Electrical Conductivity Protocol

Purpose

To measure the conductivity of the water at a freshwater hydrology site

Overview

Students will indirectly measure electrical conductivity measurements using an electrical conductivity meter.

Students will estimate the total dissolved solids from the electrical conductivity measurements.

Student Outcomes

Students will learn to,

- use an electrical conductivity meter;
- examine reasons for changes in the electrical conductivity of a water body;
- communicate project results with other GLOBE schools;
- use technology in classrooms
- collaborate with other GLOBE schools (within your country or other countries); and
- share observations by submitting data to the GLOBE archive.

Science Concepts

Earth and Space Science

Earth materials are solid rocks, soils, water and the atmosphere.

Water is a solvent.

Each element moves among different reservoirs (biosphere, lithosphere, atmosphere, hydrosphere).

Physical Sciences

Objects have observable properties.

Life Sciences

Organisms can only survive in environments where their needs are met.

Earth has many different environments that support different combinations of organisms.

Humans can change natural environments.

All organisms must be able to obtain and use resources while living in a constantly changing environment.

Scientific Inquiry Abilities

Use a conductivity meter to measure conductivity of water.

Identify answerable questions.

Design and conduct scientific investigations.

Use appropriate mathematics to analyze data.

Develop descriptions and explanations using evidence.

Recognize and analyze alternative explanations.

Communicate procedures and explanations.

Time

10 minutes

Level

All

Frequency

Weekly

Materials and Tools

Hydrology Investigation Data Sheet

Electrical Conductivity Protocol Field Guide

Electrical Conductivity Meter

Thermometer

Distilled water in wash bottle

Soft tissue

Two 100-mL beakers

Latex gloves

600-700 ml plastic water bottle

For Calibration, the above plus:

- Standard solution
- Small screwdriver (if required)
- *Electrical Conductivity Calibration Protocol Lab Guide*

Preparation

Suggested Learning Activities:

Practicing Your Protocols: Electrical Conductivity

Water Detectives (e-guide only)

Prerequisites

None

Electrical Conductivity Protocol – Introduction

Have you ever left water to evaporate from a dish? What was left after the water evaporated?

Fresh water has many natural impurities – including salts or minerals dissolved in the water that we cannot always see or smell. As water comes in contact with rocks and soil, some minerals dissolve in the water. Other impurities can enter a water body through runoff or wastewater releases. If water contains high amounts of dissolved salts, it may be harmful to use for watering crops.

We call the amount of mineral and salt impurities in the water the total dissolved solids (abbreviated TDS). We measure TDS as parts per million (ppm). This tells us how many units of impurities there are for one million units of water, by mass. For water we use at home, we prefer a TDS of less than 500 ppm, although water with higher TDS can still be quite safe. Water used for agriculture should have TDS below 1200 ppm so sensitive crops are not harmed. Manufacturing, especially of electronics, requires impurity-free water.

We use an indirect measure to find the TDS of water. One way to measure impurities in water is to find out if it conducts electricity. Pure water is a poor conductor of electricity. When certain solids (typically salts) are dissolved in water, they dissociate and form ions. Ions carry an electrical charge (either positive or negative). More ions in water mean the water will conduct electricity better.

The electrical conductivity meter measures how much electricity is being conducted through a centimeter of water. If you look at the probe end of the meter you will see that there are electrodes 1 cm apart. Conductivity is measured as microSiemens per cm (μS/cm). This is the same unit as a micromho, mho.

To convert the electrical conductivity of a water sample (μS/cm) into the approximate concentration of the total dissolved solids (ppm) in the sample, you must multiply the conductivity (μS/cm) by a conversion factor. The conversion factor depends on the chemical composition of the dissolved solids and can very between 0.54 - 0.96. For instance, sugars do not affect conductivity because they do not form ions when they dissolve. The value 0.67 is commonly used as an approximation.

TDS (ppm) = Conductivity (μS/cm) x 0.67

It is better to use a conversion factor that has been determined by your water body instead of the approximation since the impurities between water bodies can vary greatly. Drinking water with a conductivity of 750 μS/cm will have an approximate concentration of total dissolved solids of 500 ppm. Pure alpine snow from remote areas has a conductivity of about 5 - 30 μS/cm.

Table HY-EC-1: Estimated Conversion from Conductivity (μS/cm) to Total Dissolved Solids (ppm) based on Average Conversion Factor of 0.67

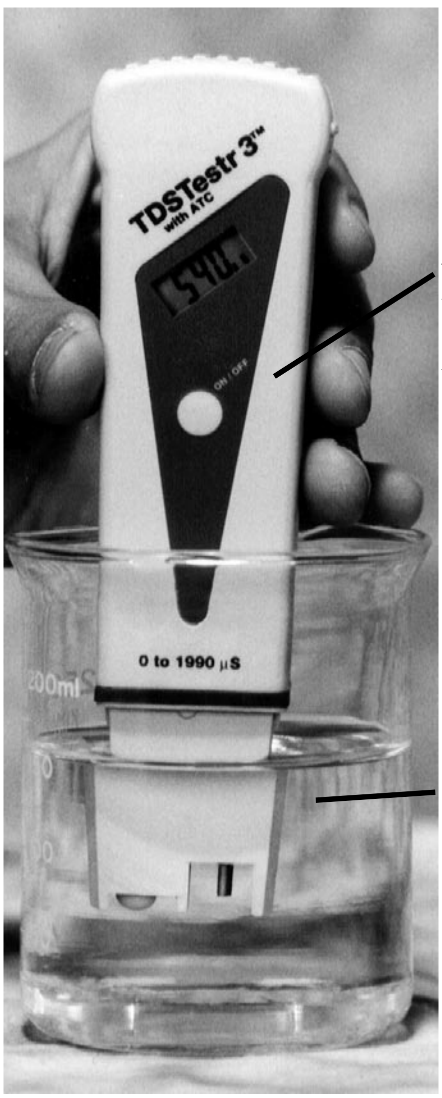
Conductivity (μS/cm)	TDS (ppm)	Conductivity (μS/cm)	TDS (ppm)
0	0	1050	704
50	34	1100	737
100	67	1150	771
150	101	1200	804
200	134	1250	838
250	168	1300	871
300	201	1350	905
350	235	1400	938
400	268	1450	972
450	302	1500	1005
500	335	1550	1039
550	369	1600	1072
600	402	1650	1106
650	436	1700	1139
700	469	1750	1173
750	503	1800	1206
800	536	1850	1240
850	570	1900	1273
900	603	1950	1307
950	637	2000	1340
1000	670	>2000	>1340

Teacher Support

Measurement Procedure

There are several manufacturers and models of conductivity meters. Some models may measure conductivity in increments of 10µS/cm; others in increments of 1.0µS/cm. If your model measures in increments of 10µS/cm, you will have to calibrate it as closely as you can to the standard solution. Your accuracy and precision will never be better than ± 10µS/cm. The meters need to be calibrated before testing the water sample. This can be done in the classroom shortly before going to the hydrology site or at the hydrology site.

Figure HY-EC-1: Using the Conductivity Meter



For measuring electrical conductivity, you will hear references to either conductivity probes or meters. For clarification, probes are the instruments that measure voltage or resistance in a water sample. Meters are instruments that convert electrical (voltage or resistance) measurements to concentrations. In order to measure electrical conductivity (or other types of measurements), both a probe and meter are required. Sometimes the probe and meter are within one instrument and cannot be taken apart. Other instruments have probes that are separate from the meters and need to be connected to the meters in order to take the water measurements.

Some conductivity meters may indicate that they have an automatic temperature compensation (ATC). Testing by the GLOBE Hydrology team has indicated that the temperature compensation on conductivity meters is generally not reliable. For this reason, all water should be brought to room temperature (20˚ - 30˚ C) for testing, even if the manufacturer claims that the meter is temperature compensated. It is very important to take the temperature of the water when doing the conductivity measurement. The temperature of the solution when the conductivity measurement is taken will help to identify errors resulting form meter error instead of actual changes in total dissolved solids.

If the water at your Hydrology Site is not between 20˚ - 30˚ C, you need to either let the water warm in the sample bucket or separate container while students take other hydrology measurements at the hydrology site, or collect a sample in a water bottle and take back to the classroom. After the water reaches 20˚ - 30˚ C, students can take the conductivity measurement.

Never immerse the meter totally in water. Only the part indicated in the instructions for the meter should be immersed in water.

Most Conductivity Meters cannot measure the high conductivity characteristic of salt waters. If your hydrology site is in salt water, you will need to follow the *Salinity Protocol.*

Quality Control Procedure

Electrical conductivity meters must be calibrated before use. Check with your meter manufacturer to be sure it stores the most recent calibration. If it does, the conductivity meter should be calibrated in the classroom or lab before going to the Hydrology Site. If your meter does not keep the most recent calibration, you will need to calibrate it just before you take your measurements taking care not to turn the meter or any associated software off. The temperature of the conductivity standard should be about 25° C.

Supporting Protocols

Water Temperature: It is important to take the temperature of water at the hydrology site following the *Water Temperature Protocol*. If the temperature at the site is not between 20° - 30° C, it is important to let a sample of water reach this temperature range.

Soil Characteristics and *Land Cover:* Soil Characteristics and Land Cover data provide information on the possible source of the materials dissolved in the water.

Atmosphere: Atmosphere data, especially precipitation, may also affect the concentration of total dissolved solids in your water.

Supporting Activities

A discussion of good conductors and poor conductors may help students understand the measurement better. To illustrate the conductivity of water, have students measure distilled water with the conductivity meter. They will find a reading near zero. Stir a small amount of salt into the water and watch the reading go up! What happens when sugar is added?

Students may also benefit from a discussion of indirect measures. Some things are difficult to measure directly. For instance, it would take a long time to count the fingers of everyone in the school! But we could estimate the number of fingers indirectly by counting the students and multiplying by 10. What other indirect measures can students think of?

Safety Precautions

Students should wear gloves when handling water that may contain potentially harmful substances such as bacteria or industrial waste.

Helpful Hints

It is a good idea to keep an extra set of batteries on hand for the conductivity tester. Many use small, flat 'watch' type batteries.

Instrument Maintenance

Electrical Conductivity Meter

1. The meter should be stored with the cap on. Never store the meter in distilled water.
2. The electrodes should be well rinsed with distilled water after use to avoid mineral deposit accumulation.
3. The electrodes should periodically be cleaned with alcohol.

Standard Solution

1. The standard should be stored in a tightly capped container in the refrigerator. Making a seal with masking tape will reduce evaporation.
2. Write the date that the standard was purchased on the bottle. Standards should be discarded after one year.
3. Never pour used standard back into the bottle.

Questions for Further Investigation

Would the conductivity of the water at your site to go up or down after a heavy rain? Why?

Would you expect the conductivity to be greater in a high mountain stream that receives fresh snowmelt or in a lake at lower elevations?

Why do you think water with high levels of TDS is harmful to plants?

Electrical Conductivity Calibration Protocol

Lab Guide

Task

Calibrate your electrical conductivity tester.

What You Need

- ❏ Electrical conductivity tester
- ❏ Standard solution
- ❏ Thermometer
- ❏ Distilled water in wash bottle
- ❏ Soft tissue
- ❏ Two 100-mL beakers or two plastic cups
- ❏ Latex gloves
- ❏ Small screwdriver

In the Lab

1. Bring the standard solution to room temperature (about 25° C).
2. Pour standard solution into each of the two clean 100-mL beakers or cups to a depth of about 2 cm.
3. Remove the cap from the electrical conductivity tester and press the On/Off button to turn it on.
4. Rinse the electrode at the bottom of the tester with distilled water in the wash bottle.
5. Gently blot dry with a tissue. Note: Do not rub or stroke the electrode while drying.
6. Put the probe of the meter into the first beaker of standard. Stir gently for 2 seconds to rinse off any dis tilled water.
7. Take the meter out of the first beaker. Do NOT rinse with distilled water.
8. Put it into the second beaker.
9. Stir gently, and then wait for the numbers to stop changing.
10. If the display does not read the value of your standard solution, you must adjust the instrument to read this number. (For most meters, you can use a small screwdriver to adjust the calibration screw on the meter until the display reads the standard value.
11. Rinse the electrode with distilled water and blot it dry. Turn off the meter and put the cap on to protect the electrode.
12. Pour the standard from the beakers into a waste container. Rinse and dry the beakers

Electrical Conductivity Protocol
Field Guide

Task

Measure the electrical conductivity of your water sample.

What You Need

- ❑ *Hydrology Investigation Data Sheet*
- ❑ Electrical conductivity meter
- ❑ Thermometer
- ❑ Distilled water in wash bottle
- ❑ Paper towel or soft tissue
- ❑ 2 100-mL beakers
- ❑ Latex gloves
- ❑ One clean 600-700 ml plastic water bottle with cap (for sample water)

In the Field

1. Fill out the top portion of the *Hydrology Investigation Data Sheet*
2. Put on latex gloves.
3. Record the temperature of the water to be tested. If water is between 20˚ – 30˚ C, go to step 5.
4. If your water is below 20˚ C or above 30˚ C, fill a clean sample bottle (600-700 mL) with the water to be tested. Cap and bring back to the classroom. Allow the water to reach 20˚ – 30˚ C, record the temperature and then proceed to step 5.
5. Rinse two 100-mL beakers two times with sample water.
6. Pour about 50 mL of water to be tested into two 100-mL beakers.
7. Remove the cap from the probe end of the meter. Press the On/Off button to turn it on.
8. Rinse the probe with distilled water. Blot it dry. Do not rub or stroke the electrode while drying.
9. Put the probe in the water sample in the first beaker. Stir gently for a few seconds. Do not let the meter rest on the bottom of the beaker or touch the sides.
10. Take the probe out of the first beaker. Shake gently to remove excess water, then put it into the second beaker *without* rinsing with distilled water.
11. Leave the probes submerged for at least one minute. When the numbers stop changing, record the value on the *Hydrology Investigation Data Sheet* by *Observer 1*.
12. Have two other students repeat the measurement using fresh beakers of water each time. The meter does not need to be calibrated for each student. Record these measurements as *Observers 2* and *3*.
13. Calculate the average of the three observations.
14. Each of the observations should be within 40µS/cm of the average. If one or more of the values is not within 40µS/cm, pour a fresh sample and repeat the measurements and calculate a new average. If all observations still are not within 40.0 of the average, discuss possible problems with your teacher.
15. Rinse the probe with distilled water, blot dry, and put the cap on the meter. Rinse and dry the beakers and sample bottle.

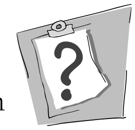
Frequently Asked Questions

1. Why does my conductivity reading slowly change?

If your conductivity meter is not temperature equilibrated with the sample, the reading will slowly drift until the meter and the sample reach the same temperature. Also if your sample temperature is very different from the surrounding air temperature, the conductivity reading can drift as the sample warms or cools to equilibrate with the air.

2. What happens if my water is really salty or brackish?

Most meters will only measure up to 1990.0 μS/cm. If your water has higher conductivity than this, the meter will not give a reading. You should use the *Salinity Protocol* to measure the dissolved solids in your water.



3. Will the meter give me an electrical shock?

No, however, you should not touch the electrode to avoid contaminating it. The tester should be handled carefully. If it is dropped into the water it may be ruined.

Electrical Conductivity Protocol – Looking at the Data

Are the data reasonable?

The conductivity tester measures conductivity from 0 to 1990.0µS/cm. Waters with conductivity values greater than 1990.0µS/cm must be tested for total dissolved solids by using the *Salinity Protocol*. As a general trend for fresh water, conductivity increases the farther the sample site is from the source. Most conductivity testers increase in units of 10.0 and have a range of error of ± 40.0µS/cm.

Conductivity may vary significantly with the type of water body and the site. It is therefore important to look at the conductivity of your own site over time. Graph your data and examine them for upward or downward trends. Pay close attention to values that may seem questionable. Check your metadata or other protocol data such as precipitation to see if your values can be explained by other environmental factors.

What do scientists look for in these data?

Scientists use conductivity data as a measure of water quality. High values can mean water that tastes bad or is too salty for watering crops. Most municipal water quality reports use conductivity or TDS measurements to show that their drinking water is within the locally established limits. Scientists also look for trends in the conductivity data. Seasonal trends are often observed for water bodies that receive a portion of their water directly from snowmelt in the spring, water bodies that are affected by land cover, or water bodies that are located in areas with definite rainy seasons. Scientists can use the seasonal data they obtain to forecast water quality issues for years to come.

Example of a Student Research Project.

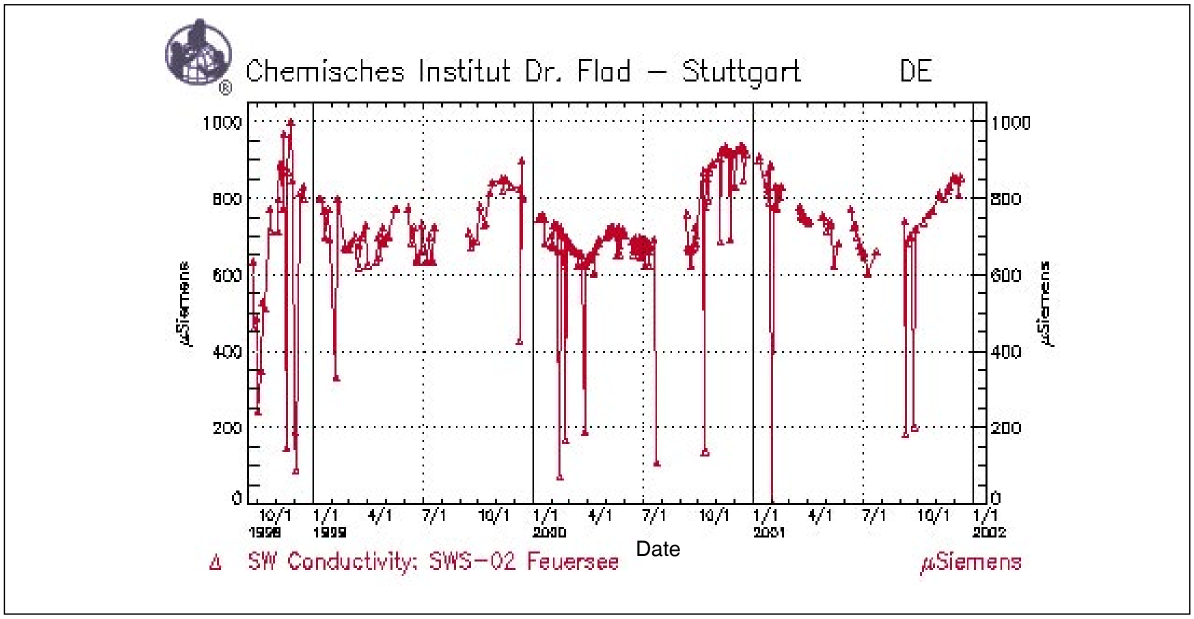
Forming a Hypothesis

A student researcher wants to investigate conductivity. She hypothesizes that annual or seasonal fluctuations in conductivity data should be apparent in GLOBE measurements.

Collecting and Analyzing Data

She starts by searching the GLOBE database for schools that have taken conductivity measurements.

Figure HY-EC-2



She then eliminates schools that have not taken measurements consistently over the course of at least one full year. After plotting the data for several schools using the GLOBE server, the student finds an interesting trend for the data from Chemisches Institut Dr. Flad in Stuttgart, Germany. This graph is shown in Figure HY-EC-2.

The water body where this school takes its measurements is Feuersee, a freshwater lake. From this plot the student noted that the conductivity measurements tend to be higher in the winter months and lower in the summer months. She then investigates further by downloading the monthly averages for conductivity values of Chemisches Institut Dr. Flad from the GLOBE Web site. These data are shown below in Table HY-EC-2.

The student then imports these data into a spreadsheet program, and she plots the data as shown in Figure HY-EC-3.

From this plot, the same overall trend can be seen, however it is not as apparent as in Figure HY-EC-1.

The student then decides to look at the trends on a seasonal rather than monthly basis. She divides the year into the four seasons and assigns the months December – February as winter, March – May as spring, June – August as summer and September – November as autumn. She calculates an average conductivity for each season. These data are shown in Table HY-EC-3.

Table HY-EC-2

Date	Cond. µS/cm
9/1998	527
10/1998	519
11/1998	789
12/1998	545
1/1999	754
2/1999	617
3/1999	675
4/1999	677
5/1999	737
6/1999	692
7/1999	665
9/1999	689
10/1999	790
11/1999	840
12/1999	760
1/2000	730
2/2000	639
3/2000	624
4/2000	654
5/2000	706
6/2000	669
7/2000	613
9/2000	681
10/2000	785
11/2000	878
12/2000	907
1/2001	859
2/2001	701
3/2001	755
4/2001	746
5/2001	697
6/2001	712
7/2001	640
9/2001	560
10/2001	752
11/2001	820
12/2001	842

Table HY-EC-3

Season	Cond. µS/cm
autumn-1998	612
winter-1999	639
spring-1999	696
summer-1999	679
autumn-1999	773
winter-2000	710
spring-2000	661
summer-2000	641
autumn-2000	781
winter-2001	822
spring-2001	733
summer-2001	637
autumn-2001	711

The student then graphs the data as shown in Figure HY-EC-5.

From this plot she is able to see the annual trend more clearly. The student makes a note that the data for August were not available for any of the years in this data set and therefore the summer season is the average of only June and July. The student then decides to plot the data a final way. This time she calculates the average conductivity values of each month for the four-year period, as shown in Table HY-EC-4.

She plots these data as shown in Figure HY-EC-5.

Here again an annual trend can be seen. The student notes that the averages for November, December and January were much higher than the other months in the year. She realizes she might not have picked the best months to represent each season. Perhaps, November – January should have been chosen for winter. This would most likely have produced a more noticeable trend. However, the student is confident that she has indeed discovered a site that shows an annual trend.

Future Research

For further investigation, the student could contact the school and ask them if they have any ideas of what could be causing this cycle.

She could also look at the seasonal patterns of other measurements, such as precipitation, to see if they might also be related.

She could also repeat this studying by looking at seasonal and monthly patterns in conductivity at other sites.

Table HY-EC-4: Conductivity (µS/cm)

	1998	1999	2000	2001	Ave.
January		754	730	859	781
February		617	639	701	652
March		675	624	755	685
April		677	654	746	692
May		737	706	697	713
June		692	669	712	691
July		665	613	640	639
August					
September	527	689	681	560	614
October	519	790	785	752	712
November	789	840	878	820	832
December	545	760	907	842	764

Figure HY-EC-3

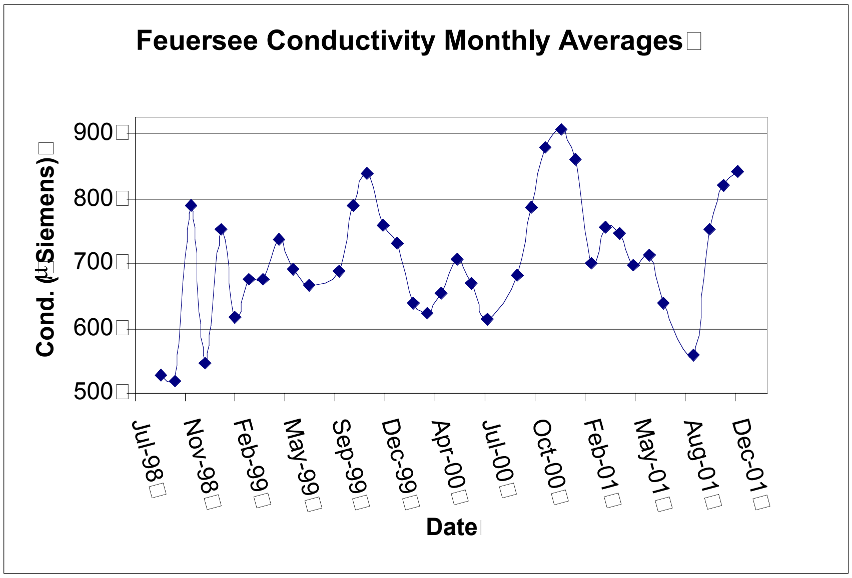


Figure HY-EC-4

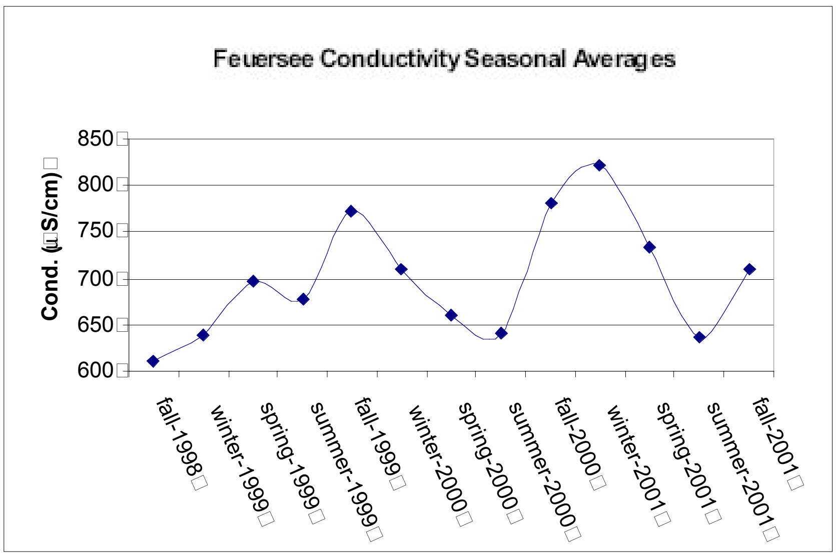


Figure HY-EC-5