and Fish,* Borton, et al., pp. 123-125, 136-137.

Now it's your turn . . .

Think about the last time you were at a stream. Let's review some of the things you might have observed or remember about good fish habitat.

- What is dissolved oxygen? Why is it important to streams and fish?

Vocabulary

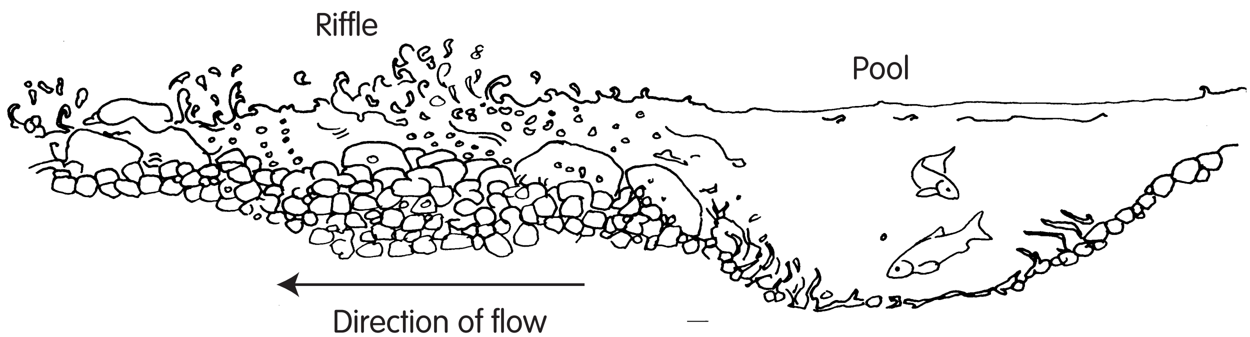
alevins
anadromous
yolk sac
fry
milt
redd
smoltification
smolts

- What are pools? What are riffles? What kind of habitat do they provide for fish? Since salmonids spawn in gravel, and gravel is usually found in riffles, riffles are often called “spawning habitat.” The amount of good quality gravel and riffles in a stream determine the number of salmonids that can spawn. The areas of a stream that provide places to eat, rest, and hide are called “rearing habitat.”
- Stonefly and other aquatic insect larvae live on, around, and under rocks in the bottom of a stream. Some are shredders, feeding on decomposing leaves. Others are scrapers, grazing on algae growing on the rocks. Still others are predators that eat other invertebrates. To move to new rocks these aquatic insects detach themselves and drift downstream. Because they are carried by the current, most are found where the current is strongest. Salmonid fry eat these larvae (or floating sandwiches) as they drift past.

Look carefully at the drawings. Answer the questions based on your own experience and the introductory information in this exercise.

Questions

Refer to this diagram as you answer Questions 1 and 2.

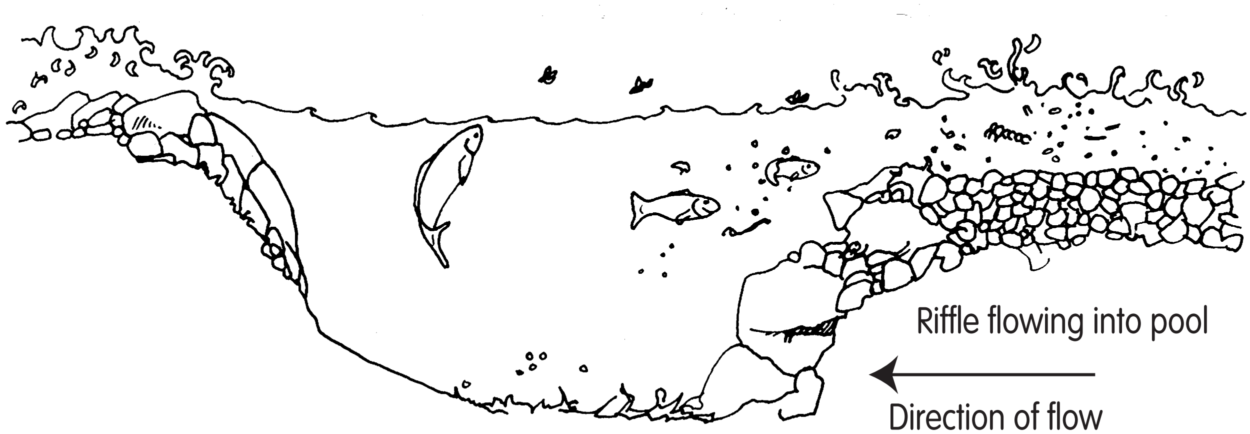


1. Will the dissolved oxygen concentration be higher at the bottom of the pools or in the riffles?

2. Which would give more shelter or protection to salmonid eggs, pools or riffles? Why?

Student sheet

Refer to this diagram as you answer Questions 3 through 5.



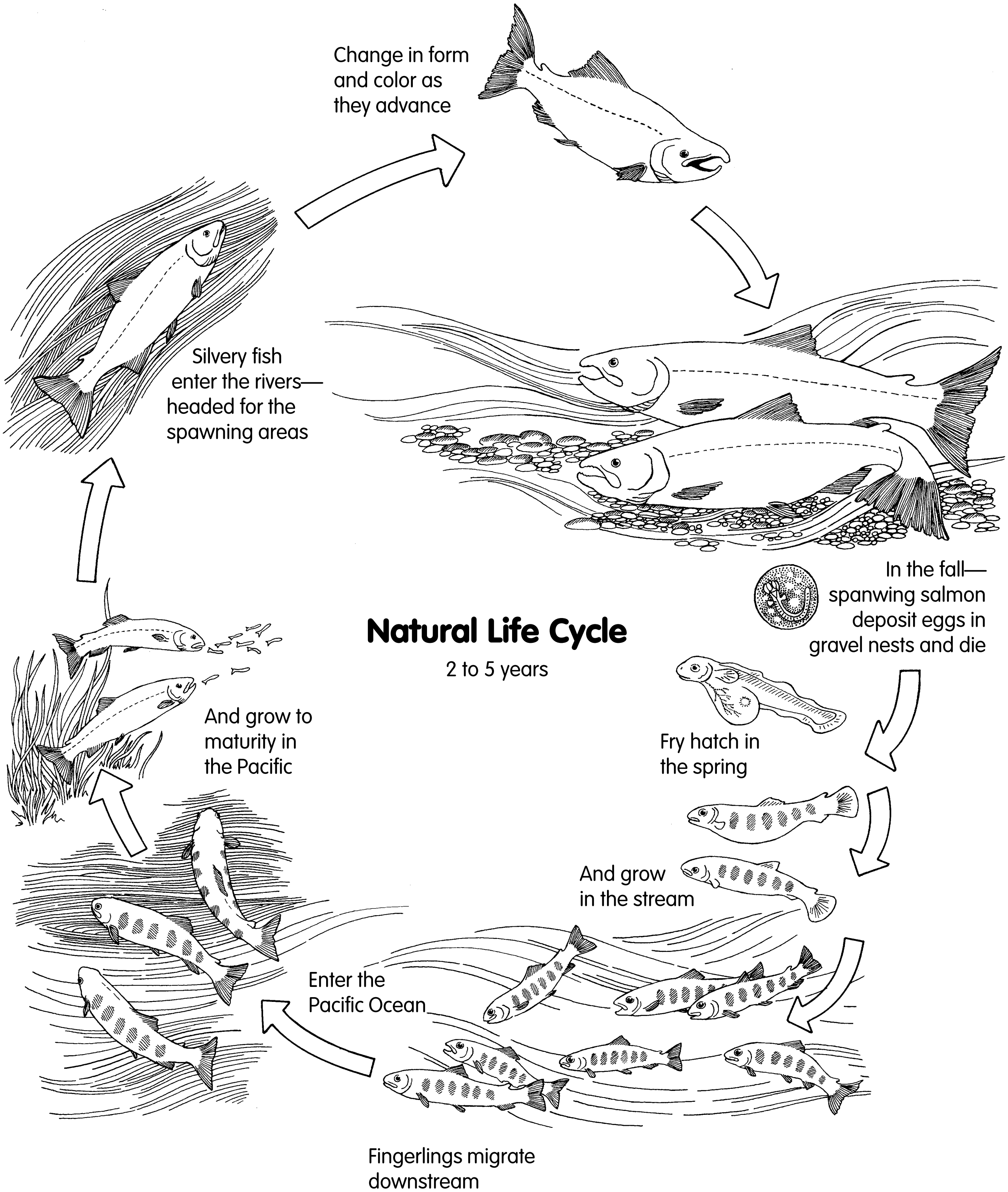
3. What happens to aquatic insect larvae as the current enters a pool and slows down?

4. Where would be the best place for salmonid fry to wait for lunch? Why?

5. Where would salmonid fry use the most energy catching food? Why?

6. Chum fry only spend as much time in the stream as it takes them to get to the ocean (one day to three weeks). Coho salmon juveniles live for a year in the stream before heading to the ocean. Steelhead and sea-run cutthroat juveniles live up to three years in the stream before heading to the ocean. If a stream has good spawning habitat but not much rearing habitat, will it be more likely to support chum or coho salmon fry? Why?

7. If a stream has both spawning and rearing habitat, which salmonid species might it support? Why?



Length of life cycle varies with species and consitions

Student sheet

Salmon language crossword puzzle

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

Objectives

The student will demonstrate understanding of the basic concepts of the salmon life cycle by completing the crossword puzzle.

Method

Students will complete the crossword puzzle, with or without the accompanying word list at the teacher's discretion.

For younger students

1. In most cases, younger students will require the word list. Using an overhead transparency of the salmon life cycle while discussing the important concepts as a group may enhance this exercise.
2. Work in pairs or as a group to solve the puzzle. Add the "Going Further" activities to help younger students grasp the concepts.

Materials

- crossword puzzle (pp. 369-371), list of clues, and word list (optional)

Background

Do you know . . .

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The salmon life cycle begins when eggs are deposited and fertilized in the gravel of cool, clean rivers and streams.

In late winter or spring, the eggs hatch. The young fish, called **alevins**, are less than one inch long. During this time they are fed from a **yolk sac** that protrudes from their bellies. As the yolk sacs are used up, the fish, now called **fry**, emerge from the gravel in late spring or summer, approximately one to three months after hatching.

The fry of some species head directly for the sea, but others might stay in freshwater for a few months to a few years. Aquatic invertebrates provide most of the food for salmon fry.

When they are ready to migrate to the sea, they go through a physiological change and are known as **smolts**. Once in the sea some spend up to five years feeding and growing before they are ready to return to fresh water.

Salmon return to spawn in the same stream where they hatched. Weeks or months after they have reached the gravel beds, the female digs a nest, or **redd**. Here she deposits up to 5,000 eggs. The male fertilizes the eggs by covering them with **milt**, a milky substance that contains the sperm. The female finishes the spawning process by covering the eggs with gravel. After spawning, the salmon's life is finished. Within a short time, it dies and the carcass drifts downstream, decaying and contributing its nutrients to the stream from which it originally came.

Procedure

Now it's your turn . . .

Do you understand how the salmon life cycle fits into the "watershed" picture? Can you name and describe the major steps of the salmon life cycle? Use the following crossword puzzle to test your knowledge about the salmon life cycle and to practice the new words you have learned.

Salmon Language Crossword Clues

Across

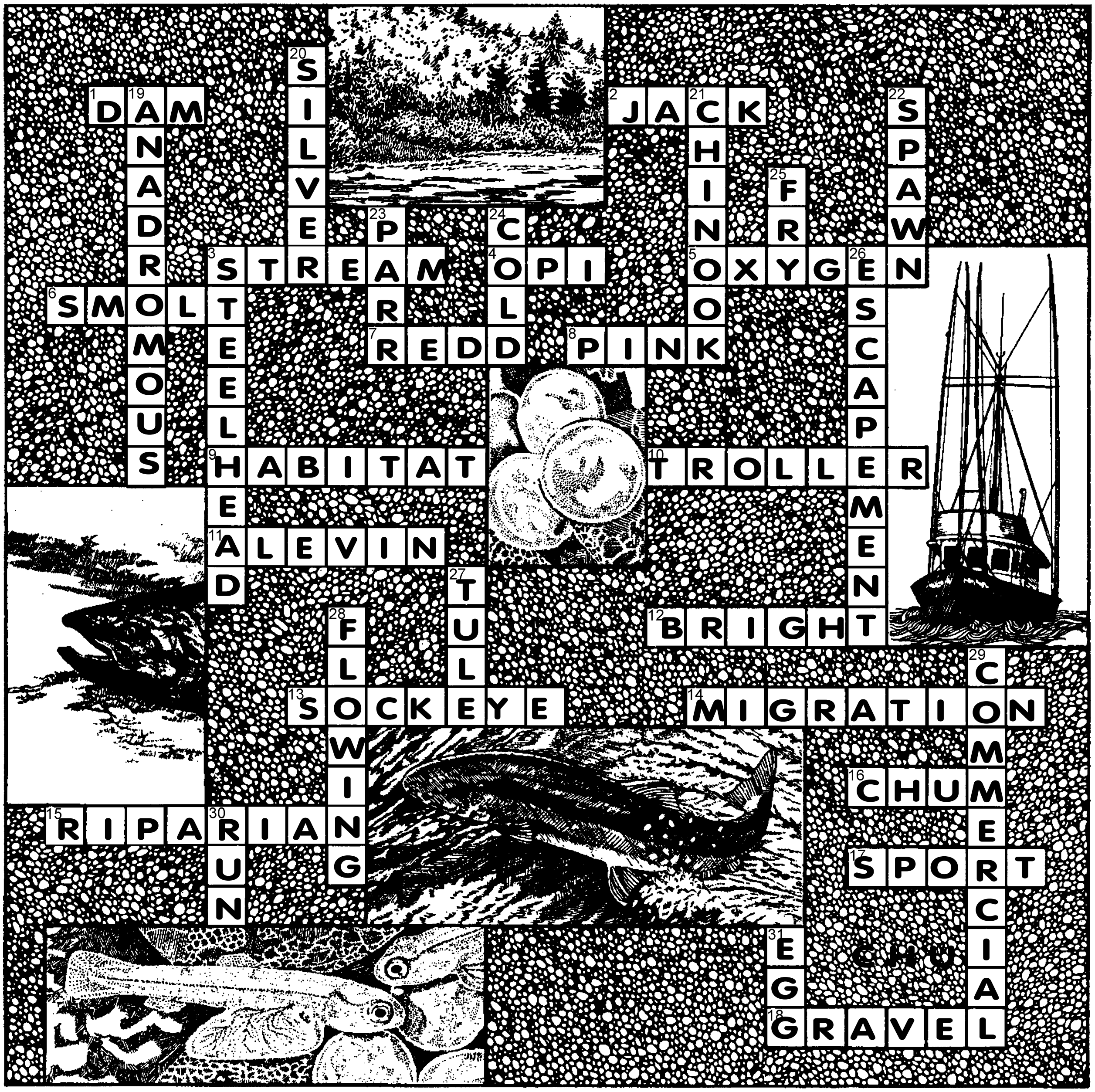
1. A major barrier to the migration of salmon and steelhead.
2. Early maturing, two-year-old coho (silver) salmon that return to spawn a year earlier than normal.
3. A healthy____ is required to produce healthy juvenile chinook and coho salmon.
4. Abbreviation for Oregon Production Index, a mathematical model used to predict the size of runs of coho salmon (based on the return of two-year-old jack salmon).
5. Salmon eggs, juveniles, and adults must have _____dissolved in the water to survive.
6. A juvenile salmon that is ready to migrate to sea is called a_____.
7. A salmon nest where eggs are deposited.
8. The shortest-lived and smallest of the Pacific salmon. The males develop a large humpback during spawning.
9. For salmon, cold water, plenty of food and good cover is excellent _____.
10. The term for commercial fishing boats and fishermen that fish for ocean salmon.
11. A newly hatched salmon with the unabsorbed yolk sac still attached.
12. Upper Columbia and Snake River fall spawning chinook salmon stocks which enter the river in excellent condition.
13. Species of salmon that usually spawn in streams having lakes in their watershed and are related to kokanee.
14. The ____ of the salmon has puzzled humans for centuries.
15. Healthy streamsides, called _____ zones, are essential for good natural salmon production.
16. Another name for dog salmon.
17. When salmon are caught for recreation and personal use, it is called ____ fishing.
18. Good spawning sites always have ____ for salmon to build redds in.

Down

3. A rainbow trout that spends much of its life in the ocean.
19. Fish that migrate from the sea to spawn in fresh water are called _____ fishes.
20. Another name for the coho salmon.
21. The largest salmon, also called a "king."
22. Term used to describe the laying of eggs by the female salmon and their fertilization by the male.
23. An older juvenile salmon with dark, oblong bars along each side is called a _____.
24. Water in which salmon live must be fairly _____.
25. Salmon that have absorbed their yolk sacs, emerged from the gravel, and are ready to feed.
26. Those salmon that are *not* caught by commercial or sport fisheries and escape to spawn in streams or hatcheries.
27. A stock of chinook salmon used in many lower Columbia River hatcheries.
28. _____ water is required around salmon eggs to deliver oxygen and carry away waste products.
29. When fish are caught and sold for profit, it is called _______ fishing.
30. The salmon entering a river system during a specific time of year are called that river's _____.
31. The ____ to fry stage in the salmon's life cycle is the period of greatest mortality.

Going further

1. After working the crossword puzzle, alphabetize all the words.
2. Write one complete sentence using each word in the crossword puzzle



Word list

alevin
anadromous
bright
chinook
chum
cold
commercial
dam
egg
escapement
flowing
fry
gravel
habitat
jack
migration
OPI
oxygen
parr
pink
redd
riparian
run
silver
smolt
sockeye
spawn
sport
steelhead
stream
troller
tule

Name

Salmon language crossword puzzle

Do you know . . .

All Pacific salmon are **anadromous**. They begin their lives in freshwater, migrate to the ocean, and return to freshwater to spawn and die. Salmon are important to Oregon's commercial and recreational fisheries.

The salmon life cycle begins when eggs are deposited and fertilized in the gravel of cool, clean rivers and streams.

In late winter or spring, the eggs hatch. The young fish, called **alevins**, are less than one inch long. During this time they are fed from a **yolk sac** that protrudes from their bellies. As the yolk sacs are used up, the fish, now called **fry**, emerge from the gravel in late spring or summer, approximately one to three months after hatching.

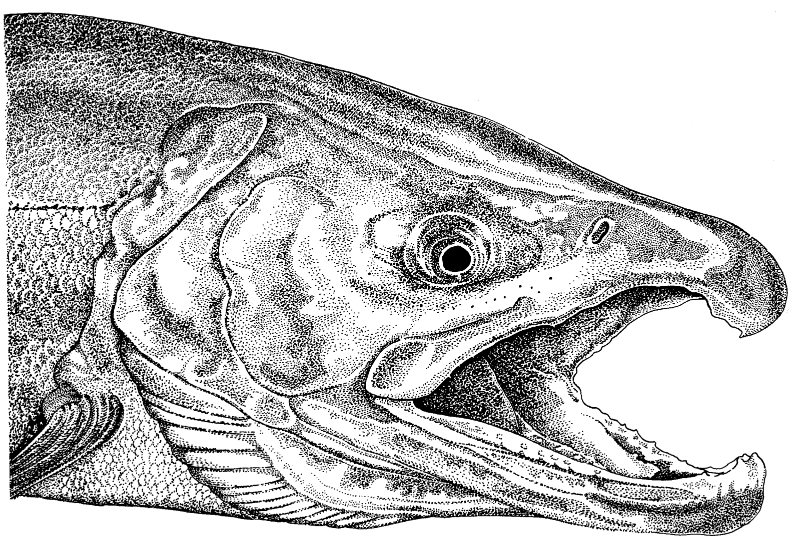
The fry of some species head directly for the sea, but others might stay in freshwater for a few months to a few years. Aquatic invertebrates provide most of the food for salmon fry.

When they are ready to migrate to the sea, they go through a physiological change and are known as **smolts**. Once in the sea some spend up to five years feeding and growing before they are ready to return to fresh water.

Salmon return to spawn in the same stream where they hatched. Weeks or months after they have reached the gravel beds, the female digs a nest, or **redd**. Here she deposits up to 5,000 eggs. The male fertilizes the eggs by covering them with **milt**, a milky substance that contains the sperm. The female finishes the spawning process by covering the eggs with gravel. After spawning, the salmon's life is finished. Within a short time, it dies and the carcass drifts downstream, decaying and contributing its nutrients to the stream from which it originally came.

Now it's your turn . . .

Do you understand how the salmon life cycle fits into the "watershed" picture? Can you name and describe the major steps of the salmon life cycle? Use the following crossword puzzle to test your knowledge about the salmon life cycle and to practice the new words you have learned.



Student sheet

Salmon Language Crossword Clues

Across

1. A major barrier to the migration of salmon and steelhead.
2. Early maturing, two-year-old coho (silver) salmon that return to spawn a year earlier than normal.
3. A healthy____ is required to produce healthy juvenile chinook and coho salmon.
4. Abbreviation for Oregon Production Index, a mathematical model used to predict the size of runs of coho salmon (based on the return of two-year-old jack salmon).
5. Salmon eggs, juveniles, and adults must have _____dissolved in the water to survive.
6. A juvenile salmon that is ready to migrate to sea is called a_____.
7. A salmon nest where eggs are deposited.
8. The shortest-lived and smallest of the Pacific salmon. The males develop a large humpback during spawning.
9. For salmon, cold water, plenty of food and good cover is excellent _____.
10. The term for commercial fishing boats and fishermen that fish for ocean salmon.
11. A newly hatched salmon with the unabsorbed yolk sac still attached.
12. Upper Columbia and Snake River fall spawning chinook salmon stocks which enter the river in excellent condition.
13. Species of salmon that usually spawn in streams having lakes in their watershed and are related to kokanee.
14. The ____ of the salmon has puzzled humans for centuries.
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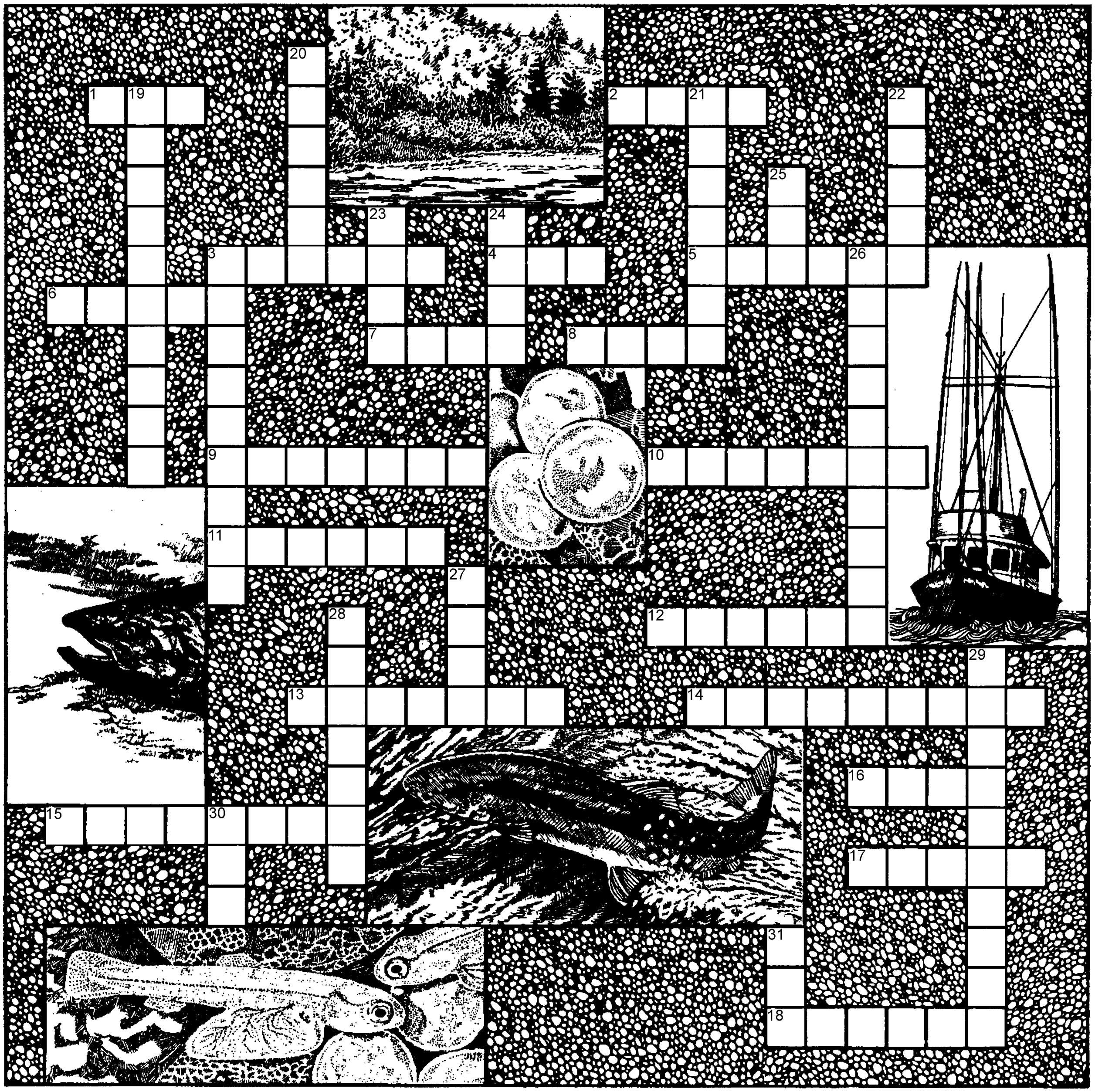
Student sheet



Word list

gravel	cold	run	stream	redd	bright	jack
sockeye	anadromous	escapement	migration	smolt	commercial	dam
alevin	OPI	habitat	egg	spawn	fry	
flowing	sport	parr	tule	steelhead	chinook	
pink	riparian	oxygen	troller	chum	silver	

Coming home!

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

Objectives

Students will (1) identify a diversity of issues affecting watersheds and salmonid populations within those watersheds, (2) create an advertising campaign designed to encourage salmonids to return to their home stream, and (3) critique and score other teams' work to assess student understanding of key watershed and fish habitat concepts.

Method

Students will investigate, write, and produce an advertising campaign, in a poster format, that features reasons for salmonids to migrate to a specific stream to spawn.

For younger students

1. To initiate the activity use examples of advertising campaigns found in children's magazines rather than those for older children and adults.
2. Modify the requirements so younger students prepare their advertising campaign on butcher paper that can be displayed on room or hallway walls. Assign different parts of the campaign to different groups of students rather than each group completing the entire campaign.
3. Review key vocabulary and components of good fish habitat with students before starting the activity.

This activity is adapted from "Salmon Stream Advertisement" created by Patrick Griffiths, Pilot Butte Middle School, 1500 NE Penn, Bend, Oregon 97701, and used with permission. Portions of the activity content are adapted from *Small Streams*, a Salmonid Enhancement Program fact sheet, Department of Fisheries and Oceans, BC Ministry of Environment, 555 West Hastings Street, Vancouver, B.C. Canada V6B5G3.

Materials

- writing materials
- colored and white paper
- 24"×36" poster board or foam core board
- markers, color pencils, paints, crayons, and other art supplies
- computer/printer (optional)
- copies of student pages 381-386

Notes to the teacher

This activity is designed as the concluding exercise of a watershed, water quality and fish habitat unit. The activity incorporates an array of skills that include art ability, graphic sense, design capabilities, creative writing, composition, research, group process, and decision making to assess student understanding and retention of key concepts about watersheds, water quality, and fish habitat. Collaborate with instructors in other curriculum areas (art, English, journalism, careers) so students understand that the study of watersheds is not limited to science.

Although it is a generally accepted fact that most salmon return to the same stream in which they were spawned, some straying to nearby streams does occur. Straying, to some extent, has been responsible for reestablishment of fish populations in streams following catastrophic natural events. Historically, straying has also provided opportunities for the exchange of genetic resources among nearby populations, thus increasing the genetic diversity of the species.

Take the time to go over these general facts with your students prior to beginning the activity. Although not using the subject of straying directly, for the purposes of this exercise, students will use the concept of good habitat to "lure" a salmon to come to their stream to spawn rather than returning to the stream of their birth.

Background

Do you know . . .

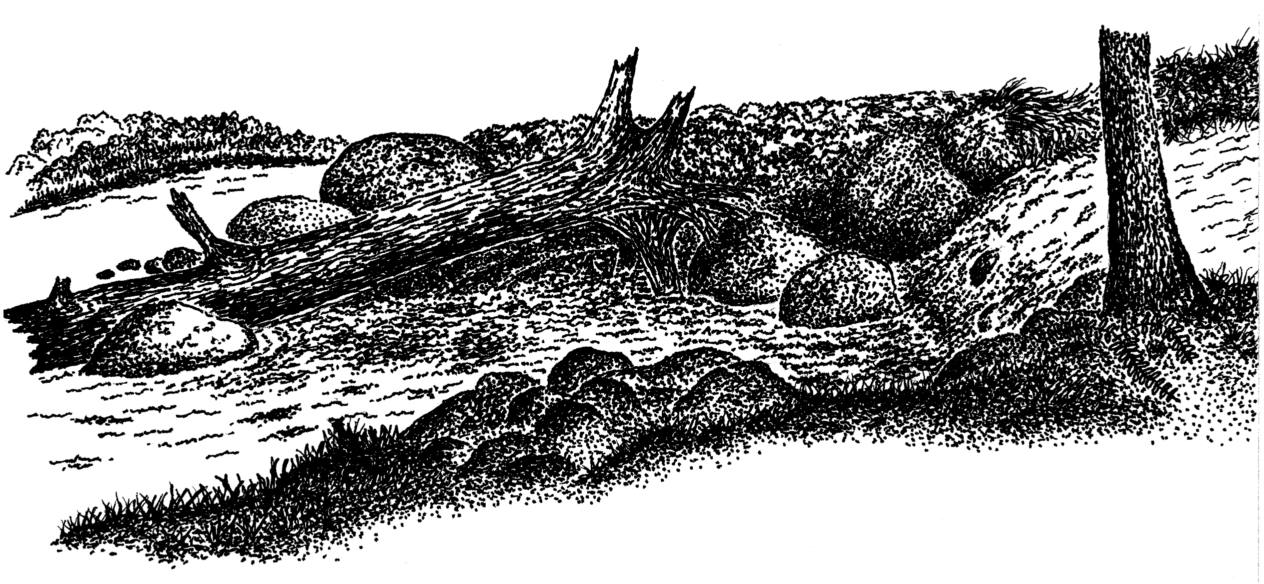
Most clean, healthy streams, no matter how small, can contribute to salmonid (salmon and trout) habitat. All salmonids—salmon, steelhead, and trout—spend at least a part of their life cycle in small streams. Some, like chum or pink salmon, may only spend a few weeks in the stream or the estuary before moving to the ocean, while others may spend three or more years before migrating. Young sockeye salmon move from small streams to rear in freshwater lakes for one or more years while still other species are permanent residents of large and small streams.

A single stream may appear insignificant as a producer of wild fish. But together, thousands of small streams throughout the Northwest account for a lot of fish production. Healthy streams are valuable, but they are fragile. They are easily damaged by poor agriculture and forestry practices, pollution, mining, and urban development.

Wild salmonids need certain stream conditions to survive. Salmonids need clean water for every stage of their life cycle. A healthy stream usually runs cool and clear over a clean gravel bottom. The silt present in cloudy water can coat incubating eggs and surrounding gravel, preventing oxygen from reaching the eggs. Without oxygen the eggs will die. In a healthy, natural stream, the flow of clean water usually remains steady. The land on both sides of a healthy stream acts as a giant sponge to soak up heavy rains. This water is then released slowly into the stream. Slow release of groundwater also prevents small streams from drying up during the warm summer months.

Aquatic organisms, including fish, have a relatively narrow temperature range for survival. Shade provided by trees and other plants that grow beside the stream helps keep the water cool and within that acceptable range. Insects that feed on the leaves and branches of these streamside plants sometimes fall into the water providing food for the fish. Mayflies and other insects that land on the water's surface to lay their eggs are also eaten by fish. Some insect eggs hatch and become part of the stream food chain. These aquatic forms of insects live on, around, and among the rocks of the streambed. These insect forms are often carried along by the water current where they become part of the menu for a fish waiting downstream.

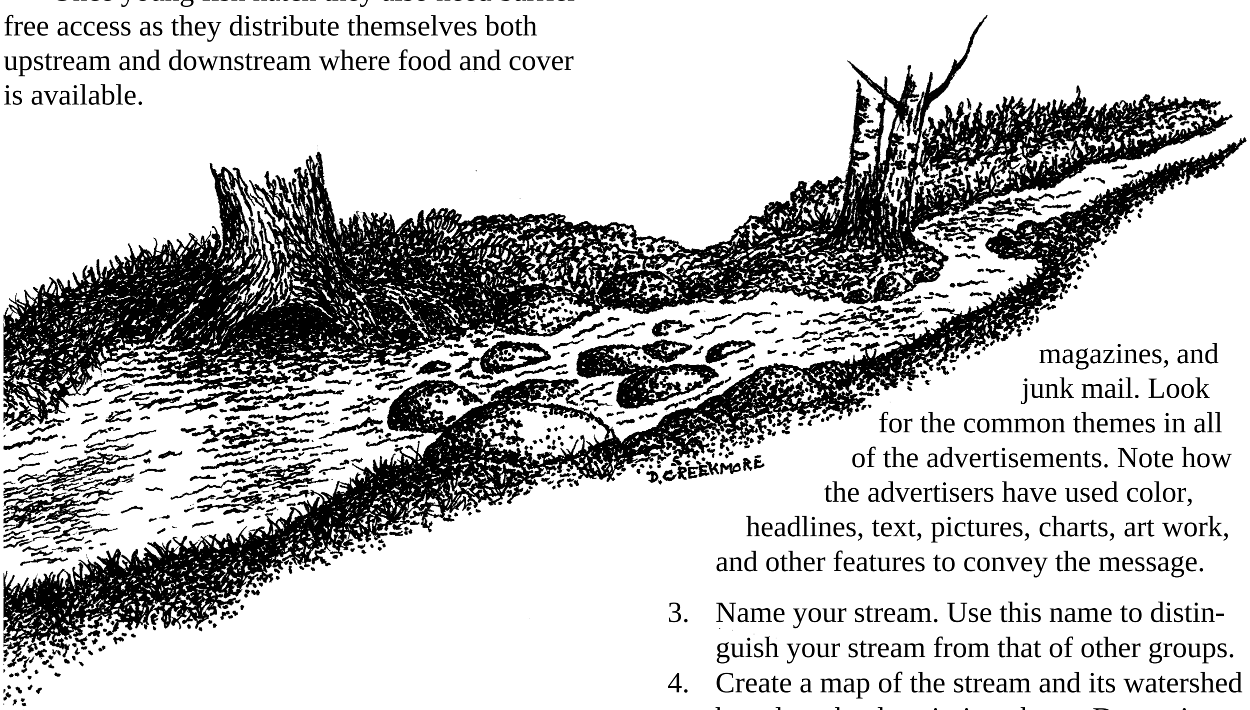
Small streams often contain natural debris such as root wads, fallen trees,



and boulders. Fish use these structures to hide from their enemies which include larger fish, birds, and small animals.

Adult migratory salmonids, like salmon and steelhead, need a barrier-free route to their spawning areas. They also need cover, both in the stream and alongside it, for protection from predators and for shaded resting areas. Salmon usually return to spawn in the same stream where they hatched. No one knows for certain how they find their way back to the same stream, although one theory is that they can smell or actually taste the water chemistry of their home stream. When they enter fresh water, salmon stop feeding. Their journey upriver is made on the energy stored while living in the ocean. Within days of spawning, adult salmon die, contributing the nutrients in their bodies to the stream from which it originally came.

Once young fish hatch they also need barrier-free access as they distribute themselves both upstream and downstream where food and cover is available.



Procedure

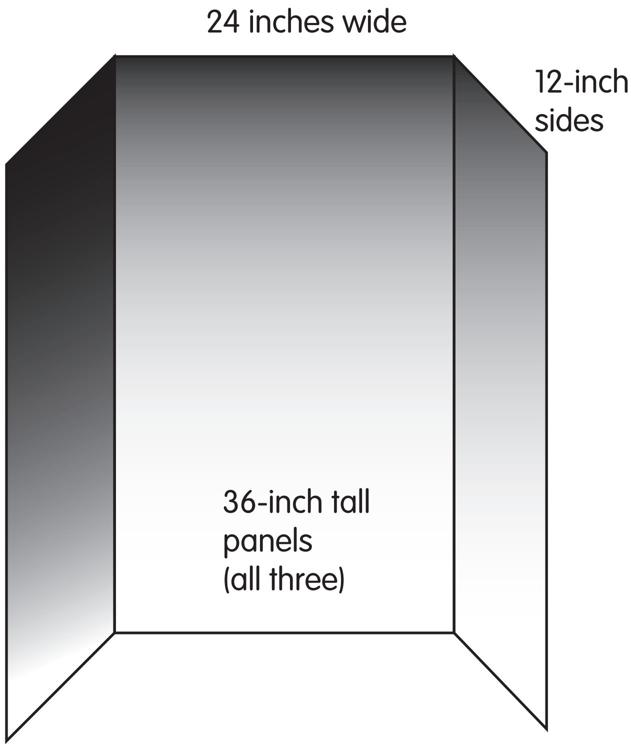
Now it's your turn . . .

You are an employee of an advertising firm that has been hired by the local watershed council. A local client has approached the watershed council for help in getting salmon to come back to the stream on his property. The stream begins in a wilderness headwater area, flows through farmland and finally through urban areas on its way to the Pacific Ocean. This stream needs salmon! You are going to break with tradition and see if you can get salmon to come back to this stream even though they did not originally grow up there. Your job is to create an advertisement that will attract salmon to this stream! The advertisement will tell salmon how great the stream is and why it is suitable place for salmon to live.

The ultimate goal of the advertisement is to communicate what salmon need to live and reproduce, impacts human activities have had on watersheds in the past, and how we can improve streams to attract salmon in the future.

1. Work in groups of three students.
2. As a group, look at examples of advertising campaigns in newspapers, a variety of magazines, and junk mail. Look for the common themes in all of the advertisements. Note how the advertisers have used color, headlines, text, pictures, charts, art work, and other features to convey the message.
3. Name your stream. Use this name to distinguish your stream from that of other groups.
4. Create a map of the stream and its watershed based on the description above. Determine where in the watershed the client wants salmon to spawn? Center your work in that area.
5. Organize your thoughts around the question "Why should salmon come and live in this stream?"

6. Create a planning guide around the main topics noted below. Use the questions following each topic to prepare for the advertising campaign and guide your research. Then, choose the points you want to emphasize in the advertisement.
   - **pH:** what is it, why is it important, how have humans altered the pH of streams, what range do salmon like best, how can humans keep pH within acceptable ranges.
   - **Temperature:** why are cool temperatures important to fish, how have human actions changed water temperatures in rivers and streams, what is the best temperature range for salmon, how can you protect a stream against drastic changes in temperature.
   - **Dissolved oxygen:** what is dissolved oxygen, why is it important to fish and other organisms, how do dissolved oxygen concentrations change naturally, how do human activities change dissolved oxygen concentrations (for worse or better) in streams, how is dissolved oxygen related to temperature, what are the best levels for salmon, and do salmon need different amounts of dissolved oxygen during different parts of their life cycle.
   - **Sediment:** what is sediment, what is it source, what is its effect on a stream (good and bad), how are excessive sediment accumulations controlled.
   - **Food:** what are the food needs for salmonids, how does the stream provide for these needs.
   - **Stream habitat:** what are the physical habitat requirements of a stream that will meet the needs of various stages of a salmon's life cycle, how will your stream keep sediment in check.
   - **Pollutants:** how might fertilizers, pesticides, or other pollutants get into a stream and how might they harm a river or stream, how are pollutant problems solved.
   - **Watershed land use activities:** how might watershed activities like mining, forestry, ranching, and farming practices, commercial and recreational fishing, dams, and urban development affect rivers and streams and salmon (good and bad), what are some alternatives, how can watershed management activities be designed to be salmon-friendly
   - **What does a healthy stream look like:** in the forest, passing through a farm, passing through a city?
7. Use butcher paper or other large pieces of paper to prepare a rough draft of the advertisement. Consider the following as you plan the display.
   - What key information will you include?
   - Where will you place the key inforamtion on the poster?
   - What colors will you use?
   - Who is your audience?
   - What are you trying to sell?
   - What graphics, pictures, or artwork will you use?
   - Will you include a map or picture of your stream to help illustrate your ideas or solutions?
   - Will you use cut-away drawings or tables and charts?
   - Will you use handwritten or typed headings? What will the headings say?
   - Will you use handwritten or typed blocks of text?
   - Will you add 3-D models? Hanging or attached?
   - Will you use interactive parts (flip cards with answers or facts) on the display?
8. Prepare the final advertisement as a tri-fold poster made from two pieces of 24"×36" poster board or ¼" foam core board. See diagram.
9. A successful project will include:
   - The stream name in a prominent location.
   - Appropriate stream, fish and watershed words.
   - Effective layout and promotional features, (quotes from visitors, headlines, etc.).



- Pictures, diagrams, artwork, and photographs to help tell the story.
- Well-organized information so that the message and the effect is clear and attractive.
- Specific methods used to improve past stream habitat problems.

10. Set up your advertisement for display. Obtain a copy of the grading sheet. Write the name of your stream in the box provided. List group member's names on the back of the grading sheet. Place the grading sheet in a location close to your advertisement. Move around the room viewing the advertisements produced by other groups. Choose two, other than your own, to score. As a group complete the grading sheet for each advertisement you have chosen. When four different groups have scored your advertisement, turn in the grading sheet to the teacher.
11. Answer the following questions.

Stream Name ____

Grading Sheet: Coming Home

Points Possible: 20 out of 20 or 10 out of 10 is a perfect score. There are very few perfect projects

Category Description	**Points possible: Group # >**	**Grader Group # ______**	**Grader Group # ______**	**Grader Group # ______**	**Grader Group # ______**	**Teacher Grade ______**
Followed directions: see instructions: size, shape, format.	**20**					
Appropriate words: examples connected to lessons	**20**					
Is the advertisement easy to read? Does it help "sell" the stream. Does it make you want to go there?	**20**					
Is the advertisement clear and attractive?	**20**					
Do pictures, diagrams or other graphics help the advertisement without confusing the message?	**10**					
Are improvement methods shown? (for making or keeping the stream in good shape?)	**10**					
Is specific information included about watershed activities? Is the information accurate?	**10**					
Is specific information included about physical habitat requirements? Is it accurate?	**10**					
Total	**120**					

Grader's Group #	What did you like best about this advertisement?	Were any items missing from this advertisement? Any other suggestions?

Questions

1. What did you like most about this activity? What did you like least? Why?
   Answers will vary.
2. How did this activity help you complete your study of watersheds and fish habitat?
   Answers will vary, but should include some thoughts to show an understanding that all parts of a watershed are connected and that what happens in the upper part of a watershed affects what is going on downstream. Students should recognize that healthy fish habitat must meet the four basic needs —food, water, shelter, and space.
3. What would you change if you were to do this activity again? Why?
   Answers will vary.
4. What were the main sources of information used to complete your research?
   Answers will vary.
5. What was the most interesting thing you learned about advertising as a means of persuasion?
   Answers will vary.

Going further

1. Convert the advertisement idea to a newspaper format. Use the ideas in "Aquatic Times," *Aquatic Project WILD* pp. 126-128 to set up the activity. Assign students to write newspaper articles about different parts of procedure 6 above, then arrange them in a newspaper format. Ask staff from the school newspaper to give a presentation about the key features of a newspaper.
2. Ask students with an interest in art to create appropriate graphics for illustrating key components of this activity. Contact the local fish and wildlife agency or other natural resource agency to see if they are interested in artwork for their programs.
3. Arrange for a "salmon fair" or other event to spotlight the needs of salmon. Ask groups to volunteer to share their advertising displays and to prepare a verbal presentation about what they have learned as a result of the activity.

Name

Coming home!

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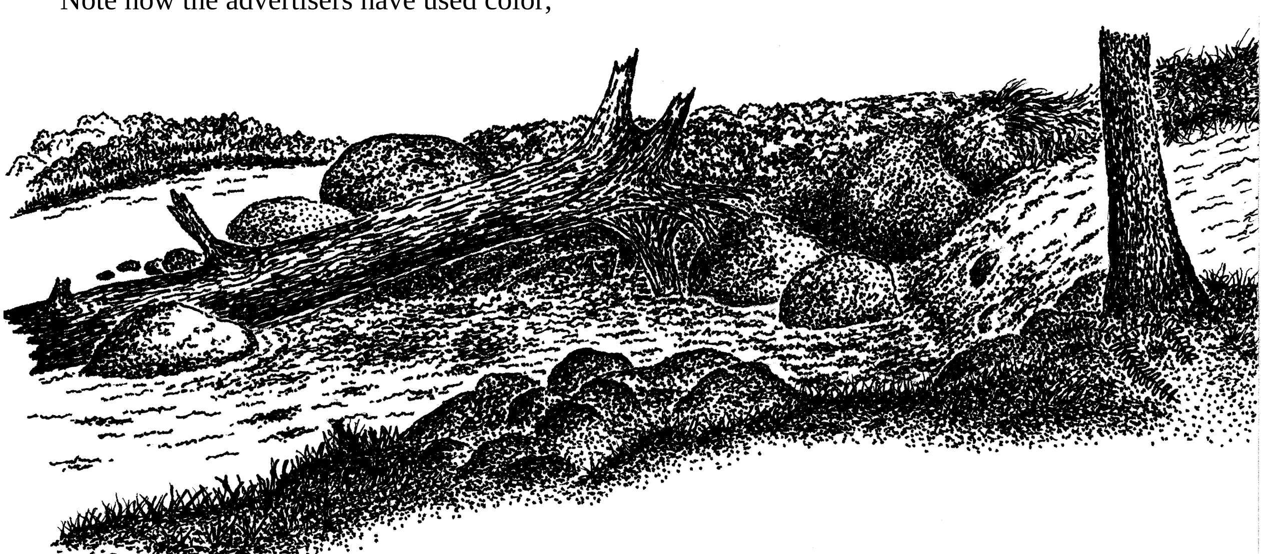

Student sheet

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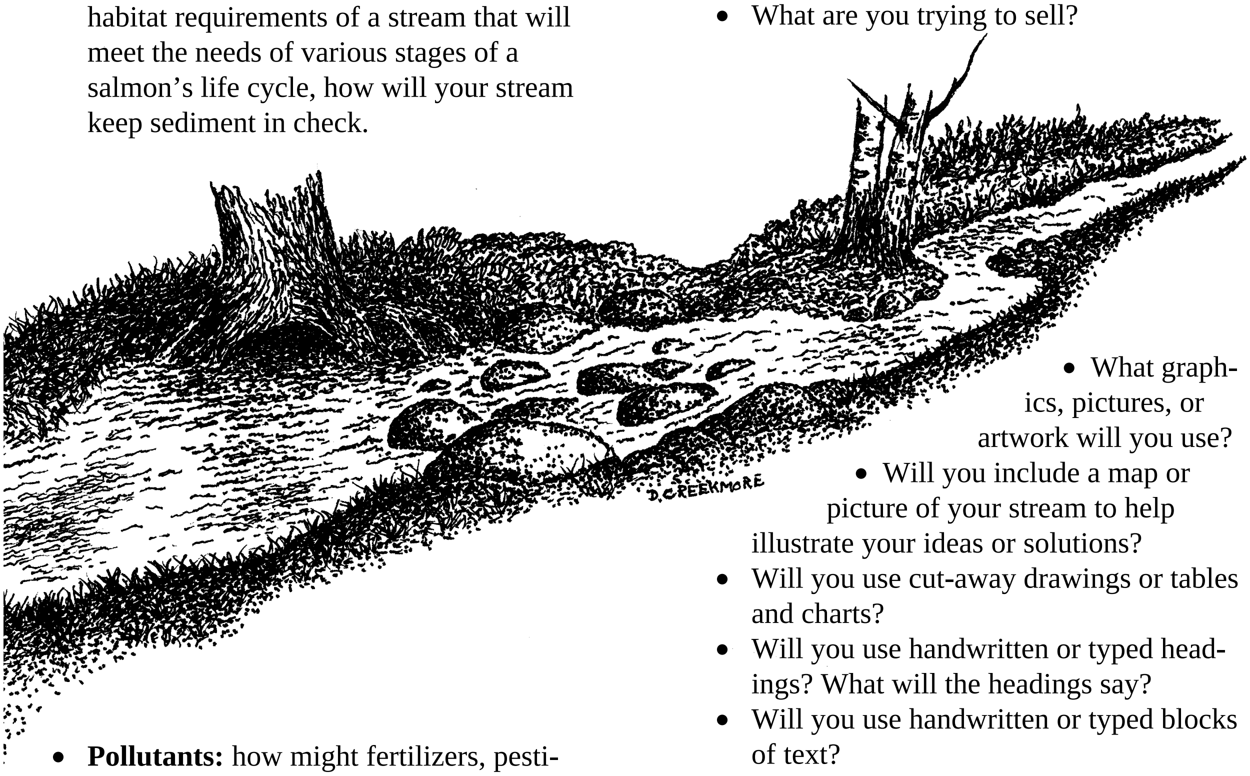

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   - Will you use interactive parts (flip cards with answers or facts) on the display?
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9. A successful project will include:
   - The stream name in a prominent location.
   - Appropriate stream, fish and watershed words.
   - Effective layout and promotional features, (quotes from visitors, headlines, etc.).
   - Pictures, diagrams, artwork, and photographs to help tell the story.
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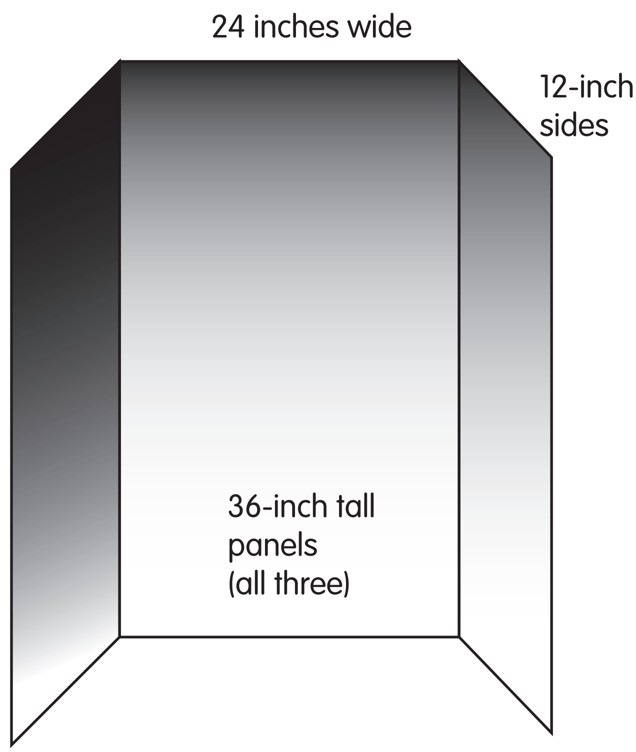
10. Set up your advertisement for display. Obtain a copy of the grading sheet. Write the name of your stream in the box provided. List group member's names on the back of the grading sheet. Place the grading sheet in a location close to your advertisement. Move around the room viewing the advertisements produced by other groups. Choose two, other than your own, to score. As a group complete the grading sheet for each advertisement you have chosen. When four different groups have scored your advertisement, turn in the grading sheet to the teacher.
11. Answer the following questions.



Questions

1. What did you like most about this activity? What did you like least? Why?

2. How did this activity help you complete your study of watersheds and fish habitat?

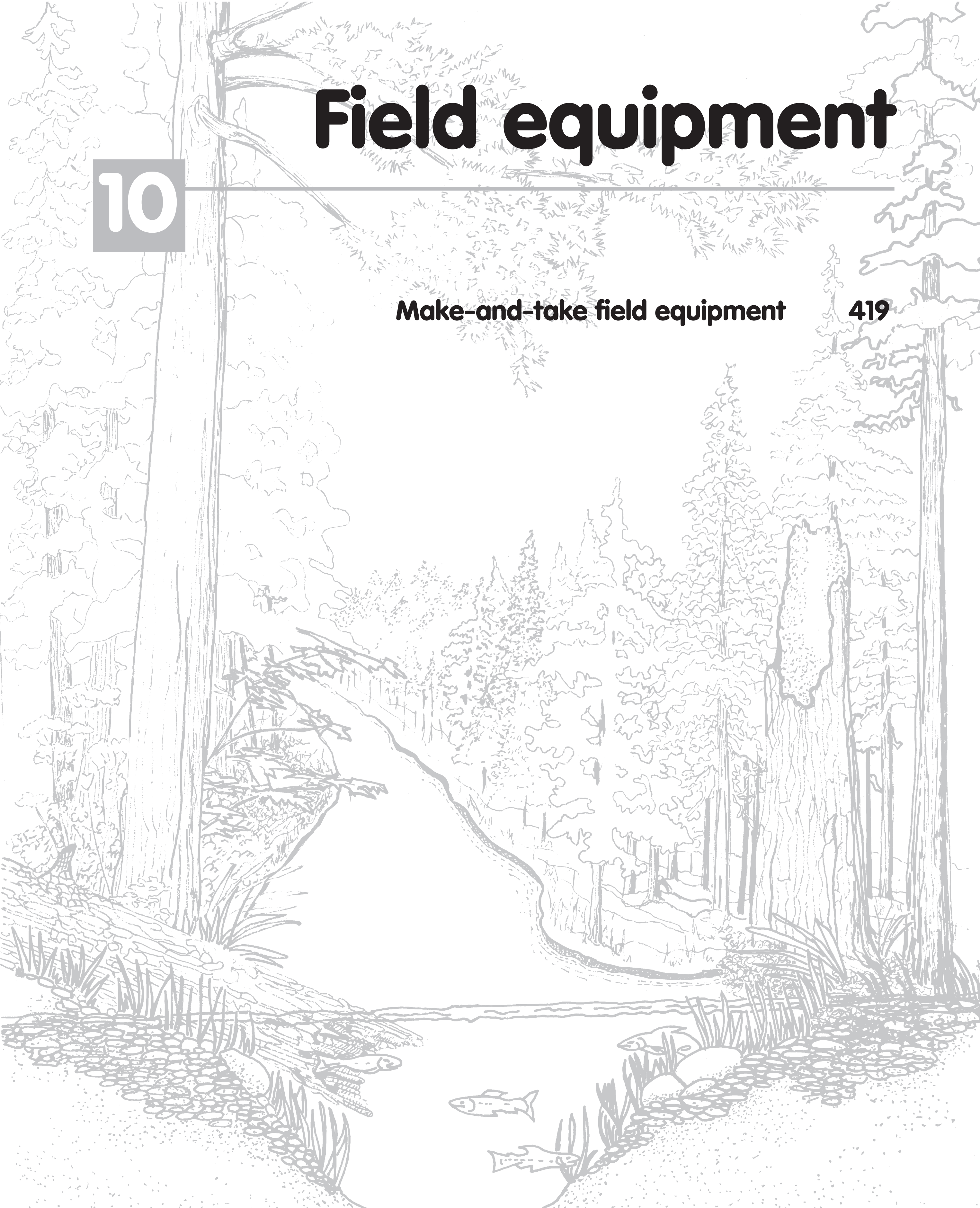
3. What would you change if you were to do this activity again? Why?

4. What were the main sources of information used to complete your research?

5. What was the most interesting thing you learned about advertising as a means of persuasion?

Field equipment

10



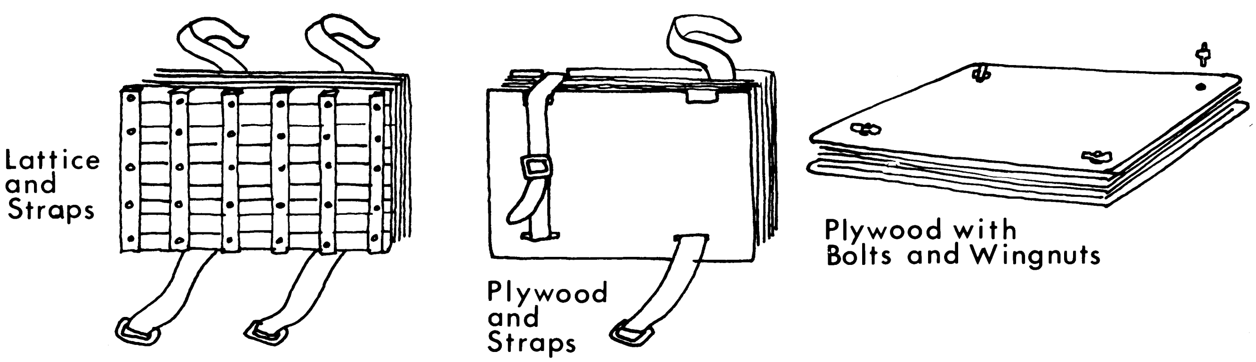
Courtesy of Oregon Department of Forestry, Salem, Oregon (Graphics Unit)

Make-and-take field equipment

"… to be a naturalist you do not need a lot of expensive equipment.… you can still study successfully and discover amazing things with the simplest of tools."
— Gerald Durrell

Plant press

A plant press can be as simple as a stack of books or as complicated as a lumbermill's kiln. Common sizes run from a 5"×8" hiker's press made of quarter-inch plywood to 18"×24" models of three-quarter inch stock. Make whatever seems to suit your needs and materials. Some simple ones using wood slats or plywood are shown below.

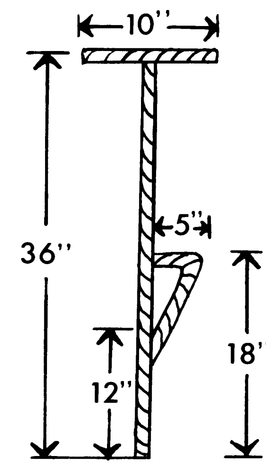


Vasculum

At times it may not be convenient to press plant specimens in the field. A large plastic sandwich box will keep specimens from drying out or from being crushed for short periods of time. Damp paper towels can be added to keep the plants fresh for longer periods.

Planting tool

A simple tool for planting willow or other unrooted cuttings can be made from a piece of rebar (concrete reinforcing rod) cut and welded to the shape shown at right.

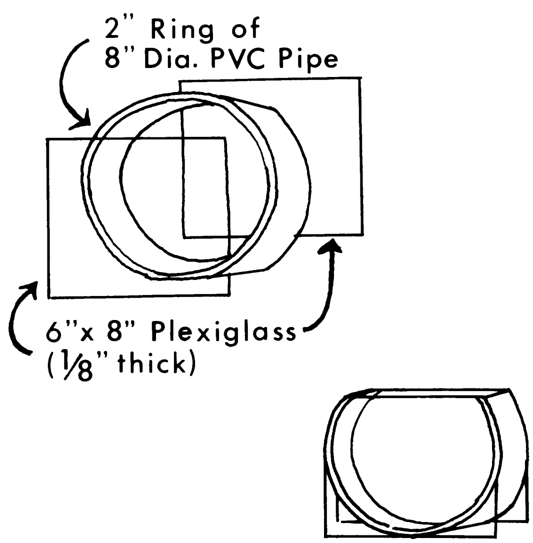


Small aquariums

For individual or small-group observations or experiments with aquatic organisms, small containers are essential. While an assortment of jam jars will work, a set of miniature aquariums will add pizazz and consistency to your classroom. Two possibilities are shown below. Feel free to adapt or invent to meet your needs and available materials.

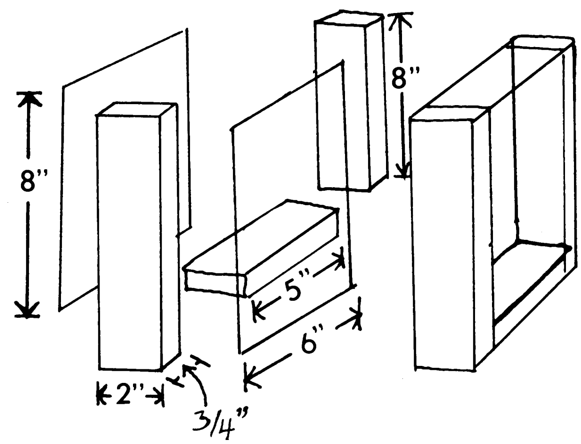
PVC Pipe

Cut a 2" ring of PVC pipe. With silicone seal, glue a piece of plexiglass to each side of the pipe, aligning the plexiglass edges with one outside PVC edge. Using the dimensions shown, the plexiglass will not cover the pipe. Do not worry about it. Clamp securely. After the silicone has completely cured, and with the clamps still in place, use a sabre saw, bandsaw or hacksaw to cut off the exposed top of the PVC pipe and the upper corners of the plexiglass.



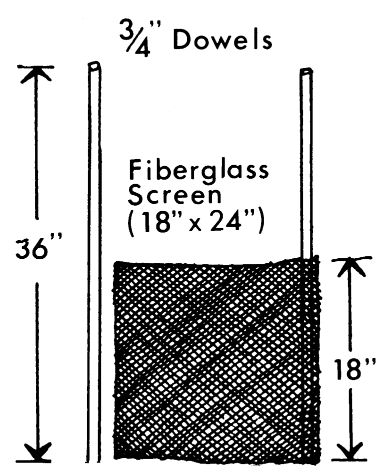
Wood

Before assembly, finish all edges of the 1"×2" cut pieces (see diagram for cutting dimensions) with a good sealer such as an epoxy paint or a finish with polyester resin. Nail the three pieces of wood together as shown using silicone seal as caulking at the joints. Glue the plexiglass sides to the wood frame with silicone seal. Clamp, and let the silicone cure completely.



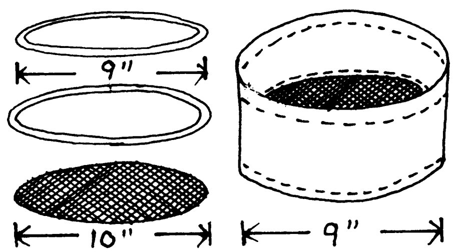
Hand screen

Stapling or tying fiberglass screen to two dowels makes a collecting screen. Disturb the upstream streambed and let the current carry insects down into the screen.



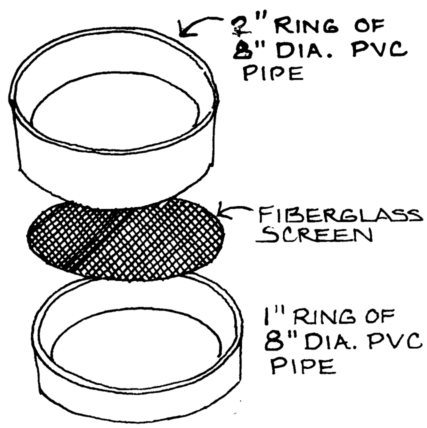
Sieves

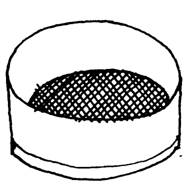
Many things can be used as a sieve to sort aquatic insects. Kitchen sieves and tea strainers are two commonly available items that will do as a start. Coffee cans with both ends cut out and screen attached to one end with solder, wire, or duct tape is an inexpensive alternative. Fiberglass screen from a hardware store, stretched over a plastic embroidery hoop, is another good starting point.



For a collapsible sieve that is easily stored, sew fiberglass screen to a cloth sleeve and attach it to two macrame rings.

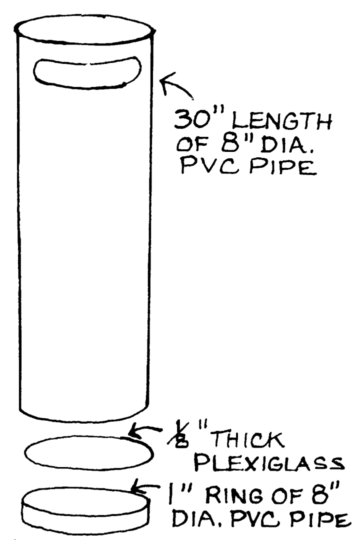
A nearly indestructible sieve can be made by sandwiching fiberglass screen and silicone seal between two rings of PVC pipe.

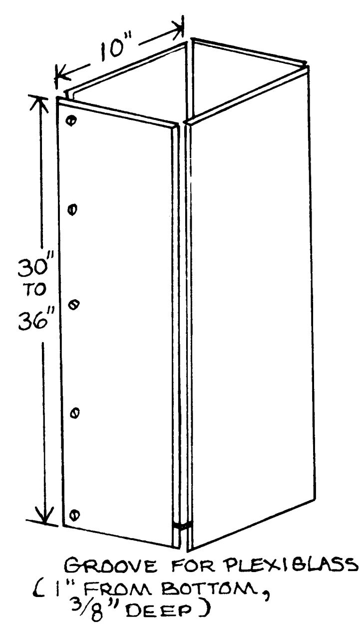




Aquascopes

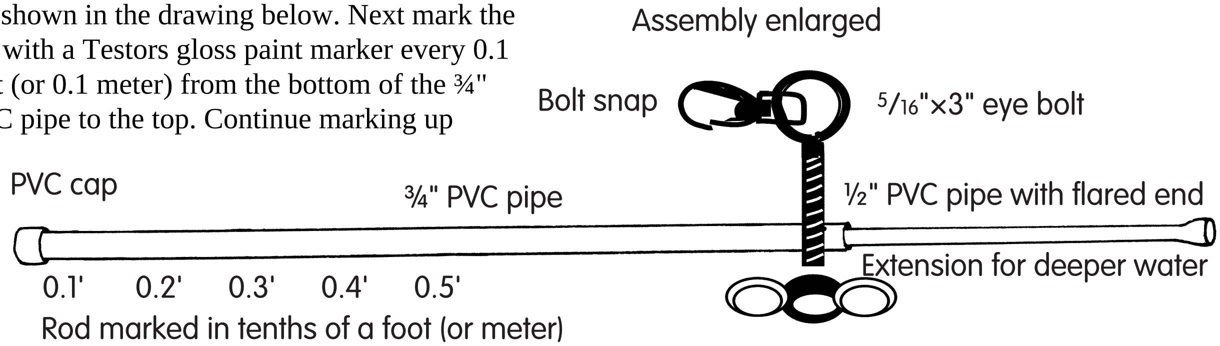
A tube that blocks reflected light and allows you to see below the surface of the water can be as simple as a bucket or ice chest with a hole cut in the bottom and a plexiglass window glued in. Below are two fancier versions, one made from cedar 1"×10"s finished with a good coat of wood sealer, and one from PVC pipe. Both use plexiglass windows glued in with silicone seal.





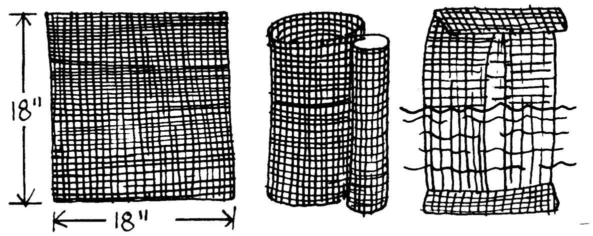
Telescoping depth stick/surveyor's rod

Two 6-foot lengths of PVC plumbing pipe that nest together (one piece half-inch diameter, and one piece three-quarter inch diameter) make a versatile tool. The flared end of the ½" pipe keeps it from dropping all the way into the larger ¾" PVC pipe. To construct the telescope, drill a hole near the top end of the ¾" PVC pipe all the way through the pipe and the ½" PVC pipe in its un-extended position. Next extend the telescoping ½" PVC pipe until it is about one foot from the end of the ¾" PVC pipe. Re-drill through the previous hole while the interior PVC pipe is in place. This hole will receive the eye bolt assembly shown in the drawing below. Next mark the rod with a Testors gloss paint marker every 0.1 foot (or 0.1 meter) from the bottom of the ¾" PVC pipe to the top. Continue marking up the side of the ½" PVC pipe while it is in its extended position. Use orange or red paint. Using yellow-colored plastic tape, mark every foot by wrapping the tape around the rod. Push the ½" PVC pipe back into the ¾" PVC pipe. Insert the eye bolt assembly into the rods, securing it with a wingnut. If the water gets deeper than 6 feet, you can pull out the eye bolt assembly, extend the ½" PVC pipe and insert the eye bolt assembly into the second hole of the telescoping rod. This gives you an 11-foot surveyor's rod. The measuring tape easily attaches to the bolt snap.



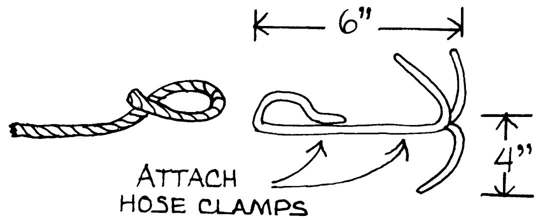
Insect rearing cages

Hatching aquatic insect larvae in a body of water is made easier by constructing a simple pillow cage from metal window screening. Join two opposite sides of an 18"×18" piece with a "drug store" fold. Flatten the cage, roll one end, add insects, roll the other end, and place the cage about halfway into the stream or aquarium. The water provides oxygen and food until the insect hatches. After hatching it can crawl above the surface to dry its wings.



Drag hook

A drag hook (grapnel, grappling hook) is useful for sampling mats of vegetation that are too far from shore to reach. A simple hook can be made from a 3-foot length of 3/8" rod. Cut two 10" and one 16" lengths. Bend the ends of all three sections to a hook. Sharpening the hooks is not necessary, is less safe, and makes them more likely to permanently snag. Bend one end of the longer section into an eye. Bind the sections together at roughly 60° angles with small hose clamps, then add a small amount of solder between the clamp and rod to help prevent the rods from turning. Attach rope to the eye, and it is ready to drag.



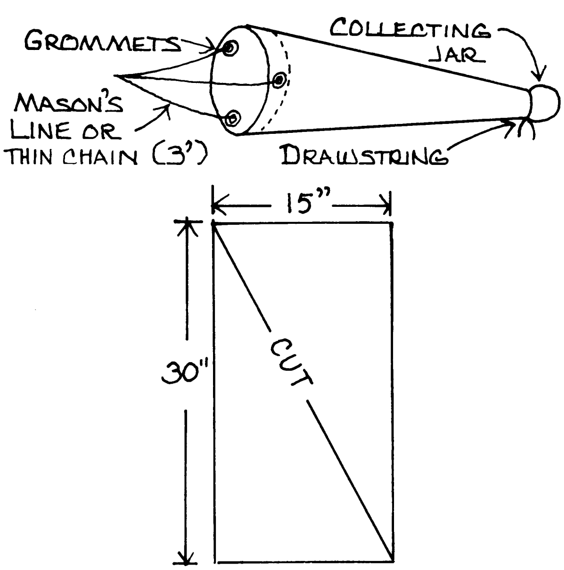
Nets

There are probably nearly as many types of nets as there are things to net. While some basic types are shown here, net designs are easily modified to suit specific purposes. For some jobs the nets illustrated may be too large, too small, too weak, or have mesh too coarse or too fine. Again, adapt to meet your needs and materials.

Plankton Net

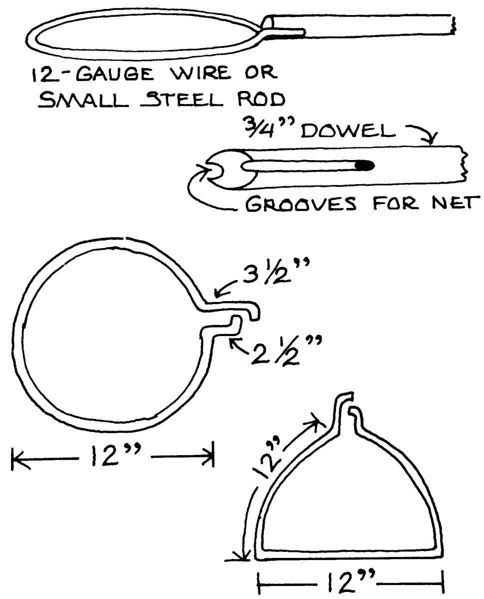
A plankton net is generally made of tightly woven material that will let water flow through but trap small solid particles. In this version, the large end is held open by a metal macramé ring, and a drawstring at the narrow end secures a glass or plastic jar to collect the concentrated solids.

Uncoated nylon fabric or silkscreen cloth are two possible choices of tightly woven fabric. Cut the fabric as shown in the diagram, sew the two pieces together into a cone, and then cut off about 4 inches at the narrow end. Hem a drawstring into the narrow end. Sew a 9-inch macramé ring into the larger end, and install three grommets as evenly spaced as possible around the larger end. Attach three pieces of strong line (such as mason’s line or thin brass chain), each 3 feet long, to the grommets. These can then be attached to a rope if the net is to be towed from a boat or a wooden pole if the net is to be towed from shore.

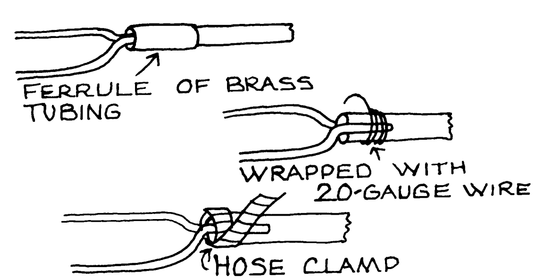


Nets with handles

Most nets with handles can be made from the same basic idea, modifying the size to fit specific needs. Make a hoop of 12-gauge wire (or steel rod if a stouter design, like a D-net, is needed) and attach to a ¾" dowel. Handle length will vary from about 3 feet for an aerial insect net to 6 feet or more for collecting from a pond or stream with steep banks.The rim is attached to the handle by two hooked prongs that fit into grooves gouged in the sides of the handle near the end. The diagrams give some starting dimensions.

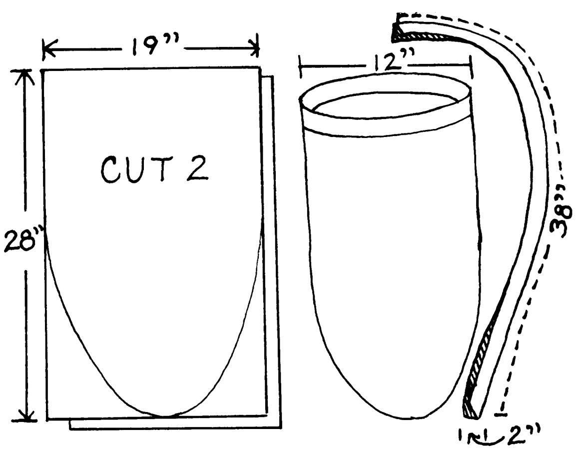


To secure the rim to the handle, wrap the handle with 20-gauge wire, use hose clamps, or find a piece of brass tubing with an interior slightly larger than the dowel to use as a ferrule. Nets can be attached by sewing them onto the rim, sliding them onto the rim (you need ferrules for this), or attaching with grommets and hog rings.



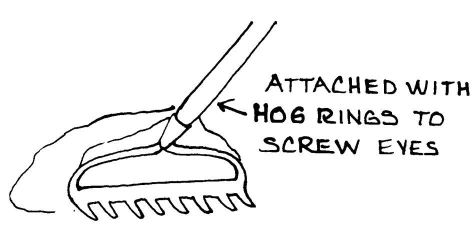
Aerial nets

Nets used to capture flying insects should be made from a coarse cloth (such as lightweight muslin) through which air can easily pass. The pattern shown is sewn around the edges. The long 4-inch strip of cloth is heavier material and is used to band the top. It should be attached so the rim can be threaded through this heavier cloth. Because these nets are sometimes torn on vegetation, a rim attached with a ferrule is recommended.



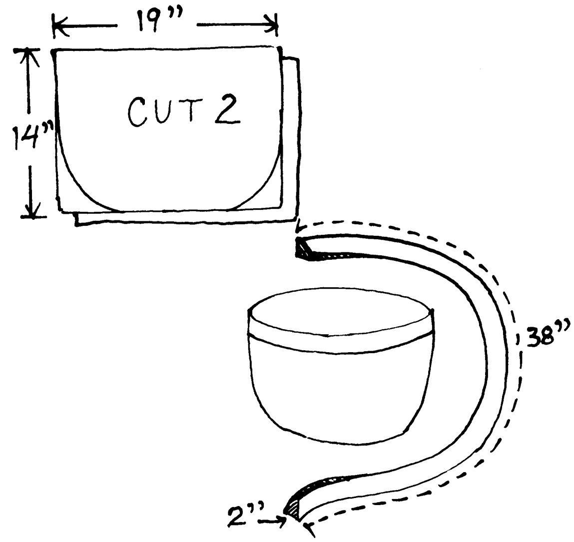
Drag rake

A garden rake fitted with a dip net bag is useful for collecting from stream or pond bottoms. The rake is used to loosen the bottom material with the net on the downstream side. Water flow will carry specimens into the net. Because unwanted silt or other material may also be carried into the net, it may be helpful to use a fabric that will let silt pass through but collect specimens of the proper size.



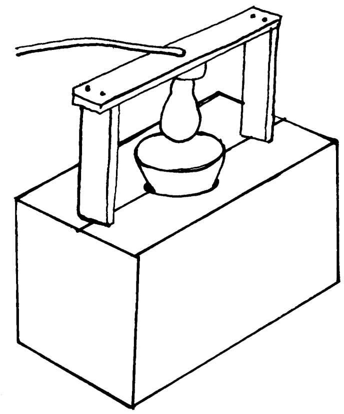
Dip nets

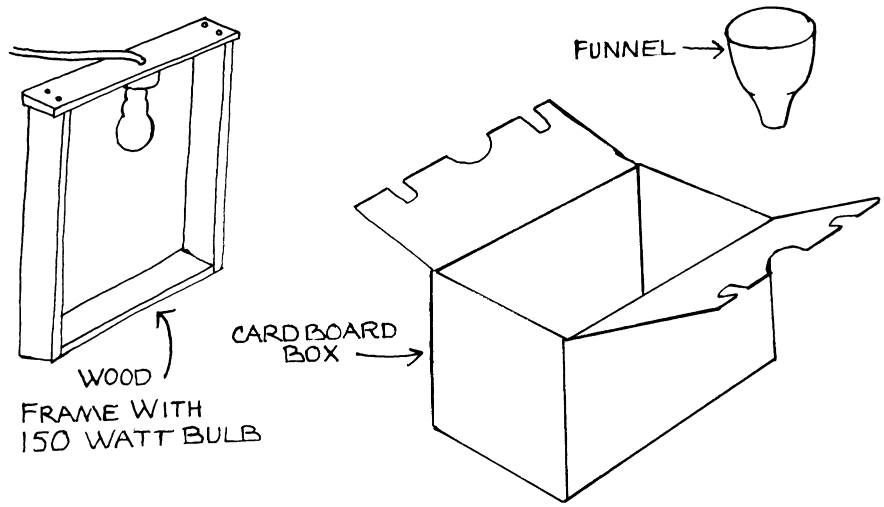
Dip nets can be made from the same lightweight muslin as aerial nets or a mesh such as mosquito or no-see-um netting. Generally, dip nets are shorter than aerial nets, with the depth slightly greater than the diameter of the rim. Again, a heavier piece of fabric is used to band the top. Possibilities for attaching the net to the rim are explained on the previous page.



Terrestrial light trap

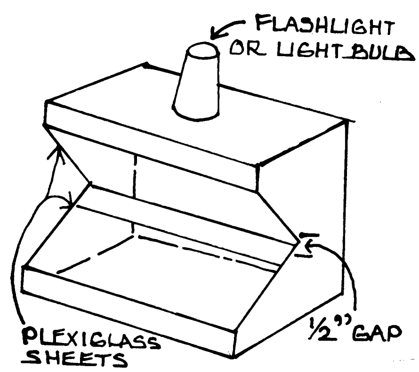
Moths and other insects attracted by light can be collected in simple light traps. A white sheet hung in front of a gas lantern is an effective trap. The insects can be collected from the sheet with a net or jar. Shown below is a type of simple trap that will collect the insects for you. Vary the dimensions according to the strength of the light source available, and vary the materials to what is readily and cheaply available. The trap at the top works best with at least a 150-watt bulb. The lower trap will be more effective if the inside is coated with white paint or aluminum foil to increase reflected light. Sections of egg carton placed in the bottom of either trap will give the captives a place to rest and hide and help prevent injury from fluttering around.

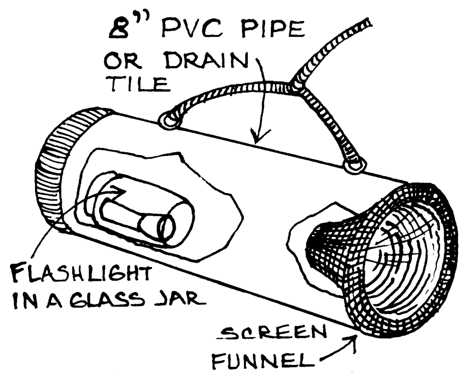




Aquatic light trap

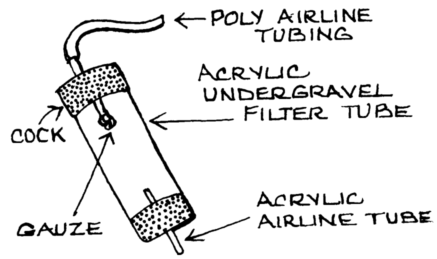
To use the same idea in water as on land, try a trap similar to the one illustrated below. This trap will be more effective if the light source is shielded so most of the illumination is directed toward the funnel end of the trap. The funnel end points downstream.

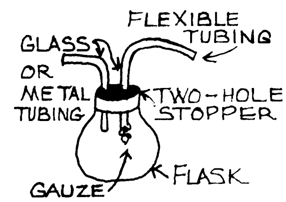




Insect aspirator

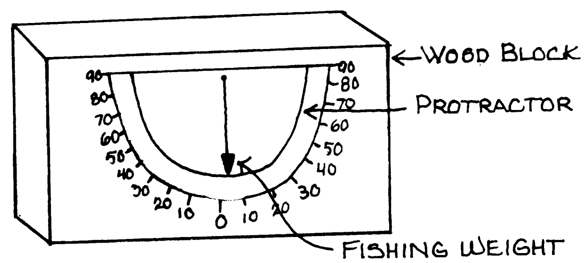
To capture small insects from foliage or nets, an aspirator (called a pooter in Britain) is handy. The one shown on the left is made from supplies found in most pet shops and the other from items available in most science classrooms. By inhaling through the flexible tube, the small insects are drawn into the large capture tube. The idea is easily adapted to many different materials.





Clinometer

To measure the slope of objects, a simple clinometer can be made from a block of wood and a protractor. Renumber the divisions with 0° at the bottom center and 90°at the end of each horizontal. A fishing weight whittled into the shape of a plumb bob and hung from thread or light fishing line makes a good pointer.



Bibliography

For more ideas on inexpensive equipment, watch for science activity books for younger students and check the background sections of various field guides. Below are listed some books that have been helpful.

Durrell, Gerald, *A Practical Guide for the Amateur Naturalist*.

Hillcourt, William, *Field Book of Nature Activities*.

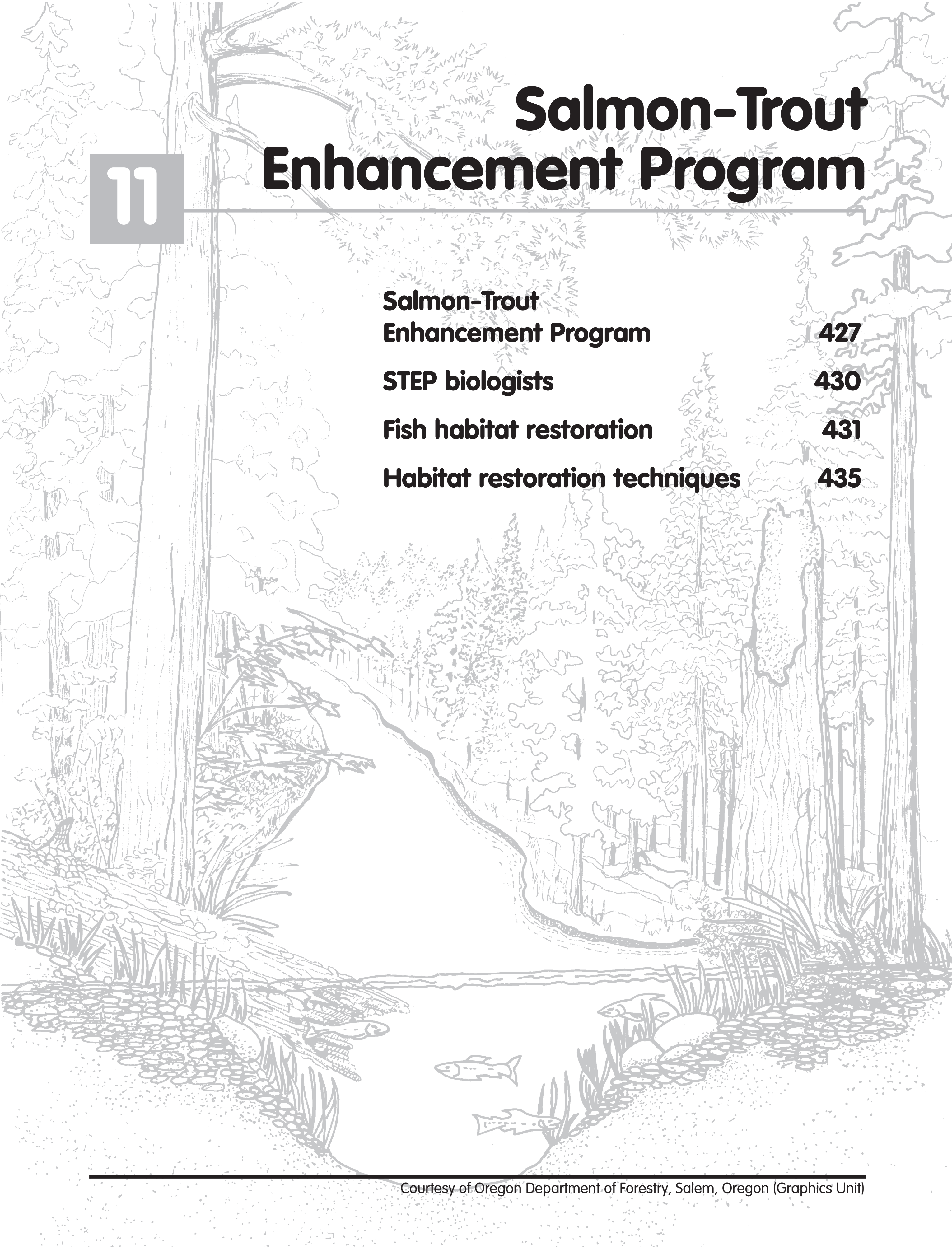
Klots, Elsie, *The New Field Book of Freshwater Life*.

National Science Teachers Association, *Classroom Creature Culture*.

Stein, Sara, *The Evolution Book.*

Usborne Hobby Guides: *The Young Naturalist,* by Andrew Mitchell and *Understanding and Collecting Rocks and Fossils*, by Martyn Bramwell

11 Salmon-Trout Enhancement Program



Courtesy of Oregon Department of Forestry, Salem, Oregon (Graphics Unit)

11 Salmon-Trout Enhancement Program

"The times of a river are measured by the salmon, and the stages in a salmon's life are measured by its color."
— Kathleen Dean Moore

What is STEP?

Recognizing that volunteers could play an important role in the restoration of native stocks of salmon, steelhead and trout, the Oregon Legislature created the Oregon Department of Fish and Wildlife's (ODFW) Salmon-Trout Enhancement Program (STEP) in 1981.

Since that time thousands of volunteers have assisted Oregon's fisheries through their involvement in STEP. They have donated money, materials, equipment, and countless hours of time and labor. STEP volunteers have completed stream habitat restoration work, conducted surveys, helped with education projects, and hatched and reared several million salmon and trout eggs—all because they care about fish and fish habitat.

What can a STEP volunteer do?

Interested citizens can help out in a variety of ways, from data collection and management to habitat restoration or education. Volunteer projects and opportunities are defined by the diversity of fish resource management needs found throughout Oregon.

Each of Oregon's watersheds has its own fish management priorities. Local biologists determine what must be done and are always on the lookout for ways volunteers can help.

Many fish projects simply *could not happen* without volunteers. Volunteers provide the extra effort needed to get the job done. Volunteer participation also frees up ODFW staff time and dollars for other important work.

Surveys

Volunteers help determine the status of fish populations and the condition of stream and lake habitats through a variety of survey projects. *Aquatic Habitat Inventories* provide information about the quality of fish habitat in streams. *Fish Population Surveys* determine the species present, their abundance, and distribution within a given stream. *Spawning Surveys* document the amount of spawning activity in a stream system. Some surveys are part of annual efforts to track a population trend within a basin. Others determine the potential impacts of proposed land use activities.

Another survey might document migration barriers caused by poorly functioning culverts. Others measure streamflows or monitor water temperatures to develop stream temperature profiles, and photographic surveys follow habitat changes over time.

Habitat restoration

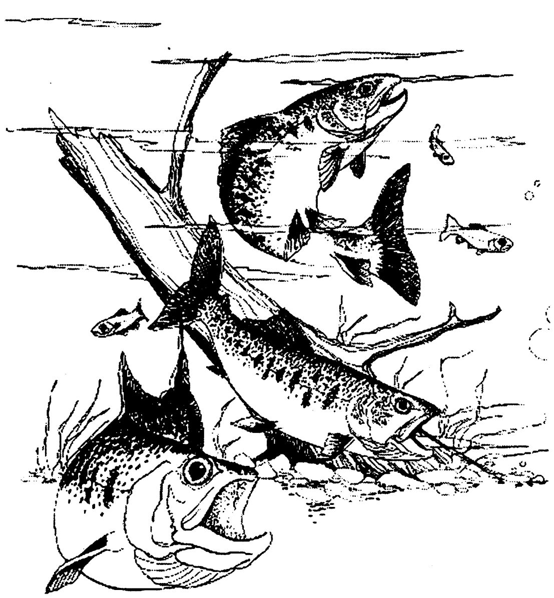
Biologists use the information gathered during surveys to identify factors that may limit fish production. For example, a stream survey might show few pools or a lack of spawning gravel, barriers to fish passage, or summer monitoring might reveal extreme water temperatures. Once needs are identified, habitat restoration projects can be designed to address those needs. Volunteers can assist with all phases of habitat restoration. These include help with funding, site selection, project design, construction and placement, equipment donation and operation, photo monitoring and report writing.

Fish culture

In those waters where natural production does not meet fish management needs, STEP volunteers may be asked to help with fish culture efforts. Volunteers can assist ODFW personnel with broodstock collection, egg incubation, and fish rearing activities. The work may take place at an ODFW facility or at a volunteer-operated site that complements public hatcheries.

Education

Education and information materials are essential to promote public awareness and understanding of fish and wildlife habitat needs. The STEP program distributes a number of publications to meet this need and to show how citizen volunteers can participate in STEP activities. *Stream Scene* is a curriculum package about watersheds, upland and riparian areas, streams, and aquatic organisms. *Storm Drain Marking* is a program to educate citizens about the ecological hazards of dumping household chemicals into storm drains. *From Fish Eggs To Fry* is a tool for setting up and maintaining a classroom aquarium to hatch fish eggs; *Why Wild?* is a supplement to help students understand how fish are adapted to their native streams. *Stream Care* is a landowner's guide for protecting and enhancing stream habitat. Related materials are also available through ODFW's Aquatic Education Program.



Other projects

Many fish management tasks provide opportunities for volunteer involvement. Some volunteers may snorkel a clear mountain stream in search of an endangered native trout or perhaps others enjoy entering data at a computer terminal. Still other volunteers might try fish salvage, fin clipping, fish stocking, or equipment maintenance. Volunteers also suggest projects like streamside plantings, identifying fish passage barriers, and acquiring access for anglers.

What's in it for me?

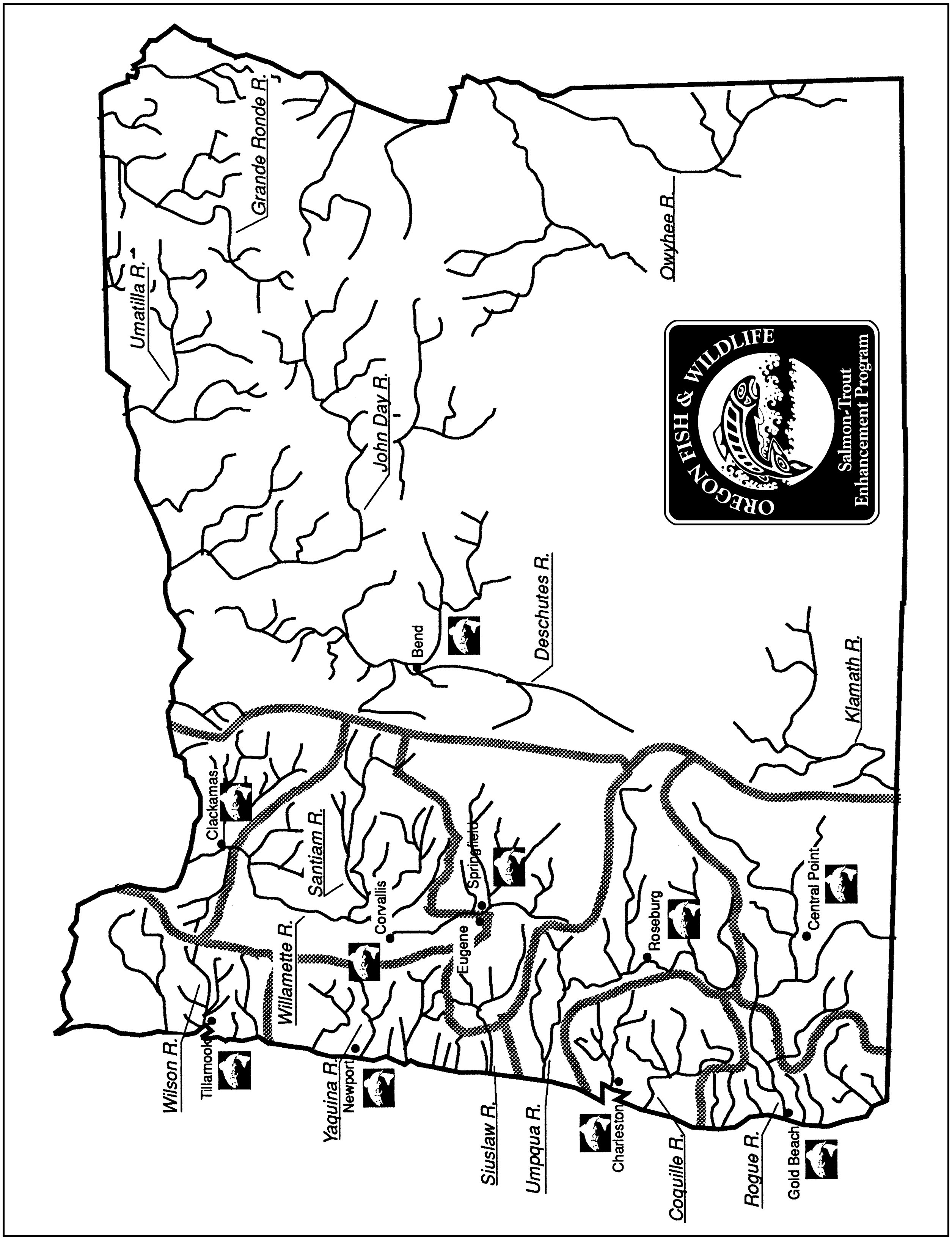
STEP is a growing program and Oregonians are eager to contribute time, muscle, money, and perseverance. The combined effort of all STEP volunteers has made an important and measurable impact toward conservation of Oregon's valuable fish resources. Participants also benefit. Volunteers come away with a better understanding of fish and the systems upon which they depend. And, they achieve a strong sense of personal accomplishment through their hard work. Do you want the satisfaction of knowing your stewardship helps fish? Come join us. You'll be glad you did.

How can I get involved?

Contact the nearest ODFW office or STEP Biologist to learn more about the needs in your area. Sign up today as a STEP volunteer—Oregon's fish need your help now!

Author's suggestion: Use a classroom incubator project as part of a lesson on fish

STEP Biologist Districts



STEP Coordinator

Oregon Department of Fish & Wildlife
PO Box 59
Portland, OR 97207
Phone: (503) 872-5252 ext 5429
Fax: (503) 872-5632

STEP Biologist
Oregon Department of Fish & Wildlife
PO Box 642
Gold Beach, OR 97444
Phone: (541) 247-7605
Fax: (541) 247-2321

STEP Biologist
Oregon Department of Fish & Wildlife
PO Box 8
Hines, OR 97738
Phone: (541) 573-1703
Fax: (541) 573-5306

STEP Biologist
Oregon Department of Fish & Wildlife
17330 SE Evelyn Street
Clackamas, OR 97015
Phone: (503) 657-2000 x235
Fax: (503) 657-6808

STEP Biologist
Oregon Department of Fish & Wildlife
61374 Parrell Road
Bend, OR 97702
Phone: (541) 388-6363
Fax: (541) 388-6049

STEP Biologist
Oregon Department of Fish & Wildlife
4909 Third Street
Tillamook, OR 97702
Phone: (503) 842-2741
(503) 842-5033
Fax: (503) 842-8385

STEP Biologist
Oregon Department of Fish & Wildlife
1495 E Gregory Road
Central Point, OR 97502
Phone: (541) 826-8774
Fax: (541) 826-8776

STEP Biologist
Oregon Department of Fish & Wildlife
7118 NE Vandenberg Ave
Corvallis, OR 97330-9446
Phone: (541) 757-4184
Fax: (541) 757-4252

STEP Biologist
Oregon Department of Fish & Wildlife
4192 N Umpqua Hwy
Roseburg, OR 97470
Phone: (541) 440-3353
(541) 440-3355
Fax: (541) 673-0372

STEP Biologist
Oregon Department of Fish & Wildlife
3150 E Main Street
Springfield, OR 97478
Phone: (541) 726-2539
Fax: (541) 726-2505

STEP Biologist
Oregon Department of Fish & Wildlife
PO Box 5430
Charleston, OR 97420
Phone: (541) 888-5515
Fax: (541) 888-6860

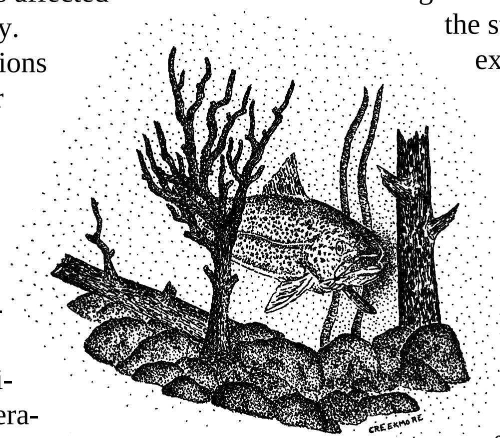
STEP Biologist
Oregon Department of Fish & Wildlife
2040 SE Marine Science Dr.
Newport, OR 97365
Phone: (541) 867-4741
Fax: (541) 867-0311

STEP Biologist
PO Box 422
Mapleton, OR 97453
Phone: (541) 268-3044
Fax: (541) 268-3044

Fish habitat restoration

Aquatic habitat restoration activities are one of the key issues in the Oregon Plan for Salmon and Watersheds. The concept of “habitat restoration” covers a multitude of ways to improve watershed function—water quality, water quantity, increased channel complexity, flood plain interaction, and the quality of riparian vegetation. Reintroducing wood to stream channels, repairing culverts, planting trees and shrubs, and opening up historical stream channels are all examples of habitat restoration projects.

A stream’s or estuary’s ability to support fish and other forms of aquatic life is affected by its ability to function properly. Stream or estuary habitat conditions are dependent on land and water management actions including road building, development, grazing, agricultural practices, forestry practices, controlled fires, and other human and natural activities within a watershed.



Fish survival in aquatic habitats is dependent on water temperature, water quality and quantity, cover, and food supply. Fish have different requirements at various stages of their lives and different species use different habitats for spawning and rearing. Understanding the different life cycle requirements and interactions among species plays an important role in sound habitat restoration.

Successful spawning and development from egg to fry require:

- absence of barriers at all flows to upstream migration of adult fish;
- spawning areas with sediment-free substrate and adequate water flows;
- a balance of pools and riffles to provide spawning and holding areas, especially deep, cool pools for species like spring chinook salmon;
- instream and streamside cover to protect adult fish from predators and to provide shaded resting areas; and
- an adequate flow of cool, well-oxygenated water through the spawning gravel.

Development from eggs to fry is a delicate process. Many things can happen to limit the number of fish that survive this stage of the life cycle. High water flows may scour eggs from the streambed. Low water can expose the redd and allow the eggs to die from temperature extremes. High sediments loads may smother the eggs in the redds and large numbers of adults spawning in a limited area may uncover eggs in one redd while building another.

Young emergent fry require quiet, slow stream flows, backwaters, or stream margins. Juvenile migratory fish live and grow in the stream for one to three years, while resident fish need suitable habitat throughout their lives. Rearing fish also need clear access to move up and down the stream, including access to the ocean for migratory fish.

Productive fish rearing habitat requires:

- low to moderate slope and streamflow velocity;
- a balance of pool and riffle habitat to provide food and cover appropriate to the species;
- a variety of substrate types to provide hiding cover for young fish and places for aquatic insects to live;

- undercut banks, stable natural debris such as fallen trees, and overhanging plants to provide cooling shade, protection for young fish and leaf litter for aquatic insect food;
- nutrients, particularly from salmon and lamprey carcasses in areas where these species were historically found, to promote growth of naturally occurring plants and other organisms beneficial to the stream;
- barrier-free migration for upstream and downstream movement;
- a stream channel that interacts with the floodplain during high water periods; and
- meandering streambanks and backwater channels to slow streamflow, add diversity, and increase the amount of habitat available to fish.

What is fish habitat restoration?

Habitat restoration is the repair of altered streams or creation of productive habitat in streams, riparian areas, uplands, and estuaries. In a properly functioning natural system, habitat restoration can help watersheds produce and support increased numbers of salmon, trout, and other wildlife.

Why are fish habitat restoration projects needed?

Many of Oregon's watersheds have suffered from the effects of human activities and support fish populations well below their historic levels. Loss of wetland and estuary habitat, spawning areas, rearing areas, streamside vegetation, instream woody debris, beaver ponds, and access to former fish production areas are all results of our treatment of the land, aquatic environment, and aquatic wildlife

To understand the need for habitat restoration, we must first recognize how land use activities affect a stream's character and how fish populations respond to reduced habitat quality within a stream. Certain aquatic and riparian habitat conditions, or limiting factors, establish the number of fish a stream can support — its carrying capacity. Limiting factors are considered for all phases of a salmon or trout's life cycle. For example, the amount and quality of gravel-rich areas are limiting factors for spawning habitat. The amount and quality of deep pools, backwater pools, or beaver dam areas limit rearing habitat for young fish.

Varying environmental factors cause fish populations to fluctuate from year to year within the limits of their habitat. Extremes in streamflow can cause wide variations in survival and production. Extended low flows may keep adults from reaching spawning areas. High winter flows can destroy eggs by scouring spawning beds or depositing sediments. Stream temperatures also affect survival. Variable ocean conditions affect smolt and adult survival. Fish populations in healthy habitats generally recover quickly from these natural events. But when habitat quality is degraded, serious reductions in fish numbers occur.

Many fish habitat problems are overcome with changes in land and water management practices, but habitat restoration activities may get the stream system on a fast track to recovery. Restoration projects are not an alternative to improvements in land and water management, but can bridge the time between past disturbances and a return of natural functions that will maintain productive fish habitat.

It is important to understand which management activities or habitat conditions are limiting fish populations so efforts to improve the situation are not misdirected, harmful, or wasted. Once limiting factors are identified by surveys or other evaluation processes, habitat restoration projects can address specific habitat needs in a given stream. Restoration practices should target the most limiting factors first.

What are some fish habitat problems?

✔ Water quality and quantity

Most aquatic organisms rely on a relatively narrow temperature range for survival. Shade plays an important role in determining water temperature. Air temperature, adjacent land forms, upslope vegetation, and land and water use also affect water temperatures. Various types of pollution negatively affect fish and aquatic insect production. Minimum streamflows are necessary to maintain good fish habitat, especially during natural low flow periods of the year. Lack of beneficial nutrients, such as those from salmon and lamprey carcasses in areas where these species were historically found, also affects water quality.

✔ Abused riparian areas

Healthy streambank conditions are important to fish production. Good riparian plant growth along a stream helps the soil store water for late summer flows, provides shade to keep water cool, holds the soil together to reduce sediment input to the stream, and contributes insects to the fish food menu.

✔ Barriers to migration

Roadway culverts, dams, dikes, and other man-made structures may artificially block spawning, rearing, and smolting migrations of fish.

✔ Lack of natural instream structure

Large and small woody debris accumulations create resting areas, scour deep pools, provide cover for fish, collect gravel for spawning beds, and are homes for aquatic insects.

✔ Lack of spawning or rearing areas

Salmon and trout species have different habitat requirements during the various stages of their life cycles. They need a balance of spawning and rearing areas with both riffles and pools in a given stream section. Suitable spawning areas have clean, porous, proper-sized gravels with an adequate flow of cool well-oxygenated water. Rearing areas with undercut streambanks, side channels, beaver ponds and other pools, instream cobble and boulders, and large woody structures, such as fallen trees, provide young fish with an environment suitable for survival and growth.

Does a fish habitat problem exist?

Before starting a habitat restoration project, find out if a habitat problem exists. Volunteers can help determine the status of fish populations and the condition of aquatic habitats through a variety of survey projects. Aquatic Habitat Inventories provide information about the quality of fish habitat in streams. Fish Population Surveys determine the species present and their abundance and distribution within a given stream. Spawning Surveys document the amount of spawning activity in a stream system. Another survey might document migration barriers caused by poorly functioning culverts. Others measure streamflows or monitor water temperatures to develop stream temperature profiles. Biologists train volunteers to conduct the surveys and help evaluate the results.

Information gathered during the surveys helps biologists identify and assess factors limiting fish production. If habitat restoration is appropriate, proceed with the following steps.

✔ Identify the problem

What is missing and what are associated limiting factors? What are the “most limiting” among the limiting factors?

✔ Develop a plan

What actions can correct the problem? Identify the best approach and develop an organized plan with clear objectives and measurable outcomes. Consider the cost/benefit factors of your actions. Use a Habitat Restoration Project Planning Worksheet provided by your local Oregon Department of Fish and Wildlife STEP biologist or habitat biologist to guide your thought process. ODFW staff can also provide a copy of the *Oregon Aquatic Habitat Restoration and Enhancement Guide*, which includes information about permits, approvals needed, and who to contact.

✔ Implement the plan

Carry out the selected action under the supervision of the STEP Biologist or other experienced habitat biologist.

✔ Evaluate the project

Include time and dollars in your plan to evaluate both the short and long term success of the project. Is it accomplishing the desired results? Are more fish present in the stream following the project? What are the measurable outcomes of the project?

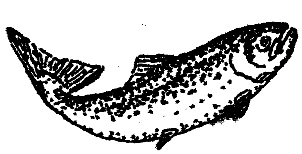
✔ Maintain the project

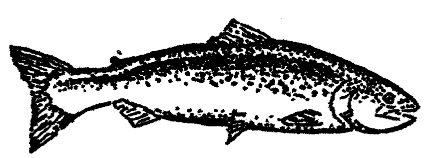
Some projects require periodic inspection and maintenance to assure the project or structure functions properly. Include time and funding to cover maintenance costs in your plan.

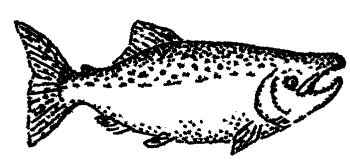
Remember, stream habitat is dynamic over time. Collections of gravel, large wood, and stream meanders will change seasonally and over the years. Large wood or other instream structures often work best if allowed some movement with natural flow events. In less heavily degraded watersheds nature can place the wood and other structures in arrangements that work best for fish.

What next?

Each project requires individual consideration to tailor the action to the need and the site. There are many techniques for accomplishing the various actions. Consult the *Oregon Aquatic Habitat Restoration and Enhancement Guide* for suggestions and ask your local ODFW fish biologist, STEP biologist, or habitat biologist for assistance in planning a restoration project.







Habitat restoration techniques

Remember one very important thing when considering habitat restoration work: Mother Nature has taken care of her watersheds and streams for a long time. Only when human interaction began affecting the picture did the function go awry.

If the problem with the stream is one of human management, that is, convincing people to change their actions or management strategies (such as limiting livestock access or restricting timber harvest), then the best form of habitat restoration is to follow nature's lead and allow the stream to recover naturally. There is no reason to place structures in the stream, just because it seems like the thing to do.

A "light touch" is best and all work done in a stream should blend into the natural pattern.

If the stream has time to recover on its own, any remaining problem areas will be evident. Those areas should be evaluated and receive appropriate attention. A "light touch" is best and all work done in the stream should blend into the natural pattern. Never underestimate the power of flowing water when planning your habitat work.

Habitat restoration is the repair of damaged streams so they may produce and support increased numbers of salmon and trout. Habitat enhancement is the creation of better or more suitable habitat within a stream. Habitat enhancement may not mean more fish, but may mean an increase in other values related to overall watershed health.

Various techniques exist for restoring and enhancing fish habitat. For any habitat rehabilitation or enhancement work to be successful, it must meet two criteria. It should be placed where it will best aid creation of the desired habitat condition and it should be designed to last for a relatively long period of time.

Restoration techniques

Following are a few examples of habitat restoration techniques. Many other techniques exist for specific problem areas in streams. If you and your students want to get involved with habitat restoration work, contact the local STEP biologist or district fish biologist for assistance.

Boulders

Very large irregular boulders create "pockets" or hiding and resting places for fish. Boulders also change the flow pattern of the water, creating greater habitat diversity. They are most often used when there is too much riffle and limited pool and hiding areas. Depth is increased by scouring, a result of the faster water velocities around the rock.

Generally, boulders are placed in clusters or along the edges of streams to create small back-water areas. Streambanks should be stable or well protected in areas where boulder placement is considered.

Rock weirs (or boulder berms)

Rock weirs are constructed in areas where long shallow riffle areas exist and sufficient spawning gravel is limited.

A rock weir consists of a collection of rocks and cobble used in combination with large boulders (which may already be found in the stream) to form a dam-like arrangement. Rocks are piled across the stream using already present boulders as a base. The rock weir is constructed with a somewhat vertical, downstream face and a gradually sloping upstream side. This design spreads the water's force over the entire structure, lessening the chance of wash out. The height of the weir varies depending upon the channel.

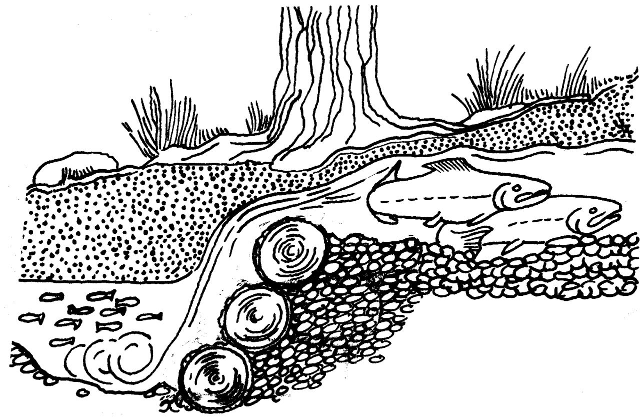
A rock weir reduces a stream's velocity, collects spawning gravels, and help restore the water table. Downstream, water plunging over a weir scours a pool and recruits gravel that is sent downstream by the flow to the next collection site.

Rock weirs are best used in series to create habitat diversity (increased pool-to-riffle ratios). Streambanks must be stable or well-protected in rock weir placement areas.

Log sills (or log weirs)

Log sills are placed across or at an angle to the stream flow, unless flow or bank stability are controlling factors. They are anchored to the stream bottom, to stable boulders, or to tree trunks along the edge of the stream.

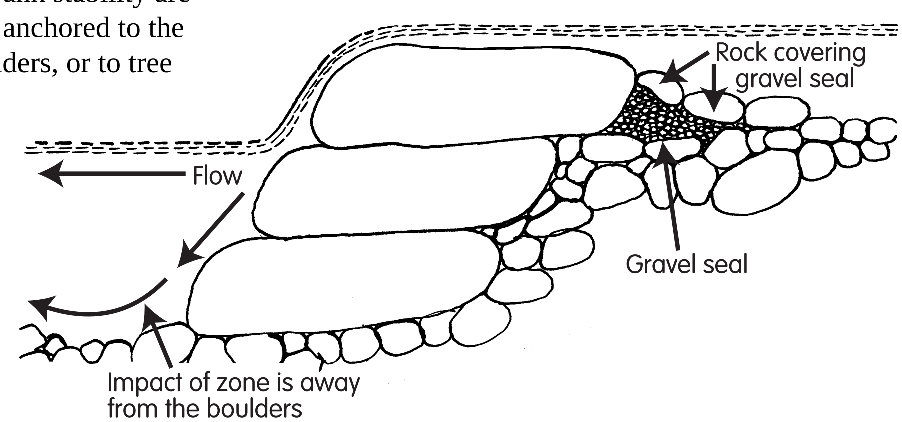
To be most effective, the logs should be at least 12" to 16" in diameter, well placed in the stream bottom to reduce washouts under the logs and keyed into the banks at least a third of their length. Often, a layer of heavy wire and erosion fabric is anchored to the log. This is placed on the streambed on the upstream side of the log sill to help complete the seal, reducing washouts under the log. Gravel collects behind the log, providing spawning area above the structure and a rearing pool on the downstream side.



Plantings

Stabilizing stream banks with tree plantings or reseeding with other vegetation can help restore streamside vegetation. Consult with local professionals, like the Natural Resources Conservation Service, to select the right species for the site.

The condition of the streambanks is related to water quality and fish production. Shade provided by the vegetation helps keep streams cool. Root systems help control erosion that would add sediments to the stream. Silt can clog gravel, smother eggs and reduce aquatic insect production.



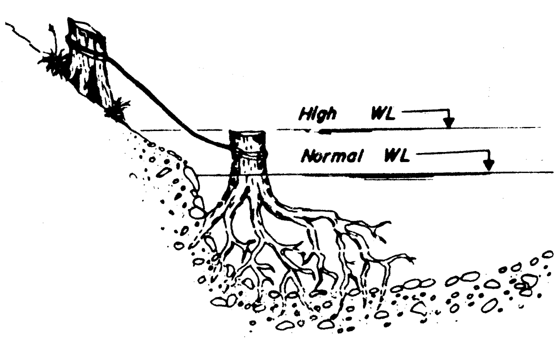
Cover logs

Cover logs provide overhead cover in sections of a stream where the water depth is adequate but cover is lacking.

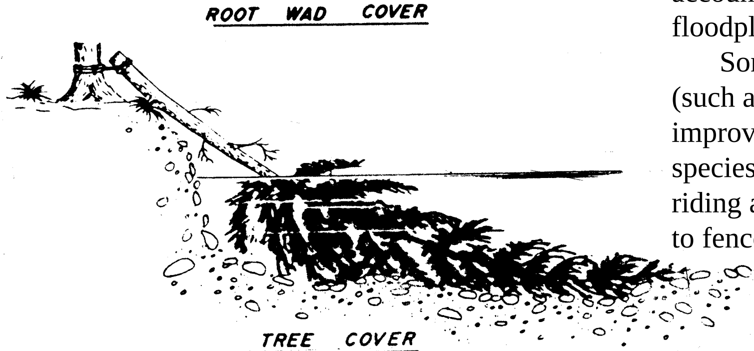
Cover logs can be any shape, length or size, but the best results are obtained by using large crooked logs with limb stubs extending several inches. Root wads are also used. Both provide an irregular surface resulting in maximum turbulence and spot scouring along the edge of the structure.

Logs are anchored to the stream bottom or the bank. Ideal locations are open pools or glides at least 6" to 8" in depth. Logs are placed parallel or at slight angles to the flow. Cover logs have the added advantage of presenting a natural appearance in the stream.

Cut trees (juniper) that are placed against and anchored to the banks are beneficial in bank stabilization. Green trees with a bushy crown work best.

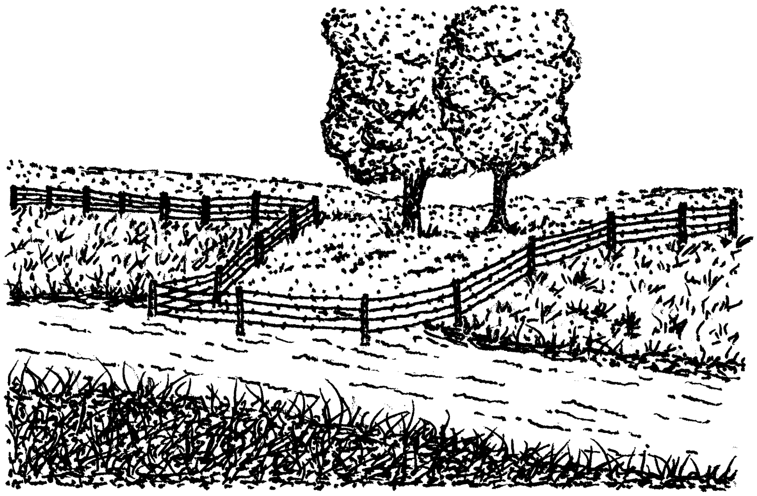


ROOT WAD COVER



TREE COVER

Source: *Stream Enhancement Guide,* Government of Canada, Province of British Columbia, Vancouver, B.C., 1980.



The trees and their branches reduce water velocities, allowing sediments to collect. Native plants then colonize these new seed beds, improving banks, narrowing and deepening the channel, and enhancing salmonid habitat.

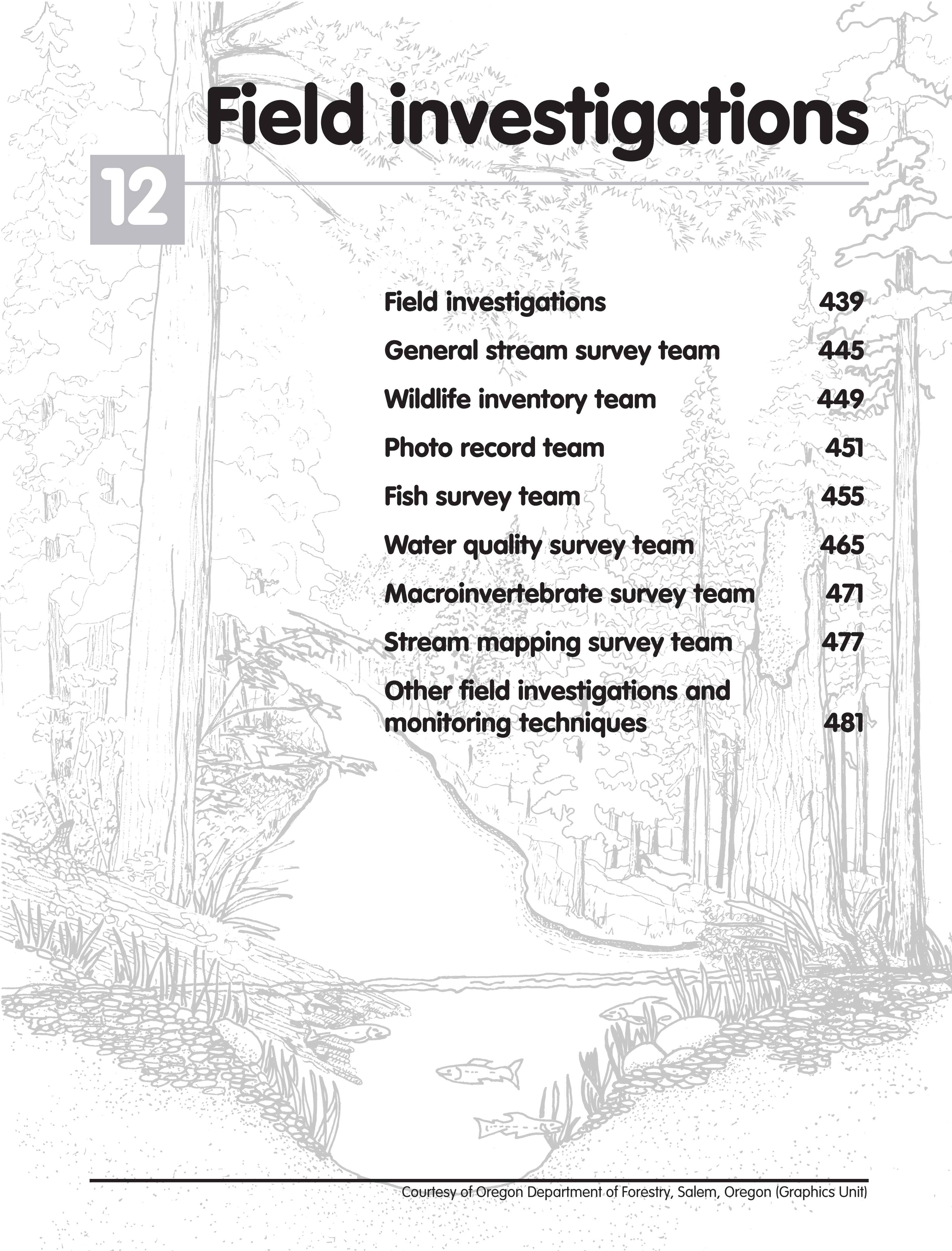
Streambank fencing

Fencing, or otherwise limiting usage of disturbed streamside areas, can help restore deteriorated streambanks, reduce excessive or unnatural nutrient and sediment loads, and protect riparian vegetation. Healthy riparian vegetation shades the stream, reduces bank erosion, and provides other benefits to fish. Fencing may be necessary to reduce impacts from agricultural or other human activities on streambanks, but it is most often used to control livestock grazing in terms of numbers of animals, season, and timing of use.

Location of riparian fences should take into account potential damage from ice, high flows, floodplain levels, and debris.

Some grazing systems and/or techniques (such as alternative water developments, upland improvements, planting of nutritious, palatable species well away from riparian areas, and/or riding and herding practices) can reduce the need to fence.

12 Field investigations



Courtesy of Oregon Department of Forestry, Salem, Oregon (Graphics Unit)

12 Field investigations

"To stick your hands in the river is to feel the cords that bind the earth together in one piece."
— Barry Lopez

Data collection and monitoring

Ideally, a classroom unit about watersheds and streams will lead to a series of field investigations where students can apply their new knowledge and skills.

Data collection, analysis, and interpretation help students develop higher learning skills. And that in itself is a valuable reason for completing field investigations. Once involved in watershed studies, it is natural to want to spend the time collecting "real" data that would be of use to someone or some agency. Properly collected data is useful to landowners, concerned citizens, and agencies. Poorly collected data of unknown quality is an unfortunate loss of significant time and money. It is important to apply guidelines that will help students collect accurate, reliable data.

Because of quality control concerns and the ever-present threat of litigation, resource agencies may be hesitant or skeptical about using student- or volunteer-collected data. They mention inconsistent training, lack of discipline in adhering to sampling protocols, variable student skill levels from one year to the next, and lack of time to provide close oversight. That does not mean student data is not useful or that students cannot achieve quality control standards. In fact, the opposite is true. But, as the teacher, the responsibility for determining, training, and meeting the quality control standards falls on your shoulders.

Adapted from original artwork by Sandra Noel, *Adopting a Stream: A Northwest Handbook,* Adopt-A-Stream Foundation, 1988.

Even though student data may not meet all the standards of a research quality study, there are many examples of students alerting communities about serious environmental problems discovered while exploring streams. Even if student data does not become part of agency data bases, students can compare data sets from previous years, draw conclusions, and make recommendations.

Opportunities do exist for well-trained students and volunteers to collect credible data and become key players in local watershed monitoring efforts. Students also develop valuable career skills and establish contacts with resource professionals. Look into partnerships with the local watershed council, soil and water conservation district, city or county planning departments, conservation organizations, and others involved in watershed work. These agencies and organizations may have funds available to assist with equipment purchases and transportation to stream sites. If a partnership does develop, be prepared to implement stringent quality control standards and to develop and maintain open avenues of communication with resource professionals.

Opportunities do exist for well-trained students and volunteers to collect credible data and become key players in local watershed monitoring efforts.

Preparing for field investigations

Field investigations reinforce watershed, upland, and riparian concepts learned in previous chapters.

By completing the field investigation techniques in this section, students learn to test for water quality parameters (dissolved oxygen and pH), measure stream velocity, and inventory stream habitat features such as riffles and pools. Other field exercises include fish population inventory, macroinvertebrate (aquatic insect) sampling, and drawing a stream map to scale.

None of the methods in this book is designed to serve as full-scale monitoring protocols although some are quite similar. When considering long-term monitoring work with your students, consult the shaded boxes for resource specialist contacts and other reference information.

Spend as much time as needed to train the students for proficiency in the field investigation procedures, especially if you plan to move into more rigorous monitoring protocols. Make it clear to students what behavioral and quality control expectations must be met.

Most of the investigations can be “practiced” in the classroom. A good rule of thumb for pre-field trip training is 95% preparation time to 5% field trip time. Do test runs of all the field activities until students are confident and accurate with the procedures.

One way to practice mapping at the school site is to use chalk to draw a stream on the tennis court, gym floor, sidewalk, or other large surface. Include curves and crossings and habitat features you want students to include on the map. Train students how to produce a map drawn to scale using this model stream. Students can practice the water quality sampling procedures on water samples brought from local ponds or other water bodies. Collect insects from a nearby stream the night before you plan to train students in macroinvertebrate sampling procedures. Use a small children’s swimming pool, aquarium, or buckets to hold the insects until the training day. Add a small aquarium pump and aerator to supply oxygen for the insects. Include rocks, aquatic plants, water-logged wood, and about two inches of stream water. Use a small aquarium net to demonstrate the sampling procedures within the container. Fish sampling cannot be completed in the classroom, but practice with data sets from other fish sampling is helpful with the data analysis process.

If training is to take place in the field, consider rotating groups of students through a series of stations. Generally, it works best to put the macroinvertebrate training station furthest upstream, followed by fish sampling, water quality, and mapping stations as you move downstream. This requires a staff person or team leader at each station. Team leaders give multiple presentations as students rotate through the stations. Remind students to keep disturbance to a minimum, both on the bank and within the stream. If the stations are spread out, turbidity will have a chance to settle before reaching the next station. When rotating stations, shift rotations upstream to keep the water as clear as possible. Plan for 45 minutes to an hour at each station so students have enough time to experience the procedures. Assign someone as the time keeper to keep the rotations moving on time.

When the training is complete, divide the students into teams to complete a "real" stream survey. The following list suggests the number of students for each team. Students can sign up for their own particular area of interest or you can assign teams based on student skill level. Each team is responsible for their own data and for contributing it to the entire group's findings. Ask the students to choose one individual from their group who will have responsibility for the equipment. Using the equipment checklist as a guide, this person must see that all equipment is gathered and ready to go before the field trip, transported to the field trip site, and returned in good condition following the field trip. Do an equipment inventory before leaving the field site.

Remind students to bring a set of dry clothes, socks, and shoes. Expect someone to fall in. Have a few towels and some extra, warm sweaters on hand.

Visit the survey site as many times as necessary before the field trip. Be thoroughly familiar with the site. Choose and mark sample site boundaries. Avoid areas of deep water, dangerous streambanks, or other safety risks. Check out bus parking and turn-around options.

- map team (5–6)
- invertebrate survey team (6–8)
- fish survey team (5)
- water quality survey team (3–4)
- photo record team (2)
- general stream survey team (2)
- wildlife inventory team (2)

One other team could research the general information below to round out the stream study.

STEP Survey and Habitat Restoration Background Preparation

_____ What species have historically occupied this area?

_____ Has the spawning run changed significantly over time?

_____ Have any "alien" species been introduced into the stream?

_____ What factors have acted to stop spawning or eliminate rearing habitat over time?

_____ What factors have served to modify the spawning or rearing habitat over time?

_____ What is the historical pattern of land use near the stream and in the watershed?

_____ What is the historical pattern of land ownership in the study area?

_____ What are the past activities of humans that have controlled vegetation or altered the stream?

_____ What are the records of water rights, terms, and conditions?

_____ What are the past governmental policies that have affected the area?

_____ What are the geomorphological and geological record of the area?

Monitoring program design

Contact local biologists or consult Chapter 3, page 44, of the Adopt-A-Stream Foundation's *Streamkeeper's Field Guide, Watershed Inventory and Stream Monitoring Methods* (ISBN 0-9652109-0-1) as a guide for setting up a monitoring program.

For specific Oregon water quality monitoring program guidelines, see *Water Quality Monitoring Guidebook.*

> To order *Streamkeeper's Field Guide*: Order from The Adopt-A-Stream Foundation, 600-128th Street SE, Everett, WA 98208, phone (206) 316-8592. The cost is $29.95 + $4.00 shipping and handling plus WA residents add $2.37 sales tax.
>
> Order the *Water Quality Monitoring Guidebook* from the Oregon Department of Environmental Quality, 1712 SW 11th Street, Portland, Oregon 97201, phone: (503) 229-5983 or the Oregon (formerly Governor's) Watershed Enhancement Board, 255 Capitol Street NE, 3rd Floor, Salem, Oregon 97310-0203.

Collecting, managing, and presenting credible data

Consult with local resource managers or see Chapter 8, page 188, of the Adopt-A-Stream Foundation's *Streamkeeper's Field Guide, Watershed Inventory and Stream Monitoring Methods* (ISBN 0-9652109-0-1) for hints about collecting credible data.

If collecting annual data from a specific stream site, students will benefit from evaluating data collected in previous years. Ask students to help devise a data storage system, both electronic and hard copies, that will make their data available for future students. Include raw data, photo records, data analyses, and other supporting information in your files. A three-ring notebook is one suggestion for keeping the data in a manageable form in one place.

Consult Chapter 9, page 205, of the Adopt-A-Stream Foundation's *Streamkeeper's Field Guide, Watershed Inventory and Stream Monitoring Methods* (ISBN 0-9652109-0-1) for hints about presenting credible data. Other data analysis and presentation ideas are found throughout *Stream Scene* and within each field investigation section.

The *Water Quality Monitoring Guidebook* also contains information about data quality, data storage, and data analysis.

Dealing with controversial issues

Stream studies can sometimes create interesting situations. Different interest groups within a community may object to student involvement in controversial issues. Consider the information below as you design the field portion of a stream studies program for your students.

> Reputable environmental education programs must provide students with opportunities to identify, investigate, and participate in the attempted resolution of environmental issues and problems in their own community. Environmental issues and problems are usually controversial due to significant differences of opinion and value differences among different groups of people. Controversy is inherent in a free democratic society, and educators often have promoted the discussion of controversial issues as essential to education for citizenship in a free society. More than a discussion of the controversial issues is needed. Students must be immersed in the identification, investigation, and resolution of environmental issues and problems in their own community.
>
> The successful resolution of environmental issues and problems requires proficiency in the following skills:
>
> - communicating effectively—orally and in writing;
> - collecting and interpreting information;
> - justifying personal decisions and action strategies on controversial issues;
> - working cooperatively with other people;

- recognizing relationships between specific events that are part of the issue resolution process and the issue itself on a more general level; and
- understanding and using selected citizen actions required to influence decisions on specific issues—persuasion, consumerism, political action, legal action, management—or combinations of these strategies.

For students to develop these kinds of skills, teachers must help students:

- recognize and clearly state issues;
- identify and evaluate relevant information;
- learn the techniques of analysis, synthesis, evaluation, and application; and
- learn to make independent judgments.

In dealing with most issues, the atmosphere of the classroom must be as neutral as possible. Teachers must be familiar with all sides of issues, stand firm for each advocate's right to be heard, and use the classroom as a stage for rational, informed debate. Teachers should be as value-fair or value-free as possible in their roles and resist the temptation to let their own positions on issues be known and thus bias the conclusions reached by students.

Adapted from *A Guide to Curriculum Planning in Environmental Education*, Wisconsin Department of Public Instruction, 1985, printed in *Clearing*, Environmental Education Association of Oregon, Issue 71, November/December 1991.

Private property rights

Do not attempt to complete a stream survey or any of the field investigations without researching land ownerships or getting permission for access from the various landowners. In Oregon, all land ownership information is part of the public record and is accessed at the county tax assessor's office. Stop by the county assessor's office and learn how land ownership information is stored. You can also get copies of plat (or ownership maps) from the tax assessor's office. Consider a field trip to the assessor's office as part of the training process.

In some areas, landowners are especially sensitive about providing access to their land. Do not enter private property along the stream without either verbal or written permission for access, even if it is not posted. If you enter private property without permission, you are trespassing and are liable for any problems that arise.

1. Contact a landowner by telephone before visiting in person. Farmers and ranchers are seldom near a telephone during normal business hours and other landowners may be away from the home during the day. Try calling during the lunch hour or in the evening, but avoid calling after 9:00 P.M. Even with written permission, you should always call in advance to let the landowner know the exact day or days you will visit.
2. Once a landowner is contacted, explain who you are, what school you represent, and what your project is about. Provide opportunities for the landowner to ask questions. Be truthful in your responses. Be prepared to describe your sampling techniques, how many individuals will be present on the property, time frame for your survey, and uses for the data collected. Consider providing a one-page description of the students' project for the landowner's reference. Ask students to help develop this information.
3. If your request is denied, be polite and understanding whether the landowner explains the reason for the decision or not.
4. While visiting the property, be respectful and use common sense. Leaving tire tracks in a newly planted field is a sure way to sour relations between your class and the landowner.

When possible, work closely with private landowners. It takes time and trust to develop good landowner relationships. Most landowners are cooperative and interested in providing meaningful experiences for students, but disrespect and poor judgment can ruin relationships with more than one landowner. Develop a communication process and provide opportunities for students to share their goals and objectives and a summary of the data obtained. Invite the land-owner to any student presentations of the data. Finally, do not underestimate the value of thank-you notes sent from you and the students.

> Adapted from "Enhancing Relationships With Private Landowners," by Jeff Tilma, *Fisheries*, September 1997.

Safety

- Consider safety at all times.
- Watch for slippery stream bottoms, undercut banks, waterfalls, and fast flowing areas. Log jams can be unstable, so walk around them. Avoid wading in fast water and water above the knees. Use a wading staff or other device for balance and felt soles or cleats to reduce slipping. If flows are too high or a route is unquestionable in terms of student safety, avoid it until it is no longer threatening or find an alternative route. Get out of the woods if conditions are windy and trees or branches are falling.
- Students should always work with a "buddy." Do not send students into the field without supervision. Make sure students know procedures to follow in the event of an emergency.
- Avoid drinking water from a stream unless it is filtered or treated.
- Know the symptoms and treatment for hypothermia. Prepare for unpredictable weather before beginning a survey. Keep a well-supplied first-aid kit and extra food, and each student should have a change of warm clothing and footware in the vehicle. Carry a small personal safety pack while in the field.
- Alert students to the possibility of hazardous waste materials. Avoid foul smelling areas, spills of unknown substances, or containers of hazardous or unidentified materials. Do not jeopardize student safety or your own. If observed, note extent from a distance and report immediately. Contact emergency response agencies like local Oregon State Police offices, the Oregon Department of Environmental Quality or the Oregon Emergency Response line (1-800-452-7888).
- Always have a plan in case of an emergency. Carry student emergency contact numbers as well as police and ambulance. Not all areas access emergency services via 911. Check before you go. Be sure the school knows exactly where you are going and when you are due to return.

General stream survey team

A general stream survey collects information about stream habitat. While walking the entire length of a survey section, fill out the *General Stream Survey* forms on page 448. Stream width, water and air temperature, and flow information needed for this survey can be obtained from the water quality team.

Checklist

- _____ clipboard, data sheets, pencil
- _____ insect repellent (if necessary)
- _____ bucket or daypack for equipment
- _____ thermometer
- _____ map (large scale, preferably 4"/mile or larger) of survey area
- _____ waders or hip boots, rain gear, extra set of clothes
- _____ polarized glasses
- _____ depth staff (marked in tenths of a foot or tenths of a meter)
- _____ watch with a second hand

Survey data: Part A

Stream, river system, county, surveyors, date: Self-explanatory.

Stream mouth location: Record township range, and section of stream mouth. Refer to map.

Survey section: Record beginning and end of survey section on each form by stream mile to nearest quarter mile. Note common landmarks at the beginning and end of the section, such as tributary mouths, bridges or other crossings, a nearby house, etc.

Stream width: Record average wetted surface width on day of survey and as it would be when at normal high flow as indicated by the high-water line.

Temperatures: Record air and water temperatures and time taken.

Flow: Record average width of stream in feet and average depth (measure across channel in at least five places) to the nearest tenth of a foot. Measure velocity by putting a float in the stream (stick, fishing bobber, orange) and timing its travel over a measured distance (at least 20 feet) in seconds. Repeat at least three times and calculate the average. Check whether bottom type is rough (gravel, cobbles, boulders) or smooth (sand, silt, bedrock). Cubic feet per second (cfs) is calculated as follows:

(Average width × average depth × velocity feet/second water travels) × 0.8 (for rough bottom) or 0.9 (for smooth bottom) = cubic feet/second

(1 cfs = approximately 450 gallons/minute).

Substrate: Record the nature of the stream bottom as an estimate of the total from the entire surveyed section.

Percentage of pools: This factor helps determine the rearing potential of the stream. Estimate what percentage of the stream's surface is quiet, slack water where fish can rest out of the current and where depth offers some cover.

Determine an individual's stride length in feet. Step off pool lengths in strides. Add totals of pool lengths (in strides) and multiply by the number of feet in each stride. Divide by the total stream length surveyed (in feet) to determine the percentage of pools (see example on the following page).

- stride length = 5 ft
- total length of pools in section = 56 strides
- total length of section = 1,320 ft
  56 strides×5 ft/stride=280 ft
  280 ft÷1,320×100=21.2% pools

Percentage of shade: Shade on the water's surface helps keep the water cool. Estimate the percentage of water surface in the section shaded during the hours of 10:00 A.M. to 3:00 P.M. Streamside vegetation is also important as it harbors insect life that contributes to the fish food supply. Notations of vegetation types, if known, would be useful.

Streamside cover type: Indicate the relative abundance of each type in the riparian area.

Erosion points: Note locations where you feel erosion is contributing to silt loads in the creek, is threatening stream stability, or is endangering an adjacent road or bridge. Give the location by river mile as closely as possible and mark location on the map.

Barriers: Note the type, height and location of each observed barrier. Although all such conditions may not prevent fish passage, if you feel there is a problem, record the site and mark on the map. It will be evaluated later by ODFW personnel to determine if correction is needed.

Instream structure (woody debris): The presence of woody debris in the stream is important to fish habitat. It helps stabilize the streambed, traps gravel, fosters insect production, and creates pools, hiding places and resting areas. Record by checking the appropriate space to indicate the relative abundance of each type.

Survey data: Part B

Valley profile: Check the space that best describes the shape of the stream valley. The stream section may have more than one type of shape.

Channel profile: Make the same judgment as above for the actual stream channel, noting undercut banks and braided or split channels. Usually a stream section will have a combination of types. Check all that are observed. If possible, note the percentage of each type in the section.

Pollution sources: Check appropriate space. If "other" is checked, describe in the comment space at the end.

Gradient: This is a judgment factor, not easily measured without a clinometer. If the percentage of pool area in the section is 30% or less, the gradient is usually steep; if between 30% and 70%, it would be moderate; if more than 70%, then classify it as flat. Reference to a contour map is helpful.

Surrounding land use: Record by checking appropriate box (or boxes, if mixed land-use exists) in the area.

Water clarity: This item indicates turbidity levels (water visibility).

Relative fish abundance: From observations and the fish survey crew.

Going further

1. The data collected in this general stream survey is very basic and often does not provide enough information for biologists to determine limiting factors within the stream. A more detailed survey protocol—an aquatic habitat inventory—is available from your nearest Oregon Department of Fish and Wildlife STEP Biologist or local watershed council office. See the list on page 430 for the STEP Biologist nearest you or pages 507-510 for a list of watershed councils.

   The Aquatic Habitat Inventory is available in three levels. The "basic" level works well for schools. Although special training is valuable, it is not required. The "intermediate" level requires training and coordination with ODFW personnel prior to completing the survey. This survey provides important information for local fish biologists. Level three is the "research quality" survey. It requires extensive training and close supervision by ODFW personnel. Data collected from all three levels of the survey is compatible with Oregon Department of Fish and Wildlife data bases and is managed through the Natural Production Program's Aquatic Inventory Project. There is no charge for these materials, but training is required for the intermediate and research quality levels.

2. The U.S. Environmental Protection Agency's (EPA) *Streamwalk* survey is similar to the survey in this book but with more detail. Contact Environmental Protection Agency, Region 10, 1200 6th Ave, Seattle, WA 98101, (206) 553-6686, to get copies of this survey. There is no charge for these materials.

3. The Adopt-A-Stream Foundation's Streamkeeper's Stream Reach Survey (pp. 93-95) is also similar to the survey in this book. In addition they have a watershed inventory protocol (pp. 32-41) that may work well for students. You can find the Stream Reach Survey and the Watershed Inventory in the *Streamkeeper's Field Guide: Watershed Inventory and Stream Monitoring Methods*. It is available for $29.95 + $4.00 shipping and handling (WA residents add $2.37 sales tax). Order this guide from the Adopt-A-Stream Foundation, 600-128th Street NE, Everett, WA 98208, phone (206) 316-8592.

General stream survey data:

Part A

GENERAL STREAM SURVEY

PART A.

Stream ________________ River System ________________

County ________________ Surveyors ________________

Date ________Stream mouth location: TWP____ R____ Sec____

Survey Data:

Survey Section: River mile___ to River mile___ Total length___ miles

Landmarks: Starting point__________ Ending point__________

Stream width__________ Ft. today__________ Ft. at high water line.

Air temp______°F Water temp______°F

Flow: Avg. width______ft. Avg. depth______ft.

Feet/sec. velocity______ Time of day ______am ______pm

Bottom type: Rough (0.8)________ Smooth (0.9)________

Calculate CFS (W × D × V × bottom factor) = ________

Substrate type, by percentage:

______________% Boulder (3′+)   ______________% Cobble (6″–3′)   ______________% Gravel (1″–6″)

______________% Sand (1″–)   ______________% Bedrock

Percentage of section in pools:

0	10	20	30	40	50	60	70	80	90	100

Percentage of section shaded:

0	10	20	30	40	50	60	70	80	90	100

Streamside cover type:

Type	Abundant	Moderate	Sparse
Conifer Trees			
Deciduous Trees			
Grass and/or shrubs			

Erosion Points: Severe________ Loc. Rm________: Moderate________

Loc. Rm________: Slight________ Loc. Rm________

Barriers:

Type	Height (ft.)	Location (rm)
Dam		
Falls		
Culvert		
Log Jam		

Instream Structure (woody debris):

Type	Abundant	Moderate	Sparse	None
Logs				
Root Wads				
Limbs				
Brush				

Part B

PART B.

Valley profile: ☐ ☐ ☐   Channel profile: ☐ ☐ ☐ ☐ ☐

Pollution Sources: Silt________ Sewage________ Industrial________

Animal waste________ Irrigation return________ Other________

Gradient: Flat__________ Moderate__________ Steep__________

Surrounding land use: Forest________ Agric.________ Range________

Suburban________

Water Clarity: Less than 1″________ Between 1′ and 3′________

Over 3′________

Water Withdrawal: Location, Rm________ Type: Ditch________

Size________ Pump________ Size________ Screened? Yes________

No________ Unknown________

Relative Fish Abundance:

Species	SIZE (inches)	NUMBER/100 FEET 0.5	6-50	50+	METHOD OF OBSERVATION Visual	In Hand
Chinook						
Coho						
Steelhead						
Rainbow						
Cutthroat						
Other						

Additional Comments: ______________________________________

Wildlife inventory team

While walking the entire length of the survey site, record any sightings of wildlife. All survey teams should report any wildlife and wildlife sign to this team.

Use the following categories to classify sightings, recording them on the form provided on p. 450.

- **Songbirds:** All other species not noted below
- **Upland game birds:** All pheasant, partridge, quail, grouse, including band-tailed pigeon and mourning dove
- **Shorebirds:** Check in a bird field guide for shorebirds commonly found in your area
- **Waterfowl:** All ducks, geese, swans, and coots
- **Raptors:** All hawks, owls, and eagles
- **Reptiles/Amphibians:** All snakes, lizards, turtles, toads, frogs
- **Mammals:** All mammal species

Mark locations of significant sightings (evidence of sensitive, threatened, or endangered species or other species of note) on the map created by the map team.

Wildlife are easily disturbed by people moving through their habitat. Consider completing a wildlife survey (especially the bird portion) in the early morning hours or when other teams are not present. Sit quietly in one place for a time to observe more wildlife.

Be careful not to duplicate sightings of the same wildlife between teams. One coordinated data sheet for each surveyed stream segment should reflect the most accurate total possible for all wildlife species. Only record the totals for each of the seven categories. Record individual species names, if known.

This information is used as an index to the relative abundance of wildlife species in the Riparian Management Area (RMA). Record other observable evidence of wildlife use such as droppings, nests, burrows, and tracks in the additional information column on the data sheet.

Adapted from *Investigating Your Environment—Wildlife*, USDA Forest Service, Pacific Northwest Region, 1993 and previous versions.

Checklist

_____ clipboard, data sheet, pencil
_____ binoculars
_____ appropriate field guides (bird, mammal, reptile/amphibian)
_____ insect repellent (if necessary)
_____ bucket or daypack for equipment

Going further

1. Contact the local Oregon Department of Fish and Wildlife and ask to speak with the wildlife diversity biologist. Find out if they need help with wildlife surveys.
2. The Adopt-A-Stream Foundation's wildlife field procedures are described on pp. 80-82 of the *Streamkeeper's Field Guide: Watershed Inventory and Stream Monitoring Methods*. It is available for $29.95 + $4.00 shipping and handling (WA residents add $2.37 sales tax). Order this guide from the Adopt-A-Stream Foundation, 600-128th Street NE, Everett, WA 98208, phone (206) 316-8592.

Wildlife Inventory Data Sheet

Stream: ______________________ Observers: ______________________

Location: ______________________ ______________________

Date: ______________________ Weather: ______________________

Time: ______________________ ______________________

Category	Number of individuals observed	Species (optional)	Additional information
Songbirds			
Upland game birds			
Shorebirds			
Waterfowl			
Raptors			
Reptiles/ amphibians			
Mammals			

Photo record team

A photo record provides a visual method of of monitoring change in the Riparian Management Area (RMA). Use one roll of 36-exposure slide film—Ecktachrome 200 ASA. A heavily shaded area may need faster film.

Record the f/stop, speed and *a careful description* of each photo taken on the photograph log provided (p. 454). This description must be sufficient for others to take an identical shot during subsequent visits. Prominent, easily defined natural locations are preferable to stakes, rocks or posts, as man-made markers may be difficult to find in later years. **Be sure the map crew makes an accurate record of photograph sites.**

Four photo points will be required the day of the initial survey and on each subsequent monitoring visit to the RMA. Points will be:

- Near the upstream boundary
- Near the mid-point
- Near the downstream boundary
  Take three shots looking upstream and three shots looking downstream at each photo point. Of the three shots facing each direction, one should be an exact meter reading, one under-exposed by one f/stop and one overexposed by one f/stop. This should ensure one good photo of each point.
- Overlook
  This photo should be taken from some point showing the relationship of the RMA to its surroundings. Try to find a site that can easily be relocated and take three shots as described on the previous page.

If using a camera that will not allow an exposure change, use a 24-exposure roll and reduce the number of shots at each site to two.

Checklist

_____ camera (preferably 35 mm)
_____ film (Ecktachrome 200 ASA, 36 exposure)
_____ clipboard, data sheet, pencil
_____ flagging
_____ insect repellent (if necessary)
_____ bucket or daypack for equipment

This should still provide at least one good photo from each point while allowing a few remaining shots of other suggested photos for the record.

The photo points listed below will require 21 exposures of a 36-exposure roll. Suggestions for the remaining shots on the roll include:

- The most common vegetation (grass, shrubs and trees at a range of not more than 4 feet, 4 shots)

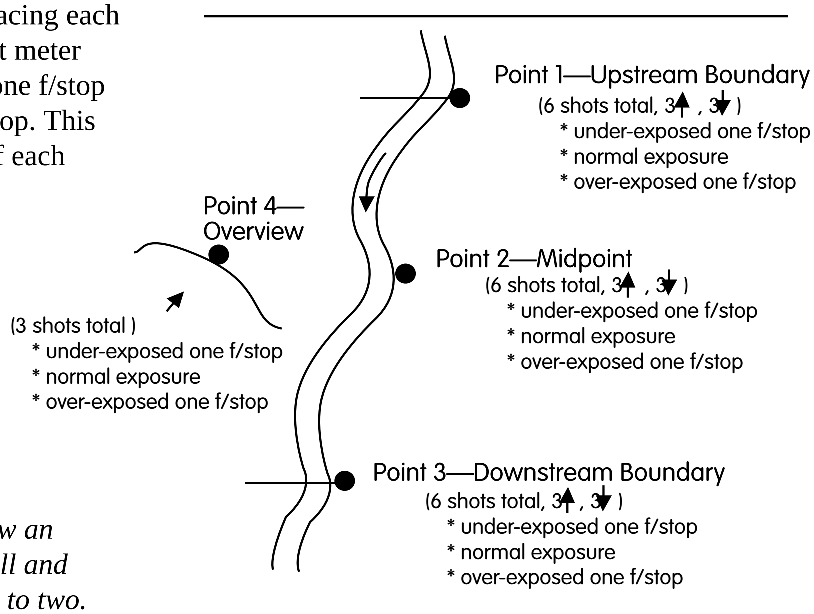


Photo Points

- One shot of a typical pool; one shot of a typical riffle
- One shot of a typical water line
- Nontypical pools
- Shots of groups performing testing procedures
- Group shot of survey teams
- Scenic or panoramic views of the area

The above photos will help complete the photo history and final report for the project.

Submit several photos from each visit to the site to appropriate agency personnel, such as a STEP biologist. A good rule of thumb includes one photo from the overlook and two photos from each of the other three points (one upstream and one downstream shot for each photopoint).

Some things to consider

- For long term accuracy and consistency, use the same camera, lens size, and film type for subsequent duplications. Also shoot the photo points as close to the same calendar date as possible each year.
- Devise a system to cross reference all points to the map. (For example: Photo Point 1-C means the third photo point in transect #1.) This "code" system must be marked on each slide or photo and on the map. Maintain a code reference sheet with the data and the photo record.
- To easily identify photos after processing, include a plot marker in each photograph (see example). Words and letters must be an inch or more in height. Attach the 8½"×11" plot marker to a clipboard. Place the plot marker in the bottom right corner of the photo plot.

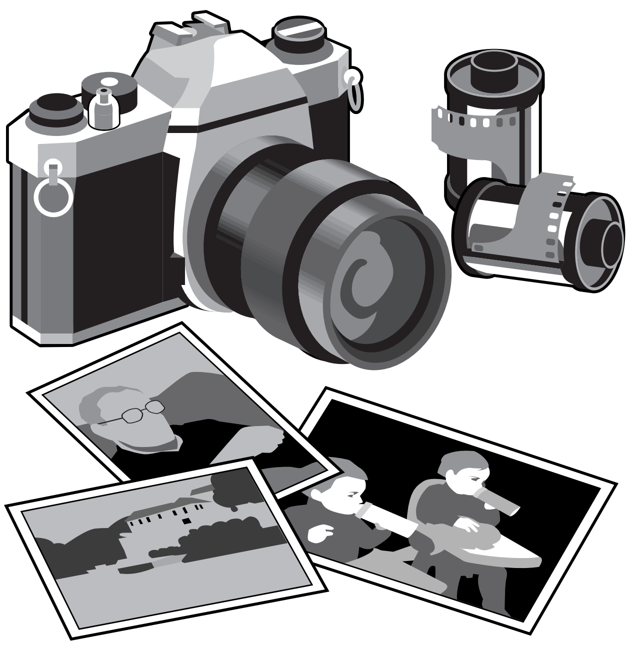
Pine Creek
Transect # 1
July 6, 1999
Plot # C
Upstream

- Record the date, project name or location, photo point reference, and photographer on each slide immediately upon receipt from the processing lab. To avoid damage to the photograph, use a fine-point felt marker to label the backs of any prints.
- Store slides or prints in clear plastic sleeves for protection from dust or handling damage. Plastic sleeves are usually three-hole punched and can be stored in a three-ring notebook.
- Try to include some permanent physical feature within the aiming point (e.g., trees, large rocks, background mountain peaks, fence panels, etc.)
- To photographically measure changes in vegetation height, include a measuring rod in the photograph. Placement of the rod must be consistent each time the photograph is taken.
- Always take careful notes as the photos are taken. Use the photo record data sheet to record this information. Include reasons why a particular photo point was chosen. It helps viewers not involved in the initial process to understand the objectives for the photos.
- Pick photo points that will monitor specific recovery sites. Consider the future desired condition when choosing the exact location for the shot. For example, if you want to record the changes in riparian vegetation, shooting the photo from the edge of the stream may only be effective for one or two years. Once the vegetation reaches a certain height, the photo point only shows a mass of vegetation. This may be dramatic but not useful for viewing long-term changes.
- Other useful shots might include a photo point every quarter mile, every visible reach (from one stream meander to the next), or other interesting points within the study reach.

- From a technical standpoint, duplicating the photo points once every two or three years is sufficient time for changes to occur in the ecological conditions of the study site. If you are doing this procedure with students, however, duplicate the photos each year (at the same time of year). Each class can then understand and appreciate the process and the need for photographic documentation as an integral part of any monitoring program.
- It is best to take slides, then have a series of prints made from selected slides. Prints are useful as field references when the next series of photos are taken.

Going further

1. For more detailed information about using photos as a monitoring tool, obtain the pamphlet *Photo Plots: A Guide To Establishing Points and Taking Photographs to Monitor Watershed Management Projects* from the Oregon (formerly, Governor's) Watershed Enhancement Board, 255 Capitol Street NE, 3rd Floor, Salem, OR 97310-0203, phone: (503) 378-3589.



Photographic Record

Stream: ____________________ Photographer: ____________________

Location: ____________________ ____________________

Date: ____________________ Weather: ____________________

Photo No.	Aperature (f/stop)	Speed	Description
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
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36			

Fish survey team

A number of Oregon's fish species are listed as threatened or endangered under the stipulations of the Endangered Species Act (ESA). **Do not proceed with any fish sampling procedures without approval of local Oregon Department of Fish and Wildlife fish district personnel.** Permits are required for sampling in some areas and sampling is not allowed in others. Some streams do not require permits. Ask first!

Checklist

- _____ fish measuring board
- _____ 100-foot tape
- _____ block nets (2)—furnished by ODFW if electrofishing
- _____ electrofishing equipment and catch nets (used only with assistance of ODFW personnel)
- _____ hand seine (4'x4')
- _____ fish anesthetic (furnished by ODFW)
- _____ clipboard, data sheets, calculator, and writing tool
- _____ thermometer
- _____ juvenile fish ID key
- _____ polarized glasses
- _____ waders or hip boots with felt soles or cleats
- _____ buckets (at least 2) for equipment and fish-holding
- _____ flagging
- _____ small dip net
- _____ plastic jar (for viewing and identifying individual fish)

Fish population sizes are a result of the chemical, biological, and physical factors surrounding them in the stream, especially those factors influencing levels of the food chains below them. This type of survey is designed to obtain information on the abundance, size and distribution of salmon and trout populations in Oregon's streams. The data collected will assist fish biologists and volunteers in determining fish habitat needs.

The fish population survey helps determine whether the stream is supporting numbers of fish consistent with its carrying capacity. It will reveal species present, age classes, condition of the fish, and some habitat conditions. Sampling for juvenile fish above suspected migration barriers helps determine if adult spawners are getting by the obstruction. Numbers of juveniles found may provide clues to spawning success.

Fish sampling can be difficult and requires good ability to identify species. Juvenile fish are difficult to identify when in hand, harder yet when seen in the water. It is sometimes impossible to distinguish between juvenile steelhead and cutthroat. Part of the training emphasizes fish identification. The illustrations on p. 462 are also useful as a guide.

Polarized glasses improve visibility significantly. Waders or hip boots must be used as a safety consideration when electrofishing. Traction devices, like felt soles, improve maneuverability in slippery streams.

Simple fish survey methods

Although it is often difficult to identify fish without having them in hand, students can at least document the presence or absence of fish and relative size classifications by simply viewing them from the streambanks. A pair of polarized sunglasses helps to cut the glare from the water's surface, making viewing easier. Fish are sometimes spooky so a quiet stealthy approach to the edge of the stream is advisable. Patience is also important. Sitting quietly on the streambank near suitable habitat can sometimes reveal interesting views of fish and their behaviors.

Angling surveys are sometimes used to document the presence of fish populations. Angling surveys can reveal the types of fish species (at least those willing to bite) in an area and provide size class information. Angling surveys also provide an opportunity to involve students in the Oregon Department of Fish and Wildlife's Angler Education program. Contact the Angler Education Coordinator, Oregon Department of Fish and Wildlife, PO Box 59, Portland, Oregon 97207, phone: 503-872-5264 ext. 5366 for more information.

Use angling surveys to teach students about "catch and release" procedures and good angling ethics. Angling efforts can focus on riffle areas or pool areas or other sites to obtain specific information about fish present in certain habitat types.

Data from angling surveys is called "creel data." One way creel data is analyzed is by "catch per unit of effort" (CPUE). In other words, how many fish did the angler catch per hour throughout the entire fishing experience.

Electrofishing method

1. Measure a representative 100-foot section of stream, placing a block net at both the upstream and downstream ends to keep fish within the reach. Secure the bottom and sides of the nets carefully so fish do not escape when crowded into the net. This also prevents new fish from coming into the sampling section from either above or below the site. Have the map crew note the sampling reach location on the survey map.
2. Note all information requested on the data sheet. All temperature and weather conditions should be noted *before* and *after* each pass as they can change considerably throughout the sampling time period.

Going further

1. Contact the nearest Oregon Department of Fish and wildlife fish district personnel for historical fish species and population information for your study stream. If it is not possible for students to collect their own data they can practice the analysis procedures and interpretations with the historical information or they can use the older information as background data for their ongoing studies.
2. For more advanced fish population monitoring procedures contact your local STEP Biologist (see map and information pages 430) or the ODFW Aquatic Inventory Project at (541) 757-4263. It may be possible for students to assist fisheries personnel with fish population surveys in local areas. Training is required for these more advanced procedures.
3. Completing a spawning survey is another way to monitor fish populations. Contact your nearest ODFW fish district personnel for more information about spawning survey opportunities in your area. Training is required for anyone participating in spawning surveys. Viewing spawning salmon, steelhead, or trout is a good way to reinforce the fish life cycle concepts presented in Chapter 9.2, page 355.
4. A snorkeling survey is another way to assess fish populations in streams. Snorkeling surveys require snorkeling gear and the ability to identify fish species under water. Snorkeling data is analyzed in a different manner. Consult with your nearest ODFW fish district before attempting snorkeling surveys.

3. Practice electrofishing techniques *outside of the sample section*. Make two complete passes in the sample section with the electro-shocker. Record the results from each pass separately on the data sheets provided.
4. As the fish are netted, place them in a bucket of stream water to which a small amount of anesthetic has been added (ODFW personnel will provide and monitor this if it is necessary to use it).
5. Using the fish measuring board, measure each fish from the tip of the snout to the fork of the tail to the nearest millimeter. Trade buckets frequently with those doing the netting to avoid overstressing the fish.
6. If possible, determine the species of fish and record all information on the data sheets provided. As soon as the data has been collected from each fish specimen, return it to a bucket of fresh water.

Keep all fish from the first pass separate from those captured in the second pass. Be sure the water in the bucket stays cool and well-oxygenated.

It is essential to work quickly to avoid harming the fish. Return all fish to the stream section from which they were taken as soon as possible.

Note:

Errors in the data may arise from several sources. It is important to note these possibilities to accurately interpret the data.

Poor netting during electrofishing may result in the loss of several fish and less accurate population estimates. Poor netting technique can be attributed to inexperience. It takes practice to learn the best techniques.

Inability to see fish as they come to the water's surface in response to the electrical current is another factor. Using polarized glasses helps.

Too much current can injure or kill fish.

Awareness of problem areas helps training and procedures move more smoothly. Consult with your STEP biologist for more information.

Analysis

Population density

Calculate the density of the fish population using the following formula:

$$N = \frac{(U_1)^2}{U_1 - U_2}$$

Where N = fish population estimate
U_1 = # fish collected in first removal
U_2 = # fish collected in second removal

Example:

$$N = \frac{(121)^2}{121-59}$$

N = 236.1 fish / 100 ft section

Standard error of the estimate

The standard error of the estimate is calculated using:

$$SE(N) = \sqrt{\frac{(U_1)^2 \times (U_2)^2 \times T}{(U_1 - U_2)^4}}$$

Where: SE(N) = standard error of estimate
T = total number of fish ($U_1 + U_2$)

Example:

$$SE(N) = \sqrt{\frac{(121)^2 \times (59)^2 \times 180}{(121-59)^4}}$$

SE(N) = 24.9 fish

The standard error of the estimate is the statistician's way of expressing the variability associated with the population estimate. Many factors, including water conductivity (determined by dissolved mineral content), pool depth, and fish size, can affect the accuracy of the sample.

Generally, the larger the standard error figure, the less reliable the population estimate.

Confidence interval

To take this estimate one step further, we can calculate the 95% confidence interval by using:

95% CI = ± 1.96 SE(N)

Where: SE(N) = standard error of estimate
CI = confidence interval

Example:

95% CI = ± 1.96×24.9
95% CI = ± 48.8 fish

In other words, there is a 95% chance the population of fish in the 100 foot section is between 187.3 and 284.9 fish (236.1±48.8 fish).

The size of the confidence interval is a function of the reduction in numbers of fish captured on the second pass compared to those captured during the first pass. The larger the reduction (more fish caught on the first pass as compared with the second pass), the better the confidence interval will be. A good rule of thumb in the field is to try for at least a 50% reduction in the fish captured on the second pass. For example, if 20 fish are captured during the first pass, the estimate will be more accurate if 10 or fewer fish are captured during the second pass.

In instances where large numbers of fish are captured on the first pass (>50 fish), or if less than a 50% reduction in fish is captured on the second pass, the confidence interval can be improved greatly by doing a third pass. A different calculation is required if a third pass is done. Your STEP biologist can provide you with the appropriate formula.

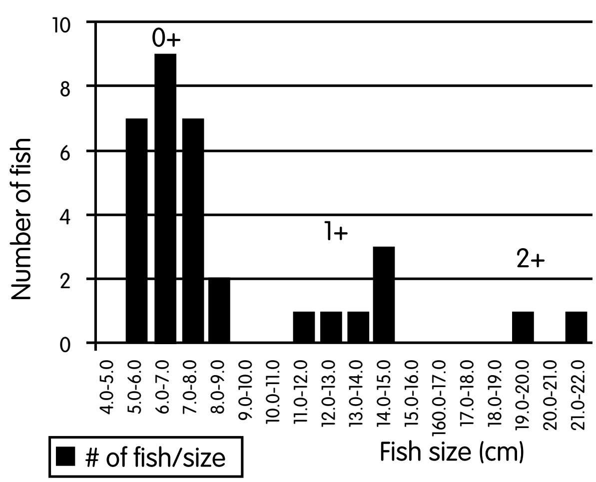
In determining the fish population in a stream reach it is not necessary to capture every fish living in the sampling site. By running through this series of calculations, an estimate of the actual population is obtained. Consistency with technique and sampling the same areas over time will provide the most reliable data for the biologists who use this information in making management decisions.

Age classes

Another way to analyze fish sampling data is to graphically represent the size distribution of the fish captured. This will show the various age classes of fish present in the stream.

Referring to the graph below, based on size distribution, three age classes of fish are likely present in the sampling area. With large numbers of fish less than 8 cm. in length, it can be concluded these fish represent young of the year (0+), the most recently hatched fish. Fish represented in larger size ranges are likely 1+ fish, that is, fish that have been in the stream for over a year. Some of the larger fish may be slow-growing two-year-old (2+) fish.

Fish-Length/Frequency Distribution



Hand-seining method

Another way to sample juvenile fish populations is with the use of a hand seine. A hand seine is composed of a 4'×4' foot piece of seine netting attached to a length of wood on either side that serves as a hand hold and aids net manipulation.

Choose a representative sampling section within the survey area. Different species of fish use different parts of a stream at various stages of their life. It is important that a good cross section of these habitats be sampled within a given area. Mark the sampling section with flagging and inform the map crew of its location.

Several small units will be sampled within the established site. Designate a starting point and ending point for each sample unit. The ending point should rest against a cutbank, pool tailout, or anything that can effectively trap fish in the area.

Measure the length and average width and depth of each unit (see diagram below).

- Measure the length of the unit from the upstream midpoint to the downstream midpoint. "Midpoint" refers to the midpoint of the current wetted width. This is most likely not a straight line from the upstream end to the downstream end of the sample unit.
- Measure at least three widths across the current wetted width of the sample unit and average.
- At each of the three places where you measured width, measure five to 10 depths (to the nearest tenth of a foot) across the current wetted width of the sample unit and average.

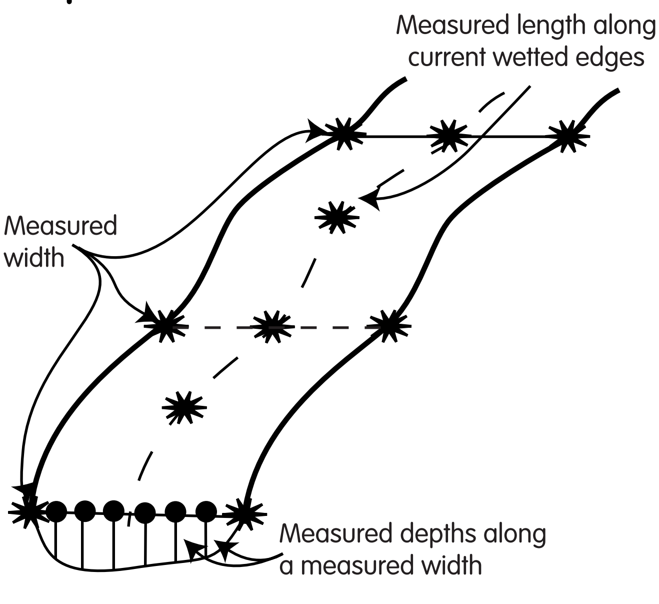
Enter these measurements on the data sheet (p. 463). Also note if the sample unit is a riffle or a pool. Try to balance the sample units between the two types.

Starting at the upstream end of the unit, walk slowly downstream, moving the seine through the water. Continue moving downstream through the section. Do not raise the net until close to a containment area such as an end point location.

Place netted fish in a bucket of fresh water to be counted, measured, and identified when each unit is completed. Record the information in the appropriate sections of the data sheets (p.463-464).

Repeat the above procedure for each sampling unit in the survey section.

Sample Unit Measurements



Analysis

Hand-seining sampling information is evaluated in a number of ways.

Calculate the area (ft^3) for each unit in the sampling reach (from Hand-seining Data Sheet, Part 2, p. 464). *Make sure all measurements are in the same units before multiplying.*

Area (ft^3) = L×W×D

Where: L = length (ft.)
W = width (ft.)
D = depth (ft. or tenths of a ft.)

Example:

Area (ft^3) = 20'×4'×3'

Area (ft^3) = 240 ft^3 or 8.9 yd^3

Note: (ft^3×0.03704 = yd^3)

Determine the size of the total sampling area by adding the areas (ft^3 or yd^3) of all sampling units.

Divide the total number of fish captured (transferred from Hand-seining Data Sheet, Part 1, p.463, to Hand-seining Data Sheet, Part 2, p. 464, for each unit sampled) by the total sampling area (ft^3 or yd^3) to get the number of fish per cubic foot or cubic yard. This figure can be analyzed by a biologist and compared to other streams with a known population density. This evaluation will indicate whether the stream is producing up to its potential.

25 fish÷240 ft^3 = 0.1 fish per ft^3

25 fish÷8.9 yd^3 = 2.8 fish per yd^3

Another way to evaluate this information is to determine the number of fish caught per unit of effort (CPUE).

CPUE = total # fish÷total # units

Example:

CPUE = 25 fish÷13 sampling units

CPUE = 1.9 fish

or

CPUE = 10 cutthroat÷13 sampling units

CPUE = 0.7 cutthroat

or

CPUE = 15 RB-ST÷13 sampling units

CPUE = 1.2 rainbow/steelhead

Data collected with the hand seining technique is evaluated differently than that obtained by electrofishing. As with electrofishing, however, consistency with technique and sampling the same areas over time will provide the most reliable information.

Notes

References useful for evaluating fish population studies:

Lagler, Karl. *Freshwater Fishery Biology*. Dubuque, IA: Wm. C. Brown, Co., 1956, pp. 167-177.

Seber, G.A., and Ed LeCren. "Estimating Population Parameters From Catches Large Relative to the Population." *Journal of Animal Ecology*, 1967, 36:631-643.

Zippin, Calvin. "The Removal Method of Population Estimation." *Journal of Wildlife Management*, January 1958, 22:82-90.

Fish Survey: Electrofishing

Key:

CH — Chinook
CO — Coho
RB-ST — Rainbow/Steelhead
CT — Cutthroat
O — Any other species (note kind if known)

Stream ______________________ River system ____________________

County ______________________ Surveyors ____________________

Date ______________________

Weather conditions: ____ cloudy (%) ____ wind (direction) ____ rain ____ clear

Streamflow: ____ very low ____ moderate ____ high Visibility: ____ less than 1' ____ 1'–3' ____ over 3'

Frequency _________ Voltage _________ Sample site: Length ________ / Avg. width ________ / Avg. Depth ________

1st pass (before/after)**:** Time ____________ / ____________ Air temperature ____________ / ____________

Water temperature ____________ / ____________

2nd pass (before/after)**:** Time ____________ / ____________ Air temperature ____________ / ____________

Water temperature ____________ / ____________

Description of sample site: ____

____

Habitat type:
- ☐ pool
- ☐ riffle
- ☐ mixed

Sample site location Start: T ______ R ______ S ______

End: T ______ R ______ S ______

Sample site # _____

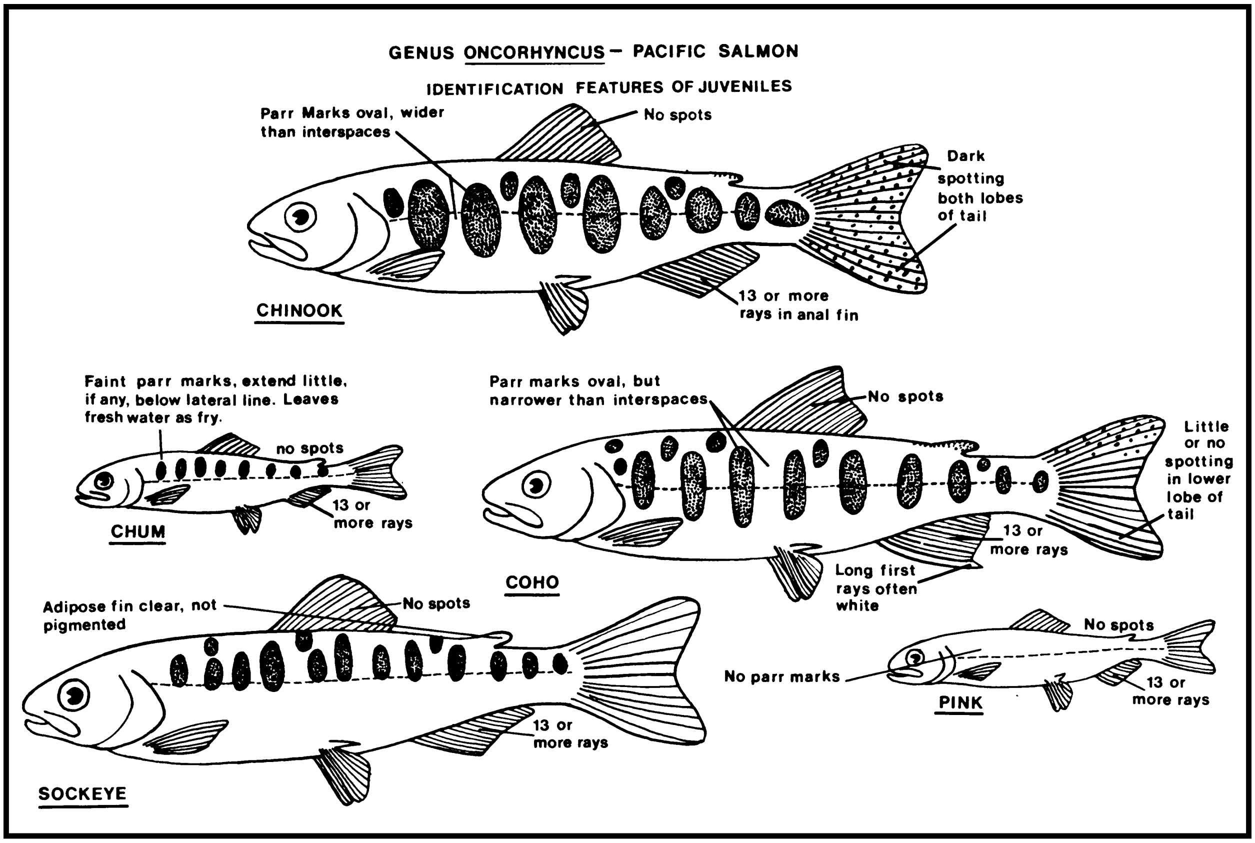
Tally non-game species by fork length group. Measure salmonids and separate each with commas.

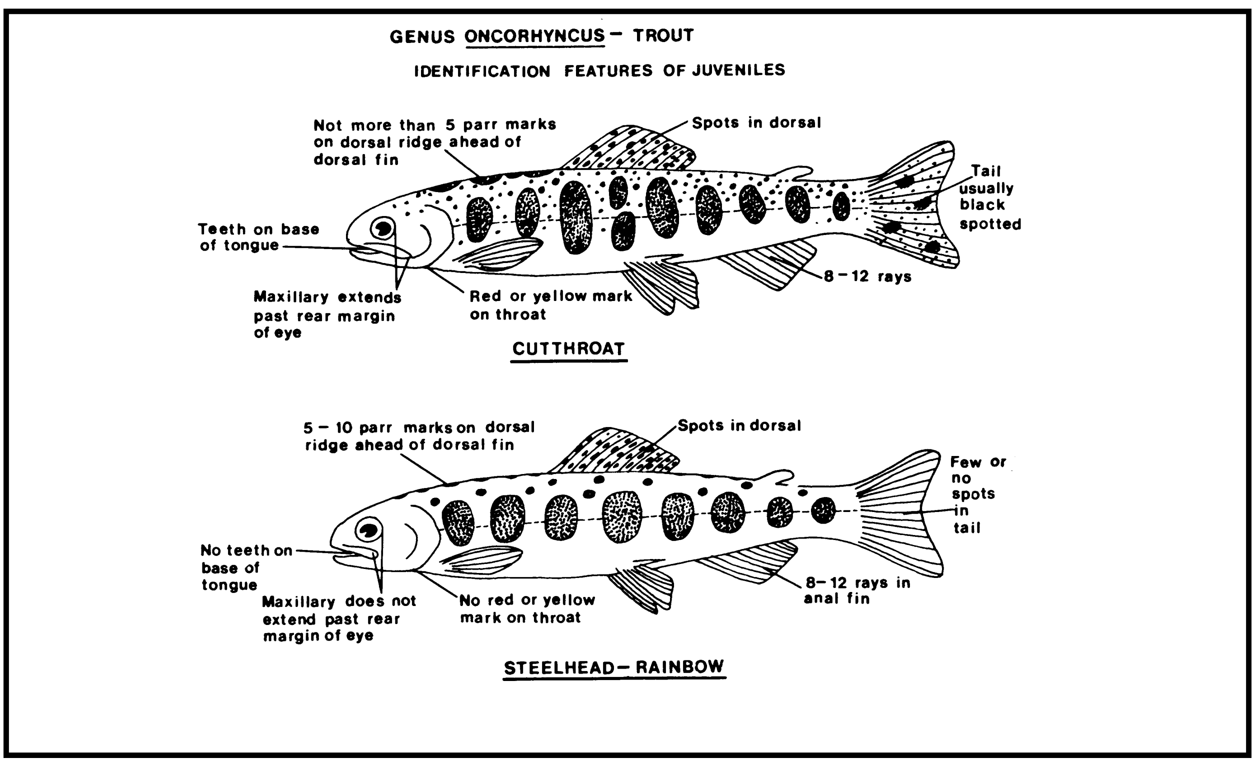
Fish code	3-5.9	6-8.9	9-11.9	12-14.9	15-17.9	18-20.9	21.23.9	24-26.9	27-29.9	30-32.9	33-35.9	36-38.9	39-41.9	>42	Pass 1
															Pass 2

Total (1st pass) = ______________________ Total (2nd pass) = ______________________

Note: Use as many sheets as necessary.

Juvenile Fish ID Key





Fish Survey: Hand-seining, Part 1

Key:

CH — Chinook
CO — Coho
RB-ST — Rainbow/Steelhead
CT — Cutthroat
O — Any other species (note kind if known)

Stream ____________________ River system ____________________

County ____________________ Surveyors ____________________

Date ____________________

Weather conditions: ____ cloudy (%) ____ wind (direction) ____ rain ____ clear

Streamflow: ____ very low ____ moderate ____ high Visibility: ____ less than 1' ____ 1'–3' ____ over 3'

Sample site: Length ________ / Avg. width ________ / Avg. Depth ________

(before/after): Time ____________ / ____________ Air temperature ____________ / ____________

(before/after): Water temperature ____________ / ____________

Description of sample site: ____

____

____

Habitat type:
☐ pool
☐ riffle
☐ mixed

Sample site location Start: T ______ R ______ S ______
End: T ______ R ______ S ______

Sampling unit #: ______

Fish collected	Lengths (mm) by species				
	CH	**CO**	**RB-ST**	**CT**	**Other**
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
Totals					

Note: Measure all fish collected or first 25 of each species and count remaining fish if large numbers are collected. Transfer totals to appropriate row on catch/unit of effort summary sheet.

Fish Survey: Hand-seining, Part 2

Stream ____________________ River system ____________________

County ____________________ Surveyors ____________________

Date ____________________

Key:

CH — Chinook
CO — Coho
RB-ST — Rainbow/Steelhead
CT — Cutthroat
O — Any other species (note kind if known)

Sample site location Start: T ______ R ______ S ______
End: T ______ R ______ S ______

Catch/unit of effort summary

Sampling Unit #	Number Caught					Unit Size (ft)				Unit Type	
	CH	CO	RB-ST	CT	Other	L	W	D	Ft^3	Riffle	Pool
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
Totals											

Water quality survey team

Air and water temperature

Take the temperature of the air and the water at the same sites where pH and dissolved oxygen tests are taken. Be sure the map crew marks the sampling sites on the map. One site will be at the upstream end and one at the downstream end of the survey area. A third site is optional.

1. Record the time of day and the air temperature at the sample site.
   - Make sure the bulb of the thermometer is clean and dry.
   - If you can see shadows, shade the bulb. (Use a hand, body, hat, or whatever, but keep it at least 2 inches away.) Direct exposure to the sun will give a "false" reading.
   - Record the temperature in both °C and °F on the data sheet. See conversion formulas on p. 469.
2. Record the time of day and the water temperature at the sample site.
   - Put the bulb of a thermometer one-half inch to 2 inches into the water where the other readings will be, or have been taken. Choose a representative section of the stream with about average water velocity. Do not use side channels or backwaters.
   - Wait two to three minutes for the thermometer to reach equilibrium.
   - Take the reading while the thermometer is still submerged.
   - Record the time each temperature was taken.
   - Record the temperature on your data sheet.

Checklist

_____ Hach or other water quality test kit (for dissolved oxygen and pH testing)

_____ thermometer

_____ 50-foot (or longer) measuring tape

_____ stopwatch (or watch with second hand)

_____ orange (or other object which will float low in the water)

_____ depth measuring rod

_____ clipboard, data sheets, and writing tool

_____ flagging

_____ bucket for equipment

pH

Water with a pH range of 6.7 to 8.6 will generally support a population of fish. Salmon and trout species generally need a pH range of 6.5 to 7.5. Note that with certain species of fish, there are also specific insects present. Data gathered from this test, along with the invertebrate survey information and other stream characteristics, can give an idea of which fish might live in a particular habitat.

For the purposes of this study, the instantaneous value of pH is sufficient.

Do the pH tests at the same sites where dissolved oxygen and temperature are tested.

1. Follow the test procedure outlined in the Hach or other type of water quality test kit. Dispose of plastic packets in the container provided.
2. Pour used water into the bucket provided by the team leader. *Do not pour water contami-*

nated with chemicals into the stream or on the streambank.

3. Perform the test procedure at least three times and determine the average.
4. Report the test sites to the map crew.
5. Record the information on the data sheet.

Dissolved oxygen

The dissolved oxygen (DO) test is one of the most important in determining water quality.

Dissolved oxygen is essential for the survival of aquatic plant and animal life. For adequate populations of game fish, dissolved oxygen should be in the 8 to 15 mg/liter range.

Perform the tests for dissolved oxygen at the same sampling sites used for pH and temperature.

1. Follow the directions outlined in the Hach or other type of water quality test kit.
2. Take at least three (five is preferred) water samples at each site. No air should be in the bottle. Sample within 2½ inches of the stream surface, at least 6 inches from the streambank, in water moving at the average velocity for the stream. Enter the results on the data sheet.
3. Report the test site to the map crew. Record the time of day the sampling procedure was conducted.
4. Dispose of plastic packets in the container provided. Pour used water in the bucket provided by the team leader. **Do not pour water contaminated with chemicals into the stream or on the streambank.**

Streamflow

Flow site selection

Select two representative sites as far apart as possible in the total study area. Sharp turns or very rough bottoms will slow the water and should not be considered representative.

Measure a 50-foot section at each site. Mark the upper and lower ends of the section for easy reference.

Width

At each flow site, measure the width to the nearest tenth of a foot in three places (see example). Select places that do not have large slack areas at the edge. Record these measurements on the data sheet and compute the average.

Depth

At each of the three places where you measured the width of the stream, measure the depth to the nearest tenth of a foot at five equally spaced places across the stream (see example). Record your measurements on the data sheet and compute the average.

Velocity

Velocity is a measure of how fast something moves. Water velocity can be measured by timing how fast a floating object travels 50 feet in a stream deep enough to float the object. Wind can be a factor, so use an object that floats low in the water—an orange, fishing bobber, stick or leaf). Dye specifically designed for streamflow determinations may also be used. Calculate the velocity using the formula below.

The average of three to five trials should give a good velocity figure.

$$V = \frac{50 \text{ ft}}{x \text{ sec}}$$

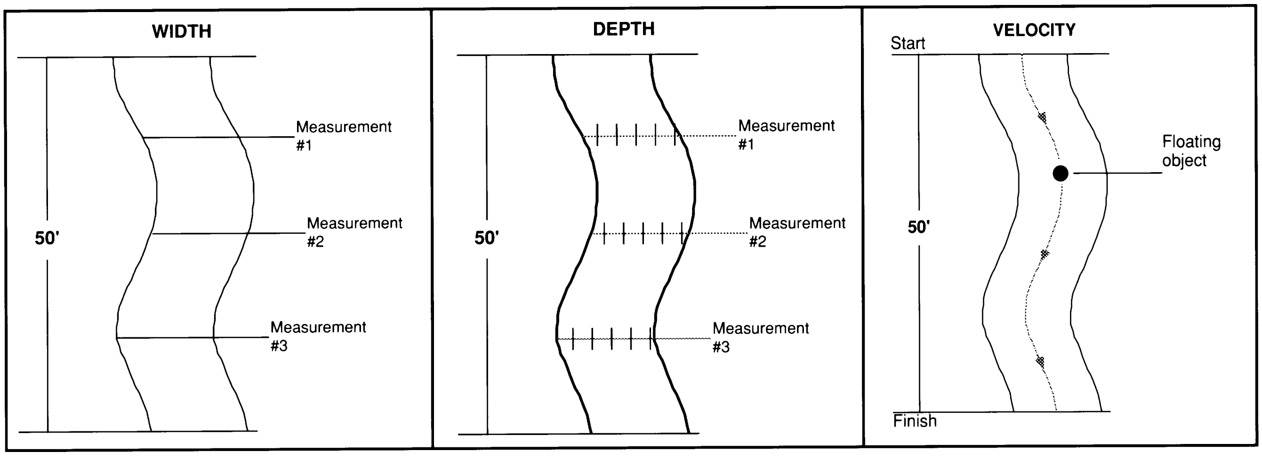
Where: x is the number of seconds it takes object to float 50 ft

V = Velocity

Example: If your object floats 50 feet in 25 seconds, velocity is:

$$V = \frac{50 \text{ ft}}{25 \text{ sec}}$$

$$V = 2 \text{ ft/sec}$$



Bottom factor

Look at the bottom of the stream. If it is rubble, gravel or plants, the bottom factor (a) = 0.8. If the bottom is smooth mud, silt or bedrock, the bottom factor (a) = 0.9.

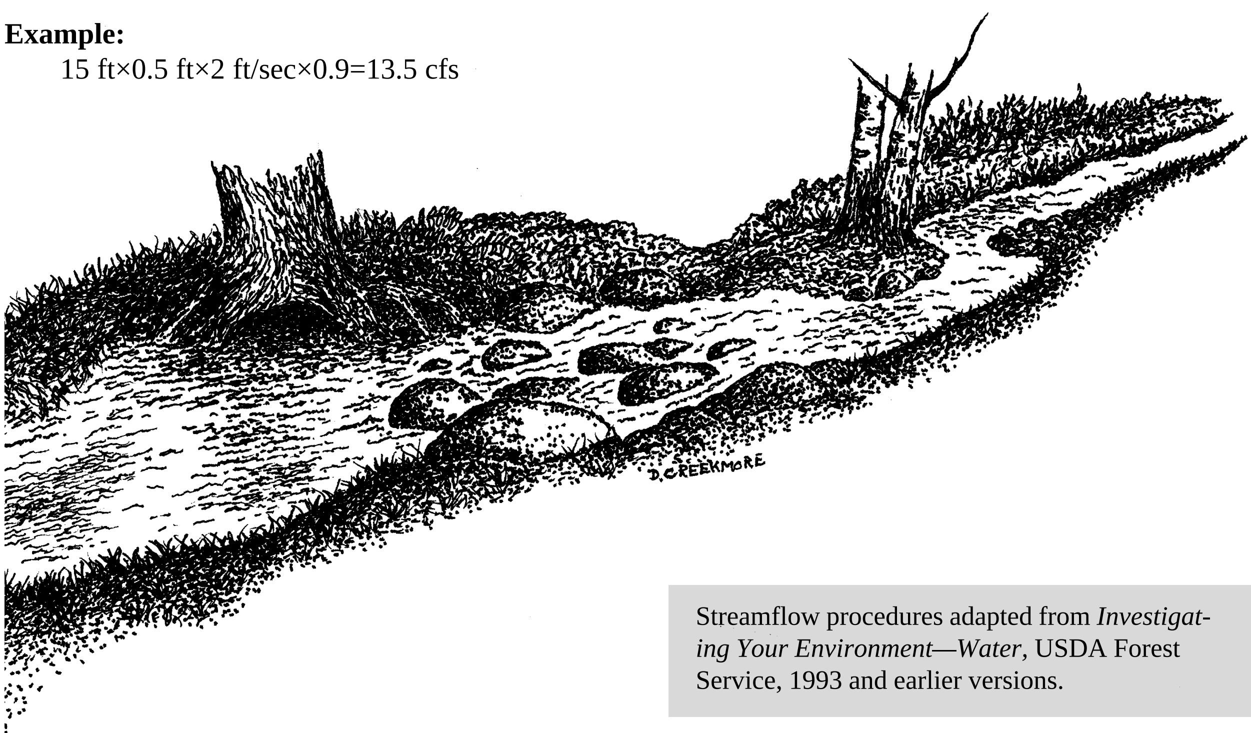
Streamflow

Compute streamflow (discharge) in cubic feet per second (cfs) using the formula below for each of the two sites.

Streamflow in cubic feet per second (cfs) = width×depth×velocity×bottom factor

Example:

15 ft×0.5 ft×2 ft/sec×0.9=13.5 cfs



Streamflow procedures adapted from *Investigating Your Environment—Water,* USDA Forest Service, 1993 and earlier versions.

Going further

1. If your students have mastered the basic water quality sampling procedures and want to do more, consider becoming part of the Oregon Plan for Salmon and Watersheds monitoring team. One of the requirements of the Oregon Plan for Salmon and Watersheds is monitoring to determine the status and trends of salmon populations and of stream and landscape conditions that affect them. Many different agencies, volunteer groups, and private citizens are involved in data collection, so it is important to apply a consistent approach to all monitoring efforts. These standardized statewide monitoring procedures for water quality were developed by a water quality monitoring team established in 1998. The protocols rely heavily on Oregon Department of Environmental Quality and Oregon Department of Forestry procedures. The protocols are packaged in the *Water Quality Monitoring Guide Book*. The guidebook describes methods for getting specific, field-based data about your site, reach and watershed and for successfully assessing water quality. Protocols are provided for monitoring:

   - stream temperature
   - stream macroinvertebrates
   - sediments
   - dissolved oxygen
   - surface water conductivity
   - pesticides and toxins
   - surface water pH
   - fecal coliform
   - nitrogen and phosphorus

   Properly collected data is useful to landowners, concerned citizens, and agencies. Poorly collected data of unknown quality is an unfortunate loss of significant time and money. The guidebook provides guidelines to accurately collect data that will help everyone work toward a solution to restoring healthy watersheds and fish populations.

   Additional training may be necessary for you and your students to use the protocols described in the *Water Quality Monitoring Guidebook*.

   To get a copy of the *Water Quality Monitoring Guidebook* contact the Oregon Department of Environmental Quality, 1712 SW 11th Street, Portland, Oregon 97201, phone: (503) 229-5983 or the Oregon (formerly Governor's) Watershed Enhancement Board, 255 Capitol Street NE, 3rd Floor, Salem, Oregon 97310-0203.

2. The Adopt-A-Stream Foundation's Streamkeeper's streamflow (pp. 108-117) and other water quality sampling procedures (pp. 168-183) are described in the *Streamkeeper's Field Guide: Watershed Inventory and Stream Monitoring Methods*. It is available for $29.95 + $4.00 shipping and handling (WA residents add $2.37 sales tax). Order this guide from the Adopt-A-Stream Foundation, 600-128th Street NE, Everett, WA 98208, phone (206) 316-8592.

Temperature data record

Date: _______ Observers: ___________________

	Air temperature			Water temperature		
	°C	°F	Time	°C	°F	Time
Site 1						
Site 2						
Site 3 (optional)						

Note: 9/5 °C + 32 = °F 5/9 (°F – 32) = °C

pH data record

Date: _______ Observers: ___________________

	Sample 1	Sample 2	Sample 3	Ave.
Site 1				
Site 2				
Site 3 (optional)				

DO data record

Date: _______ Observers: ___________________

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Time
Site 1							
Site 2							
Site 3 opt.							

Date: ______________ Observers: ____

Streamflow Data Sheet

Site #1

Measure	1					2					3					Average
Width (low water)	________ ft					________ ft					________ ft					w = ______
Depth	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
	Average ________ ft					Average ________ ft					Average ________ ft					d = ______
Velocity (Distance/Time)	____ ft ÷ ____ sec = ________ ft/sec					____ ft ÷ ____ sec = ________ ft/sec					____ ft ÷ ____ sec = ________ ft/sec					v = ______
Bottom factor:	rubble, gravel, or plant a = 0.8 smooth mud, silt, or bedrock a = 0.9															a = ______

Streamflow (r) = w X d X v X a

Streamflow site #1 = ________ X ________ X ________ X ________ = ________ ft^3/sec

Site #2

Measure	1					2					3					Average
Width (low water)	________ ft					________ ft					________ ft					w = ______
Depth	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
	Average ________ ft					Average ________ ft					Average ________ ft					d = ______
Velocity (Distance/Time)	____ ft ÷ ____ sec = ________ ft/sec					____ ft ÷ ____ sec = ________ ft/sec					____ ft ÷ ____ sec = ________ ft/sec					v = ______
Bottom factor:	rubble, gravel, or plant a = 0.8 smooth mud, silt, or bedrock a = 0.9															a = ______

Streamflow (r) = w X d X v X a

Streamflow site # 2 = ________ X ________ X ________ X ________ = ________ ft^3/sec

Macroinvertebrate survey team

Aquatic insects are a major food source for fish. In the same way food availability affects the distribution of fish in a stream, aquatic insects live in that part of the stream that provides the right food source.

In this activity you will learn about the types of aquatic insects, how they feed, where they feed, the role they play in the stream, and what they can tell us about stream health.

Checklist

_____ sorting screens (1-mm sieve)—optimal
_____ magnifying glass or hand lens
_____ containers for sorting (cartons and/or ice cube trays)
_____ forceps and probes
_____ single-edge razor blade (for scraping rocks)
_____ eyedroppers
_____ small artist's paintbrushes
_____ clipboard, data sheet, and writing tool
_____ field guides and/or other identification aids
_____ bucket for equipment
_____ collecting net (D-frame aquatic sampling net is recommended)
_____ viewing scope for substrate

1. When you arrive at the stream, look for different habitats where fish and insects live. Examples are **pools** where the water is deep and the surface is fairly quiet, **riffles** where the water is shallow and ripples over the rocks, and **backwaters** at the stream's edge that are shallow and quiet. These habitats are identified primarily by characteristics of water flow. The size of rocks in the stream, the amount of leaf or fine woody litter, and large woody debris (branches or logs) also help determine the distribution and abundance of invertebrates.

2. Use the following procedures to collect a sample from each of the habitat types—riffles, pools, and backwaters.

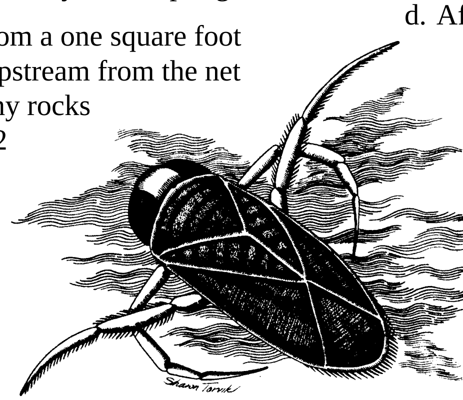
   a. To avoid disturbing the sample area, approach the habitat type from the downstream end. Place the D-frame aquatic sampling net or other sampling device firmly on the bottom, perpendicular to the flow at the lower end of your sampling site.

   b. Collect a sample from a one square foot area immediately upstream from the net opening. Pick up any rocks that are more than 2 inches in diameter and while holding them underwater in front of the net, gently rub, scrape, or brush their surfaces so the water will carry any dislodged organisms into the net. Place "cleaned" rocks outside of the sample area.

   c. If present include coarse organic matter (primarily leaf, needle, and fine wood litter) and pieces of water-logged branches and wood in your sample.

   d. After larger rocks and debris have been rubbed and set aside, stir up the bottom of the one foot square sample area to a depth of at least 1 inches to 2 inches, allowing the current to carry particles and organisms into the net.

   e. Collect at least three samples per habitat type (riffles, pools, backwaters) to get an average count per habitat.



3. Wash the material from the sieve into a shallow white pan. Add just enough stream water to cover the sample. (Optional: Wash each sample into a 1-millimeter sieve, then wash the materials into the sorting pan.)

4. Use tape and a waterproof marker to label the sections of the ice cube tray. Use labels like mayflies, stoneflies, caddisflies, beetle larvae, dragonflies, and others appropriate for the area you are sampling. You may need to consider subdividing some of the groups, for example, stony case caddisflies and organic case caddisflies. Fill the labeled ice cube tray with stream water. Using forceps, plastic spoons, eyedroppers, or small brushes gather the insects and place them in the appropriately labeled cube

5. Use a dichotomous key to separate invertebrates into functional feeding groups: shredders, scrapers, filtering collectors, gathering collectors, and predators. (See below or consult other similar guides.)

6. Count the kinds of invertebrates and the numbers of each kind for each functional feeding group. Enter these numbers on the data sheet. Complete the percentage of each group/habitat from the numbers.

   To gain a better idea of the variety of organisms, list invertebrates within each functional feeding group by "kind." Riffle beetles and mayflies are different kinds. If you can tell two different types within a "kind" (e.g., two different caddisflies), but do not know the specific names, simply list them as "caddisfly A" or "caddisfly B."

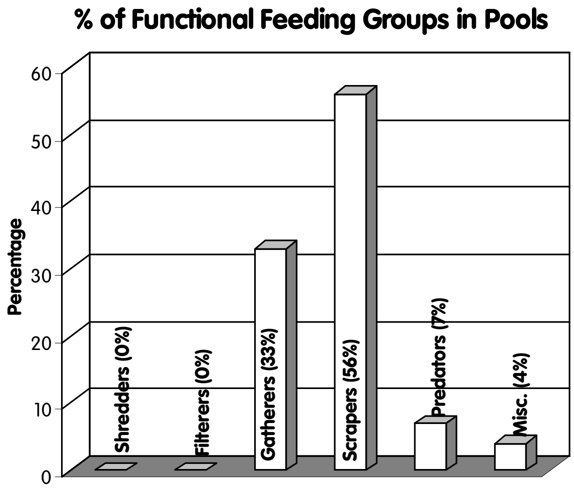
7. If possible, estimate the kinds and types of substrates where you sample and record on the data sheet *before* you collect the sample. An aquascope, or clear plastic mounted at the end of a long styrofoam box, will help cut surface water turbulence. Refer to the sizes

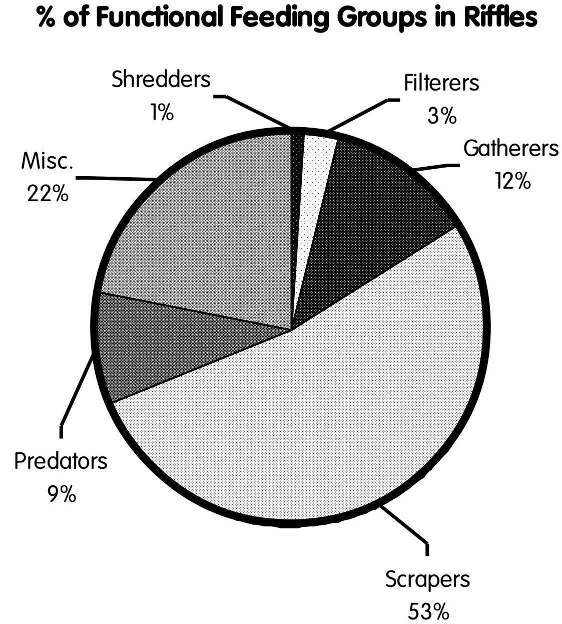
Aquatic Insect Guide

Builds a portable "house" or case to live in	**Caddisfly**
If case is made of material that was once living (wood, leaves, etc.)	**Shredder**
If case is made of mineral material (rocks, sand grains)	**Scraper**
Has two tails, without abdominal gills	**Stonefly**
If dark and uniformly colored	**Shredder**
If large and brightly colored and/or mottled	**Predator**
Has three tails (sometimes two), with abdominal gills	**Mayfly**
If flat, sometimes egg-shaped	**Scraper**
If cigar-shaped	**Gathering Collector**
Worm-like, without true legs	**Flies**
If <1 cm long, 1 pair stubby "legs," head well developed	**Gathering Collector (Midge)**
If >1.5 cm long, head reduced, often found in leaf litter	**Shredder (Cranefly)**
Antennae modified as tiny fans	**Filtering Collector (Blackfly)**
Free-living, 3 pairs of legs	**Odonates/Beetles**
If large, with gills at end of abdomen	**Predator (Damselfly, Dragonfly)**
If no gills, usually tough outer covering, jaws often easy to see	**Beetles**
Dark brown; tough outer covering	**Gathering Collector (Riffle Beetle)**
Color varied; abdomen soft-bodied	**Predator (Beetle)**

Adapted from: Bill Hastie, "What Wiggles in Winter Water," *Oregon Wildlife*, December 1983, p. 15.

Example Bar and Pie Graphs





listed on the chart for rock categories. Use the following categories for organic material:

- Coarse organic matter (primarily leaf needle and fine wood litter >1 mm in diameter)
- Fine organic matter (<1 mm to 0.45 mm)
- Large wood (logs, stumps, branches)

For each sampling site list substrates as percentages (e.g., 25% sand, 50% cobble, 25% coarse organic matter). The total of all substrate types should equal 100%.

Analysis

The analysis compares samples, either as habitat types within a small stretch of stream (a reach), as different reaches along one stream, or even as samples from different streams.

a. After sorting has been completed, calculate the percentage of each functional feeding group to the total. Total = number of shredders + filtering collectors + gathering collectors + scrapers + predators.

Example:

Habitat 1—Backwaters
# of shredders = 10
Total invertebrates = 20

$$\frac{\text{Shredders}}{\text{Total}} \times 100 = \text{ \% shredders}$$

$$\frac{10}{20} \times 100 = 50\% \text{ shredders}$$

b. Draw a bar or pie graph (see examples below) showing percentages for each functional feeding group for the each habitat type).

c. Compare these graphs for all of your study all habitat types: riffles, pools, and backwaters. Consider whether the proportion of each functional feeding group fits what you might expect in each habitat. For example, when a lot of leaf litter is present, many shredders could be expected. In a sunny spot with an abundance of algae, more scrapers should be found.

Going further

1. If your students want to get more involved with macroinvertebrate sampling, consider becoming part of the Oregon Plan for Salmon and Watersheds monitoring team. One of the requirements of the Oregon Plan for Salmon and Watersheds is monitoring to determine the status and trends of salmon populations and of stream and landscape conditions that affect them. Many different agencies, volunteer groups, and private citizens are involved in data collection, so it is important to apply a consistent approach to all monitoring efforts. These standardized statewide monitoring procedures for water quality were developed by a water quality monitoring team established in 1998. The protocols rely heavily on Oregon Department of Environmental Quality and Oregon Department of Forestry procedures. The protocols are packaged in the *Water Quality Monitoring Guide Book*. The guidebook describes methods for getting specific, field-based data about your site, reach and watershed and for successfully assessing water quality. Protocols are provided for monitoring:

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   - nitrogen and phosphorus

   Properly collected data is useful to landowners, concerned citizens, and agencies. Poorly collected data of unknown quality is an unfortunate loss of significant time and money. The guidebook provides guidelines to accurately collect data that will help everyone work toward a solution to restoring healthy watersheds and fish populations.

   Additional training may be necessary for you and your students to use the protocols described in the *Water Quality Monitoring Guidebook*.

   To get a copy of the *Water Quality Monitoring Guidebook* contact the Oregon Department of Environmental Quality, 1712 SW 11th Street, Portland, Oregon 97201, phone: (503) 229-5983 or the Oregon (formerly, Governor's) Watershed Enhancement Board, 255 Capitol Street NE, 3rd Floor, Salem, Oregon 97310-0203.

2. The Adopt-A-Stream Foundation's Streamkeeper's macroinvertebrate sampling procedures are described on pages 129-163 of the *Streamkeeper's Field Guide: Watershed Inventory and Stream Monitoring Methods*. It is available for $29.95 + $4.00 shipping and handling (WA residents add $2.37 sales tax). Order this guide from the Adopt-A-Stream Foundation, 600-128th Street NE, Everett, WA 98208, phone (206) 316-8592.

Team members ______________________________

Date ______________________
Stream ______________________
Site ______________________

Data Sheet for Macroinvertebrate Feeding Groups

Numbers of organisms/functional feeding group

		Habitat type:		Habitat type:		Habitat type:	
		Kinds	Numbers	Kinds	Numbers	Kinds	Numbers
Shredders							
Filtering collectors							
Gathering collectors							
Scrapers							
Predators							
Miscellaneous							
Substrate (% composition)	Boulders (>12")						
	Cobble (3"-12")						
	Gravel (0.2"–3")						
	Sand (<0.2")						
	Silt (<0.2")						
	Clay (<0.2")						
	Organic material						
Notes							

Stream mapping survey team

A map is an integral part of any stream monitoring project. It is a permanent record of the stream, showing its original state, data collection sites, where changes may be effective, what changes were made, and what effect the changes had. It also makes it possible for others to find test sites on the stream.

Identify features

Include features that are useful for orientation or that could be foundations for instream structures, stream width and bends. Also record the scale used to draw the map and an arrow showing true north.

Examples of general features are:

- logs in the stream
- logs over or along stream
- root wads
- large boulders (2½' to 3')
- gravel bars
- falls
- rapids
- chutes (include dimensions)
- photo points
- water analysis points
- cliffs
- islands
- pools and pool depth
- undercut banks
- tributaries
- stream width
- riffles
- cutbanks (height)
- 100-foot marks
- fish sampling points
- invertebrate fish sampling points

Along streams with little streamside vegetation, indicate on map:

- vegetation that may provide shade (note time when areas are in shade)

Along streams with a shallow profile, note:

- floodplain width (if significant)

Checklist

_____ 100-foot tape (2)
_____ ruler
_____ gridded mylar (10 squares to the inch, or graph paper treated with Stormproof® or other water repellent if possible)
_____ pencil (doesn't smear when wet)
_____ clipboard
_____ magnetic compass
_____ flagging
_____ depth staffs (3) marked off in tenths of ft. (or meters)

Scale

Accuracy of the scale determines the accuracy of the map. A convenient scale for mapping quarter-mile sections is 1"=100'. Using this scale, a quarter mile of stream (1,320 ft) will fit on legal size (8½"×14") paper.

Use 10-square-per-inch graph paper, with each square representing a 10'×10' area.

True north

An arrow indicating true north makes the map easier to use and more accurate. It can also help determine stream shading, where cover is needed, and other physical factors.

To compensate for the difference between true and magnetic north, you would need to set your compass. For example: if the magnetic declination is 21ºE (determined by looking at a topographic map of the area), then set your compass bearing at 339º (360º–21º=339º). (See Figure A on next page.) This offsets the compass variation of 21ºE for your locality. Check a topographic map for your area for the local declination.

Hold the stream grid map with the long axis parallel to the long axis of the stream. Place the compass on top of the map and adjust until the compass arrow is centered on the north point (see Figure B). Mark along a straight side of the compass parallel to the "direction of travel arrow." This is true north.

If you have a compass with a mechanical means for adjusting the declination, read the directions that came with the compass.

Figure A

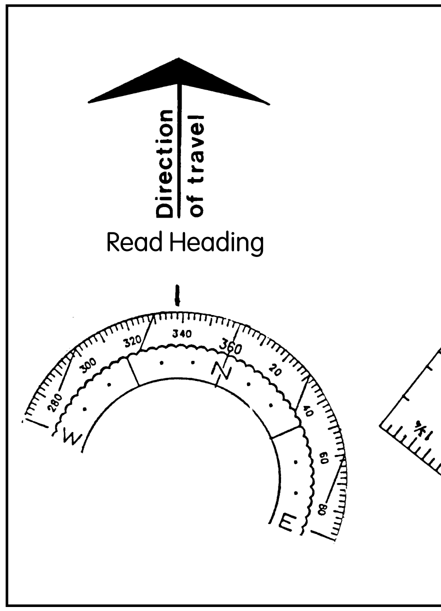
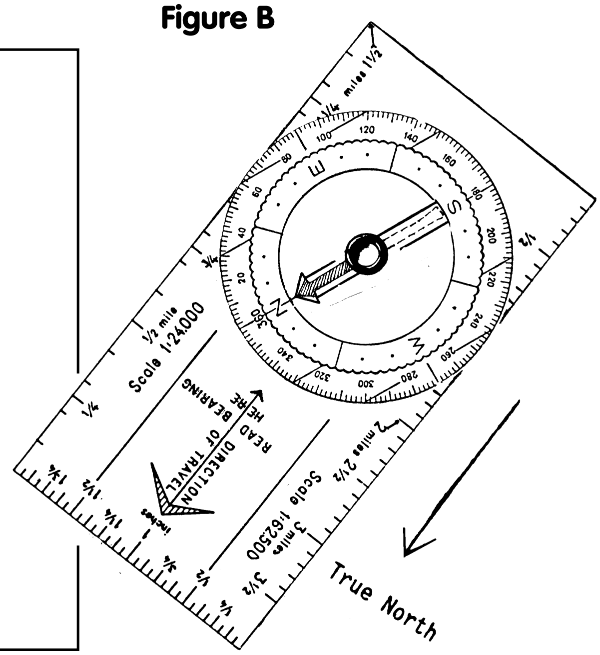


Figure B

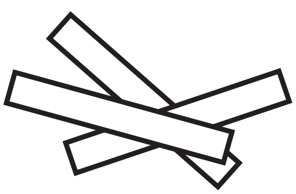


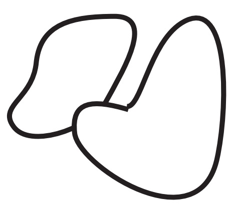
Symbols

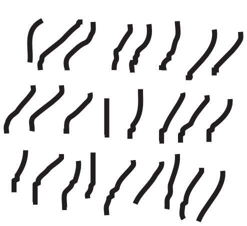
Use symbols to represent features on the map. The simpler the symbols, and the closer to pictures of the features represented, the better. Some symbols useful for streams are shown below.


log


rapids


log jam


rocks


riffle


overhanging bank or cutbank

Mapping team

The map made during the survey is a sketch showing relevant features. The mapping team of six should be divided as follows:

1. A team of two (Tape Team A) measures 100' lengths of the streambed. One person stands at the beginning of the section while the other walks up the stream to the 100' mark. Both stay in place until the recorder has finished the section.
2. A team of two (Tape Team B) measures active channel and floodplain width at the beginning of each section and again wherever significant change in width of these two parameters occurs. This team should stay near the recorder.
3. The depth measurer (one person) uses a depth measuring rod to measure the deepest point of each pool and reports depths to the recorder.
4. The recorder and a helper walk up the streambed and sketch in the features using the tape as a guide for placement.

5. When the recorder reaches the end of the section, Tape Team A moves up to the next 100-foot section and the process is repeated. There are slightly more than thirteen 100' sections in a quarter mile.
6. After the survey, the sketch should be traced and redrawn into a finished master map. Copies of this master can be used to show data collection sites, proposed changes and actual changes.

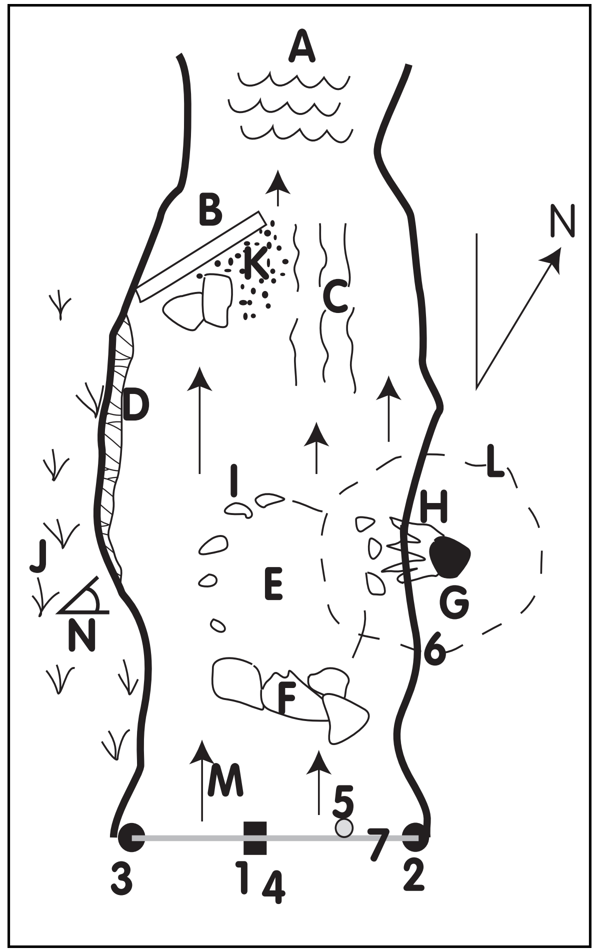
Mapping an angle

To map the angle of a bend in the stream:

1. Stand at the bend and hold the map so the portion that has been mapped is parallel to the drawing.
2. Place the compass on top of the map with the "direction of travel arrow" parallel to the portion that has been mapped and mark along the edge of the compass.
3. Without changing the position of the map, turn the compass so the "direction of travel arrow" now points along the new angle of the stream and mark along the edge of the compass. This will accurately show the angle of the bend.
4. Make sure that the position of the bend is accurately marked according to the established scale.

Going further

1. Additional ideas for mapping investigations are found on pages 68-72 of the Adopt-A-Stream Foundation's *Streamkeeper's Field Guide: Watershed Inventory and Stream Monitoring Methods*. It is available for $29.95 + $4.00 shipping and handling (WA residents add $2.37 sales tax). Order this guide from the Adopt-A-Stream Foundation, 600-128th Street NE, Everett, WA 98208, phone (206) 316-8592.



Legend

A. Rapids
B. Log
C. Riffle
D. Overhang/cutbank
E. Pool
F. Boulders
G. Tree (alder)
H. Root wads
I. Cobbles
J. Marsh
K. Gravel bar
L. Alder's canopy
M. Glide
N. Photo Point

1. Recorder with gridded map
2. Person with pole
3. Person with pole
4. Recorder's helper
5. Depth measurer with pole
6. Person holding end of tape at 100' also measures floodplain
7. Person holding end of tape for width of stream also measures floodplain

Stream Mapping Example

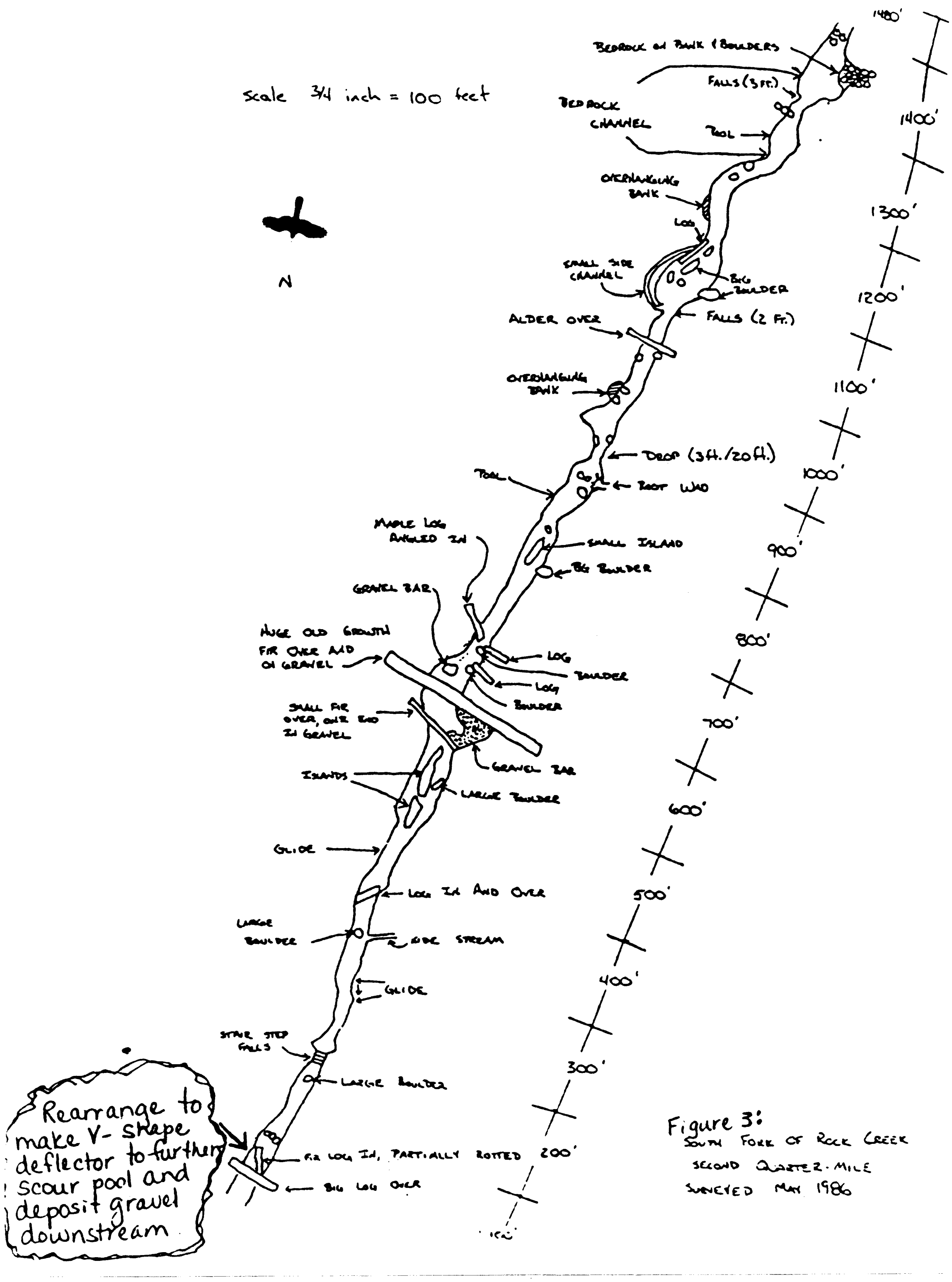


Figure 3: South Fork of Rock Creek
Second Quarter-Mile
Surveyed May 1986

Other field investigations and monitoring techniques

Vegetation monitoring

A stream in a deteriorating trend develops soil and water characteristics that result in decreased riparian area width, decreased height and vigor of water-loving plants, and decreased vegetation overhang and canopy. In addition, the less drought resistant shrubs and trees such as willows and cottonwoods are replaced by more drought resistant species such as sagebrush and bunchgrass. Ground cover is lost, exposing more bare soils as plant density decreases.

Conversely, as a riparian area heals, the vegetation trends reverse. The riparian area width expands, vegetation increases in height and vigor, vegetation overhang and canopy cover improve, and more water-dependent plant species thrive.

Variables such as riparian area width and canopy cover can be monitored to determine whether the overall health and vigor of a riparian area is improving or deteriorating over time.

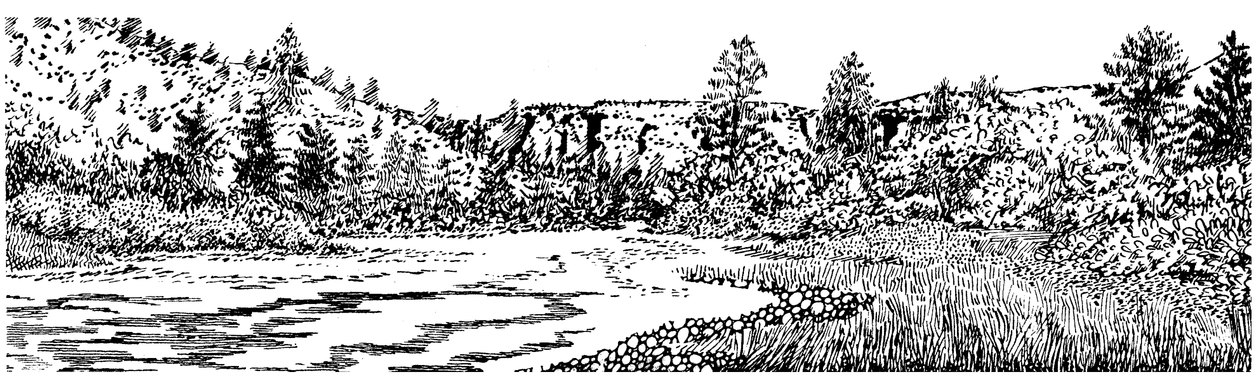
See the *Streamkeeper's Field Guide: Watershed Inventory and Stream Monitoring*, pages 83-85 for ideas about vegetation monitoring in riparian zones.

A **line transect** is a way to monitor the percentage of soil surface covered by vegetation at a specific site. This monitoring technique works well in upland areas. A line transect is a series of continuous points along a random line of a given distance. A team of two or more measure the length of line intersected by each species or plant type (grasses, forbs, shrubs, litter, bare ground). The length of line intersected by each species or plant type is divided by the total length of the line giving a percentage of soil surface covered by that species or type. Three lines are averaged together for the average percent cover.

Contact the nearest office of the Bureau of Land Management and talk with a rangeland specialist. They can provide you with more information about how to complete a line transect.

A **toe-point transect** is another method of estimating the percentage of plant cover types. Step off a total of 200 paces, 100 on each side of the stream for riparian area cover types or back and forth in an upland transect area as long as you do not count the same area twice. Each time your right toe hits, note what kind of vegetation

The *Streamkeeper's Field Guide* is available for $29.95 + $4.00 shipping and handling (WA residents add $2.37 sales tax). Order this guide from the Adopt-A-Stream Foundation, 600-128th Street NE, Everett, WA 98208, phone (206) 316-8592.



or ground cover is touched by the toe of your shoe. Keep a tally of each cover type (grasses, forbs, shrubs, litter, bare ground). Divide each by 200 to obtain the percentage cover composition for each cover type.

A **solar pathfinder** is a tool to measure the effects of stream surface shading by vegetation or topographic features. The solar pathfinder is a transparent dome that reflects a panoramic view of the area around the study site. It allows shading objects to be identified and mapped. Using know radiation values you can determine a quick estimate of the absolute energy available to the stream surface. The manufacturer provides worksheets to facilitate this process. The Solar Pathfinder is available from Solar Pathways, Inc., 7800 Highway 82, PO Box 914, Glenwood Springs, Colorado.

Other vegetation monitoring parameters include vegetative overhang, streamside cover ratings, streambank stability ratings, canopy closure, canopy distribution, forage utilization, shrub age classes, and tree size classes. Contact your nearest resource agency for more information about these techniques. It is also helpful to develop a complete plant species list for the area of concern with notes about relative abundance and density of plant types.

Stream cross-section profile

Cross-section profiles help track changes in a streambed and its banks in response to management changes. For example, a badly degraded streambank is stabilized with juniper riprap to protect the raw cutbank. The streambed at the site is wide and shallow. Livestock have been removed from the pasture for a five year period. A baseline cross-section profile is completed at a permanent transect site shortly after the habitat restoration work is completed. The cross-section profile is repeated over a span of several years. Ideally, the graphic representation of the cross section profile measurements should show a narrowing and deepening of the channel as recovery occurs.

See the *Streamkeeper's Field Guide: Watershed Inventory and Stream Monitoring*, pages 97-99, for instructions in completing cross-section profiles.

Other monitoring needs

Other watershed and stream parameters, both physical and chemical, are regularly monitored by various resource agencies. Students can assist with some of these procedures. Culvert surveys to evaluate fish passage problems, stream bottom surveys to evaluate the extent to which the cobbles and gravels are embedded or unavailable for use by fish or macroinvertebrates, and other water quality parameters including alkalinity, biochemical oxygen demand, nutrients, phosphorus, bacteria, conductivity, turbidity, and solids.

Natural resource agencies can provide information about monitoring the physical parameters noted above.

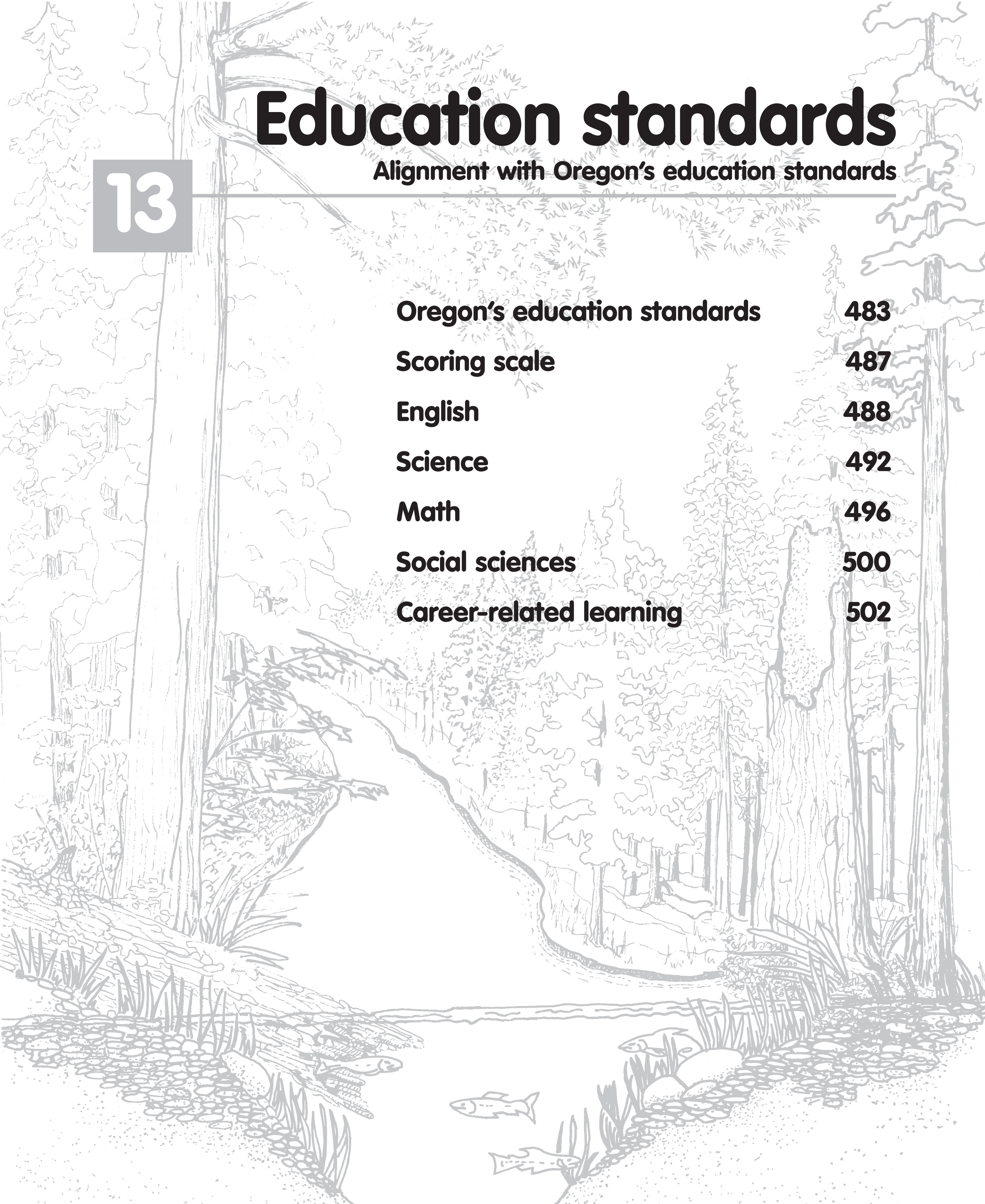
The *Water Quality Monitoring Guidebook* contains additional information about monitoring sediments, road hazards, turbidity, conductivity, pesticides and toxins, and fecal coliform. To get a copy of the *Water Quality Monitoring Guidebook* contact the Oregon Department of Environmental Quality, 1712 SW 11th Street, Portland, Oregon 97201, phone: (503) 229-5983 or the Oregon (formerly Governor's) Watershed Enhancement Board, 255 Capitol Street NE, 3rd Floor, Salem, Oregon 97310-0203.

See the *Streamkeeper's Field Guide: Watershed Inventory and Stream Monitoring*, pages 179-182, for monitoring information about other water quality parameters.

13

Education standards

Alignment with Oregon's education standards



Courtesy of Oregon Department of Forestry, Salem, Oregon (Graphics Unit)

Education standards

13

Alignment with Oregon's education standards

*"You cannot teach a man anything;
you can only help him find it within himself."*
—Galileo

Standards-based education

Standards-based education has been under development in Oregon since 1991, when the state legislature passed Oregon's Educational Act for the 21st Century. The Act recognizes that tomorrow's students will need higher skills to compete in college and employment and to function successfully in a more complex society. It requires public schools to establish higher standards and be even more accountable for helping students reach those standards in reading, writing, math, science, and other basic subjects.

Oregon educators are working together to closely link curriculum, instruction, and assessment—what and how teachers teach and evaluate students—based on statewide academic standards. These content standards define what students should know and do to be considered proficient in specific academic areas. Currently, at the benchmark years of grades 3, 5, 8, and 10, students are assessed to measure achievement of the content standards. Assessment tools for grade 12 are under development. Student mastery of the content standards are also assessed through regular classroom assignments scored with state scoring guides. Performance standards define what students are expected to achieve on the state tests and the classroom work samples.

> *"The expectations are higher with the new school reforms. Now you have to meet a benchmark before you can go on to the next step. You won't be able to just slide through anymore."*
>
> — La Grande High School student

Students who meet or exceed the grade 10 performance standards receive a Certificate of Initial Mastery (CIM). Students then select a broad career area of interest, called an endorsement area, to focus their studies in their junior and senior years of high school. The six endorsement areas are arts and communications, business and management, health services, human resources, industrial and engineering systems, and natural resource systems. Students participate in a blend of school-, work-, and community-based learning experiences within their chosen endorsement area. As they participate and learn in that endorsement area, students achieve grade 12 academic standards, career related learning standards, participate in a career-related learning experience, and are awarded a Certificate of Advanced Mastery (CAM).

Standards-based education provides consistency for teaching and learning in Oregon, but local school districts are free to develop curriculum appropriate to the needs of their students within that framework. Teachers are more focused on what they require of students and how their classroom curriculum, instruction and assessment work together to help students achieve the necessary results. Expectations are higher for everyone. Using *The Stream Scene: Watersheds,* *Wildlife and People* to study watersheds can help students and educators meet those expectations.

Stream Scene and Oregon's education standards

Stream Scene can contribute significantly to achievement of academic content area standards at all grade level benchmarks.

The subject of watersheds extends across several disciplines and throughout most grade levels. Students study their own watershed and become personally involved in what is happening in their own back yard. Through a number of activities students evaluate how their watershed fits into the larger perspective of the state and the Northwest.

Each *Stream Scene* activity is evaluated for its contribution to successful attainment of state standards in English, mathematics, science, social sciences, and career-related learning. Only those standards to which *Stream Scen*e could substantially contribute to student success were included for each academic content area. Many of the activities actually apply to more standards than the codes indicate, but if scoring did not directly apply to the standard, it was not included. Educators must make a number of personal decisions about how the standards apply to specific activities. Those decisions may provide more opportunities for alignment. Add or delete codes from the matrices as you develop familiarity with the process and the activities.

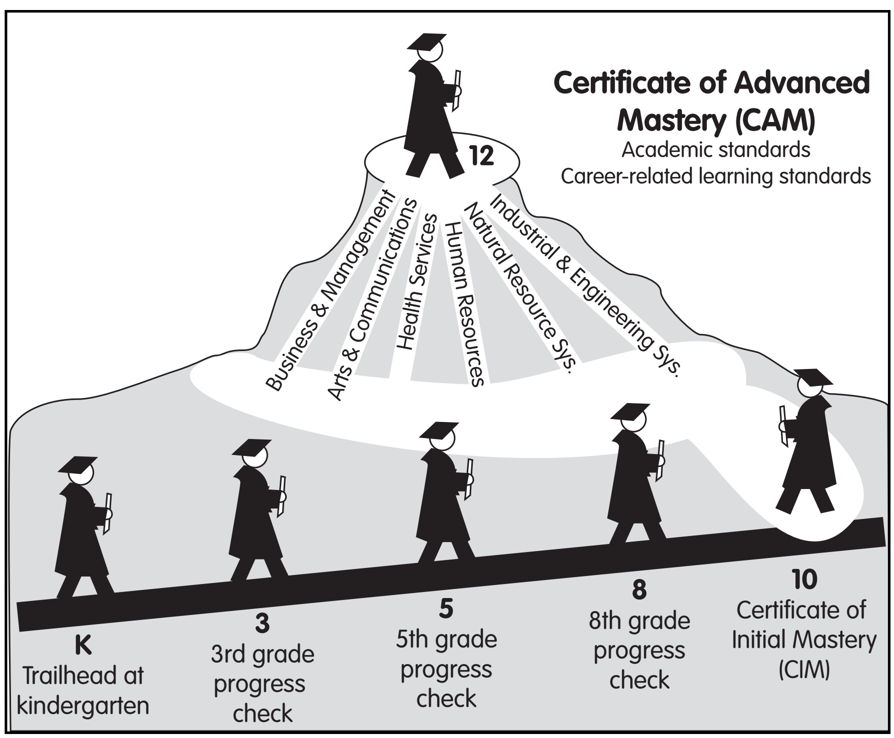
Contact the Oregon Department of Education for the most current examples of benchmarks for each content area standard.

Use the matrices as a guide to identify activities that align with the specific academic content area standard you want students to achieve. The alignments may not apply to all age groups or grade levels. Assess each activity individually to see if it is appropriate for your students, what benchmarks it may address, what modifications are needed, and how you will assess student work. See the "For Younger Students" and "Going Further" sections in each activity for modification ideas.

The standards are numbered from one to five near the top of each column, based on the number of standards included for that subject area. Watch for a special code "✻" that indicates additional ways to align with the standards for that activity or subject area. The standards are cross-referenced by number and explained on the facing page as are the appropriate "✻" codes. The following letter codes indicate how the activity aligns with the standard.

S Activity directly aligns with the content area ***standard*** as it is written and if assessed

A Road Map: Higher Standards for Oregon Students



Oregon Department of Education, Office of Professional Technical Education specifically for that standard. The activity may not be appropriate for all grade levels.

E Use one or more activities from the chapter ***extension*** lists (derived from a number of other related curriculum materials) with a *Stream Scene* activity to align with the subject area standard. *Do not* assume that all extension activities on the list will align with the standard under discussion. Grade level is usually noted on each of the extensions. To get copies of curriculum materials from which the extensions were referenced, see the list in the "Resources" section starting on page 519.

A Alignment with the standard can occur with ***additional*** information from the chapter content, other activities, "Going Further" additions to the activity, modifications, or supplementary input from the teacher.

W This activity would work well as a ***student work sample*** for state assessment procedures in this academic content area. If the majority of the standards within any one strand are addressed, and if the general constraints of the appropriate scoring guide are met, the activity and its associated extensions would work well as a student work sample. For example, if all four standards within the scientific inquiry strand have either an *S* or *E* code, consider using this activity for potential student work samples.

Note: Two letters separated by a slash (e.g., S/E) indicates that alignment may vary with grade level and age group of students.

Scoring guide examples for writing, speaking, scientific inquiry, and math follow the *Stream Scene* correlations for each of the content areas and are based on state scoring guides provided by the Oregon Department of Education, Office of Assessment and Evaluation. State scoring guides offer specific, consistent criteria on a 1–6 point scale against which teachers score students' classroom work. Get the most current official scoring guides from the Oregon Department of Education, Office of Assessment and Evaluation, 255 Capitol Street NE, Salem, OR 97310-0203. Use the 1–6 point scoring scale on the following page as a reference when grading student work samples.

This alignment and the following scoring guide examples were prepared by educators from the Harney County Watershed Education Project Committee. Tori Anderson (Grade 5), Dave Courtney (Grades 9-12), Judy Miller (Grades 9-12), and Linda Pelroy (Grades 2-3), with oversight provided by Lydia Hayes (Burns-Hines School District Curriculum Director), participated in the project as part of a staff development grant from the Science-Math Consortium for Northwest Schools (SMCNWS). Sallie Peila, Harney ESD Learning Resource Center, provided the related literature search in Chapter 14.5 starting on page 533. Many thanks for their efforts.

Web sites for Oregon education standards

Most Oregon Department of Education publications and other information about the Oregon Educational Act for the 21st Century can be found on the department's World Wide Web home page at:
http://www.ode.state.or.us

The Oregon Public Education Network (OPEN) maintains an excellent web site of resources for educators at:
http://www.open.k12.or.us

The Oregon Education Association provides many useful resources for educators related to teaching and learning, helping students succeed, and standards-based education on its web site at:
http://www.oregoned.org

Scoring scale

6 *Exemplary*

Work at this level is both exceptional and memorable. It is often characterized by distinctive and unusually sophisticated problem-solving approaches and solutions.

5 *Strong*

Work at this level exceeds the standard. It is thorough, complex and consistently portrays exceptional control of content, skills, and problem-solving strategies.

4 *Proficient*

Work at this level meets the standard. It is strong, solid work that has many more strengths than weaknesses. Work at this level demonstrates mastery of content, skills, and problem-solving strategies and reflects considerable care and commitment.

3 *Developing*

Work at this level shows basic, but inconsistent mastery and application of content and skills. It shows some strengths but tends to have more weaknesses overall.

2 *Beginning*

Work at this level is often superficial, fragmented, or incomplete. It may show a partial mastery of content and skills, but it needs considerable development before reflecting the proficient level of performance.

1 *Exploring*

Work at this level is minimal. It typically portrays a lack of understanding and use of appropriate skills and strategies. Work at this level may contain major errors.

Oregon's Academic Content Area Standards and Their Correlation With *Stream Scene* Activities

Key

- **S** Activity aligns with **standard** as written.
- **E** Activity aligns with standard when accompanied by one or more **extension** activities listed at end of each chapter's content section.
- **A** Activity aligns with standard when modified or accompanied by **additional** information from “Going Further” section in each activity, chapter content, or other source.
- **W** Activity would work well as a student **work sample** for state assessment procedures in this academic content area.
- **❋** See following page for notes cross-referenced by number.

English

	Work Sample	Reading ❋1	Literature ❋1	Writing ❋2					Communication			
				1	2	3	4	5	1	2	3	4
The Water Cycle				A	A	A	A	A	A	A	A	A
Water Drop Crossword						A	S					
A Sense of Place	W			S/E	E	A	E	A	S	A	E	A
Tour of a Topo												
What a Relief												
Snow Way				S								
Hold That Raindrop	W			S/E					E	E	E	E
Timing is Everything	W			S/E					E	E	E	E
Winter Watersheds				S/E					E	E		E
Water? Right!	W			S					E	E	E	E
A Dirty Subject	W			S/E	E				E	E	E	E
Made in the Shade				S								
Passin’ Through				S								
Things That Go Bump	W			S/E	E				E	E	E	E
Go With the Flow				S/E								
A Study In Streamflows				E					A	A	A	A
Too Much of a Good Thing				S								
When It’s Hot				S								
Temp. & Respiration Rate				S								
A South Twin Story				S						A	A	A
Lakes and pH												
Don’t Runoff				S/E	E			A				
Build a “Bug”									S			
Water Wigglers	W			S/E					E/A	E/A	E/A	E/A
Riffles and Pools				S/E					A	A	A	A
Salmon Language						A	S					
Coming Home	W			S	S	S	S	S	❋3	❋3	❋3	❋3
Home Wet Home				S								
The Stream Doctor				S								
Clack. Carrying Capacity												
Stream Survey	W			❋2	❋2	❋2	❋2	❋2	❋3	❋3	❋3	❋3
Wildlife Inventory	W			❋2	❋2	❋2	❋2	❋2	❋3	❋3	❋3	❋3
Photo Record	W			❋2	❋2	❋2	❋2	❋2	❋3	❋3	❋3	❋3
Fish Survey	W			❋2	❋2	❋2	❋2	❋2	❋3	❋3	❋3	❋3
Water Quality Survey	W			❋2	❋2	❋2	❋2	❋2	❋3	❋3	❋3	❋3
Macroinvertebrate Survey	W			❋2	❋2	❋2	❋2	❋2	❋3	❋3	❋3	❋3
Stream Mapping	W			❋2	❋2	❋2	❋2	❋2	❋3	❋3	❋3	❋3

English content standards

Writing

1. Communicate knowledge of the topic, including relevant examples, facts, anecdotes, and details.
2. Structure information in clear sequence, making connections and transitions among ideas, paragraphs, and sentences.
3. Use varied sentence structures and lengths to enhance flow, rhythm, and meaning in writing.
4. Select words that are correct, functional, and appropriate to audience and purpose. Use correct spelling, grammar, punctuation, capitalization, paragraph structure, sentence construction, and other writing conventions.
5. Use a variety of modes and written forms to express ideas.

Communication

1. Communicate knowledge of the topic, including relevant examples, facts, anecdotes, and details.
2. Structure information in clear sequence, making connections, and transitions among ideas, sentences, and paragraphs.
3. Select words that are correct, functional, and appropriate to audience and purpose.
4. Use eye contact, speaking rate, volume, enunciation, oral fluency, vocal energy, and gestures to communicate ideas effectively when speaking.

Contact the Oregon Department of Education, Office of Assessment and Evaluation, 255 Capitol St. NE, Salem, OR 97310-0203 for the most current benchmark examples for each content area standard.

Code translations

❋1 Achieve alignment with reading and literature content standards with reading assignments from outside sources. See the list of fiction and non-fiction books related to water, rivers, wetlands, and ponds in he Chapter 14.5 starting on page 533. When incorporating literature into the lessons, ask students to identify important issues and concepts about water found in the literature sources, explore the historical significance of rivers, recognize themes that occur in river literature, and recognize how authors express their ideas through river analogies.

Students can then write about issues addressed in the selections, analyze the historical character of rivers, discuss themes in literary selections, demonstrate examples of how authors use rivers to express their thoughts, and develop their own style using various forms of literature as models for writing about rivers.

For more information about incorporating reading and literature studies into lessons about water, watersheds, and rivers, contact Rivers Project, Southern Illinois University, PO Box 2222, Edwardsville, IL 62026-2222, (618) 692-2446. Ask for Rivers Project, *Language Arts*, one of a series of six river units based on the study of a local river basin.

❋2 If teacher specifically scores for these standards in the writing portion of the activity or scores a journal assignment or report associated with the activity, then alignment with the standard is achieved.

❋3 If the teacher requires a presentation related to this activity and scores for these communication standards, then alignment with the standard is achieved.

Writing: Elementary Level
Sample Scoring Guide

Oregon Benchmarks Grades 3 & 5

Name: ____________________

Date: ____________________

Grade: ____________________

Teacher: ____________________

Task Description: Alone Pair Group

____

____

____

____

A. Ideas and Content
* Stays on topic
* Main ideas stand out
* Clear and focused
* Detailed
* Interesting

Score: 6 5 4 3 2 1

B. Organization
* Logical order
* Inviting introductions and ending
* Smooth transitions
* Supporting details

Score: 6 5 4 3 2 1

C. Sentence Fluency
* Flows smoothly
* Varied sentence length or patterns
* Sounds natural

Score: 6 5 4 3 2 1

D. Conventions
* Correct usage
* Accurate spelling, punctuation, capitalization
* Easy to read
* Correct paragraphing

Score: 6 5 4 3 2 1

Keys:

6 Exemplary	**3 Developing**
5 Strong	**2 Beginning**
4 Proficient	**1 Exploring**

Scored by: ____________________

Writing: Secondary Level
Sample Scoring Guide

Oregon Benchmarks Grades 8 & 10

Name: ____________________

Date: ____________________

Grade: ____________________

Teacher: ____________________

Task Description: Alone Pair Group

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A. Ideas and Content
* Stays on topic
* Main ideas stand out
* Clear and focused
* Detailed
* Interesting

Score: 6 5 4 3 2 1

B. Organization
* Logical order
* Inviting introductions and ending
* Smooth transitions
* Supporting details

Score: 6 5 4 3 2 1

C. Sentence Fluency
* Flows smoothly
* Varied sentence length or patterns
* Sounds natural

Score: 6 5 4 3 2 1

D. Conventions
* Correct usage
* Accurate spelling, punctuation, capitalization
* Easy to read
* Correct paragraphing

E. Citations
* Bibliographic references used and punctuated correctly
* In text footnotes used correctly

Score: 6 5 4 3 2 1

Keys:

6 Exemplary	**3 Developing**
5 Strong	**2 Beginning**
4 Proficient	**1 Exploring**

Scored by: ____________________

Speaking: Elementary Level
Sample Scoring Guide

Oregon Benchmarks Grades 3 & 5

Name: ______________________________

Date: ______________________________

Grade: ______________________________

Teacher: ______________________________

Task Description: Alone Pair Group

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A. Content
* Main idea is clear
* Relevant details used
* Information stays on topic

Score: 6 5 4 3 2 1

B. Organization
* Strong introduction, body and conclusion
* Follows logical sequence
* Uses smooth transitions

Score: 6 5 4 3 2 1

C. Language
* Uses appropriate words
* Language use shows variety
* Adequately explains difficult words
* Correct grammar
* Word choice enhances message

Score: 6 5 4 3 2 1

D. Delivery
* Volume
* Rate of speech
* Pronunciation
* Eye-contact
* Involvement in topic

Score: 6 5 4 3 2 1

Keys: **6 Exemplary** **5 Strong** **4 Proficient** **3 Developing** **2 Beginning** **1 Exploring**

Scored by: ______________________________

Speaking: Secondary Level
Sample Scoring Guide

Oregon Benchmarks Grades 8 & 10

Name: ______________________________

Date: ______________________________

Grade: ______________________________

Teacher: ______________________________

Task Description: Alone Pair Group

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A. Content
* Information stays on topic
* Performance has a purpose
* Main ideas have supporting details

Score: 6 5 4 3 2 1

B. Organization
* Organized message
* Follows a natural order
* Has a beginning, middle, and end

Score: 6 5 4 3 2 1

C. Language
* Vocabulary appropriate
* Grammar effective
* Language use shows variety
* Word choice enhances message

Score: 6 5 4 3 2 1

D. Delivery
* Volume
* Rate of speech
* Pronunciation
* Eye-contact
* Involvement in topic

Score: 6 5 4 3 2 1

Keys: **6 Exemplary** **5 Strong** **4 Proficient** **3 Developing** **2 Beginning** **1 Exploring**

Scored by: ______________________________

Oregon's Academic Content Area Standards and Their Correlation With *Stream Scene* Activities

Key

S Activity aligns with **standard** as written.

E Activity aligns with standard when accompanied by one or more **extension** activities listed at end of each chapter's content section.

A Activity aligns with standard when modified or accompanied by **additional** information from "Going Further" section in each activity, chapter content, or other source.

W Activity would work well as a student **work sample** for state assessment procedures in this academic content area.

❋ See following page for notes cross-referenced by number.

Science

	Work Sample	Unifying Concepts and Processes					Physical Science		Life Science		Earth Science		Scientific Inquiry ❋1				Science-Personal Social Perspectives	
		1	2	3	4	5	1	2	1	2	1	2	1	2	3	4	1	2
The Water Cycle	W	S		E	S/E		E	S				S			E	E	S	
Water Drop Crossword		S		E	E		S	S				S						
A Sense of Place	W	E	E	E	E								E	E	E	E	E	E
Tour of a Topo		S	S															
What a Relief				S											S			
Snow Way				S	S							A				S		
Hold That Raindrop	W			E		S/E					S/E		E		E	E	E	E
Timing is Everything	W			E		S/E					S/E		E		E	E	E	E
Winter Watersheds	W	S/A			S			S		S		S			S	S	S	
Water? Right!	W			E		S/E					S/E		E		E	E	E	E
A Dirty Subject	W	E	E	E	E	E/A				S/E			A		S/E	E	E	E
Made in the Shade	W	S	S/A	S		A									S	S		
Passin' Through			A	S		A						S			S	S	S/A	
Things That Go Bump	W	E	E	E	E	E/A				S/E			A		S/E	E	E	E
Go With the Flow	W	S/E		S/E	S						S							
A Study In Streamflows																S	E	
Too Much of a Good Thing	W	S		S											S	S	S	
When It's Hot			S/E						A						E	S/E		
Temp. & Respiration Rate	W	S	S/E						A						E	S/E		
A South Twin Story													E			S/E		
Lakes and pH	W				S								E	E	E	S/E	E	A
Don't Runoff	W			S/E							S/E	E	E		E	E		
Build a Bug	W								S	S/A								
Water Wigglers	W								S/E	S/E					S/E	S/E		
Riffles and Pools	W	S/E	S/E						S/E	S/E			E			S/E	E	
Salmon Language					E/A	E/A			S	S								
Coming Home	W		S	S					S	S					S	S	S	
Home Wet Home			A	A		A	S				A							
The Stream Doctor		S			S											S		
Clack. Carrying Capacity										S						S		
Stream Survey	W				S								❋2	❋2	❋2	❋2	S/A	
Wildlife Inventory	W				S				A	A			❋2	❋2	❋2	❋2	S/A	
Photo Record	W				S								❋2	❋2	❋2	❋2	S/A	
Fish Survey	W				S					S			❋2	❋2	❋2	❋2	S/A	
Water Quality Survey	W				S			S					❋2	❋2	❋2	❋2	S/A	A
Macroinvertebrate Survey	W				S				S	S			❋2	❋2	❋2	❋2	S/A	
Stream Mapping	W			S	S								❋2	❋2	❋2	❋2	S/A	

Science content standards

Unifying concepts and processes

1. Use concepts and processes of change, constancy, and measurement.
2. Use concepts and processes of systems, order, and organization.
3. Uses concepts and processes of evidence, models, and explanation.
4. Use concepts and processes of evolution and equilibrium.
5. Uses concepts and processes of structure and function.

Physical science

1. Identify structures and properties of matter.
2. Describe chemical and physical changes.

Life science

1. Describe the characteristics, structure, and functions of organisms.
2. Explain the interdependence of organisms in their natural environment.

Earth and space

1. Identify the structure of the Earth system and changes that can occur in its physical properties.
2. Explain changes occurring within the lithosphere, hydrosphere, and/or atmosphere of the earth.

Contact the Oregon Department of Education, Office of Assessment and Evaluation, 255 Capitol St. NE, Salem, OR 97310-0203 for the most current benchmark examples for each content area standard.

Scientific inquiry

1. Formulate and express scientific questions and hypotheses to be investigated.
2. Design scientific investigations to address and explain questions and hypotheses.
3. Conduct procedures to collect, organize, and display scientific data.
4. Analyze scientific information to develop and present conclusions.

Science in personal and social perspectives

1. Describe how daily choices of individuals, taken together, affect global resource cycles, ecosystems, and natural resource supplies.
2. Explain risks and benefits in personal and community health from a science perspective.

Code translations

❋1 Many of the “Going Further” opportunities at the end of each activity can help a student achieve alignment with the standard.

❋2 If the teacher requires data collection, data analysis/interpretation, and a presentation related to this activity and scores for these specific inquiry standards, then alignment with the standard is achieved.

Scientific Inquiry:
Elementary level
Sample scoring guide

Oregon Benchmarks Grades 3 & 5

Name: ______________________________________

Date: ______________________________________

Grade: ______________________________________

Teacher: ____________________________________

Task Description: Alone Pair Group

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A. Framing the Investigation
* States question with related information
* Question/hypothesis is based on background information.
* Designs a question that can be tested.

Score: 6 5 4 3 2 1

B. Designing the Investigation
* Design a safe, logical procedure that collects enough data.
* Communicates an easy to follow plan with only one variable.
* Create a plan that will answer the question/hypothesis.

Score: 6 5 4 3 2 1

C. Collecting and Presenting Data
* Data matches plan and is complete.
* Pictures, diagrams, models, and/or charts are used to show data.
* Show results in a way that are clear and correct.

Score: 6 5 4 3 2 1

D. Analyzing and Interpreting
* Explain results clearly.
* Use results to explain what happened.
* Clearly summarizes the experiment.

Score: 6 5 4 3 2 1

Scored by: ___________________________________

Keys:
6 Exemplary
5 Strong
4 Proficient
3 Developing
2 Beginning
1 Exploring

Scientific Inquiry:
Secondary level
Sample scoring guide

Oregon Benchmarks Grades 8 & 10

Name: ______________________________________

Date: ______________________________________

Grade: ______________________________________

Teacher: ____________________________________

Task Description: Alone Pair Group

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A. Framing the Investigation
* Provides background science knowledge that is relevant to the investigation.
* Question/hypothesis is based on background information.
* Formulates a question that can be tested.

Score: 6 5 4 3 2 1

B. Designing the Investigation
* Uses scientific knowledge and procedures to propose design that will provide adequate data.
* Communicates clear, logical procedure with only one variable.
* Presents a design that will answer the question/hypothesis.

Score: 6 5 4 3 2 1

C. Collecting and Presenting Data
* Records data consistent with the planned procedure.
* Data is accurate and complete.
* Creates accurate displays for observations or measurement.
* Presents results in a way that is understandable and correct.

Score: 6 5 4 3 2 1

D. Analyzing and Interpreting
* Uses scientific concepts, models, and/or terminology to explain results.
* Use results of the investigation to support conclusions.
* Provides evidence to clearly review or summarize the investigation.

Score: 6 5 4 3 2 1

Scored by: ___________________________________

Oregon's Academic Content Area Standards and Their Correlation With *Stream Scene* Activities

Key

- **S** Activity aligns with **standard** as written.
- **E** Activity aligns with standard when accompanied by one or more **extension** activities listed at end of each chapter's content section.
- **A** Activity aligns with standard when modified or accompanied by **additional** information from "Going Further" section in each activity, chapter content, or other source.
- **W** Activity would work well as a student **work sample** for state assessment procedures in this academic content area.
- ❋ See following page for notes cross-referenced by number.

Math

	Work Sample	Calculations/ Estimations			Measurements			Statistics and Probability			Algebraic Relationships		Mathematical Problem Solving			
		1	2	3	1	2	3	1	2	3	1	2	1	2	3	4
The Water Cycle		S/E	E			S				E	S					E
Water Drop Crossword																
A Sense of Place	W	E/A				E	E	E		E	E	E		E		
Tour of a Topo																
What a Relief																
Snow Way										S		S				
Hold That Raindrop						S/E				E						
Timing Is Everything						E				S/E		S				
Winter Watersheds						E				E						
Water? Right!						E				E						
A Dirty Subject	W	S/E				S/E	E	E	S/E	S/E	S/E	S/E	E	E	E	
Made in the Shade										S						
Passin' Through										S						
Things That Go Bump	W	S/E				S/E	S/E	E	S/E	S/E	S/E	S/E	E	E	E	
Go With the Flow																
A Study in Streamflows	W	S					S	S	S	S	S/E	S	E	E	E	A
Too Much of a Good Thing		S				S				S					S	S
When It's Hot					S					S/E		S				
Temp. & Respiration Rate					S	S				S/E		S				
A South Twin Story										S		S				
Lakes and pH					S					E						
Don't Runoff		E		E		E	E			E	E					
Build a Bug					S	S										
Water Wigglers	W								S	S/E	S	S				
Riffles and Pools										E		E				
Salmon Language																
Coming Home																
Home Wet Home																
The Stream Doctor		S								S		S				
Clack. Carrying Capacity	W	S					S				S	S				
Stream Survey	W	S	S		S	S	S			S	S	S				
Wildlife Inventory		S							A	S		A				
Photo Record																
Fish Survey	W	S		S	S	S	S	A	S	S	S	S	S	S	S	S
Water Quality Survey	W	S	S	S	S	S	S	S	S	S	S	S				
Macroinvertebrate Survey	W	S			S					S	S	S				
Stream Mapping	W	S	S	S	S	S	S		S	S	S	S				

Mathematics content standards

Calculations and estimations

1. Compute with whole numbers, fractions, decimals, and integers, using paper and pencil, calculators, and computers.
2. Use estimation to solve problems and check the accuracy of solutions.
3. Apply number theories, mathematical rules, and algorithms to solve problems.

Measurement

1. Determine appropriate units, tools, and techniques to measure the degree of precision and accuracy desired in particular situations.
2. Apply direct methods of measurement in metric, U.S. customary, and other systems.
3. Apply indirect methods of measurement (e.g., formulas, estimates).

Statistics and probability

1. Determine the probability that an event will occur.
2. Carry out and describe experiments using measures of central tendency and variability.
3. Create charts, tables, and graphs, and use statistics to summarize data, draw inferences, and make predictions.

Algebraic relationships

1. Use mathematical expressions and algebraic operations to solve equations.
2. Represent patterns and mathematical relationships using symbols, graphs, numbers, and words.

Mathematical problem solving

1. Represent patterns and mathematical relationships using symbols, graphs, numbers, and words.
2. Develop and apply problem-solving strategies accurately to solve problems.
3. Communicate solution process in an easily understood manner.
4. Review solutions to see if they are accurate and reasonable.

Contact the Oregon Department of Education, Office of Assessment and Evaluation, 255 Capitol St. NE, Salem, OR 97310-0203 for the most current benchmark examples for each content area standard.

Mathematics:
Elementary level
Sample Scoring Guide

Oregon Benchmarks Grades 3 & 5

Name: ____________________

Date: ____________________

Grade: ____________________

Teacher: ____________________

Task Description: Alone Pair Group

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A. Conceptual Understanding

* Task changed into mathematical ideas
* Data from task is used

Score: 6 5 4 3 2 1

B. Processes and Strategies

* Pictures, diagrams, models and/or symbols are used
* Reasonable skills/strategies are used

Score: 6 5 4 3 2 1

C. Communicate Reasoning

* Thinking of solution process is clearly shown
* Thinking presentation is clear and organized

Score: 6 5 4 3 2 1

D. Verification

* Work is verified using a reasonable strategy

Score: 6 5 4 3 2 1

Keys: **6 Exemplary** **5 Strong** **4 Proficient** **3 Developing** **2 Beginning** **1 Exploring**

Scored by: ____________________

Mathematics:
Secondary level
Sample Scoring Guide

Oregon Benchmarks Grades 8 & 10

Name: ____________________

Date: ____________________

Grade: ____________________

Teacher: ____________________

Task Description: Alone Pair Group

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____

A. Conceptual Understanding

* Chooses mathematical ideas that are relevant to the situation
* Creates a model or diagram to show understanding
* Makes good connections to other situations

Score: 6 5 4 3 2 1

B. Processes and Strategies

* Demonstrates effective use of the processes and/or strategies
* Shows evidence of clarity, organization, continuity and reasoning.
* Uses more than one strategy and/or procedure when it is appropriate

Score: 6 5 4 3 2 1

C. Communicate Reasoning

* States the ideas and strategies/processes used to reach results
* Clearly communicates reasoning, the connections made and how they are relevant
* Matches the language, symbols, and communications forms to the information and audience

Score: 6 5 4 3 2 1

D. Verification

* Solution process is reasonable in relation to the task.

Score: 6 5 4 3 2 1

Keys: **6 Exemplary** **5 Strong** **4 Proficient** **3 Developing** **2 Beginning** **1 Exploring**

Scored by: ____________________

Oregon's Academic Content Area Standards and Their Correlation With *Stream Scene* Activities

Key

- **S** Activity aligns with **standard** as written.
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- **A** Activity aligns with standard when modified or accompanied by **additional** information from "Going Further" section in each activity, chapter content, or other source.
- **W** Activity would work well as a student **work sample** for state assessment procedures in this academic content area.
- ❊ See following page for notes cross-referenced by number.

Social Sciences

	Work Sample	History			Geography			Social Science Analysis				
		1	2	3	1	2	3	1	2	3	4	5
The Water Cycle					E		S/E			A	A	A
Water Drop Crossword					A							
A Sense of Place	W		S/E	S/E	S/E	S/E	S/E	E	E	E	E	E
Tour of a Topo					S							
What a Relief					S							
Snow Way												
Hold That Raindrop	W	E	E		E	E	E	E	E	E	E	E
Timing is Everything	W	E	E		E		E	E	E	E	E	E
Winter Watersheds	W	E	E		E	E	E	E	E	E	E	E
Water? Right!	W	E	E		E	E	E	E	E	E	E	E
A Dirty Subject	W	E	E		E		E	E	E	E	E	E
Made in the Shade												
Passin' Through							A	S/A			S/A	
Things That Go Bump	W	E	E		E		E	E	E	E	E	E
Go With the Flow												
A Study in Streamflows	W		E				E	E	E	E	E	E
Too Much of a Good Thing												
When It's Hot							S/E			A		E
Temp. & Respiration Rate							E			A		E
A South Twin Story												
Lakes and pH							S/E		E		S/E	E
Don't Runoff							E		E	A	S	
Build a Bug												
Water Wigglers							S/E		S/E			
Riffles and Pools	W	E	E	E			S/E		E		E	
Salmon Language												
Coming Home					S/A		S/A	S/A		S/A		
Home Wet Home						A	A					
The Stream Doctor											A	
Clack. Carrying Capacity												
Stream Survey	W				S	S	S	❊2	❊2	❊2	❊2	❊2
Wildlife Inventory	W	❊1	❊1	❊1			A	❊2	❊2	❊2	❊2	❊2
Photo Record	W	❊1	❊1	❊1		A	A	❊2	❊2	❊2	❊2	❊2
Fish Survey	W	❊1	❊1	❊1			S	❊2	❊2	❊2	❊2	❊2
Water Quality Survey	W	❊1	❊1	❊1			S	❊2	❊2	❊2	❊2	❊2
Macroinvertebrate Survey	W	❊1	❊1	❊1			S	❊2	❊2	❊2	❊2	❊2
Stream Mapping	W	❊1	❊1	❊1	S	S	S	❊2	❊2	❊2	❊2	❊2

Social studies content standards

History

1. Understand and interpret relationships in history, including chronology, cause and effect, change, and continuity over time.
2. Understand and interpret events, issues, and developments in the history of one's family, local community, and culture.
3. Understand and interpret the history of the state of Oregon.

Geography

1. Locate places and explain geographic information or relationships by reading, interpreting, and preparing maps and other geographic representations.
2. Identify and explain physical and human characteristics of places and regions, the processes, that have shaped them, and their geographical significance.
3. Explain how humans and the physical environment impact and influence each other.

Social science analysis

1. Identify, research, and clarify an event, issue, problem, or phenomenon of significance to society.
2. Gather, use, and evaluate researched information to support analysis and conclusions.
3. Understand an event, issue, problem, or phenomenon from multiple perspectives.
4. Identify and analyze characteristics, causes, and consequences, of an event, issue, problem, or phenomenon.
5. Identify, compare, and evaluate outcomes, responses, or solutions, then reach a supported conclusion.

Code translations

❋1 Achieve alignment with history content standards by including an oral history component to these activities. Include research about Oregon's history and settlement in the area near the study stream.

❋2 Most water issues today have significant social impacts. Include this component into the data collection and research process for these activities to achieve alignment with the standard.

Contact the Oregon Department of Education, Office of Assessment and Evaluation, 255 Capitol St. NE, Salem, OR 97310-0203 for the most current benchmark examples for each content area standard.

Oregon's Academic Content Area Standards and Their Correlation With *Stream Scene* Activities

Key

- **S** Activity aligns with **standard** as written.
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- **A** Activity aligns with standard when modified or accompanied by **additional** information from "Going Further" section in each activity, chapter content, or other source.
- **W** Activity would work well as a student **work sample** for state assessment procedures in this academic content area.
- **❊** See following page for notes cross-referenced by number.

Career-related Learning

Career-related Learning	Work Sample	Personal Management 1	Problem Solving 1	Communication 1	Teamwork 1 ❊3	Organizations & Systems 1 ❊4	Employment Foundations 1 ❊5	Career Development 1 ❊6
The Water Cycle	W	S/A	S		S/A			
Water Drop Crossword								
A Sense of Place				S/A				A
Tour of a Topo								A
What a Relief		S/A						A
Snow Way								A
Hold That Raindrop	W		S	S	S			
Timing Is Everything								A
Winter Watersheds	W	S/A	S/A	S	S			A
Water? Right!			S			A		A
A Dirty Subject	W	S/A	S	S				
Made in the Shade			S					
Passin' Through	W	S/A	S		S			
Things That Go Bump			S					A
Go With the Flow			S		S			A
A Study in Streamflows			S/A					
Too Much of a Good Thing		S/A	S/A					A
When It's Hot								A
Temp. & Respiration Rate	W	S/A	S/A	S	S/A			A
A South Twin Story								
Lakes and pH								
Don't Runoff			S		S			A
Build a Bug	W	S	S	S	S			A
Water Wigglers	W	S/A	S	S	S			A
Riffles and Pools								
Salmon Language								
Coming Home	W	S	S	S	S			A
Home Wet Home				S				A
The Stream Doctor								A
Clack. Carrying Capacity								A
Stream Survey	W	S/A	❊1	❊2	❊3			
Wildlife Inventory	W	S/A	❊1	❊2	❊3			
Photo Record	W	S/A	❊1	❊2	❊3			
Fish Survey	W	S/A	❊1	❊2	❊3			
Water Quality Survey	W	S/A	❊1	❊2	❊3			
Macroinvertebrate Survey	W	S/A	❊1	❊2	❊3			
Stream Mapping	W	S/A	❊1	❊2	❊3			

Career-related learning standards

Personal management

1. Exhibit appropriate work ethic and behaviors in school, community, and workplace.

Problem solving

1. Apply decision-making and problem-solving techniques in school, community, and workplace.

Communication

1. Demonstrate effective communication skills to give and receive information in school, community, and workplace.

Teamwork

1. Demonstrate effective teamwork in school, community and workplace.

Organization and systems

1. Describe how individuals fit into organizations and systems.

Employment foundations

1. Demonstrate both academic knowledge and technical skills required for successful employment within a career endorsement area.

Career development

1. Demonstrate career development skills in planning for post high school experiences.

Code translations

❋1 Set the stage for the field investigation activities with a realistic scenario for the watershed. Provide students with a reason for planning the research, collecting the data, and presenting the results.

❋2 If the teacher requires a presentation related to this activity and scores for communication standards, then alignment with the standard is achieved.

❋3 Any of the activities could involve teamwork if students perform the work in groups. Some activities are better suited to the team approach than others.

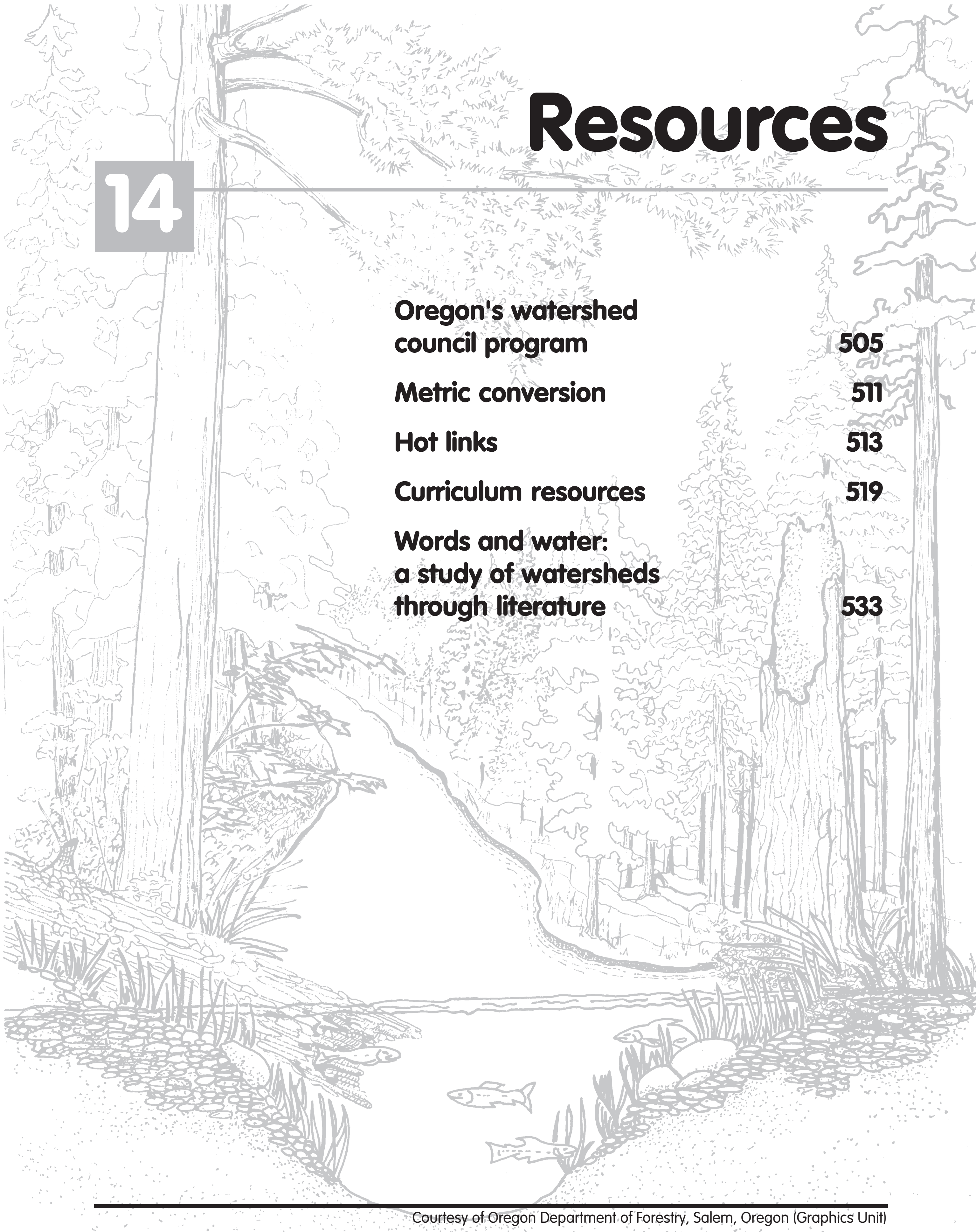
❋4 See suggestions in the "Going Further" sections. Create opportunities for students to work with individuals from organizations. Ask for a representative to come to the class to share how they fit into the organization as a whole.

❋5 Include options for students to research both the academic knowledge and technical skills required for employment in the career endorsement area best addressed by these activities.

❋6 Include discussions of careers associated with the activity. Provide examples of how watershed studies cross discipline boundaries.

Contact the Oregon Department of Education, Office of Assessment and Evaluation, 255 Capitol St. NE, Salem, OR 97310-0203 for the most current benchmark examples for each content area standard.

14 Resources



Courtesy of Oregon Department of Forestry, Salem, Oregon (Graphics Unit)

14.1 Oregon's watershed council program

"A long pull, and a strong pull, and a pull all together."
— Charles Dickens

What are local watershed councils?

Watershed councils are locally organized, voluntary, non-regulatory groups established to improve the condition of natural resources in the state's watersheds. In Oregon, nearly 90 recognized councils are engaged in a wide range of watershed work.

The 1995, the Oregon legislature unanimously passed House Bill 3441 to provide guidance on the formation of watershed councils. However, House Bill 3441 makes it clear that formation of a council is a local government decision, with no state approval required. Watershed councils are required to represent the interests in the basin and be balanced in their makeup. Watershed councils offer local residents the opportunity to independently evaluate watershed conditions and identify opportunities to restore or enhance conditions. Through the councils, partnerships between residents, local, state, and federal agency staff and other groups are developed. Through these partnerships and the resulting integration of local efforts, the state's watersheds are protected and enhanced.

How local watershed councils are formed

Establishment of a council is a local government decision made by a city, county, water supply, or sewer district. In practice, recognition of councils has been by formal letter, resolution, or order, usually from a county commission. Two primary guidelines are provided by the legislation: (1) that the watershed council be a voluntary, local group and (2) that the council represent a balance of interested and affected persons within the watershed. Watershed councils are composed of people from the local communities. They represent local knowledge and understand the local community and its complexities.

Some watershed councils form as non-profit corporations or adopt other formal organizational structures while others organize as informal groups. Many councils work closely with local soil and water conservation districts, council of governments, and resource conservation and development districts.

The role of local watershed councils

Watershed councils work across jurisdictional boundaries and across agency mandates to look at the watershed in its entirety. The primary purpose of the watershed council is to address watershed conditions from ridgetop to ridgetop. The council also plans and implements projects to protect or improve natural resources, educates people about watershed conditions and functions, and monitors changes in the watershed.

The council is a forum to bring local, state, and federal land management agencies together with local property owners and private land managers. It provides local people with a voice in natural resource management that can significantly influence watershed management decisions. Councils can also be a tool that watershed management decision makers use to disseminate information to the public, gauge local sentiment on specific management issues, and coordinate a broad-based review of management plans.

Watershed councils do not have any specific authority or ability to regulate land or water use.

They work as an advisory body but also undertake specific restoration, education, and monitoring projects. As a group that is recognized by local government, they incur no more or less liability to local governments than any other locally appointed advisory group (e.g., planning commission, design review board, etc.).

Local watershed councils and the Oregon plan

Local watershed councils are an essential part of The Oregon Plan. The Oregon Plan originally had two components: the Coastal Salmon Restoration Initiative, which deals with recovering coho salmon runs in coastal basins, and the Healthy Streams Partnership, which deals with improving water quality statewide to meet federal Clean Water Act standards. A third component addressing the restoration of potentially threatened steelhead trout has been added to The Oregon Plan and it is envisioned that eventually the plan will become a comprehensive approach to sustaining watershed health to meet the habitat requirements of all species.

Watershed councils, working through their local networks and relying upon technical expertise from local, state, and federal agencies, are compiling and analyzing data on current watershed conditions and developing prioritized work plans to solve natural resource problems. They are monitoring watershed conditions, tracking the effects of restoration work, and providing data to a centralized repository so that the overall effect of The Oregon Plan can be quantified. Watershed councils are also working hard to provide information and raise public awareness about watershed health issues. Helping people realize that they have an individual role and responsibility for the state's natural resources will, in the long run, help ensure the future viability of our watersheds.

Local watershed councils and GWEB

The Governor's Watershed Enhancement Board (GWEB) was directed by the 1995 Oregon legislature to support the work of local watershed councils. GWEB provides grant funds for activities that benefit the state's watersheds, provides technical assistance through its member agencies, and administers funding for implementation of The Oregon Plan. When evaluating applications for grant funds, GWEB gives preference to projects that are proposed or endorsed by watershed councils. Councils may also apply to GWEB for funding for coordinator salaries and council administrative costs. GWEB provides informational materials to councils, sponsors workshops for council members, and has developed a watershed assessment manual to provide uniform protocols for assessing current watershed conditions.

Watershed councils in Oregon

Active watershed councils as of June 1999.

Applegate R WS Council
2816 Upper Applegate Rd
Jacksonville OR 97530
Phone: (541) 899-8036

Bakeoven WS Council
2325 River Rd Ste 3
The Dalles OR 97058
Phone: (541) 296-6178
Fax: (541) 296-7868

Banks WS Council
PO Box 428
Banks OR 97106
Phone:
Fax:

Bear Creek WS Council
Rvcog PO Box 3275
Central Point OR 97502
Phone: (541) 664-6676
Fax: (541) 664-7927

Bridge Cr WS Council
31444 West Branch Road
Mitchell OR 97750
Phone: (541) 462-3882
Fax: (541) 462-3882

Bully Cr WS Coalition
2200 Sixth Ave
Vale OR 97918
Phone: (541) 473-3365
Fax:

Calapooia WS Council
33630 Mcfarland Rd
Tangent OR 97389
Phone: (541) 967-5927 ext 117
Fax:

Chetco WS Council
PO Box 75
Smith River Ca 95567
Phone: (707) 487-3516
Fax:

Clackamas Rbc
PO Box 1869
Clackamas OR 97015-1869
Phone: (503) 650-1256
Fax: (503) 657-8955

Claggett Cr Ws Group
C/O 505 Sandy Dr N
Salem OR 97303
Phone: (503) 399-5233
Fax:

Clatsop Coord Council
750 Commercial St, Rm 205
Astoria OR 97103
Phone: (503) 325-0435
Fax: (503) 325-0459

Columbia Sl WS Council
7040 NE 47th Ave
Portland OR 97218-1212
Phone: (503) 281-1132
Fax: (503) 281-5187

Coos Watershed Assn
PO Box 5860
Coos Bay OR 97420
Phone: (541) 888-5922
Fax: (541) 888-6111

Coquille Watershed Assn
382 N Central Blvd
Coquille OR 97423
Phone: (541) 396-2229
Fax: (541) 396-3963

Crook County WS Council
498 SE Lynn Blvd
Prineville OR 97754-2840
Phone: (541) 447-4214
Fax:

Deschutes Cnty WS Council
PO Box 894
Bend OR 97709
Phone: (541) 383-7146
Fax: (541) 383-7638

Ecola Creek WS Council
PO Box 368
Cannon Beach OR 97110
Phone: (503) 436-1739
Fax:

Elk-Sixes R WS Council
93987 Elk River Rd
Port Orford OR 97465
Phone: (541) 332-4772
Fax:

Elk-Sixes R WS Council
PO Box 666
Gold Beach OR 97444
Phone: (541) 247-2755
Fax: (541) 247-8058

Euchre Cr WS Council
PO Box 666
Gold Beach OR 97444
Phone: (541) 247-2755
Fax:

Evans Cr WS Council
2360 Pine Grove Rd
Rogue River OR 97537-9609
Phone: (541) 582-0062
Fax:

Fairview Cr WS Plan Group
2115 SE Morrison
Portland OR 97214
Phone: (503) 231-2270
Fax: (503) 231-2271

Fifteen Mile WS Council
2325 River Rd Ste 3
The Dalles OR 97058
Phone: (541) 296-6178
Fax: (541) 296-7868

Flores Cr/New R WS Cncl
PO Box 85
Langlois OR 97450
Phone: (541) 348-9961
Fax:

Fulton-Gordon WS Council
PO Box 405
Moro OR 97039
Phone: (541) 565-3216
Fax: (541) 565-3430

Gerking Canyon WSC
PO Box 405
Moro OR 97039
Phone: (541) 565-3216
Fax: (541) 565-3430

Gilliam-East John Day WSC
PO Box 427
Condon OR 97823
Phone: (541) 384-3768
Fax: (541) 384-2167

Glenn & Gibson Creek WS
2308 Ptarmigan St NW
Salem OR 97304
Phone: (503) 362-6860
Fax:

Goose Lk Fishes Wrkng Grp
513 Center St
Lakeview OR 97630
Phone: (541) 947-6003
Fax:

Grande Ronde Model WS
10901 Island Ave
La Grande OR 97850
Phone: (541) 962-6590
Fax: (541) 962-6593

Grass Valley WS Council
PO Box 405
Moro OR 97039
Phone: (541) 565-3216
Fax: (541) 565-3430

Harney County WS Council
HC 71 4.51 Hwy 205
Burns OR 97720
Phone: (541) 573-2064
Fax:

Hood R WS Council
2990 Experiment Stn Dr
Hood River OR 97031
Phone: (541) 386-2275
Fax:

Hunter Cr/Pistol RWSC
PO Box F
Gold Beach OR 97444
Phone: (541) 247-2754
Fax:

Illinois V WS Council
PO Box 352
Cave Junction OR 97523
Phone: (541) 592-3770
Fax:

Johnson Cr WS Council
525 Logus St
Oregon City OR 97045
Phone: (503) 239-3932
Fax: (503) 239-3946

Klamath Bsn WS Adv Cncl
20554 N Malin
Malin OR 97632
Phone: Fax:

L Butte Cr WS Council
1094 Stevens Rd
Eagle Point OR 97524
Phone: (541) 826-2908
Fax:

L Columbia WS Council
12589 Hwy 30
Clatskanie OR 97016
Phone: (503) 728-9015
Fax:

L Nehalem WS Council
PO Box 249
Nehalem OR 97131
Phone: (503) 368-7424
Fax:

L Rogue WS Council
PO Box 666
Gold Beach OR 97444
Phone: (541) 247-2755
Fax: (541) 247-8058

Long Tom WS Council
751 S Danebo Ave
Eugene OR 97402
Phone: (541) 683-6578
Fax: (541) 683-6998

Lost Cr WS Group
81868 Lost Valley Lane
Dexter OR 97431
Phone: (541) 937-3351
Fax: (541) 937-3351

Malheur WS Council
2925 SW 6th Ave Ste 2
Ontario OR 97914
Phone: (541) 889-2588 ext 115
Fax:

Mary's River WS Council
PO Box 1041
Corvallis OR 97339
Phone: (541) 758-7597
Fax: (541) 754-4252

McKenzie WS Council
40240 Mohawk Rvr Rd
Marcola OR 97454
Phone: (541) 933-3318
Fax:

McKenzie WS Council
PO Box 1025
Corvallis OR 97339
Phone: (541) 741-5235
Fax: (541) 766-8336

Mid Coast WS Council
344 SW 7th St Ste A
Newport OR 97365
Phone: (541) 265-9195
Fax: (541) 265-9351

Mid Deschutes WS Council
625 SE Salmon Ave #6
Redmond OR 97756-9580
Phone: (541) 923-8018
Fax:

Mid Fk Willamette Council
PO Box 1216
Oakridge OR 97463
Phone: (541) 782-2219
Fax:

Mohawk WS Partnership
28750 Fox Hollow Rd
Eugene OR 97405
Phone: (541) 683-1155
Fax: (541) 465-6483

N Fk John Day WS Council
PO Box 95
Monument OR 97864
Phone: (541) 934-2141
Fax: (541) 934-2312

N Santiam WS Council
35403 Francis St
Lyons OR 97358
Phone: (503) 897-2606
Fax: (503) 897-2606

Necanicum WS Council
HCR 63 Box 950
Seaside OR 97138
Phone: (503) 738-8188
Fax: (503) 738-8188

Nestucca WS Council
PO Box 255
Hebo OR 97122
Phone: (503) 842-2240
Fax:

Netarts Bay WS Council
6385 Tillamook Ave
Bay City OR 97107
Phone: (503) 377-4000
Fax: (503) 377-4010

Nicolai-Wickiup WS Council
Rt 4 Box 593-K
Astoria OR 97103
Phone: (503) 458-6881
Fax:

Pine Hollow WS Council
PO Box 405
Moro OR 97039
Phone: (541) 565-3216
Fax: (541) 565-3430

Port Orford WS Council
PO Box 1327
Port Orford OR 97465
Phone:
Fax:

Powder Basin WS Council
3990 Midway Dr
Baker City OR 97814
Phone: (541) 523-7121
Fax: (541) 523-2184

Pringle Cr WS Council
Pub Wrks 555 Liberty St SE
Salem OR 97301
Phone: (503) 588-6211
Fax: (503) 588-6025

Pudding River WS Council
PO Box 55
Scotts Mills OR 97375
Phone: (503) 873-6146
Fax:

Rickreall WS Council
Polk County Courthouse
Dallas OR 97338
Phone: (503) 623-9237
Fax: (503) 623-6009

S Coast WS Council
PO Box 666
Gold Beach OR 97444
Phone: (541) 247-2755
Fax: (541) 247-8058

S. Santiam WS Council
33630 McFarland Rd
Tangent OR 97389
Phone: (541) 967-5927 ext 120
Fax: (541) 928-9345

Sandy Basin WS Council
PO Box 868
Sandy OR 97055
Phone: (503) 630-2382
Fax: (503) 630-2341

Scappoose Bay WS Council
34017 Slavens Rd
Warren OR 97053
Phone: (503) 229-5988
Fax:

Siuslaw WS Council
PO Box 422
Mapleton OR 97453
Phone: (541) 268-3044
Fax: (541) 268-3044

Skipanon WS Council
523 Turlay Rd
Warrenton OR 97146
Phone: (503) 861-3669
Fax:

SW Coos WS Council
Rt 1 Box 1370a
Bandon OR 97411
Phone: (541) 347-9584
Fax:

Ten Mile Basin Partnership
PO Box L
Lakeside OR 97449
Phone: (541) 759-2414
Fax: (541) 759-4752

Tillamook WS Council
6385 Tillamook Ave
Bay City OR 97107
Phone: (503) 377-4000
Fax: (503) 377-4010

Tryon Cr Partnership
6039 SW Knights Bridge
Portland OR 97219
Phone: (503) 244-0641
Fax:

Tryon Cr WS Council
10750 Boones Ferry Rd
Portland OR 97219
Phone: (503) 823-5596
Fax:

Tualatin WS Council
1080 SW Baseline Bldg B Ste B-2
Hillsboro OR 97123
Phone: (503) 648-3174 ext 116
Fax: (503) 681-9772

U Chewaucan WS Council
PO Box 67 Ranger Dist
Paisley OR 97636
Phone: (541) 943-3114
Fax:

U Klamath WS Council
2316 S 6th Ste C
Klamath Falls OR 97601
Phone: (541) 882-5409
Fax: (541) 882-5409

U Nehalem WS Council
16747 Timber Rd
Vernonia OR 97064
Phone: (503) 429-2401
Fax: (503) 429-2401

U Rogue WS Council
PO Box 1128
Shady Cove OR 97539
Phone: (541) 878-3800
Fax: (541) 878-3800

U South Frk John Day Basin
Izee Rt Box 750
Canyon City OR 97820
Phone: (541) 477-3828
Fax:

Umatilla Basin WS Council
PO Box 1551
Pendleton OR 97801
Phone: (541) 276-2190
Fax: (541) 276-8130

Umpqua Basin WS Council
1758 NE Airport Rd
Roseburg OR 97470
Phone: (541) 672-6507
Fax: (541) 440-3424

Walla Walla WS Council
PO Box 68
Milton OR 97862
Phone: (541) 938-7086
Fax: (541) 938-6639

Williams Cr WS Council
PO Box 94
Williams OR 97544
Phone: (541) 846-9175
Fax:

Winchuck WS Council
11243 Winchuck River Rd
Brookings OR 97415
Phone: (541) 469-5462
Fax:

Yamhill WS Council
2200 W 2nd St
Mcminnville OR 97128
Phone: (503) 472-6403
Fax: (503) 472-2459

Young's Bay WS Council
Rt 1 Box 990
Astoria OR 97103
Phone: (503) 325-8609

Metric conversion

14.2

"There is measure in all things."
— Horace

Length				
Symbol	**When you know**	**Multiply by**	**To find**	**Symbol**
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km

Area				
Symbol	**When you know**	**Multiply by**	**To find**	**Symbol**
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.08	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha

Mass (weight)				
Symbol	**When you know**	**Multiply by**	**To find**	**Symbol**
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 pounds)	0.9	tonnes	t

Volume				
Symbol	**When You Know**	**Multiply by**	**To find**	**Symbol**
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3

Temperature
(exact)

Symbol	When You Know	Multiply by	To find	Symbol
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Length

Symbol	Unit	Number of meters
km	kilometer	1,000
hm	hectometer	100
dkm	decameter	10
m	meter	1
dm	decimeter	0.1
cm	centimeter	0.01
mm	millimeter	0.001

Area

Symbol	Unit	Number of square meters
km^2	square kilometer	1,000,000
ha	hectare	10,000
a	are	100
ca	centare	1
cm^2	square centimeter	0.0001

Mass
(weight)

Symbol	Unit	Number of grams
t	metric ton or tonne	1,000,000
kg	kilogram	1,000
hg	hectogram	100
dkg	decagram	10
g	gram	1
dg	decigram	0.1
cg	centigram	0.01
mg	milligram	0.001

Volume

Symbol	Unit	Number of grams
cm^3 (or cc)	cubic centimeters	0.000001

Capacity

Symbol	Unit	Number of liters
kl	kiloliters	1,000
hl	hectoliter	100
dkl	decaliter	10
l	liter	1
dl	deciliter	0.1
cl	centiliter	0.01
ml	milliliter	0.001

Temperature
Celsius scale

°C	degree Celsius
0°C	freezing point of water
100°C	boiling point of water

Source: This chart is reprinted with permission from the *Project Learning Tree Supplementary Activity Guide for Grades K-6* (Washington, D.C.: American Forest Institute, 1977).

Hot links

14.3

"Knowledge is of two kinds. We know a subject ourselves, or we know where we can find information upon it."
— Samuel Johnson

Websites are amazing sources of information. But, they are also very dynamic. The following websites were active as of June 1999. These sources may help students locate information useful in their watershed studies.

Water cycle

Water Cycle Index
http://www-k12.atmos.washington.edu/k12/pilot/water_cycle/index.html
An educational module of water cycle activities.

The Hydrologic Cycle
http://agen521.www.ecn.purdue.edu/AGEN521/icon.html
Designed for a college course this site includes some good graphics.

NASA's Observatorium—The Hydrologic Cycle
http://www.observe.ivv.nasa.gov/nasa/earth/hydrocycle/hydro2.html
An attractive site on water and atmosphere.

NSF Geosciences Unidata Integrated Earth Information Server
http://atm.geo.nsf.gov/
Climatic information, including instructional materials

Oregon Climate Service
http://www.ocs.orst.edu/
Information on weather and climate in Oregon.

USDA NRCS Weather and Climate Data
http://www.ftw.nrcs.usda.gov/climate_data.html
A source of information on past and current weather and climate.

Watersheds

Surf Your Watershed
http://www.epa.gov/surf/
This US Environmental Protection Agency (EPA) site provides maps and other information for individual watersheds nationwide.

Watershed Internet Resource Links (For the Sake of the Salmon)
http://www.4sos.org/rvwtrshd.html
A good list of internet links.

Office of Wetlands, Oceans and Watersheds
http://www.epa.gov/OWOW/
The EPA office that is responsible for wetlands, oceans, and watersheds.

Portland Regional Watershed Information
http://www.upa.pdx.edu/CWSP/WATSHED/region.htm
Want to know what's happening in Portland's watersheds? Look here.

Welcome to the Oregon Plan for Salmon and Watersheds
http://www.oregon-plan.org/
The Oregon Plan is the State of Oregon's effort to restore salmon, trout, and other aquatic resources to productive and sustainable levels.

Locally Organized Watershed Councils In Oregon
http://www.oregon-plan.org/supplement12-97/st-14e03.html
Watershed Councils are a good place to get involved with others in improving our watersheds.

The Watershed Management Council
http://watershed.org/wmchome/
The Watershed Management Council is non-profit educational organization dedicated to the advancement of the art and science of watershed management

USDA-NRCS Conservation Programs
http://www.nrcs.usda.gov/NRCSProg.html
The Natural Resources Conservation Service works to improve conservation and management of private lands.

The Sturgeon General's Website (Environment Canada)
http://www.sturgeongeneral.org/
Lots of information on watersheds and fisheries in the Pacific West.

River Network
http://www.teleport.com/~rivernet/
River Network's mission is to help people organize to protect and restore rivers and watersheds.

Uplands

National Agricultural Library: Water Quality Information Center
http://www.nal.usda.gov/wqic/
A starting point for information of the connections between agriculture and water quality.

USDA-NRCS Soils Data
http://www.ftw.nrcs.usda.gov/soils_data.html
Background information on soil and its management.

USDA-NRCS Plants Data
http://www.ftw.nrcs.usda.gov/plants_data.html
Background information on the importance and management of plants.

Backyard Conservation (NRCS)
http://www.nhq.nrcs.usda.gov/CCS/Backyard.html
Information from NRCS to help improve conservation at the backyard level.

Riparian areas

Fact Sheets: Functions and Values of Riparian Areas
http://www.magnet.state.ma.us/dfwele/river/rivfstoc.htm
Basic information on the importance or riparian areas and how they work.

Wetland and Riparian Links US Bureau of Reclamation
http://www.usbr.gov/ecology/linkslow.html#wetlands
A source of other places to go for information.

Riparian Topics Bibliography
http://glinda.cnrs.humboldt.edu/wmc/rip_bib/rip_index.html
A huge bibliographic database on riparian topics.

PLANTS National Database Home Page
http://plants.usda.gov/plantproj/plants/index.html
A site with basic botanical information on an incredible number of plants.

Riparian Areas (Oregon State University Extension Service, Malheur Experiment Station)
http://www.primenet.com/~mesosu/ripiarian.htm
Basic information on the importance of riparian areas.

Riparian Resources Home Page
http://quarles.unbc.ca/nres/ackerman/riparian-res.htm
A Canadian list of internet resources and links on riparian topics.

Riparian Communities and Related Topics: An Annotated Bibliography
http://www.npwrc.usgs.gov/resource/LITERATR/RIPARIAN/RIPARIAN.HTM
A searchable database from USGS listing articles on various aspects of riparian management.

Classification and Management of Montana’s Riparian and Wetland Sites
http://www.rwrp.umt.edu/ClassDocs/toc.html
A look at how to describe and manage riparian and wetland sites.

Hydrology

Oregon Water Resources Department (WRD)
http://www.wrd.state.or.us/
Includes information on water rights, precipitation and streamflow data, and predictions of water availability.

The River Continuum Concept
http://www.oaa.pdx.edu/cae/programs/sti/pratt/rcc.html#mid
An illustrated explanation of the river continuum concept.

Hydrology Web Home Page
http://terrassa.pnl.gov:2080/EESC/resourcelist/hydrology.html
Hydrology resources for everyone from professionals to kids.

IRN's RiverBasics
http://www.irn.org/basics/basic.html
International Rivers Network's links to understanding rivers.

Water quality

Christy's Very Basic Web Page
http://www.mwsc.edu/~cjj4684/
Links to water quality web sites.

Internet Resources Related to Water Quality
http://www.soils.agri.umn.edu/research/mn-river/doc/links.html
Links to water quality resources.

National Water Quality Inventory (US EPA)
http://www.epa.gov/OWOW/305b/
Information on water quality across the US.

Monitoring Water Quality, from US EPA
http://www.epa.gov/OWOW/monitoring/

Oregon Department of Environmental Quality (DEQ)
http://waterquality.deq.state.or.us/wq/
The Department of Environmental Quality (DEQ) is the state agency responsible for protecting Oregon's public water for a wide range of uses.

US EPA's Nonpoint Pollution Control Program
http://www.epa.gov/OWOW/NPS/
Includes information on the Clean Water Act, nonpoint source pollution control programs, and links to related sites.

Environmental Contaminants Encyclopedia
http://www.aqd.nps.gov/toxic/index.html
Information on specific pollutants from the National Park Service.

Aquatic organisms

The Aquatic Ecology Page
http://www2.netdoor.com/~pinky/aquatic.htm
Links to internet resources on aquatic life and ecology.

Internet Resources: Salmon and Watersheds (Oregon Sea Grant)
http://seagrant.orst.edu/links/salmsites.html
More links to internet resources on watersheds and salmon from Oregon Sea Grant.

For the Sake of the Salmon
http://www.4sos.org
This site includes a variety of valuable pages, including teacher resources, internet links for many subjects, and lists of publications.

The BC Salmon Page
http://www.canfisco.com/bc-salm2.html
The story of salmon in British Columbia.

Does something smell fishy?
http://www.cco.caltech.edu/~salmon/fishes.html
Information and links on various salmon species.

National Marine Fisheries Service
http://www.nmfs.gov/
The agency responsible for recovery of salmon in the Pacific Northwest under the Endangered Species Act.,

Fisheries Links, US Bureau of Reclamation
http://www.usbr.gov/ecology/linkslow.html#fisheries
Links to fisheries organizations.

Hot Topics: Salmon
http://seagrant.orst.edu/hot/salmon.html
The opening page of Oregon Sea Grant's salmon site.

Salmon Preservation: A Case Study in Successful Environmental Conflict Resolution
http://www.cyberlearn.com/online.htm
A look at the complex set of interacting factors that have influenced declining salmon populations.

Aquatic Invertebrates
http://education.lanl.gov/resources/ntep95/Aquatic_Insects/Waterbugs.html
Includes web pages on insect identification and classroom insect activities.

Teaching resources

Educating Young People About Water
http://www.uwex.edu/erc/ywc/index.html

Global Rivers Environmental Education Network
http://www.econet.apc.org/green/

American Rivers, Northwest Office, Salmon Day Curriculum
http://www.amrivers.org/nw-curric1.html

National Wildlife Federation, Environmental Education
http://www.nwf.org/nwf/education/index.html

California Environmental Education
http://ceres.ca.gov/education/
An incredible collection of links and resources

National Teacher Enhancement Program
http://www.education.lanl.gov/RESOURCES/NTEP95/
Ideas for teaching units on terrestrial and aquatic insects, mammals, and birds

Materials for Teachers
http://www.4sos.org/teach_mat/teachers.html
A list of curricula and other materials from For the Sake of the Salmon.

Alaska Aquatic Educational Resources
http://www.state.ak.us/local/akpages/FISH.GAME/sportf/geninfo/aq_ed/aeindex.htm

Selected Internet Resources in the Geosciences and Related Fields, with an Emphasis on the Pacific Northwest
http://glinda.cnrs.humboldt.edu/wmc/geolinks.html#hydro
Lots of information on geosciences, including hydrology.

University of California Museum of Paleontology
http://www.ucmp.berkeley.edu/
A wealth of resources for science teachers, including a glossary of ecological terms (http://www.ucmp.berkeley.edu/glossary/glossary.html)

Unit Conversion Calculator
http://www.omnis.demon.co.uk/conversn/convjvsc.htm
Need to convert gallons to cubic feet? Here's your site!

Online Maps from USGS
http://edcwww.cr.usgs.gov/glis/hyper/guide/1_dgr_demfig/index1m.html
Download USGS maps from the Internet.

Other resources

USGS Biological Resources Division
http://www.nbs.gov/

Glossary of Water Quality Terms
http://www.wqa.org/WQIS/Glossary/GlossHome.html

The EnviroLink Library
http://library.envirolink.org/
"The most comprehensive resource of environmental information available on the Internet."

Curriculum resources

14.4

"The whole art of teaching is only the art of awakening the natural curiosity of young minds for the purpose of satisfying it afterwards."
— Anatole France

Videos

Birth of a Salmon

Department of Fisheries and Oceans
Communications Branch
Suite 400-555 West Hastings St.
Vancouver, BC V6B5G3
(604) 666-1847

6 minutes, 1976, e-j-s

The complex workings of salmon embryology are simplified and beautifully photographed in this short presentation.

The Bull Trout Story – A Living Legend

Portland General Electric
Attention: Diane Bricker
Environmental Services Department
121 SW Salmon Street
Portland, OR 97204
(503) 464-8526

17 minutes, 1992, j-s-c-a

Many of our bull trout populations have reached a critical point. With habitat protection, enhancement efforts, and good stewardship, they can make a comeback. This video describes a comeback story, gives information on the bull trout's life cycle and distinguishing characteristics.

Cascade Watershed: The Sandy River Basin

Northwest Film and Video Center
1219 SW Park Avenue
Portland, OR 97205
(503) 221-1156

21 minutes, 1987, video, j-s-c-a
Rental: $20.00

The Sandy River, a major tributary of the Columbia River, springs from Sandy and Reid Glaciers on Oregon's Mt. Hood and travels its 57-mile channel from wilderness to urban development. Advanced students in Experiential Biology at Cleveland High School investigated the varied wildlife and habitats of the river and consulted with professional biologists and representatives from environmental organizations to produce this excellent visual introduction to the study of watersheds.

The Coho Salmon Puzzle

Washington Department of Natural Resources
9701 Blomberg Street SW
Olympia, WA 98504
(360) 902-1609

20 minutes, 1989, videotape, s-c-a
nominal fee for duplication

This well-produced videotape explores the history and habitats of coho salmon throughout a large river basin. It focuses on the interrelationships of spawning and rearing habitats and on the importance of floodplains, wetlands, and tributaries as winter habitats.

Fishing is Fun

Department of Fisheries and Oceans
Communications Branch
Suite 400-555 West Hastings St.
Vancouver, BC V6B5G3
(604) 666-1847

12 minutes, 1987, videotape, e-j-s

Second in trilogy narrated by children. The intrinsic as well as the extrinsic aspects of sport fishing are examined through a young boy's experience.

Part 1: A Good and Careful Harvest
Part 3: Silver Swimmers

A Good and Careful Harvest

(Commercial Fishing)
Department of Fisheries and Oceans
Communications Branch
Suite 400-555 West Hastings St.
Vancouver, BC V6B5G3
(604) 666-1847

12 minutes, 1987, videotape, e-j-s

Part one of a trilogy, narrated by children. A young girl and boy discuss the gear and operations of commercial salmon boats (gillnetter, seiner, troller).

Part 2: Fishing is Fun
Part 3: Silver Swimmers

Healthy Watersheds

Publication Orders
Extension & Station Communications
Oregon State University
422 Kerr Administration Building
Corvallis, OR 97331-2119
(541) 737-2513

20 minutes, 1994, color videotape, e-j-s-c-a
$20.00 (includes shipping/handling). Order #VTP 019

This video takes viewers to the Cascade Mountains of Central Oregon where students from nearby towns learn to analyze their local watersheds. It examines all parts of a watershed, including streams, stream life, soils, vegetation, wildlife, and humans. It emphasizes the interdependence of a watershed's individual elements and the consequences of removing or damaging even one of the elements. The video demonstrates a variety of watershed survey techniques and discusses their importance in managing various resources.

Life Cycle of the Anadromous Salmonid

Contact: Jeff Self
Washington Elementary School
3322 Dolbeer Street
Eureka, CA 95503
(707) 441-2547
(707) 441-3323 (FAX)

20 minutes, 1988, j-s-c-a
$20.00

This is an excellent video about the salmon life cycle with beautiful photography and an easy to follow narrative.

Macroinvertebrates and the River Continuum

Oregon Department of Fish and Wildlife
PO Box 59
Portland, OR 97207
(503) 872-5264

20 minutes, 1990, j-s-c-a
$8.00 plus $2.50 s/h. Call for order form.

Includes instructions for sampling aquatic invertebrates, discusses the river continuum, and the relationship of aquatic invertebrates to fish populations. This video is designed to be used with *The Stream Scene: Watersheds, Wildlife and People.*

Oregon's Natural Resources: Here Today—Here Tomorrow

Governor's Watershed Enhancement Board
255 Capitol St. NE 3rd Floor
Salem, OR 97310-0203
(503) 378-3589 ext. 825

11 minutes, 1998, videotape, j-s-c-a

Fifty years ago, Soil and Water Conservation Districts across Oregon joined the Natural Resources Conservation Service to demonstrate voluntary conservation practices that private landowners could use to conserve and protect our state's precious soil, water, animal, plant, and air resources. As the challenge to care for our resources grew, the State of Oregon created the Governor's Watershed Enhancement Board as a means to support watershed restoration and also launched a community-based approach to watershed restoration through local watershed councils. This video illustrates the success of locally led efforts to offer resource solutions. It is also available at local extension offices and most state agency libraries.

Return of the Salmon

Videotape Orders
Oregon Sea Grant Communications
ADS 402
Oregon State University
Corvallis, OR 97331
1-800-375-9360 or 541-737-2716

30 minutes, 1995, videotape, j-s-c-a, $25.00 purchase, $5.00 rental, Order # ORESU-V-95-001

Knowledgeable observers from the Northwest give their views on the effects and meaning of the salmon decline. The complex factors contributing to the salmon decline are shown, including habitat loss and damage, overfishing, the inadequacy of hatcheries, and unfavorable ocean conditions. The video concludes with coastal residents describing how they are taking action to restore the salmon.

Silver Swimmers

Department of Fisheries and Oceans
Communications Branch
Suite 400-555 West Hastings St.
Vancouver, BC V6B5G3
(604) 666-1847

12 minutes, 1987, videotape, e-j-s

Third in a trilogy of videos narrated by children. A young native Indian boy observes and comments on the traditional and modern day fishing and preserving methods.

Part 1: A Good and Careful Harvest
Part 2: Fishing is Fun

Storm Drain Marking Program

Contact your local STEP Biologist to borrow a copy of this videotape.

2.5 minutes, 1990, videotape, j-s-c-a

The video discusses the scope and purpose of the storm drain marking project as part of British Columbia's Salmonid Enhancement Program, but it is applicable anywhere. The storm drain marking program shows how volunteers can mark storm drains to alert people to the harm common household products can cause fish. It is an excellent way for students, especially elementary schools, to get involved in salmonid enhancement projects and create public awareness.

Strangers in Our Waterways

Publication Orders
Extension & Station Communications
Oregon State University
422 Kerr Administration Building
Corvallis, OR 97331-2119
(541) 737-2513

28 minutes, 1994, videotape, j-s-c-a $30.00, order# VTP 023

Goldfish, carp, largemouth bass, brown trout, zebra mussels, mysis shrimp, aquarium plants. What do all these seemingly unrelated organisms have in common? In their native waters, these organisms are benign. But when transplanted to other waters, they may cause problems for native organisms. These problems may lead to an unbalanced ecosystem, affecting many other organisms and species – including humans. This video reveals how the introduction of non-native organisms – fish, shellfish, and even aquarium plants – have affected native organisms in and around our waterways. While there are no easy solutions to the problem, there are ways to avoid making it worse. This video explores research to help reduce or prevent negative impacts of non-native species.

Way of a Trout

Trout Unlimited
1500 Wilson Blvd, #310
Arlington, VA 22209
(703) 284-9421

30 minutes, color videotape, j-s-c-a
$30.00 plus shipping

This video covers a year in the life of a trout and the many pitfalls a fish must face throughout its life.

We All Live Downstream

Publication Orders
Extension & Station Communications
Oregon State University
422 Kerr Administration Building
Corvallis, OR 97331-2119
(541) 737-2513

29 minutes, 1996, color videotape, j-s-c-a
$30.00, order # VTP 021

This educational video examines Oregon's Tualatin River, a waterway that struggles to survive under pressure from nonpoint source pollution. Its subject matter has implications for most every watershed in the country. Like many fresh water surface and groundwater supplies across our nation, the Tualatin absorbs pollution from a variety of sources. The video covers how local residents and government officials are trying to reduce nonpoint source pollution. It also offers tips to help each of us play an active role in cleaning up our nation's drinking water supplies.

Resources available from STEP biologists

Contact your local STEP biologist for more information about the following resources.

Surveying Oregon's Streams "A Snapshot In Time," Aquatic Inventory Project Training Materials and Methods For Stream Habitat Surveys: slide presentation and field training, contact your local STEP biologist.

Introduction to STEP: slide presentation, contact your local STEP Biologist to schedule a presentation about Oregon's Salmon-Trout Enhancement Program.

Maps/equipment/ supplies

Pacific Northwest Watersheds Map

Timothy Colman, Publisher
Good Nature Publishing Company
1904 Third Avenue #415
Seattle, WA 98101
1-800-631-3086

Oregon Drainage Basin Maps

Oregon Water Resources Department
Commerce Building
158 12th St. NE
Salem, OR 97310
1-800-624-3199
www.wrd.state.or.us/publication/pdfs/publist99.pdf
(pages 6-8 map choices, page 9, order form)

Aquascope

Seaview Underwater Viewer
Item #2027, $18.99
Marine Wholesalers
619 S. 600 W.
Salt Lake City, UT 84101
(801) 355-2940

Water Quality Test Kits

Hach Co., Inc.
PO Box 389
Loveland, CO 80539-9986
1-800-227-4424

Cole-Palmer
72245 North Oak Park Avenue
Chicago, IL 60648
1-800-323-4340

CHEMetrics, Inc.
Route 28
Calverton, VA 22106
1-800-356-3072

LaMotte Chemical Products Co.
PO Box 329
Chestertown, MD 21620
1-800-344-3100

D–Frame Nets

Wards Natural Science Establishment
5100 West Henrietta Rd
PO Box 92912
Rochester, NY 14692-9012
1-800-962-2660

Temperature Data Loggers

Onset Computer Corporation
PO Box 3450
Pocasset, MA 02559-3450
(508) 759-9500

Posters

Salmon Life Cycle Posters

Eight posters showing the life stages of a salmon. $18.00 set. 20% surcharge for non-BCTF members Catalog available upon request

BCTF (British Columbia Teacher's Federation)
Lesson Aids
#100 – 550 W. 6th Avenue
Vancouver, BC V5Z 4P2
(604) 871-2181

Trout, Salmon, and Char of North America

$10.95 plus shipping. Catalog available upon request

Ed Lusch
Windsor/Nature Discovery LLC
1000 S. Bertelson #14
Eugene, OR 97402
1-800-635-4194

Salmon Come Back

Full color migrating salmon design with black border. Created for Adopt-A-Stream by artist Sandra Noel. 18”×24”, $12.00.

Adopt-A-Stream Foundation
600 128th Street SE
Everett, WA 98208

Acid Rain Posters

$2.75 plus shipping

Clearing
Environmental Learning Center
19600 S. Molalla Avenue
Oregon City, OR 97045
(503) 657-8400

A Stream Continuum

Shipping and handling charges only ($4.00) for educators. All others $10 plus shipping and handling.

Oregon Chapter
American Fisheries Society
PO Box 722
Corvallis, OR 97339
(541) 753-0442

Pacific Salmon Life Cycle

Nominal fee for shipping and handling.

Fritz Kraus
Alaska Department of Fish and Game
333 Raspberry Road
Anchorage, AK 99518
(907) 267-2265

Salmon Alphabet Poster

A full color poster, 48 x 80 cm, with illustrated salmon words from A to Z. $10 plus 20% surcharge for non-BCTF members.

BCTF Lesson Aids
#100 – 550 W. 6th Avenue
Vancouver, BC V5Z 4P2
(604) 871-2181

Pacific Salmon of North America Poster

Timothy Colman, Publisher
Good Nature Publishing Company
1904 Third Avenue #415
Seattle, WA 98101
1-800-631-3086

Miscellaneous

Egg to Fry Display

A wooden display rack holding four securely mounted glass vials. Salmon eggs, eyed eggs, alevins, and fry development stages are preserved in the vials.

$22 plus 20% surcharge for non-BCTF members

BCTF Lesson Aids
#100 – 550 W. 6th Avenue
Vancouver, BC V5Z 4P2
(604) 871-2181

Stuffed Dissection Fish

An excellent fabric likeness of a coho salmon. All internal parts are attached with velcro and easily removed. Excellent resource for fish dissections with any salmonid species. $275 Canadian plus shipping.

Pacific Seam Works
3731 Winston Cr.
Victoria, BC V8X 1S2
(250) 388-3730
corrine@pinc.com

Puppets

Five, well-made stylized sock puppets of the salmon life cycle stages (egg, alevin, fry, adult, spawner)

$45 plus 20% surcharge for non BCTF members.

BCTF Lesson Aids
#100 – 550 W. 6th Avenue
Vancouver, BC V5Z 4P2
(604) 871-2181

Games

Upstream Racers—An Educational Board Game

Includes a colorful game board, rules, die, pawns and predator capture canisters plus 20 pages of related learning activities.

$18 plus 20% surcharge for non BCTF members.

BCTF Lesson Aids
#100 – 550 W. 6th Avenue
Vancouver, BC V5Z 4P2
(604) 871-2181

Insect Reference Books

Merritt and Cummins, *An Introduction to the Aquatic Insects of North America*, Kendall Hunt Publishing Company, 1984. (Can be obtained from Oregon State University Bookstore, 1-800-595-0357).

Needham and Needham, *A Guide to the Study of Freshwater Biology*, Holden-Deay, Inc., 5th Edition, 1962. (Available from OSU Bookstore).

Pennak, Robert, *Fresh Water Invertebrates of the United States*, 2nd Edition, Wiley Publishing Company, 1978.

Lubell, Winifred and Cecil, *Exploring A Brook: Life in the Running Water,* Parents Magazine Press, New York, 1975.

McCafferty, W. Patrick, *Aquatic Entomology: The Fisherman's and Ecologists' Illustrated Guide to Insects and Their Relatives*, Jones and Barlett Publishers, Massachusetts, 1981.

Related curricula

❋ Denotes good sources of Activity Extensions.

Adopting a Stream: A Northwest Primer

Steve Yates, $9.95, University of Washington Press, PO Box 50096, Seattle, WA 98145-5096

Filled with information on habitat needs, water quality, and salmonids, this book tells how school, community, or sports groups can restore a nearby creek…and in the process learn much about biology, ecology, economics, and the effects of watershed activities on our streams.

Adopting a Wetland: A Northwest Guide

Steve Yates, $5.00, Adopt-A-Stream Foundation, PO Box 5558, Everett, WA 98206

An ideal resource for schools, community groups, and individuals interested in restoring and/or protecting their neighborhood wetland areas. Information is in simple terms. Guide provides introduction to wetland plants. Information on marsh life, wetland types and identification, their values and benefits, mitigation and legislative issues, developing an action plan, etc., as well as technical appendixes on wetland plants and wildlife, scientific classification and a basic observation checklist.

❋*Aquatic Project WILD*

$5.00 plus shipping and handling. Oregon Department of Fish and Wildlife, PO Box 59, Portland, OR 97207, (503) 872-5264.

Developed by Western Regional Environmental Education Council. Contains many excellent, interdisciplinary water-related activities for grades K-12.

Aquatic Resources Education Curriculum

C. Boyd Pfeiffer and Mark Sosin, $25 + $4 s/h, Future Fisherman Foundation, 1033 N. Fairfax St., Suite 200, Alexandria, VA 22314, Call 703-519-9691 for order form or 847-364-1222 for credit card or purchase order.

Contains information on teaching fishing techniques, water safety, and aquatic life. Units include A Fishing Primer; Becoming A Better Angler; Understanding Fish and Their Environment; Water Resources For Our Future; and Careers.

California's Salmon and Steelhead: Our Valuable Natural Heritage

$20.00, Diane Higgins, 4649 Aster Avenue, Mckinleyville, CA 95521 (707) 839-4987.

These materials were developed for grades K–6. It is divided into sections dealing with biological aspects of salmon and steelhead and habitat needs of the various species.

Clean Water, Streams, and Fish: A Holistic View of Watersheds

Wendy Borton, et al., $12 + $3 s/h, Washington State Office of Environmental Education, 2800 NE 200th, Seattle, WA 98155-1418 (206) 365-3893, http://cifl.ospi.wednet.edu.

Focuses on human dependence and human impact on water quality of the Northwest. Covers water quality, life cycle of salmon, stream ecology, and environmental/economic tradeoffs. It is specific to Washington state, but most is applicable elsewhere.

The Creek Book

UBC Press, $10.95 + s/h, Raincoast Book Distribution, 8680 Cambie St., Vancouver, B.C. V6P 6M9, 1-800-663-5714.

Nice drawings and descriptions of plants and animals found in this ecosystem. Some student worksheets included.

Discover a Watershed: The Everglades

Robinson, George B. and Sandra C., Lane, Jennie, $15.95 plus shipping, The Watercourse, 201 Culbertson Hall, Montana State University, Bozeman, MT 59717-0057, (406) 994-5392

A curriculum package designed to study the Everglades ecosystem from a watershed approach. Has many applications and ideas appropriate for other watersheds.

Discovering Salmon, A Learning and Activity Book

Nancy Field and Sally Machlis, $4.95 +s/h, Dog-Eared Publications, PO Box 620863, Middleton, WI 53562-0863, (608) 831-1410 (phone and fax) or 1-888-DOG-EARS, http://www.dog-eared.com

Covers life cycle, different species of salmon, river geography, predators, and hatcheries. Primarily geared to elementary students.

✻*Earth: The Water Planet*

Jack Gartrell, et al., $18.50 + $4.25 s/h. Special Publications, National Science Teachers Association, 1840 Wilson Blvd., Arlington, VA 22201-3000, 703-243-7100 or 1-800-722-6782, http://www.nsta.org

An excellent collection of elementary/middle school water activities. The book is divided into five sections: Groundwater; Reshaping the Surface of the Earth; Raindrops Keep Falling On My Head; Water Everywhere; and Investigating the Physical Properties of Water. Each section includes readings and hands-on activities.

Field Identification of Coastal Juvenile Salmonids

WR Pollard, et al., $12.95 + s/h, Harbour Publishing, PO Box 219, Madeira Park, BC Canada VON 2HO, (604) 883-2730.

A guidebook designed primarily for juvenile salmonid identification in Canadian waters, but has application throughout the Northwest.

Field Manual for Water Quality Monitoring

(11th edition), Mark Mitchell and William Stapp, 2050 Delaware, Ann Arbor, MI 48103, $19.95 + s/h order from GREEN, Catalog # WQM020, 206 S. 5th Ave., Suite 150, Ann Arbor, MI 48104, (734) 761-8142, or fax (734) 761-4951.

Manual designed for school classes, community groups, and individuals to understand and conduct nine water quality tests and determine their relationship to each other; become familiar with sources of water pollution and potential ways to help remedy the particular problem; and understand the significance of the data collected. The instructional model has two components: The Environmental Problem Solving Component and The Action Research Component.

Fish Eggs to Fry: Helping Kids Raise Fish

Bowers, Patty, et al., Oregon Department of Fish and Wildlife, PO Box 59, Portland, OR 97207, (503) 872-5264, or call to obtain from local STEP Biologist.

This manual provides all the information an Oregon teacher would need to raise salmon or trout eggs in a classroom incubator.

The Fish Hatchery Next Door

Hastie, Bill and Bowers, Patty, Contact Aquatic Education Coordinator, Oregon Department of Fish and Wildlife, PO Box 59, Portland, OR 97207, (503) 872-5264, or contact your local Oregon hatchery.

This package will help you create a successful visit to a fish hatchery with students of all ages. Fish hatcheries play an important role in maintaining the balance between human demands and the needs of Oregon's diverse wildlife.

Fish in the Floodlights

BCTF Lesson Aids, #100-550 W. 6th Avenue, Vancouver, BC V5Z 4P2, (604) 871-2181

Nine short dramas; ideal for theme units and integrated activities.

Forestry and Water Quality

George W. Brown, OSU Bookstores, Inc., Memorial Union, Oregon State University, Corvallis, OR 97339

Up-to-date review of research describing the impacts of forest practices on the quality of water in forest streams. Originally intended for use in watershed management classes, it is now a standard reference for watershed management, forest hydrology, and environmental management.

Gently Down the Stream

James Boland, BCTF Lesson Aids, #100-550 W. 6th Avenue, Vancouver, BC V5Z 4P2, (604) 871-2181

This is a curriculum package developed for a fish hatchery field trip in British Columbia, but is applicable elsewhere.

✻ *Groundwater: A Vital Resource*

Cedar Creek Learning Center, free, Citizen Action Office, Tennessee Valley Authority, 400 W. Summit Hill Drive, Knoxville, TN 37902

A good collection of activities for grades 3-12 related to groundwater. Units include The Water Cycle; Water Distribution in Soils; Water Quality; and Community Impacts.

How to Catch and Identify the Gamefish of Oregon

E. A. Lusch, Frank Amato Publications, PO Box 02112, Portland, OR 97202

A practical guide to fish identification for anglers and other interested individuals.

Identification of Physical Habitats Limiting the Production of Coho Salmon in Western Oregon and Washington

Gordon Reeves, Fred Everest, and Thomas Nickelson, 1989, USDA Forest Service PNW General Technical Report PNW-GTR-245, available from Gordon Reeves, PNW Research Station, 3200 SW Jefferson Way, Corvallis, OR 97331.

An important first step in attempts to increase production of salmonids by habitat manipulation is to identify limiting factors. This report provides a systematic approach for utilizing fish habitat data derived from watershed surveys to estimate the number produced for each particular life stage of coho salmon in fresh water. Quantitative measurements of the total amount of habitat present (e.g. spawning gravel, pools, riffles, glides, etc.) are coupled, through the use of a key, with the survival rate between life history stages and the amount of habitat needed per individual at each stage to yield estimates of the potential summer population level and smolt output. In addition, variables such as gradient, summer and winter water temperatures, adult escapement, and hatchery fish introduction are addressed.

Investigating Aquatic Ecosystems

William A. Andrews, Prentice-Hall Canada, Inc., Scarborough, Ontario, 1987.

A textbook with an introduction to the basic principles of freshwater ecology. Includes field and laboratory studies and thought-provoking questions.

Investigating Your Environment

USDA Forest Service, Pacific Northwest Region, Public Affairs, Natural Resource Education, Portland, Oregon, 1993 and earlier additions.

An interdisciplinary curriculum for grades 7–12, this large package contains activities to study basic environments (soil, water, forests, plants, wildlife), unique environments (built, desert, dunes, marine, pond, range, riparian, wilderness), extending your investigations, investigation spin-offs, and a thorough appendix of resources and ideas.

Leapfrogging Through Wetlands

Margaret Anderson, Nancy Field and Karen Stephenson, $7.95 +s/h, Dog-Eared Publications, PO Box 620863, Middleton, WI 53562-0863, (608) 831-1410 (phone and fax) or 1-888-DOG-EARS, http://www.dog-eared.com.

This book helps young people understand the significance of wetlands in ecosystems throughout North America. Readers learn about the vast array of plant and animal life associated with wetlands. Educators will find this book an excellent companion for *WOW! The Wonders Of Wetlands* and *Project WET*.

Learning to Love Streams

Izaak Walton League of America, 1401 Wilson Boulevard, Level B, Arlington, Virginia 22209

Materials about water quality and pollution.

Living in Water — An Aquatic Science Curriculum

(3rd edition) $23.95 + $4 s/h, Kendall Hunt, 4050 West Mark Drive, PO Box 1840, Dubuque, IA 52004-1840, 1-800-228-0810.

This is a basic hands-on aquatic science curriculum for grades 4 -6. The material provides extensive background on the basic principles and concepts of aquatic ecology, from the solubility of water and its effects on the distribution of aquatic life, to adaptations to aquatic environments, food web interactions, and the importance of aquatic research.

The Magnificent Journey

Free, Bonneville Power Administration, Public Involvement Office, PO Box 12999, Portland, OR 97212, 1-800-425-8429

This is the life story of Onco, a chinook salmon from Idaho. Contains information about habitat and threats. Poster of salmon and steelhead included.

Make It Work! Rivers: The Hands On Approach to Geography

Andrew Haslam, Two-Can Publishing Ltd, Chicago, IL 60661.

One of a four-part "Make-It-Work" series of books which use colorful realistic models and exercises to engage children in interactive hands-on projects. For ages 8 and older.

OBIS Ponds and Lakes

$18.95, Delta Education, Inc., Box M, Nashua, NH 03061-6102, (603) 889-8899

The eight activities in this module are geared to the explorations of aquatic sites and the plants and animals that live there and their behaviors.

OBIS Streams and Rivers

$18.95, Delta Education, Inc., Box M, Nashua, NH 03061-6102, (603) 889-8899

The eight activities in this module are designed as investigations of aquatic life in streams and rivers. Specialized activities include feeding behaviors of crawdads and water striders, and the impact of a simulated oil spill on the environment.

Oregon Environmental Atlas

Carolyn Young, $10.00, Portland State University, Media Publications, PO Box 1394, Portland, OR 97207

Includes valuable statewide information on Oregon landforms, surface water, ground water, hydrologic cycle, uses of water, water quality, water pollutants, and related issues in addition to other environmental concerns such as air quality, solid and hazardous wastes, toxic issues, nuclear wastes, and noise pollution.

The Pond Book

UBC Press, $10.95 + s/h, Raincoast Book Distribution, 8680 Cambie St., Vancouver, B.C. V6P 6M9, 1-800-663-5714.

Nice drawings and descriptions of plants and animals found in this ecosystem. Some student worksheets included.

❊ *Project WET*

The Watercourse, 201 Culbertson Hall, Montana State University, Bozeman, MT 59717-0057, (406) 994-5392, Contact Project WET coordinator for Oregon, The High Desert Museum, (541) 382-4754.

Project WET is an interdisciplinary water education program intended to supplement a school's existing curriculum. The goal of the program is to facilitate and promote the awareness, appreciation, knowledge, and stewardship of water resources through the development and dissemination of classroom-ready teaching aids.

Project WILD

ODFW, PO Box 59, Portland, OR 97207, (503) 827-5264, $6.00 plus $2.50 shipping

Contains a broad range of excellent activities. Interdisciplinary and geared to environmental and conservation education emphasizing wildlife.

Rivers and Streams, Habitat Pac

$5.00, National Institute for Urban Wildlife, 10921 Trotting Ridge Way, Columbia, MD 21044

Includes teacher overviews, lesson plans, students worksheets and a poster.

Rivers Curriculum Guide

Rivers Project Southern Illinois University, PO Box 2222, Edwardsville, IL 62026-2222, (618) 650-2000

A series of six rivers-based units written by teachers participating in the Rivers Curriculum Project funded by the National Science Foundation. The units include biology, chemistry, earth science, geography, language arts, and mathematics.

Salmon Below the Surface

BCTF Lesson Aids, #100-55- W. 6th Avenue, Vancouver, BC, V5Z 4P2, (604) 871-2181

Seven science activities for use with *Salmonids in the Classroom*, Intermediate, also suitable for grades 8-10.

Salmon Kit

$200, Pacific Science Center, 200 2nd Avenue N., Seattle, WA 98109

Includes 10 activities, 3 computer disks, filmstrips, slides, magnifying lenses, thermometers, laminated salmon cards, activity outlines and worksheets.

Salmonids in the Classroom — Primary Package (K-3)

Includes video cassette and 8 life cycle posters, $60.00 plus 20% surcharge for non BCTF members, Intermediate Package (4-7): includes video cassette, $70.00 plus 20% surcharge for non BCTF members, BCTF Lesson Aids, 105-2235 Burrand Street, Vancouver, BC Canada, V6J 3N9, (604) 731-8121

Primary package is a study of salmonids taught through an illustrated story of Chucky Chum. Intermediate package is divided into three units on life cycle, harvesting, and enhancement. Units cover biological aspects, salmonid habitat, the fishing experience, and salmonids in today's world. Ideas for integration in all subject areas. This is geared to British Columbia, but basic concepts are adaptable to any area.

Save Our Streams

Izaak Walton League of America, 1401 Wilson Boulevard, Level B, Arlington, VA 22209

This packet of materials on stream care and water quality includes background information, activities, teaching guide, and guidelines for how to adopt and monitor a stream.

Sourcebook for Watershed Education

Cole-Misch, et al, Global Rivers Environmental Educators Network (GREEN), 206 S. 5th Ave., Suite 150, Ann Arbor, MI 48104, (734) 761-8142 or FAX (734) 761-4951, Item # WQM080, $29.95

This book contains strategies for program development, teaching and evaluation as well as learning activities and materials. It also focuses on providing direction to those interested in establishing or enhancing a watershed education program using an interdisciplinary, participative approach.

Streamkeeper's Field Guide: Watershed Inventory and Stream Monitoring Methods

Murdoch, Tom, et al., $29.95 + $4.00 s/h, Adopt-A-Stream Foundation, 600-128th St SE, Everett, WA 98208, (425) 316-8592

Background information on how streams and their surrounding watersheds function, detailed methods on watershed inventory and stream monitoring for volunteers, tips on presenting data, and stories about Streamkeepers putting watershed inventory and stream monitoring information to use in the protection and restoration of our nation's streams.

The Stream Scene: Watersheds, Wildlife, and People

Patty (Farthing) Bowers, et al. Contact Aquatic Education Coordinator, Oregon Department of Fish & Wildlife, PO Box 59, Portland, OR 97207, (503) 872-5264.

This stream ecology publication targets students in grades 6-12. Units include Water Cycle, Watersheds, Uplands, Riparian Areas, Hydrology, Water Quality, and Aquatic Organisms. Student worksheets, field data sheets, and other resources are included.

Streamwalk Manual

US-EPA, Krista Rave, Eco-081, 1200 6th Ave, Seattle, WA 98101, (206) 553-6686

A standardized, easy-to-use screening tool for monitoring stream corridor health. It is designed for use by lay people who are interested in learning more about their streams and rivers.

Update!

BCTF Lesson Aids, #100-550 West 6th Avenue, Vancouver, BC V5Z 4P2, (604) 871-2181

New and revised activities, handouts, and cooperative learning strategies for use with *Salmonids in the Classroom, Primary.*

✻ *Water Education*

The Comprehensive Water Education Book: Daugs, Donald R., et al., International Office for Water Education, Utah Water Research Laboratory, Utah State University, Logan, UT 84322-3200, (801) 797-3182 or 1-800-922-4693

Geared to grades K-6, the many excellent activities in this manual help students develop a scientific attitude about water.

Watershed Restoration: Principles and Practices

Williams, Jack, et al., $30.00 + s/h, American Fisheries Society, Publication Fulfillment, PO Box 1020. Sewickley, PA 15143, (412) 741-5700

In straightforward, easy-to-understand language, this practical guidebook will give you an in-depth understanding of the principles of watershed restoration; how to build partnerships for a restoration program; practices and strategies for achieving restoration; what works and what doesn't; and what is in store for the future. In addition to providing the scientific, social, and policy frameworks for conducting restoration, the book spotlights how citizen groups, communities, conservation coalitions, private interests, and management agencies are working together to restore watersheds.

Watershed Stewardship: A Learning Guide

#EM 8714, Oregon State University Extension Service, Corvallis, OR 97310, $32.00

This resource is useful for watershed group members, landowners and managers, and volunteers involved with watershed restoration. It is a 22-chapter guide that provides information about forming effective partnerships, watershed basics, watershed assessments, strategies for enhancing watershed resources, and implementing effective restoration projects.

✻ *Watershed Uplands Scene: Catching the Rain*

Ferschweiler, Kate, Kermit Horn, and Al Hughes, Environmental Education Association of Oregon, $15.00, Contact Education Coordinator, Governor's Watershed Enhancement Board, 255 Capitol Street NE, Salem, OR 97310-0203, (503) 378-3589 ext. 825

This package provides a model for students to learn fundamental concepts about their local watershed while developing information-gathering, problem-solving, group interaction, and public presentation skills. Unit 1 explores the biophysical aspects of a watershed—weather and climate, soils vegetation, and wildlife. Unit 2 introduces the human uses—urban, forestry, recreation, and agriculture, and Unit 3 provides an opportunity for students to apply knowledge and skills learned in the previous section to local land-use management issues.

Wetland Walk Manual

US-EPA, Krista Rave, Eco-081, 1200 6th Avenue, Seattle, WA 98101, (206) 553-6686

A standardized, easy-to-use screening tool for monitoring wetland health. It is designed to give citizens the opportunity to become partners in learning about wetlands and at the same time collect information and data which help identify trends in wetland health and location.

✻ *4-H Wetland Wonders*

Virginia Thompson, Dave Price, Connie Reid, Oregon State University Extension Service, 5390 4-H Road NW, Salem, OR 97304, (503) 371-7920.

This curriculum guide for grades 4-5 is focused on wetlands and water quality issues. Lessons begin with the water cycle and extend through watersheds, ground water, home water uses, and wetland plants, soils, and animals.

WOW! The Wonders of Wetlands

Kesselheim, Alan, et al., Environmental Concern, Inc., $15.95 plus shipping, The Watercourse, 201 Culbertson Hall, Montana State University, Bozeman, MT 59717-0057, (406) 994-5392

This curriculum package is for all educators. It contains background material for those educators preparing wetland study units. It also contains material on organizing a wetlands field trip, making inexpensive sampling equipment, and getting involved in wetland enhancement and stewardship.

Words and water

14.5

A study of watersheds through literature

"The love of learning, the sequestered nooks, and all the sweet serenity of books."
— Henry Wadsworth Longfellow

"To stick your hands in the river is to feel the cords that bind the earth together in one piece," writes Barry Lopez. Much as Lopez considers the river a way to bind the earth together, we can use a study of watersheds to bind together a multi-disciplinary approach to learning. A study of watersheds is not just a study in science. Watersheds stretch across state and national boundaries as well as across the disciplines, reaching through lessons of mathematics, social science, and literature to help children and adults gain a deeper understanding of our water resource and how we affect it. Incorporating literature into a study of watersheds is especially valuable. Through stories, we vicariously experience the lives of people and wildlife in a water world. Stories and analogies help us understand the importance of humans acting as stewards of the water environment.

The first requirement of a watershed study is to let students experience first hand their own watershed—outside of the classroom walls. Then, using studies across the disciplines, allow students to explore the watershed from a variety of angles. Combining literature and writing activities helps students discover how other writers feel about watershed topics. Students can then communicate their own feelings and what they learn with a number of different techniques.

Following are a few examples of elementary-level children's literature related to water, watersheds, and wildlife. Each entry lists the grade level and a brief description of the piece. Contact your local Education Service District or public library for more titles and information. Explorations on the Internet may yield even more titles. For guidance in centering an entire language arts unit around watersheds, contact the Illinois Rivers Project, Southern Illinois University, PO Box 2222, Edwardsville, IL 62026-2222, phone: (618) 692-2446, fax: (618) 692-3359, e-mail: rivers@siue.edu, or website: http://www.siue.edu/OSME/river. Ask for ordering information about the Rivers Project Curriculum series, which includes materials for language arts, mathematics, geography, earth science, chemistry, and biology.

The Adventures of Tom Sawyer

Gr. 4–7

by Mark Twain, Scholastic, Inc

The American classic adventure of a boy growing up in a 19th century Mississippi River town.

Argyle Turkey Goes to Sea

Preschool–Gr. 3

by James E. Davis, DLM Teaching Resources

On the way to see a whale in the ocean, Argyle Turkey sees a pond, a stream, a swamp, a lake, a river, a waterfall, and finally, a whale in the bay.

Sallie Peila, Harney ESD Learning Resource Center, prepared this literature list. Many thanks for her efforts.

Beavers Beware!
Preschool–Gr. 3
By Barbara Brenner, Bantam Books
A family with a house on the river finds two beavers cutting down trees and building a lodge on their dock. A Bank Street Ready-to-Read book.

Come Back Salmon
Gr. 3–6
by Molly Cone, Little Brown and Co.
True story of a group of students that helped reclaim a local stream so that salmon could once again spawn there.

Fish Eyes
Preschool–Gr. 3
by Lois Ehlert, Scholastic Inc.
A counting book depicting the colorful fish a child might see if he turned into a fish himself.

Fish Is Fish
Preschool–Gr. 3
by Leo Lionni, Scholastic Inc.
A minnow wants to follow his tadpole friend—who becomes a frog—onto land.

Freshwater Alphabet Book
Preschool–Gr. 3
by Jerry Pallotta, The Trumpet Club
A colorful alphabet book introducing some familiar and some unusual aquatic animals.

The Hole in the Dike
Preschool–Gr. 3
by Norma Green, Scholastic Inc.
When a young boy in Holland sees a small trickle of water leaking through the dike, he bravely spends the night with his finger in the hole in order to save his country from a flood.

How Many Fish?
Preschool–Gr. 1
by Rachel Gosset, Scholastic Inc.
Beginning readers count the fish in ponds, lakes, and streams.

In a Small, Small Pond
Preschool–Gr. 2
by Denise Fleming, Scholastic Inc.
A rhyming text describes the seasonal changes in a frog's little pond.

McElligot's Pool
Gr. K–3
by Dr. Seuss, Random House
A young boy fishes in McElligot's pool with high hopes.

Over the Steamy Swamp
Preschool–Gr. 3
by Paul Geraghty, Harcourt Brace Jovanovich
A hungry mosquito starts a food chain in a steamy swamp as each hungry animal both preys and is preyed upon.

Paddle to the Sea
Gr. 3–6
by Holling Clancy Holling, Houghton Mifflin Company
The journey of an Indian boy in a small canoe traveling from Lake Superior to the Atlantic Ocean.

Rain Drop Splash
Preschool–Gr. 3
by Alvin Tresselt, Scholastic Inc.
Rain becomes a puddle, then a lake, and grows larger and larger until it reaches the sea.

A River Ran Wild: An Environmental History

Gr. 1–4

by Lynne Cherry, Harcourt Brace Jovanovich Publishers

An environmental history of the Nashua River, from its discovery by Indians through the polluting years of the Industrial Revolution to the ambitious cleanup that revitalized it. A Reading Rainbow book.

A Salmon for Simon

Gr. K–4

by Betty Waterton, Groundwood Books

Simon, a young Native boy, has been trying to catch a salmon all summer but when the opportunity finally arrives he must decide whether to take it home or let it go.

Squishy, Misty, Damp and Muddy, The In-Between World of Wetlands

Gr. K–6

by Molly Cone, Sierra Club Books

An introduction to the many kinds of wetlands, their importance in our lives, the plants and animals that live there, and why we must work to preserve these habitats.

Swimmer

Gr. K–6

by Shelley Gill, PAWS IV Publishing

The story of the Chinook salmon. Swimmer's journey over 10,000 miles illustrates the cycles of life for the salmon and the girl Katya, who is coming of age.

Water Dance

Gr. K–6

by Thomas Locker, Harcourt, Brace and Company

An innovative and beautiful picture book that follows water's constant dance—a poetic text and complementary paintings contain hundreds of fascinating facts about water.

Water's Way

Preschool–Gr. 3

by Lisa Westberg Peters, Scholastic Inc.

Tony watches water change from clouds to rain to frost, until it finally becomes snow, and he can try his new sled.

What Makes it Rain? The Story of a Raindrop

Gr. K–3

by Keith Brandt, Troll Associates

Where the River Begins

Gr. K–3

by Thomas Locker, Puffin Books

Two boys and their grandfather camp and hike to follow the river to its source.

15

Glossary

Courtesy of Oregon Department of Forestry, Salem, Oregon (Graphics Unit)

Glossary

15

"The chief merit of language is clearness,
and we know nothing detracts so much from this as do unfamiliar terms."
— Galen

abdomen: An insect's body has three parts: head, thorax, and abdomen. The abdomen is the segment farthest from the head.

acid rain: rainwater carrying acidic atmospheric pollutants (commonly nitrous or sulfuric oxides) in solution, scientifically known as acidic deposition.

acid shock: the effect a rapid increase in the level of acidity has on organisms.

acid: corrosive substances with a pH less than 7.0; acidity is caused by high concentrations of hydrogen ions.

adaptation: changes an organism makes to adjust to a different or changing environment.

aerobic: processes requiring oxygen.

alevin: newly hatched fish with yolk sac attached.

alkaline: substances with a pH greater than 7.0 that form corrosive substances in water; alkalinity is caused by high concentrations of hydroxyl ions.

anadromous fish: fish that migrate from saltwater to fresh water for spawning.

anaerobic: processes not requiring oxygen.

anchor ice: heavy ice build-up along stream edges.

antenna: one of the paired sensory organs on the head of insects and other arthropods.

anterior: toward the head

aquatic area: water area of a stream, lake or wetland measured at the high water level.

aquatic: organisms that live in or frequent water.

aquifer: layers of porous underground rock that act as water reservoirs**.**

area of influence: see *riparian area of influence*

arid: dry; areas without adequate precipitation to support woody vegetation.

autotrophy: production of organic compounds from inorganic compounds by plants and bacteria.

average streamflow: average discharge of a stream over a 12-month period.

baseflow: that portion of the flow of a river or stream that is relatively consistent throughout the year.

basic: alkaline.

bedload sediments: sediments too heavy to be constantly suspended in water.

beneficial uses: a list of water uses with utilitarian benefits for people.

benthic: pertaining to the bottom of a body of water.

Best Management Practices: a defined set of methods for land management activities with the least detrimental environmental effects.

biochemical oxygen demand (BOD): the amount of oxygen needed for biological decomposition and chemical oxidation of sediments.

BOD: biochemical oxygen demand.

body: center section of a riffle or pool.

boulders: rocks larger than 12 inches in diameter.

braided: a stream channel that splits and comes back together.

buffer strips: strips of vegetation left to protect streams during forest operations or other types of human activities.

canopy: upper layer formed by forest trees.

carrying capacity: number of organisms a particular habitat can support throughout a year without damage to either organisms or habitat.

cartographer: a person who makes maps.

caudal fin: a fish's rearmost fin, also called the tail.

cerci: a pair of small sensory appendages on the posterior end of some insects.

cfs: cubic feet per second.

Clean Water Act: federal law, originally passed in 1972, that governs nationwide water quality standards.

climate: the general atmospheric conditions—characterized by temperature, precipitation, and wind—of a particular region of the earth.

coarse particulate organic matter (CPOM): primarily leaf, needle, and fine woody debris larger than 1 mm in diameter.

cobble: rock from 3 to 12 inches in diameter; also called rubble.

coliform: a type of bacteria found in the feces of animals. High concentrations are generally an indicator of contamination by manure or sewage.

collectors: aquatic invertebrates that feed on fine material in water.

colloids: very fine sediments, such as clays. Because of their small size these particles can remain suspended for long periods, and be carried farther than other sediment particles.

compound eye: insect eyes made up of many small visual units.

concrete frost: the impermeable layer formed when the surface layer of soil freezes, preventing water infiltration.

condensation: conversion of water from vapor to liquid.

coniferous: cone-bearing, generally needleleaf trees.

consumers: organisms that depend on other organisms for their food.

contour interval: difference in elevation between two adjacent contours.

contour/contour lines: lines on maps that pass through points of the same elevation.

contour: imaginary line on the ground, all points of which are the same elevation above or below a specific datum. A datum is a reference point used in surveying.

cover: vegetation or other features that provide shelter for wildlife.

CPOM: coarse particulate organic matter.

cubic feet per second: a unit of measure for water; a volume of water 1 foot high, 1 foot across, and 1 foot deep, passing a given point every second.

cutbanks: highly eroded, steep streambanks with little vegetation.

deciduous: trees that shed their leaves.

declination: angular difference between magnetic north and true (geographic) north at the point of observation; it is not constant but varies with time because of the "wandering" of the magnetic north pole.

declination: the angular difference between true north and magnetic north.

decompose: breakdown of organic materials to inorganic materials.

dendritic drainage: the patterns formed when streams and their tributaries of a watershed have a branched, tree-like appearance.

deposition: depositing of material by a stream, generally at points of reduced velocity.

detachment: part of the erosion process that occurs when a soil particle is broken loose from the soil surface.

dissolved oxygen concentration (DO): amount of oxygen dissolved in water.

dissolved solids: solid (generally inorganic) material carried in solution by water.

diversity: number of species in a particular community or habitat.

divide: point where two watersheds connect

DO: dissolved oxygen concentration.

dorsal: the back. A fish's dorsal fin is the largest fin on the back.

drainage: a watershed.

drought: extended period of less than average rainfall.

ecosystem: community of organisms in a given area together with their physical environment and its characteristic climate.

ecotone: habitat formed by the transition from one distinctly different habitat to another; an edge.

edge: habitat formed by the transition from one distinctly different habitat to another; an ecotone.

eggs: rounded shelled reproductive body from which young hatch.

electrofishing: using an electric current to sample fish populations.

elevation: distance above or below sea level.

energy base: organic material available for organisms to feed upon.

engulfers: organisms that ingest their prey whole.

entrainment: portion of the erosion process that occurs when detached soil particles are moved with runoff.

ephemeral: streamflow that only occurs during and shortly after extreme precipitation or snowmelt conditions.

erosion: movement of soil by water and wind.

escapement: number of fish remaining for reproduction.

eutrophication: a process that occurs in waters that are rich in nutrients, characterized by the rapid growth of plants, followed by the depletion of oxygen due to the demand, BOD, for decay processes.

evaporation: conversion of water from liquid to vapor.

filtering collectors: aquatic invertebrates that feed by filtering small organic particles from the water.

fine particulate organic matter (FPOM): organic material less than 1 mm in diameter.

fine sediments: particles in water less than 0.2 of an inch in diameter.

first-order stream: stream channel with no tributaries.

fish ladder: a stair-stepped fishway with water flowing over it.

fishway: a human-made structure to help fish move around obstacles in streams or rivers.

flocculated: sediments that have formed loose aggregates—they are more likely to settle to the bottom than particles that have not aggregated.

flood: streamflow greater than the channel can contain.

floodplain: area along a stream or river that is subject to flooding.

forage: vegetation consumed by wild or domestic grazing animals.

forbs: plants with soft stems, other than grasses.

Forest Practices Act: legislation regulating all forest activities on state and private land.

FPOM: fine particulate organic matter.

fry: recently hatched fish, after yolk sac has been absorbed.

functional feeding groups: classification of aquatic invertebrates according to their mode of feeding.

gathering collectors: aquatic invertebrates that feed on particles deposited or growing on the bottom of a stream channel.

gills: an organ used by fish and aquatic insects to extract dissolved oxygen from water.

glide: in a river, a shallow trough, generally with a sand or gravel bottom.

gradient: degree of slope, or steepness of a geographic feature.

gravel: rock that is 0.2 to 3 inches in diameter.

groundwater: water found underground in the spaces between soil particles.

habitat: an area that meets an organism's needs for food, water, and shelter.

hachure: any series of lines used on a map to indicate the general direction and steepness of slopes; these lines are often used to denote a depression (hole) in the land.

hand-seine: hand-held net used to capture fish.

head: upstream end of a riffle or pool.

headwaters: beginning of a watershed; unbranched tributaries of a stream, generally less than 25 feet wide.

helical flow: the corkscrew fashion that a column of water travels—caused by the Coriolis effect (from the earth's rotation) and friction present in larger streams and rivers.

herbaceous: plants with soft rather than woody stems.

heterotrophy: production of energy from organic compounds; heterotrophs are not capable of producing their own food.

humus: decayed organic matter in or on the soil's surface.

hydrology: study of the distribution, circulation and properties of water.

hyporheic: groundwater zone extending below and to the sides of a stream.

impoundment: structure built to store water, commonly a reservoir or pond.

index contour: the thicker brown lines on a topographic map; these lines usually have an associated number that indicates the elevation along the line.

infiltration: entry of water into soil.

intermittent stream: a stream that does not flow year-around.

ion: an electrically charged atom or molecule; ions combine readily with other atoms or molecules.

irrigation diversion: water taken from a stream to provide water for crops.

large wood: trees or parts of trees large enough to be retained in a river or stream for several seasons; sometimes defined as greater than four inches in diameter.

lateral habitat: linear habitat occurring along the edge of another habitat.

latitude: angular distance in degrees, minutes, and seconds, of a point north or south of the equator.

leaching: movement of dissolved particles by the percolation of water through soils.

lethal limits: extremes in the range of conditions in which an organism can survive.

limiting factors: conditions that establish the population or range of a specific animal or species.

Lincoln Index: method used to estimate the size of a small animal population.

log sill: logs placed in the streambed to slow water, create pools, and trap gravel.

longitude: angular distance in degrees, minutes, and seconds, of a point east or west of the Greenwich meridian.

LWD: large woody debris.

macroinvertebrates: animals without backbones large enough to be seen with the unaided eye.

mandible: jaw.

map, topographic: map that presents the horizontal and vertical positions of the features represented.

map: any concrete or abstract representation of the distributions of features that occur on or near the surface of the earth or other celestial bodies.

maxillae: sharp gripping structures on the mouth of an insect.

meanders: curved "S"–shaped stream channels.

meridian: great circle of the surface of the earth passing through the geographical poles and any given point on the earth's surface. All points on a given meridian have the same longitude.

mesothorax: the second, or middle, segment of an insect's thorax.

metabolic rate: the speed of the physical and chemical processes (e.g. digestion and respiration) taking place in an organism.

metathorax: the third, or most posterior, segment of an insect's thorax.

mg/l: milligrams of a substance per liter of total; equal to parts per million (ppm).

microclimate: climate of a localized area, for example a north-facing hill slope.

microhabitat: a localized habitat described by more specific environmental conditions than the larger habitat that contains it .

midreaches: larger streams carrying the water from several tributaries, generally 25 to 250 feet wide.

milt: milky substance used by male salmon to fertilize eggs.

minimum average streamflow: lowest average streamflow for any one month during a 12-month period.

multiple-use: a system of management that uses an area for a variety of purposes.

nitrates: nitrogen compounds, often functioning as plant nutrients.

nitrogen (N): a common element that is an essential plant nutrient.

nocturnal: animals that are active at night and rest during the day.

non-point source pollution: pollutants that enter waterways from broad land areas as a result of the way the land is used.

ocelli: in insects, tiny simple eyes.

odonates: order of insects containing dragonflies and damselflies.

operculum: gill cover of a fish.

organic material: substances that were once alive or part of living organisms.

orientation: establishing the correct relationship in direction with reference to points of the compass; the state of being in correct relationship in direction with reference to the points of the compass.

parallel drainage: the pattern created when folds in the earth's surface form valleys that are nearly parallel to each other.

parr marks: dark circular markings on sides of juvenile salmonids.

parr: young salmon after the yolk sac has been absorbed. (fry - fingerling).

perennial: streams that flow throughout a year.

periphyton: diatoms and other algae.

pH: measure of the hydrogen ions that determine the acidity or alkalinity of a solution; the pH scale ranges from 1 (acid) to 14 (alkaline), with 7.0 as neutral; the scale is logarithmic, with a change of 1.0 representing a tenfold increase, a change of 2.0 representing a hundredfold increase, etc.

phosphorus (P): a common element that is an essential plant nutrient

photosynthesis: the process plants use to convert carbon dioxide and water into simple sugars.

piercers: predatory organisms that suck body fluids of their prey.

pinch periods: part of the year when conditions are least favorable for an organism's survival.

plankton: microscopic plants and animals carried by currents.

plant associations: species of plants commonly found together in plant communities.

pocket water: small areas of relatively still water behind boulders or other obstructions.

point source pollution: air or water pollutants entering the environment from a specific point or conveyance.

pools: deeper and slower waters in a stream or river.

population: group of individuals of a specific kind, in a given area at a given time.

porous: having a structure filled with tiny openings.

posterior: the rear; the end farthest from the head.

ppm: parts per million; units per equivalent million units; equal to milligrams per liter (mg/l).

precipitation: rain, snow, hail, or sleet falling to the ground.

predator: an animal that hunts and kills other animals for food.

prey: an animal that is hunted or killed by another for food.

primary production: organic material produced by plants and bacteria from inorganic material and sunlight; producers.

prime meridian: meridian of longitude 0 degrees, used as the origin of measurements of longitude; the meridian of Greenwich, England, is the internationally accepted prime meridian on most charts.

Prior Appropriation Doctrine: the system of water rights built on the principle "first in time, first in right," which gives the whoever uses water first a superior right.

producers: plants that manufacture food from inorganic nutrients.

prothorax: the segment of an insect's thorax closest to the head.

Public Land System: public lands are subdivided by a rectangular system of surveys established and regulated by the Bureau of Land Management. The standard format for subdivision is by townships measuring 6 miles (480 chains) on a side. Townships are further subdivided into 36 numbered sections of 1 square mile (640 acres) each.

quadrangle: four-sided area, bounded by parallels of latitude and meridians of longitude used as an area unit in mapping.

radial drainage: the pattern formed when streams drain a central high point, such as a mountain top and create a pattern similar to the spokes on a wheel radiating out from the mountainous hub.

rain shadow: an area that receives less rain because of its position on the leeward side of a mountain or other geologic landform.

reach, stream: a length of stream defined by some common characteristic.

rearing habitat: places in a stream that provide food, resting places and shelter for young fish.

redd: a nest in the stream substrate in which spawning salmon and trout lay their eggs—the eggs incubate in the substrate until hatching.

relief: elevations and depressions of the land or sea bottom.

relief: the difference in elevation between the highest points and lowest points on a map; the configuration of the earth's surface.

residual soils: soils developed in place from underlying rock formations and the surface plant cover.

resources: matter and energy available for use by organisms.

retention: amount of organic material kept in a stream and processed.

riffles: fast, shallow waters of a stream.

riparian area of influence: transition area between riparian area and upland vegetation.

riparian area: wet soil areas directly influenced by the water of a stream, lake or wetland.

riparian management area: area managed by Board of Forestry for protection of riparian values along streams designated as contributory or significant because of their fishery, domestic use, or recreational values.

Riparian Rights Doctrine: the system of water rights based on proximity to the water supply, giving landowners adjacent to a water body the right to use it.

riprap: rock covering used to protect streambanks from erosion.

river continuum: a conceptual model examining the change in composition of aquatic invertebrate communities in running water systems.

rock deflector: rock structure built in streams to redirect water flow, and create pools and pocket water.

rock weir: rock dams built in a stream to create pools, slow water, and trap gravel.

rock wing deflector: see *wing deflector*.

root wad: the mass of roots at the base of an uprooted tree.

rubble: rock from 3 to 12 inches in diameter; also called cobble.

run: in a river, an area of smooth flow with slow to moderate velocity.

runoff: water that drains over the surface of the land.

salmonid: a fish in the salmon or trout family.

saltation: the movement of sand or fine sediment by short jumps above the ground or stream bed under the influence of a current too weak to keep it permanently suspended.

sand: loose, gritty particles of worn or disintegrated rock, usually deposited along the shores of bodies of water, in river beds, or deserts.

saturated soil: soil that has absorbed as much water as is possible.

scale: relationship existing between a distance on a map, chart, or photograph and the corresponding distance on the earth.

scale: relationship between the distance on a map and the distance it represents on the earth (1:24000 or 1" to 24,000").

scoured: removal of gravel and other material by flowing water.

scrapers: aquatic invertebrates that feed by scraping the surface of rocks, primarily harvesting algae.

secondary production: organic material produced by processing other organic material; consumers.

section: one thirty-sixth of a township.

sediment: solid particles carried and deposited by water.

shredders: aquatic invertebrates that feed on the leaves or wood that fall into a stream.

silt: tiny, fine particles, such as soil or sand, suspended in and deposited by water.

smolt: a juvenile anadromous fish that has undergone physical changes to prepare for life in saltwater.

smoltification: physiological changes enabling a juvenile salmonid to migrate from fresh water to saltwater.

snow courses: a designated series of locations used to collect data on seasonal snowfall.

snow water content: the amount of water produced by melting snow.

soil frost: ice crystals formed between soil particles.

soil moisture: the amount of water held in soil.

soil texture: a description of soils based on the size of soil particles.

soil: loose upper layer of the earth in which plants grow; made up of inorganic material, organic material, air, and water.

spawning habitat: area a fish needs to spawn; frequently refers to gravel beds.

spawning: in fish, the act of laying and fertilizing eggs.

specific heat: quantity of heat necessary to raise the temperature of one gram of a given substance one degree Celsius.

stalactite frost: Frozen soils with large, loose ice crystals. Water can easily infiltrate frozen soils with stalactite frost.

stormflow: water entering a stream from a particular precipitation event.

straight: unsplit or non-curving stream channel.

stream order: a system used to classify and analyze streams.

streambed: part of the stream over which a column of water moves.

streamflow hydrograph: a chart showing the rise and fall of the level of a stream over time.

streamflow: volume of water carried by a stream.

sublimation: water changing directly from solid to vapor.

substrate: inorganic material that forms the bottom of a stream.

subsurface flow: water that flows through the spaces in soil particles below the surface of the land.

surface flow: rainfall that does not infiltrate into the soil, but flows over the surface until it reaches the stream.

surface runoff: see *surface flow*.

surface water: water on the land surface, such as ponds, lakes, rivers, streams, marshes, and wetlands.

suspended sediments: particles carried in water without being dissolved.

tail: downstream end of a riffle or pool.

tailout: downstream end of a pool.

TDS: total dissolved solids.

telemetry: data collected at a distance from the source, often by radio or satellite transmissions.

terrestrial: living on land.

thalweg: line of maximum velocity (depth) in a stream.

thermal pollution: addition of heat energy to the environment. It may be transferred by heated air or water and causes localized temperature increases.

thorax: An insect's body has three parts: head, thorax, and abdomen. The thorax is the center part, between the head and abdomen.

TLm: tolerance limit median.

tolerance limit median (TLm): point at which 50 percent of a population cannot survive.

topographic map: a map that uses contour lines and symbols to represent the human-created and natural features of a mapped area.

total dissolved solids (TDS): total amount of dissolved material in water.

Total Maximum Daily Load (TMDL): a plan that defines the acceptable level of pollutants that can enter the stream and the sources of those pollutants for streams listed as "water quality limited" under the Clean Water Act.

total suspended sediments (TSS): total amount of undissolved material carried in water.

township: a six square-mile segment of land, the basic unit of the Public Land System Survey.

toxic: poisonous.

transpiration: loss of water from plants through evaporation and as a byproduct of photosynthesis.

transported soils: soils moved by gravity, wind or water.

trellis drainage: the pattern that occurs in regions of sedimentary rock where faults create streams that flow nearly parallel to each other with tributaries joining at right angles.

tributaries: streams that carry water to other bodies of water.

TSS: total suspended sediments.

turbidity: degree to which light penetration is blocked because water is muddy or cloudy.

understory: the layer of vegetation below the canopy, but above the surface of the ground.

universal solvent: a substance in which most other substances can dissolve. While water cannot dissolve everything, it can dissolve more substances than any other known material.

uplands: the drier parts of a watershed, outside the aquatic and riparian areas.

USGS: the United States Geological Survey is a branch of the federal government's Department of the Interior responsible for creating many types of maps.

velocity: speed.

ventral: the front, or lower, surface of an organism.

vitelline vein: a vein running through the yolk sac of young fish, it is responsible for absorbing oxygen from the water.

water column: moving mass of water contained by a streambed.

water spiral: corkscrew pathway a column of water travels; caused by the Coriolis effect (from the earth's rotation) and friction.

water table: upper level at which the soil is saturated with water.

watershed: all the land area that drains into a particular body of water.

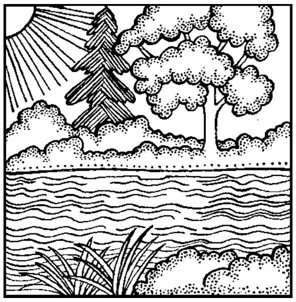
watershed: the land area from which water flows toward a common stream in a natural basin.

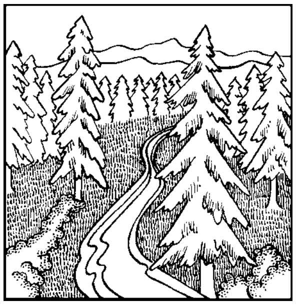
wetlands: lands where water saturation is the dominant factor determining the nature of soil development and the types of plant and animal communities—sloughs, ponds, marshes.

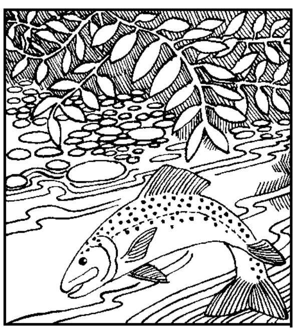
wildlife: any animal that is not tamed or domesticated.

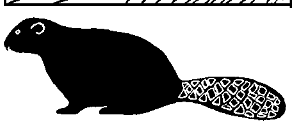
wing deflector: a structure built into a stream to redirect water flow, and create pools or pocket water.

yolk sac: sac attached to a newly hatched fish containing a balanced diet for its early growth.









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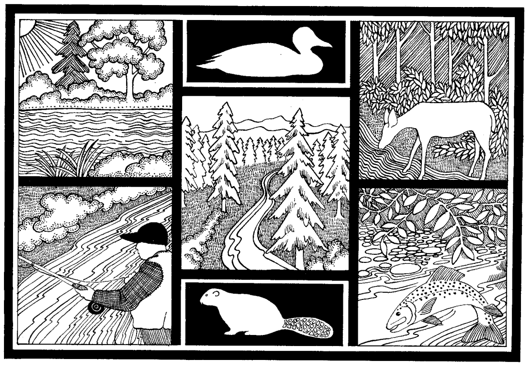

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