LESSON 4 — The Layered Look: Where Fresh and Salt Water Meet

KEY CONCEPTS

Fresh water tends to flow above salt water.
Stratification occurs in estuaries where fresh water meets salt water.
Puget Sound can be described as an estuary.
Point and non-point sources of pollution may enter the Sound through fresh water run-off.

OBJECTIVES

Students will predict what happens when fresh and salt water meet.
Students will create an experimental model of fresh water flowing into salt water.
Students will apply the results from their model to make inferences about data presented photographically.

PROCESS SKILLS

observing, classifying, predicting, measuring, communicating, inferring, interpreting data

KIT MATERIALS

32 copies of Activity Sheet #4A - *The Layered Look*
2 copies of a photograph showing muddy, fresh water on the surface of Puget Sound near the shore
Transparency #4A - *Circulation in Puget Sound*
The Surface Water video
For each group of four students:
one clear plastic container
food coloring
one paper cup
straight pin
salt
teaspoon

NON KIT MATERIALS

tap water
paper towels
VCR and monitor

VOCABULARY

run-off - rainfall that is not absorbed by the soil and eventually reaches surface water bodies. Surface water pollution can occur when this rain "runs off the land, carrying pollutants on the ground into local rivers and lakes.
estuary - a semi-enclosed arm of the sea where incoming seawater is diluted with fresh water coming from rivers draining the land
surface water - all the water we see in oceans, lakes, rivers, streams, and wetlands
salinity - refers to the concentration of salts dissolved in water
point source pollution - a source of pollution from a single point of conveyance, such the discharge pipe from a sewage treatment plant or a factory
non-point pollution - pollution that enters water from dispersed and uncontrolled sources (such as carrying pesticides or fertilizer residues, or failing septic tanks) rather than through a pipe

Freshwater flows to Puget Sound sub-basins

Water movement plays an important role in shaping both the beaches and the health of Puget Sound. Tides circulate water in the Sound while rivers add freshwater and the materials it carries. The freshwater flows reaching each of the four major sub-basins of Puget Sound differ because of the size and nature of the watershed. Sixty percent of the total fresh water entering the Sound flows into the Whidbey Sub-basin from the drainages of three of the largest rivers in the area, the Skagit, Stillaguamish, and Snohomish. These rivers collectively drain about 50 percent of the Sound. The Main Sub-basin receives 20 percent of the fresh water entering the Sound from the Puyallup, Green/Duwamish, Sammamish, and Cedar Rivers. No major rivers flow into the Hood Canal Sub-basin, but Hood Canal receives 10 percent of the fresh water entering the Sound through minor rivers (Skokomish, Dosewallips, Duckabush, Hamma Hamma, and an unnamed offshoot of the Skokomish River). The Southern Sub-basin receives less than 10 percent of the drainage into the Sound even though it has a large drainage area (Burns, 1985). It is fed mostly by small rivers and streams (the only major rivers are the Nisqually and the Deschutes).

ESTUARINE PROCESSES

Flow patterns

Estuaries have a distinctive pattern of water movement created by the action of the tides and the presence of fresh water. Since estuaries like Puget Sound are extensions of the ocean, they are affected by the tides which pump large volumes of water back and forth, in and out of the Puget Sound basin. Fresh water entering the Sound from streams and rivers is lighter or less dense than saltwater and tends to float and flow over the top of seawater. As it does this, some of the saltwater is mixed up with the fresh water, creating a brackish (less salty) layer at the surface (about 30 to 190 feet or 10 to 60 meters deep in various parts of the Puget Sound region). This surface layer flows seaward under the force of gravity, eventually reaching the Pacific Ocean. To replace the seawater in the deep layer which was mixed into the surface layer, more seawater is drawn into the estuary from the ocean. This characteristic net estuarine circulation (seaward at the surface and landward below) exists throughout Puget Sound and the Straits of Georgia and Juan de Fuca.

The two-layered estuarine pattern described above is complicated in Puget Sound by the presence of various islands and channels. For example, the blocking effect of Vashon Island disrupts the two-layered flow pattern in East Passage, where cur-

rents at all depths are generally to the south, and in Colvos Passage, where currents are generally to the north (See Transparency #2A). The relatively shallow sills that divide the sub-basins of the Sound also disrupt the two-layered flow pattern. Implications of these complicated flows are that as much as one-half to two-thirds of the outflowing surface water from the Puget Sound Main Sub-basin may be diverted before going through Admiralty Inlet (Ebbesmeyer and Barnes, 1980). Researchers have estimated that as much as one-third to one-half of the outflowing water makes a submarine return trip through the depths of the Main Sub-basin instead of exiting to the Strait. More recent modeling efforts appear to indicate that about one-quarter of the outflowing water returns to the Main Sub-basin (Cokelet, 1987). The same type of complicated flow pattern can be inferred in the other sub-basins set off by sills (Ebbesmeyer and Barnes, 1980).

Exchange with the ocean

What are the implications of these flow patterns? An important physical characteristic of an estuary is its ability to exchange water with the open ocean. Exchange helps cleanse the deep basins of the Sound and prevent them from becoming naturally stagnant from organic decay. Exchange also plays a critical role in governing the fate and effects of contaminants that enter Puget Sound. It has the potential to carry dissolved waste products out to sea. However, in Puget Sound south of Admiralty Inlet, the diversion and remixing of surface water mentioned above limits the amount of exchange with the open ocean.

Puget Sound is not a pipe or open drain that will carry dissolved or suspended contaminants directly out to sea. The process is short-circuited by the recirculation of surface water and the settling of sediments. For example, fresh water on the surface of the Main Sub-basin takes about a week to get from the mouth of the Duwamish River to the Admiralty Inlet sill. Then much of it spends an additional 10 days going back to its starting point. It must make the trip twice, on the average, before reaching the Strait of Juan de Fuca. Computer simulations of water movements have shown that after three months, only half of the water released in East Passage escape to the open ocean. Implications of this estuarine recirculation and resulting slow exchange with the ocean that any contaminants carried in the surface water remain in the area for some time, and can be spread throughout the Sound before exiting to the Strait or settling out. In addition, any contaminants or items that wash up onto or adhere to shorelines (e.g., plastic garbage and oil) are likely to never leave the Sound.

For additional information on Puget Sound circulation, see State of the Sound 1988 Report, Puget Sound Water Quality Authority, from which the above material is taken.

This lesson contains two activities. Both may take 30-45 minutes to complete.

Activity 1 - Where Fresh and Salt Water Meet

1. Review the names and locations of the major rivers that enter Puget Sound. Reinforce that the rivers bring fresh water to the salty water of Puget Sound.

   QUESTION **"What do you think happens when fresh water from rivers and streams flows into the salt water of Puget Sound?"**

   ANSWER *Record students' responses for later reference. Explain that this activity will explore what happens when these waters meet.*

2. Distribute to students Activity Sheet #4A - *The Layered Look* . Point out the diagram of the equipment setup. For best observation, remind students to gently pull the pin out of the cup.

   QUESTION **"What do you think you will see when the fresh water runs into the salt water?"**

   ANSWER *Have students record their prediction on the data sheet.*

3. Divide students into working groups of four and distribute the materials required. Display the two copies of the photograph showing muddy, fresh water on the surface of Puget Sound near the shore. Students will observe this photograph to complete the last "Analysis and Interpretation" question.

4. When all groups have completed the experiment, examine the list created in Procedure #1. Compare observations of the model and students' ideas of what might happen when salt and fresh water meet.

Please look ahead to Lesson 5: Creature Features which introduces research reports students will complete. You may choose to present Lesson 5 before this lesson to allow more time for completion of the student reports.

3. You may choose to have students work together in their small group to begin answering the "Analysis and Interpretation" questions, or work on them together as a class when all groups have completed the activity.

QUESTION **"What do you think happens to the fresh water that flows onto the salt water?"**

ANSWER Discuss students' ideas.

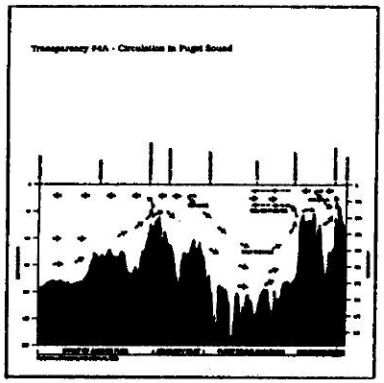
Activity 2 - Moving Water

1. Display Transparency #4A - *Circulation in Puget Sound*. See Teacher Background for a detailed interpretation of this diagram.

2. Explain that Puget Sound could be described as an ESTUARY.

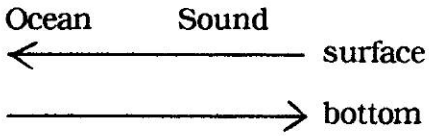
QUESTION **"The fresh water entering the Sound brings more than just fresh water to dilute the salt water. What else does the fresh water carry to the Sound?"**

1.



The main idea to convey is:

Fresh water entering the Sound is lighter (less dense) than the salty ocean water and tends to float and flow over the top of salt water. As it does, some of the salt water is mixed up with the fresh water, creating a less salty (brackish) layer at the surface (30-190 ft. in various parts of the Sound). This brackish surface layer flows seaward, eventually reaching the Pacific Ocean. To replace the surface layer, more deep sea water is drawn into the estuary from the ocean. Estuarine circulation = seaward at surface and landward below.



2. An ESTUARY is a semi-enclosed arme of the sea where seawater, brought in by the tides, is diluted with fresh water coming from the land.

ANSWER *The fresh water may carry:*

1. *materials that end up as sediment on the beaches or in the bottom of the Sound (students remember about Lesson 2);*
2. *nutrients and organic matter from the decay of plants and animal matter in the watersheds;*
3. *pollutants from the watershed that affect water quality and the health of sediments. Fresh water run-off may carry excess nutrients, bacteria, or toxic chemicals, including pesticides and herbicides.*

3. Show the videotape, *Surface Water* (9 minutes). Discuss the sources of point and non-point pollution.

2. Nutrients and organic matter are the "fertilizers" for phytoplankton growth (productivity) while river flows are generally a minor contributor to the Sound's productivity. Some local areas are greatly affected by nutrients carried into the Sound.

3. Lesson 11: "Sound Choices" will develop further understanding of the concepts presented in the video. Students will see that they and their families can contribute to the solutions by making "sound choices".

TEACHER ANSWER KEY

The Layered Look
Analysis and Interpretation

1. Write one sentence which describes how fresh water will usually behave when it meets salt water.

   Fresh water will usually float over the tope of the salt water when the two meet.

2. As a scientist studying the effects of pollution, you want to take water samples from different depths at the mouth of the Duwamish River as it enters Puget Sound.

   a. At which depth would you expect to find the freshest water?

      The freshest water will likely be found near the surface.

   b. At which depth would you expect to find the saltiest water?

      The saltiest water will likely be found at the bottom.

3. During the winter, surface water taken from the mouth of the Skagit river is almost entirely fresh.

   a. How do your experimental results help explain this observation?

      Fresh water will float on top of salt water.

   b. What is happening in the Skagit Basin that might explain this observation?

      The increased rainfall and runoff in the winter months increases the volume of fresh water flowing into the Sound, increasing the likelihood of fresh water at the surface near the mouth of the river.

4. From your teacher, obtain the photograph showing surface water near a Puget Sound shoreline.

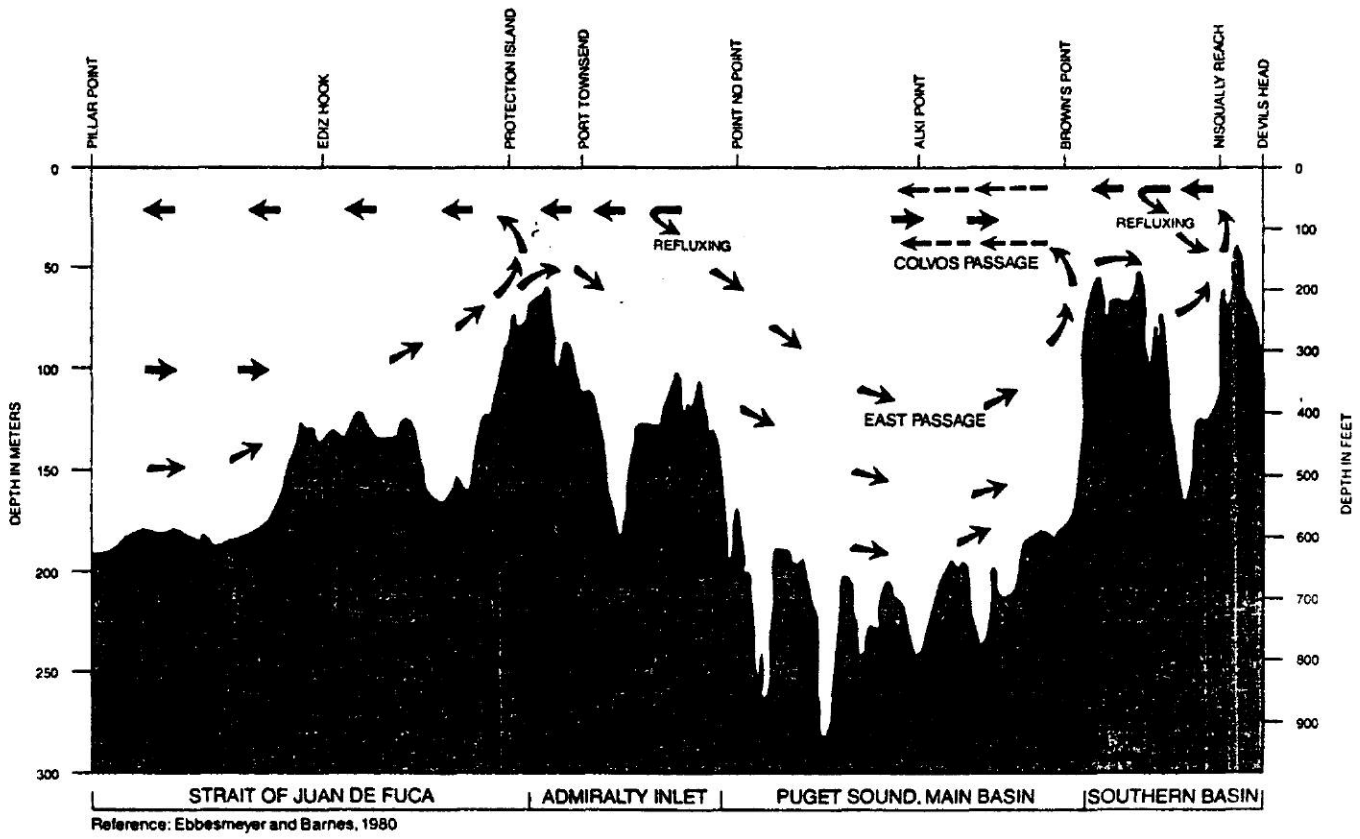
   a. Record observations (what you actually see in the photograph).

      Answers will vary.

   b. Suggest an explanation. (This is called an inference).

      Accept reasonable explanations that follow from the observations. The photograph was taken in January, 1990, near Skiff Point on Bainbridge Island. It was taken following a very rainy period of several days. The muddy, murky fresh water that ran off the land was sitting on the salty water of Puget Sound.

Circulation in Puget Sound



Reference: Ebbesmeyer and Barnes, 1980

Activity Sheet #4A

Name _____

Date _____

The Layered Look

Prediction What do you predict will happen when the pin is removed from the cup and the fresh water flows into the salt water?

_____

_____

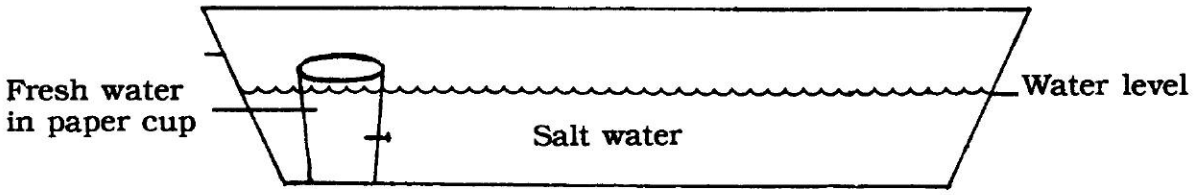
_____

1. Obtain one paper cup and a clear plastic container. The paper cup will represent a river, the plastic container will represent Puget Sound. A pin hole in the cup will provide the river current.

2. Place 5 drops of food coloring in the cup. Fill the cup full with cold, tap water.

3. Obtain one straight pin. Stick the pin in the cup midway between the top and the bottom. LEAVE THE PIN IN THE CUP. Place the cup at one end of the container.

4. Place 4 teaspoons of salt in the plastic container. Fill the container with cold, tap water to a depth about one inch below the top of the cup. Stir to dissolve the salt. Your setup should look something like the drawing below:



NOTE: Make certain the salt water is above the pin in the cup.

5. Wait until the water in the container has stopped moving. Wait at least 60 seconds. To start your river flowing, gently and slowly pull out the pin. DO NOT disturb the water more than necessary.

6. Observe the results.

7. After 5 minutes, make a drawing below, showing the location of the fresh water in the model.

Name _____

Date _____

The Layered Look
Analysis and Interpretation

1. Write one sentence which describes how fresh water will usually behave when it meets salt water.

2. As a scientist studying the effects of pollution, you want to take water samples from different depths at the mouth of the Duwamish River as it enters Puget Sound.

   a. At which depth would you expect to find the freshest water?

   b. At which depth would you expect to find the saltiest water?

3. During the winter, surface water taken from the mouth of the Skagit river is almost entirely fresh.

   a. How do your experimental results help explain this observation?

   b. What is happening in the Skagit Basin that might explain this observation?

4. From your teacher, obtain the photograph showing surface water near a Puget Sound shoreline.

   a. Record observations (what you actually see in the photograph).

   _____

   _____

   _____

   b. Suggest an explanation. (This is called an inference).