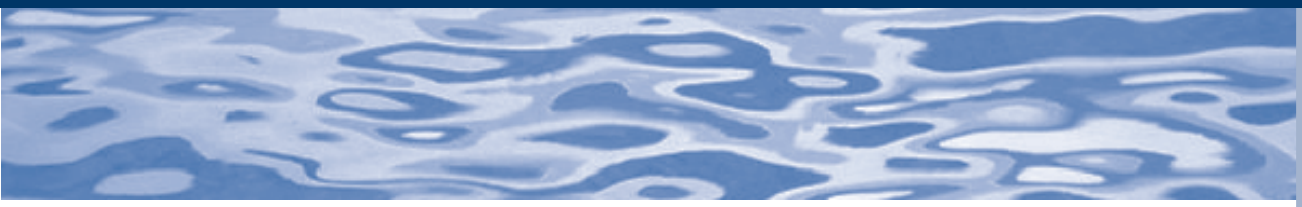
What's in the Water?



Purpose: To observe and list abiotic factors in specific ecosystems.

Duration:
Classroom
40 minutes
Outdoors
50 minutes

Setting:
Classroom
Outdoors

Summary: In this exercise, students will observe and list abiotic factors in an aquatic system and measure four of them (pH, dissolved oxygen, turbidity, and temperature).

Background: For background information:

• The Resource pages provided with this activity give additional information about each factor, including how that factor may vary at different locations, during different times, and some suggested discussion questions.

• The Chemical Properties section of the Utah Stream Team Manual defines each factor and discusses how the factor changes due to natural and human influences, why the factor is important in aquatic ecosystems, how to take a sample, and how to interpret the results.

Materials:

- pH test kits *
- Dissolved oxygen test kits *
- Turbidity tubes *
- Field thermometers *
- Pencils
- Bucket
- Copies of the student worksheet
- Copies of the chemical sampling instruction sheets
- Waste bottles (e.g., empty pop bottles)
- Clipboards

* For information on equipment for loan or for purchase, contact USU Water Quality Extension at (435) 797-2580 or www.extension.usu.edu/waterquality

Classroom Activity: 1. Ask students to list all the abiotic factors they can think of in an aquatic system *(e.g., solar radiation, physical structure of the stream or lake, surrounding landscape, weather, and the properties of water itself).*

2. Tell them they will be testing four of these factors that relate specifically to the water – pH, dissolved oxygen (DO), turbidity and temperature.

3. Define each of these factors. Talk about why these factors are important in an aquatic ecosystem, what can naturally influence these factors, and what humans can do to influence these factors.

4. Explain to the students that they will be going out to a stream (or other water body) to measure pH, DO, turbidity, and temperature. Sampling instruction sheets are found at the end of this lesson. You may want to review the actual testing procedures before going into the field.

Field Activity:

1. Set up a station for each factor (pH, DO, turbidity, and temperature).

At each station, provide:

- Sampling instruction sheets (if possible, laminate these!)
- Waste bottles
- The appropriate testing kit
- Sample bottles if you are not near the stream

Safety First!
Always consider safety factors when working near water.

2. Divide the students into four groups. Provide each group with clipboards, pencils, and worksheets. Explain to the students that each group will start at a different station, and rotate so they will measure all the factors.

3. Have the students fill out the site observations section of the student worksheet before beginning their measurements. Have them follow the instructions for measuring each factor found on the sampling instruction sheets.

4. Have the students record their results on the student worksheet. You can choose to have one record keeper per group, or have each student record all the information.

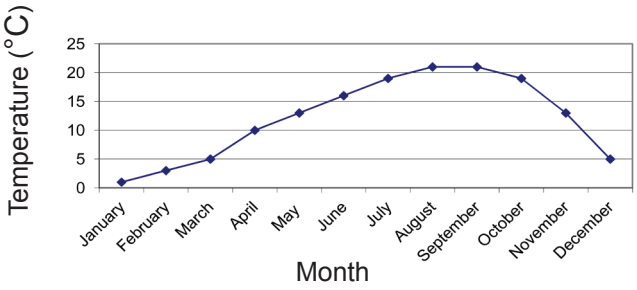
ACTIVITY EXTENSIONS:
- Use other water sources to compare results.
- Sample the same station on multiple dates to compare results.
- Take measurements on "modified samples" – see the Utah Stream Team Manual Chemical Properties Section for more information.

Applying the Data:

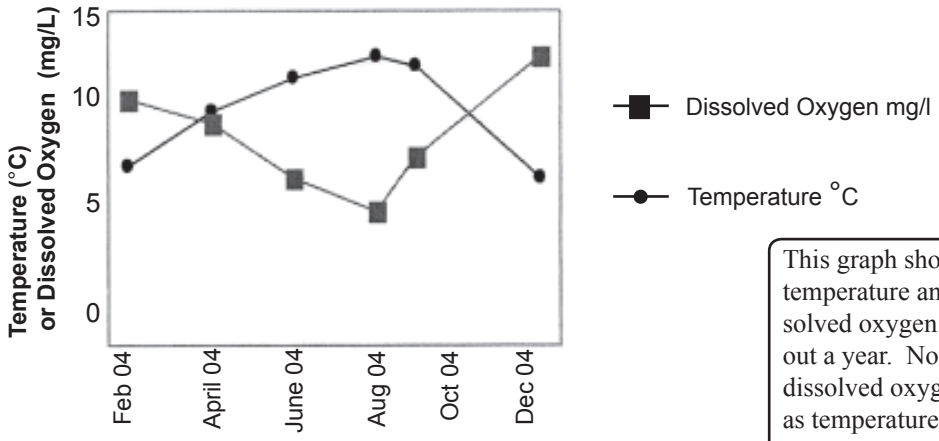
Have the students compile and graph the data to demonstrate a particular pattern. For example:

- Create a time series graph to show changes in one factor over time.
- Create a graph comparing the results from different water sources.
- Create a graph comparing the results from different teams.
- Create a graph that shows sample statistics (e.g., the mean and standard deviation or range of different student measurements).
- Create a graph that shows the relationship between different factors (e.g., samples at different times or from different sources).

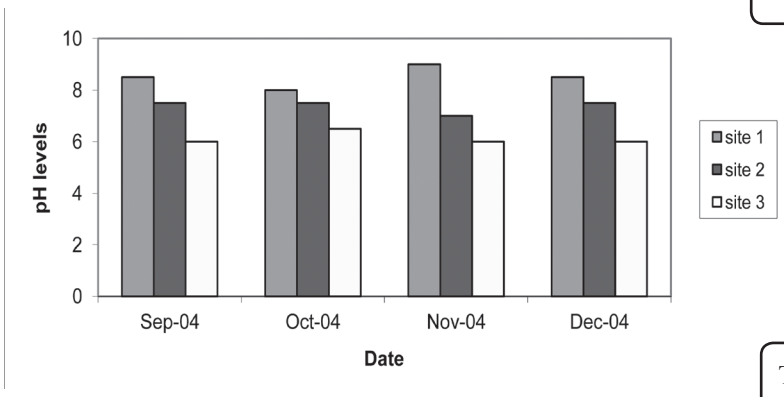
See sample graphs below and on the following page.



This graph shows temperature change throughout a year at one site.



This graph shows both temperature and dissolved oxygen throughout a year. Note how dissolved oxygen drops as temperature rises.



This graph shows pH levels over time at three different sites.

Further Discussion: (See additional discussion questions relating to each measurement in the Resource pages.)

1. Why would previous weather conditions be of interest when looking at stream conditions?

Often it can take hours or days for the runoff from a storm or snowmelt to reach the water and travel down the river. Therefore, previous weather may be as important as today's weather in explaining your results.

2. How do you think the abiotic factors you observed at the site may have affected your measurements?

- *Hot weather may result in extra snowmelt upstream and increase flows. Sunny weather may increase photosynthesis at your site, and therefore increase dissolved oxygen and pH levels. Higher flows from storms or snowmelt may increase the turbidity in your stream.*
- *Soils in the watershed will affect the chemical composition of the runoff that reaches the stream. Topography (the steepness of the land) will determine whether the stream is steep and fast or slow and wide, which will affect dissolved oxygen and temperature.*
- *Vegetation along the stream provides shade and protects the banks from erosion.*
- *Land uses along the stream and in the watershed will determine what type of pollutants may enter the stream (e.g., sediment from agriculture or logging, metals and oils from roads, or fertilizers from golf courses).*

3. Discuss variability in the data, or discuss why the measurements may be variable.

There is always natural variability in ecosystems (see the discussion question above). When we take measurements, we also introduce some variability due to differences in observers (eye sight, experience) and limitations of the equipment.

4. Discuss why the results might change under the following conditions. (See the Resource pages that follow about each parameter to help guide this discussion).

- *seasons*
- *from year to year*
- *throughout the day*

Student Worksheet

Name: _____ Group #: _____
Date: _____ Site ID: _____

Site Observations:

Type of waterbody (e.g., stream, lake, wetland):_____
Weather today: _____
Weather yesterday: _____
Air temperature: _____
Water appearance (e.g., clear, brown, foamy, milky): _____
What type of land uses are in the immediate area?_____
What type of land uses are in the surrounding area?_____
Is the area shaded by trees? _____
List all other abiotic factors you can observe that might be important in this aquatic ecosystem: _____
_____

ABIOTIC FACTOR	YOUR RESULTS	COMPARE YOUR RESULTS TO ALLOWABLE RANGE IN UTAH	DOES THE WATER MEET UTAH'S REQUIREMENTS? (Y/N)
pH		6.5 to 9.0	
Dissolved Oxygen	ppm (mg/l)	Minimum of 6.5 mg/l for cold water fisheries and 5.5 mg/l for warm water fisheries.	
Turbidity	NTUs	An increase of 10 NTUs from previous data.	
Temperature	°Celsius	Maximum of 20 °Celsius for cold water fisheries and the maximum temperature for warm water fish is 27 °Celsius.	

pH Sampling Instructions

Time – 2 minutes
Persons – 1
Materials – pH strips

Step 1
Dip one strip of indicator (litmus) paper into the stream and pull it out quickly.

Step 2
Wait 1 minute.

Step 3
Compare the color of the litmus paper to the pH color key on the pH box.

Step 4
Record the number associated with the correct color match on the student worksheet.

Remember: Take pH readings directly in the stream. If this cannot be done safely, collect water in a bucket or a sample bottle and immediately take the pH reading.

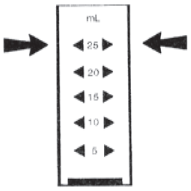
In Utah:
The allowable range of pH is 6.5 to 9.0.

Dissolved Oxygen Sampling Instructions

Sunlight can damage the ampoules in your DO kit. Keep them shaded at all times.

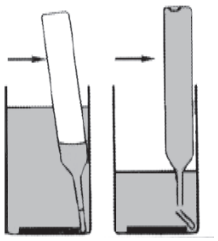
Time – 3 minutes
Persons – 1
Materials – Chemetrics Dissolved Oxygen Sampling Kits

Step 1



1. Pre-rinse collection bottle with stream water.
2. Fill the sample cup to the 25 ml mark with your sample.

Step 2

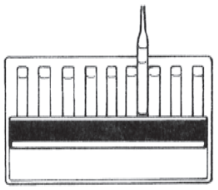


1. Place the glass ampoule in the sample cup.
2. Snap the tip by pressing the ampoule against the side of the cup.
3. The ampoule will fill, leaving a small bubble that will help you mix the contents.

Step 3

1. Mix the contents of the ampoule by turning it up and down several times, allowing the bubble to travel from end to end each time.
2. Wipe all liquid from the outside of the ampoule.

Step 4



1. Wait 2 minutes for color development.

Step 5

1. With the sun (or another light source) shining on the comparator (rack of colored tubes) from directly above, place the dissolved oxygen ampoule between the color standards for viewing. It is important that the ampoule be compared by placing it on both sides of the color standard tube before deciding that it is darker, lighter or equal to the color standard.
2. Record the concentration of the best color match.

In Utah:
The minimum concentration for coldwater fish is 6.5 mg/l.
The minimum concentration for warmwater fish is 5.5 mg/l.

Turbidity Sampling Instructions

Step 1 - Collect your sample

1. Dip the tube into the water at your sampling site and fill to the top. Be careful to sample flowing water and not the stream bottom. Do not stand upstream from the area you are sampling.

Time – 2 minutes
Persons – 1
Materials – Turbidity Tube

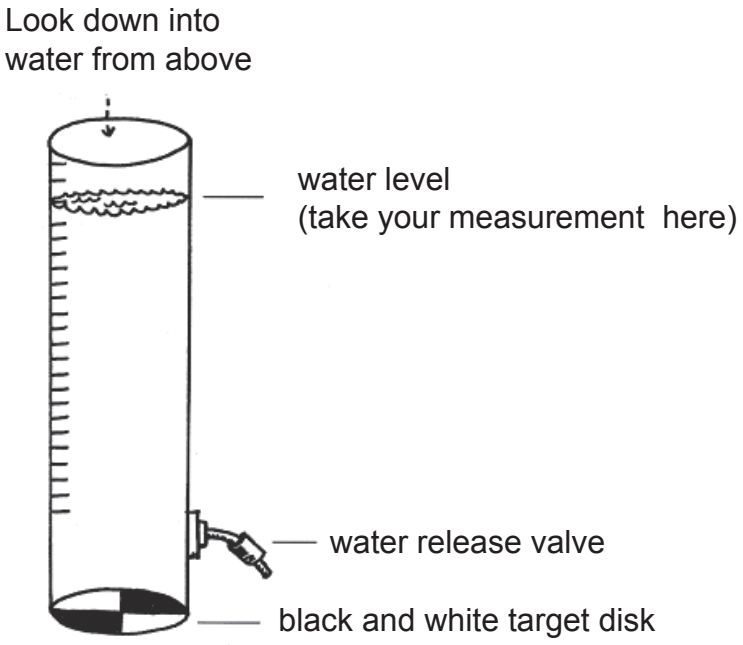
Step 2 - Take your measurement

(see figure below for help)

1. Take your filled turbidity tube to a shaded spot. If there is no shade, use your body to block the sun from shining on the tube.
2. With your hand over the opening, shake the tube vigorously. This will help to re-suspend any sediment that has settled to the bottom.
3. Look down through the tube toward the target disk on the bottom.
   - If the disk is visible, record the water level in centimeters (cm).
   - If the disk is not visible, slowly release water from the release valve until the disk becomes visible. Note the water level in centimeters (cm) on the student worksheet.

Step 3 - Convert from centimeters (cm) to turbidity units (NTUs)

1. Match your turbidity measurement in centimeters to the corresponding NTU using the conversion chart on the back of this page. Record on the student worksheet.



Turbidity Conversion Chart

Turbidity Conversion Chart	
Distance from bottom of tube (cm)	NTUs
< 6	>240
6 to 7	240
7 to 8	185
8 to 9	150
9 to 10	120
10 to 12	100
12 to 14	90
14 to 16	65
16 to 19	50
19 to 21	40
21 to 24	35
24 to 26	30
26 to 29	27
29 to 31	24
31 to 34	21
34 to 36	19
36 to 39	17
39 to 41	15
41 to 44	14
44 to 46	13
46 to 49	12
49 to 51	11
51 to 54	10
54 to 58	9
58 to 60	8
Over the top	6

In Utah:
An increase of more than 10 NTUs (from one time to another or from one location to another downstream) violates water quality criteria.

Temperature Sampling Instructions

Time – 2 minutes
Persons – 1
Materials – Thermometer

Step 1

1. Dip the thermometer into a moving part of the stream or river.

2. Wait for the temperature to stop changing (at least 1 minute).

Step 2

1. Read the temperature and record on the student worksheet.

Converting Fahrenheit to Celsius: **°C = (5/9) x (°F - 32)**

Converting Celsius to Fahrenheit: **°F = [(9/5) x °C] + 32**

In Utah:
The maximum temperature allowed for warm water fisheries and aquatic wildlife is 27° C (81° F).

The maximum temperature allowed for cold water fisheries and aquatic wildlife is 20° C (68° F).

pH

What is pH?
pH is a measurement of how acidic or alkaline (basic) the water is. pH is measured on a scale of 0 to 14, with 0 being the most acidic, and 14 being the most basic. Distilled water, which has no impurities, is neutral, and has a pH of 7.

Refer to the Utah Stream Team Manual for more information on the definition and importance of pH to fish and other aquatic life, and how natural and human activities affect pH levels.

pH must be measured in the field. The pH will change if the water is collected and stored, and will not reflect the true value at the site.

Discussion Questions for pH:

1. Why does the pH of rainwater or snowmelt increase as the water moves over a landscape?

Soils in Utah contain acid neutralizing minerals, such as calcium and magnesium compounds, which are dissolved by the water as it moves through the soil and over the land. These minerals neutralize the acid in the rain. In some areas, the geology does not contain these minerals (for example the Adirondack Mountains in New York) and the acids in the water are not neutralized.

2. What is acid rain?

Acid rain is caused by air pollution such as sulfur and nitrogen oxides, which dissolve in rain water and form strong acids. Soils in Utah contain enough neutralizing compounds to buffer these acids (see #1), but in poorly buffered soils, lakes and streams can become so acidic that fish and other organisms cannot survive.

3. How does pH affect living organisms?

pH affects the function of membranes in living organisms. Therefore even moderately acidic waters may irritate the gills of fish and aquatic insects, and may reduce the hatching success of eggs. Many amphibians are particularly vulnerable because their skin is so sensitive to pollution.
Changes in pH may also affect the chemicals in the water. For example, ammonia is harmless to fish in water that isn't acidic, but becomes much more toxic in acidic water. Lower pH causes certain heavy metals to dissolve, resulting in toxic concentrations of these metals when the pH is low.

pH (continued)

Suggested sources of water samples, with expected results and explanation.

Water Source	Expected result	Explanation
Rain water	low (~5.6-6.0)	Natural rainwater is slightly acidic because the rain dissolves atmospheric carbon dioxide, forming carbonic acid.
Snowmelt	low (~5.6-6.0)	Like rain, snow is slightly acidic. During rapid snow-melt events, snowmelt may run directly into the streams with no buffering by contact with soils.
Stream water	varies (6.5-9.0)	The results will vary depending on geography, location, season, and the time of day. See UST Manual.
Tap Water	neutral (~7.0)	Dissolved calcium, magnesium and other compounds in most Utah surface and groundwater neutralizes the water.
Groundwater	neutral to high (7.0-8.5)	Same as above, but may be more alkaline because the groundwater has more contact with buffering materials due to the longer storage time.
Ponds/lakes (high productivity)	high (>9)	Will vary according to local geology and may vary during the day if many aquatic plants are present. Photosynthesis removes the carbonic acid from water, making the water more alkaline (increasing pH). This effect is strongest in the late afternoon of a sunny day.
Sphagnum (peat moss) bogs	low (5-6)	Sphagnum and other mosses absorb calcium and magnesium, and release hydrogen ions into the water, lowering the pH.

Dissolved Oxygen (DO)

What is Dissolved Oxygen?
Dissolved oxygen (DO) is a measurement of the concentration of the O_2 molecules that are actually dissolved in water. This is the form of oxygen that fish and aquatic insects need.

Oxygen is not very soluble in water. At most, about 12 parts of oxygen can dissolve in a million parts of water (12 mg/liter). The maximum amount of oxygen that can dissolve in water is called saturation concentration. The saturation concentration decreases as water temperature or elevation increases.

Refer to the Utah Stream Team Manual for more information on the definition and importance of DO to fish and other aquatic life, and how natural and human activities affect DO levels.

DO must be measured in the field. The DO will change if the water is collected and stored, and will not reflect the true value at the site.

Discussion Questions for Dissolved Oxygen:

1. How does oxygen get into water?
   Oxygen is dissolved into water by contact with the atmosphere, or from aquatic plants that produce oxygen during photosynthesis. Therefore, oxygen will be higher in turbulent stream water (mixing with the atmosphere) or in water with many plants (but only during the day, when photosynthesis can occur).

2. How does oxygen get used up in water?
   The respiration of animals and plants uses oxygen. Bacterial decomposition of dead organic materials can also be a major factor, and may cause the dissolved oxygen to be completely consumed in deep pools or lakes. Some chemical reactions (oxidation reactions) also require and consume oxygen.

3. How will dissolved oxygen concentrations be affected by the dumping of yard clippings or the runoff of animal manure?
   The decomposition of organic materials such as these may use all the available oxygen in the water. Secondary treatment by municipal treatment plants removes the organic material from the water for just this purpose. Before municipal wastewater was treated properly, many rivers and streams had fish kills and dead zones caused by low oxygen as this waste decomposed.

Dissolved Oxygen (continued)

Suggested sources of water samples, with expected results and explanation.

Water Source	Expected Results	Explanation
Fast moving cool stream	high (>10 mg/l)	Turbulence mixes atmospheric oxygen into the water. The water may even be super-saturated.
Still water (e.g. productive pond water)	may vary throughout the day: lower at night (<4 mg/1) and much higher in the late afternoon. (>10 mg/l)	No turbulence to mix the oxygen. Plants produce oxygen, but the plants respiration and decay may also use it up.
Warm water	low (<8 mg/l)	Warm water holds less oxygen than cold water.
Stream water in a closed jar without any plants	low to moderate (6-8 mg/l)	No plants to produce oxygen, no opportunity for mixing with atmospheric oxygen. Note: microscopic plants may complicate results.
Stream water in a closed jar with leaf litter (dead or decaying plants)	low (<6 mg/l)	Decaying plants/leaf litter use the oxygen in the water.

Turbidity

What is Turbidity?
Turbidity is a measure of how much suspended material is in the water. Turbidity may be caused by eroded sediment, organic debris, suspended minerals, or by microscopic plants growing in the water.

Refer to the Utah Stream Team Manual for more information on the definition and importance of turbidity to fish and other aquatic life, and how natural and human activities affect turbidity levels.

The turbidity will change if the water is collected and stored, and will not reflect the true value at the site if the particles settle to the bottom. Make sure you shake a stored sample before measuring turbidity.

Discussion Questions for Turbidity:

1. Why does turbidity often increase in a stream when the flow increases?
   As the velocity of water increases, the increased energy of the water can carry more sediment. In very quiet waters the sediment will settle out. This is easily demonstrated by shaking a closed bottle with water and a little sand or silt. The sand stays suspended until the bottle is placed down, at which point the sand or silt will settle. Note that the heavier sand particles settle first.

2. How might different land uses (logging, agriculture, construction) affect turbidity of nearby streams?
   All of these activities may disturb the land and increase the potential for erosion. In all cases, turbidity might increase, especially during a rainstorm or if snowmelt runs off over these disturbed sites. Irrigation return flows may carry sediment directly from the field back to a stream.

3. Why does turbidity matter in a stream?
   In most streams, turbidity is a measurement of the amount of suspended sediment (silt, etc.) in the stream. Most streams can handle a certain amount of sediment (depending on the size and shape of the stream). However, if a major source of additional sediment occurs (from eroding banks or from changes in land uses), the stream may receive more sediment than it can transport. In these cases, the sediment will settle and may cover up important habitat for aquatic insects, or smother the eggs of fish.

Turbidity (continued)

Suggested sources of water samples, with expected results and explanation.

Water Source	Expected Results	Explanation
A river or stream in the mid-summer to early fall	low	Flows are generally lower in the early fall, so the water doesn't have as much energy to carry sediment.
A river or stream in the spring	high	Flows are generally higher in the spring, so there is more energy to carry sediment.
Productive pond	high	Algae and other plant matter (rather than inorganic sediment) will cause the water to be turbid.
NOTE: If you cannot sample where there is varying turbidity, use the following to demonstrate turbidity.		
Clear water/Tap water	low	Clear water has few suspended solids, so it will have the lowest turbidity.
Water with 2 grams of silt per gallon	higher	Turbidity is a measurement of the suspended solids in the water so adding silt will cause the turbidity to be higher.
Water with 2 grams of sand per gallon	moderate	Turbidity is a measurement of the number of suspended soilds in the water (not the mass) so, 2 grams of sand will be less turbid than 2 grams of silt.

Temperature

What is Temperature?
Temperature is the measure of how much heat energy water contains. A stream's temperature is affected by the season, but also by the source of water, the geographic area of the stream, the shape of the channel, and whether the stream is shaded. Most aquatic organisms require a specific temperature range, and many of our sport fish require cold water.

Refer to the Utah Stream Team Manual for more information on the definition and importance of temperature to fish and other aquatic life, and how natural and human activities affect temperature levels.

Temperature must be measured in the field. The temperature will change if the water is collected and stored, and will not reflect the true value at the site.

Discussion Questions for Temperature:

1. Draw a graph of the temperature of a high mountain stream for an entire year. Draw another line on the graph to show how the temperature might change as you move further down the river.

Temperatures in streams can change beyond the obvious seasonal differences. The temperature in streams is often cold near the headwaters (snowmelt or shallow springs) and warm up as the stream moves down through the watershed. Shading (riparian vegetation) and the width and depth of the stream will all affect a stream's temperature.

2. How will groundwater entering a stream affect its temperature?

Groundwater is usually colder than surface water and therefore would probably cool the stream. Some areas in Utah, however, have hot springs which introduce heat and minerals to a stream. Because the temperature of the groundwater doesn't fluctuate much throughout a year, a stream with a major groundwater component may show less seasonal variability than a stream fed entirely by surface runoff.

3. Discuss how different land uses (e.g., logging, road building, agriculture, urban uses) might affect temperature.

The major influences on temperature in a stream are exposure to the sun and exposure to heated surfaces. Any activity that causes a stream to become shallower and wider (this can happen when too much sediment enters a stream) will cause the stream to heat more rapidly. When trees along the banks are removed, the loss of shading can cause the stream to heat up. Water that is diverted (such as for irrigation) and then returned to the stream usually heats up. Finally, streams with small flows will heat faster than streams with lots of water, so removing water from a stream can cause an increase in temperature.

Temperature (continued)

Suggested sources of water samples, with expected results and explanation.

Water Source	Expected Result	Explanation
A stream or river in the late summer / early fall	warmer	Warm air temperatures, plus no source of cold water (e.g., snowmelt) cause streams to be warmer in the late summer / early fall.
A stream or river in the spring or winter	cooler	Cold air temperatures, plus snowmelt in the spring lowers the temperature of the water.
A stream near its headwaters	cooler	The water source is snowmelt or groundwater. These streams are also usually shaded by trees and bushes.
A stream after it has traveled through a large valley or through a city	warmer (compared to the headwater stream)	The water warms as it travels away from the headwaters due to solar radiation and heat transfer from the stream bed and banks. Areas with little riparian vegetation (no shading) will heat faster. Streams with concrete banks (e.g., urban areas) will absorb heat from these artificial banks.
Near a hot spring	warmer	Hot spring water will mix with the stream water, raising the temperature.