WATER-QUALITY MONITORING FIELD PROCEDURES MANUAL

Tuolumne County Stream Team

4th Edition, Prepared by Terry Strange, Strange Aquatic Resources

Information compiled from US Environmental Protection Agency and California State Water Resources Control Board *Clean Water Team*

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Thank you for your commitment to help assess the health of your watershed. Volunteers are **THE** critical component to the success of a water quality-monitoring program. The purpose of this manual is to orient you with the procedures for water-quality monitoring.

Thank you for becoming a water quality monitor!

Contact Information for your Water Quality Monitoring Coordinator:

_____
(Name)

_____
(Phone and Email)

Other Citizen Volunteer Water Quality Monitoring Supporters

Sierra Nevada Alliance: since 1993, the Alliance, a non-profit organization, has been protecting and restoring Sierra lands, water, wildlife and communities. The Sierra Watersheds Program goal is to ensure that the Sierra's 24 major watersheds have active, informed efforts to restore and protect their rivers, lakes and streams thereby protecting critical habitats and restoring watershed health in the Sierra Nevada. We do this by networking, distributing information, offering financial support, hosting trainings and workshops, inspiring and educating. www.sierranevadaalliance.org

South Yuba River Citizens League RiverScience program focuses on the development of scientifically valid restoration efforts and community-based monitoring. SYRCL's RiverScience program uses water quality monitoring and analysis, research, education, advocacy, and collaboration to help protect and restore the Yuba Watershed. With over 70 trained volunteers from the community, SYRCL's River Monitoring Program is now completing its 4th year of collecting water quality data.

www.syrcl.org

Clean Water Team (CWT) is the citizen-monitoring program of the California State Water Resources Control Board. The CWT Coordinators are members of the Regional Programs Unit, Watershed Pollution Prevention Section. The mission of the Clean Water Team is *"to build and support the States Watersheds' Stewardship through involvement in Citizen Monitoring in order to reduce and prevent water pollution."*

http://www.swrcb.ca.gov/nps/mission.html

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Section One: Orientation and Basic Sampling Methods

1. Introduction

Thank you for being a volunteer for the Tuolumne County Water Quality Monitoring Program. The future health of the waterways in Tuolumne County depends upon your efforts for quarterly chemical water testing and yearly stream assessment surveys. You are extremely appreciated!

This manual will address protocol and considerations for every aspect of your sampling procedures, to help you- and to insure the sampling happens in an accurate, scientific manner. Data collected from your quarterly samples will be entered into a database and results will be evaluated by the State Water Resources Control Board. Determinations for future efforts to improve water quality in the waterways in Tuolumne County will be based upon your efforts.

Tuolumne County and the State Water Resources Control Board hope that you will enjoy the experience of being a quarterly monitor. It's not always an easy job! Please allocate enough time for your sample collection, your knowledge of the monitoring date and do not hesitate to contact the monitoring coordinator if you have any needs, questions or schedule changes.

Every quarter the monitoring coordinator will contact you to confirm your monitoring date and time. **Please be prompt in answering back!** Please try to inform us of scheduling considerations well in advance of your time, since samples are meant to be collected at the same time of day from month to month. This will give us time to re-schedule you or find a replacement monitor for that month. Call Amy Augustine at (209) 532-7376.

2. Safety Considerations

One of the most critical considerations for a volunteer monitoring program is the safety of its volunteers. All volunteers should be trained in safety procedures and should carry with them a set of safety instructions and the phone number of their monitoring coordinator. Safety precautions can never be overemphasized.

The following are some basic safety rules.

At the site:

- ✓ Always monitor with at least one partner. Always let someone else know where you are, when you intend to return, and what to do if you do not come back at the appointed time.

- ✓ Have a first aid kit handy. Know any important medical conditions of team members (e.g., heart conditions or allergic reactions to bee stings). It is best if at least one team member has First Aid/CPR training.

- ✓ Listen to weather reports. Never compromise your safety if severe weather is predicted or if a storm occurs while at the site.

- ✓ Never wade in swift or high water (above knee height).

- ✓ If you drive, park in a safe location. Be sure your car doesn't pose a hazard to other drivers and that you don't block traffic.

- ✓ Put your wallet and keys in a safe place, such as a watertight bag you keep in a pouch strapped to your waist. Without proper precautions, wallet and keys might end up downstream.

- ✓ Never cross private property without the permission of the landowner. Tuolumne County directions lead you to private property, verify with the County or Water Monitor that permission has been granted.

- ✓ Watch for irate dogs, farm animals, wildlife (particularly snakes), and insects such as ticks, hornets, and wasps. Know what to do if you get bitten or stung. Advise your partners if you are allergic, and carry a sting kit with you to the field.

- ✓ Watch for poison oak and other types of vegetation that can cause rashes and irritation.

- ✓ Never drink the water in a stream. Assume it is unsafe to drink, and bring your own water from home. After monitoring, wash your hands with antibacterial soap before eating.

- ✓ Do not walk on unstable stream banks. Disturbing these banks can accelerate erosion and might prove dangerous if a bank collapses. Disturb streamside vegetation as little as possible.

- ✓ Be very careful when walking in the stream itself. Rocky-bottom streams can be very slippery and can contain deep pools; muddy-bottom streams might also prove treacherous in areas where mud, silt, or sand have accumulated in sink holes. If you must cross the stream, use a walking stick to steady yourself and to probe for deep water or muck. Your partner(s) should wait on dry land ready to assist you if you fall. Do not attempt to cross streams that are swift and above the knee in depth.

- ✓ If you are sampling from a bridge, be wary of passing traffic. Never lean over bridge rails unless you are firmly anchored to the ground or the bridge with good hand/foot holds.

- ✓ **If at any time you feel uncomfortable about the condition of the stream or your surroundings, stop monitoring and leave the site at once. Your safety is more important than the data!**

When using chemicals:

- ✓ Know your equipment, sampling instructions, and procedures before going out into the field. Prepare labels and clean equipment before you get started.

- ✓ Keep all equipment and chemicals away from small children. Many of the chemicals used in monitoring are poisonous. Tape the phone number of the local poison control center to your sampling kit.

- ✓ Avoid contact between chemical reagents and skin, eye, nose, and mouth. Never use your fingers to stopper a sample bottle (e.g., when you are shaking a solution).

- ✓ Know chemical cleanup and disposal procedures. Wipe up all spills when they occur. Return all unused chemicals to your program coordinator for safe disposal.

- ✓ Close all containers tightly after use. Do not switch caps. Let us know if you think you did, or if items are lost.

- ✓ Know how to use and store chemicals. Do not expose chemicals or equipment to temperature extremes (such as in a parked car during the summer) or long-term direct sunshine.

- ✓ Rinse test vials with deionized or distilled water after each test; dry hands and outside of vial.

- ✓ Wipe up spills when they occur.

- ✓ **Do not pour used chemicals or samples onto the ground or into the creek! Place all solutions and used chemicals in a waste container and dispose of them down a sink connected to a sewer system (not a septic tank) or return them to the program coordinator.**

Some items you may want to bring with you when monitoring:

1. Water (canteen)
2. Watch (for recording times)
3. Compass
4. Pocket knife
5. Camera
6. Water shoes
7. Metric tape measure
8. Flashlight or head lamp and batteries
9. Small towel
10. Waterproof pen
11. Fingerless gloves or hand warmers
12. Sunscreen and sunglasses
13. Trash bag
14. Yard or meter stick
15. Insect repellent
16. Raingear, fleece jacket, polypropylene long underwear
17. Extra pair of pants, shirt, socks (wool)
18. Hat
19. Food snacks – Energy bar, fruit, and nuts
20. Cooler with blue ice (if collecting grab samples to be taken back to lab)
21. Binoculars
22. Emergency survival blanket
23. Whistle

Section Two: Collecting Procedure

1. Water Sampling

General Sampling Techniques

Always sample away from the stream bank in the main current and upstream from where you are standing, in or near the stream. Your behavior should never affect the water sample. The outside curve of the stream is often a good place to sample since the main current tends to hug this bank. Take measurements within the river/creek itself if high river flows are not a problem. This usually means a water depth of less than knee height at the deepest part of the site. If there is a high flow level in the river/creek, then collecting water using the sampling poles provided by the program may be advisable. Collect all your samples from the same location in the river.

Sampling Pole Techniques

Rinse out the sampling bottle attached to the pole 2-3 times with creek water. While standing downstream, put sampling pole perpendicular to bottom of stream. Push it underwater so the sample comes from the middle of the water column. Allow to fill with water and bring bottle to shore. Immediately measure for temperature, pH, and conductivity. Get a fresh water sample every time for each additional parameter: dissolved oxygen, turbidity, fecal coliform, metals and nutrients.

Screw-Cap Bottle Technique

This technique is used to collect water samples in screw-cap sample bottles for tests such as turbidity, fecal coliform, heavy metals and nutrients.

A. Label the bottle with the site number, date, time and your name or initials. Use waterproof pen, if possible.

B. Remove the cap from the bottle just before sampling. Avoid touching the inside of the bottle or the cap. In high flows, use a sampling pole. Rinse the sampling bottle on the pole 3 times prior to decanting water into sample bottle. If you accidentally touch the inside of the bottle, use another one.

C. Wading. Try to disturb as little bottom sediment as possible. In any case, be careful not to collect water that contains bottom sediment. Stand facing upstream. Collect the water sample in front of you (upstream).

D. Hold the bottle near its base and plunge it (opening downward) below the water surface. Collect a water sample 6 to 12 inches beneath the

surface or mid-way between the surface and the bottom if the stream reach is shallow.

E. Turn the bottle underwater into the current and away from you (upcurrent).

F. Leave a small air space, so that sample can be shaken before analysis.

G. Check off the test on your appropriate field data sheet. This is important because it tells the monitoring coordinator which bottle goes with which site.

H. If the samples are to be analyzed in the lab (e.g. coliform and metals), place them in the cooler for transport to the laboratory.

Section Three: Water Monitoring Parameters

1. Air Temperature

How to Measure Air Temperature

Hang the thermometer on a tree branch in the shade for 10 minutes to equilibrate. Keep it away from cool water, hot rocks, and your body.

Step 1: First record the thermometer ID number on your data sheet.

Step 2: To measure the air temperature, hold the thermometer at arm's length, shaded from direct sunlight, at shoulder height.

Step 3: When using the meter, allow the temperature reading to stabilize at a constant temperature reading.

Step 4: Return the thermometer to the branch and recheck temperature in 10 minutes.

Step 5: Return the thermometer to the branch and recheck temperature in 5 minutes.

Step 6: Keep all readings within a 20 minute time frame

2. Water Temperature

Water temperature is the measure of the average kinetic energy of water molecules. It is measured on a linear scale of degrees Celsius or degrees Fahrenheit. The formula for conversion between Fahrenheit and Celsius is: (?F - 32) x 5/9 = ?C. Always indicate whether temperature has been recorded in degrees Celsius or degrees Fahrenheit.

Importance of Water Temperature

Temperature is one of the most important water quality parameters. Aquatic organisms from microbes to fish are dependent on certain temperature ranges for their optimal health. Optimal temperatures for fish depend on the species: some survive best in colder water, whereas others prefer warmer water. If water temperatures are outside this optimal range for a prolonged period of time, organisms are stressed and can die. Temperature affects the oxygen content of the water (oxygen levels become lower as temperature increases); the rate of photosynthesis by aquatic plants; the metabolic rates of aquatic organisms; and the sensitivity of organisms to toxic wastes, parasites, and diseases.

Factors Affecting Water Temperatures

Natural Factors

- Sunlight energy such as seasonal and daily changes, effects of shade (cover), and air temperature
- Wind speed at water surface
- Stream flow
- Depth of water
- Inflow of groundwater which is usually colder than creek water
- Inflow of surface water including a drainage ditch or another creek
- Color and turbidity of water (suspended sediment absorbs heat)

Human Factors

- Removal of riparian vegetation
- Soil erosion, filling in deep pools that were once cold, dark refugia for fish
- Stormwater runoff from hot impervious surfaces
- Alterations to stream morphology, substrate and flow
- Cooling water discharges from power plants
- Water diversion or storage resulting in decreased flows
- Water originating from surface or bottom of reservoir

Acceptable Water Temperature Ranges

Acceptable ranges cannot be assigned without understanding the aquatic ecosystem. The maximum tolerable temperature depends on the species.

Species	Growth	Maxima	Spawning*	Embryo Survival**
Bluegill	32^{0}C (90^{0}F)	35^{0}C (95^{0}F)	25^{0}C (77^{0}F)	34^{0}C (93^{0}F)
Carp		21^{0}C (70^{0}F)	33^{0}C (91^{0}F)	
Channel catfish	32^{0}C (90^{0}F)	35^{0}C (95^{0}F)	27^{0}C (81^{0}F)	29^{0}C (84^{0}F)
Largemouth bass	32^{0}C (90^{0}F)	34^{0}C (93^{0}F)	21^{0}C (70^{0}F)	27^{0}C (81^{0}F)
Rainbow trout	19^{0}C (66^{0}F)	24^{0}C (75^{0}F)	9^{0}C (48^{0}F)	13^{0}C (55^{0}F)
Sockeye salmon	18^{0}C (64^{0}F)	22^{0}C (72^{0}F)	10^{0}C (50^{0}F)	13^{0}C (55^{0}F)
Coho Salmon	16.5^{0}C (62^{0}F)	22^{0}C (72^{0}F)		
Steelhead	20.5^{0}C (69^{0}F)	24^{0}C (75^{0}F)		
Chinook		24^{0}C (75^{0}F)	6-13^{0}C (43-55^{0}F)	5-13^{0}C (41-55^{0}F)

* The optimum or mean of the range of spawning temperatures reported for the species.
** The upper temperature for successful incubation and hatching reported for the species

Maximum weekly average temperature for growth and short-term maximum temperatures for selected fish Adapted from EPA's *Draft Volunteer Stream Monitoring: A Method Manual. An Analysis of the Effects of Temperature on Salmonids of the Pacific Northwest with Implications for Selecting Temperature Criteria.* Sullivan, K., D.J. Martin, R.D. Cardwell, J.E. Toll, and S. Duke. 2000

How to Measure Water Temperature and pH

The same meter is used to test both water temperature and pH. It is a red meter that reads both parameters on the LCD display. This meter reads more accurately when presoaked in 1" of water. Information about pH follows this section.

Step 1: **Presoak:**
First remove meter cap and presoak the pH meter/ thermometer in 1" of river water, in the shade upright in a container for at least 10 minutes, with the **power off.** Be sure water level stays below the meter's buttons.

Step 2: **To turn the meter on and check the battery status:**
Press and hold the MODE button until the Liquid Crystal Display (LCD) lights up. All the used segments on the LCD will be visible for 1 second (or as long as the button is pressed), followed by the percent indication of the remaining battery life (e.g. % 100 BATT). The meters have been calibrated before monitoring day. This will be shown by the work CAL shown in the display.

Step 3: **Taking measurements:**
Submerge the electrode into river water or the sampling arm vessel while stirring it gently. Do not get it wet above the cap line. The measurements should be taken when the stability symbol (small clock) on the top left of the LCD disappears. The pH value automatically compensated for temperature is shown on the primary LCD while the secondary LCD shows the temperature of the sample. Take the first water temperature reading simultaneously with the pH reading. Both will be displayed at the same time. Tell the recording partner your reading for each. Turn off the meter after each set of temperature and pH readings. Turn back on for each of the three readings.

Step 4: **To freeze the display:**
While in measurement mode, press the SET/HOLD button. HOLD appears on the secondary display and the reading will be frozen on the LCD (e.g. pH 5.7 HOLD). Press any button to return to normal mode.

Step 5: **To turn the meter off:**
While in normal mode, press the MODE button. OFF will appear on the secondary display. Release the button. Store the meter upright with the electrode in a drop of water in the cap.
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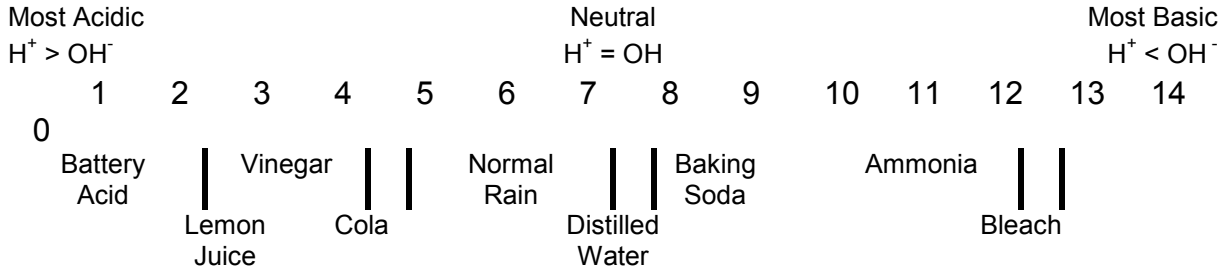
3. pH

pH is a term used to indicate the alkalinity or acidity of a substance as ranked on a scale from 1.0 to 14.0. As acidity increases the pH gets lower. The pH scale measures the logarithmic concentration of hydrogen (H+) and hydroxide (OH-) ions, which make up water ($H+ + OH- = H_2O$). When both types of ions are in equal concentration, the pH is 7.0 or neutral. Below 7.0, the water is acidic (there are more hydrogen ions than hydroxide ions). When the pH is above 7.0, the water is alkaline, or basic (there are more hydroxide ions than hydrogen ions). Since the scale is logarithmic, a drop in the pH by 1.0 unit is equivalent to a 10-fold increase in acidity. So, a water sample with a pH of 5.0 is 10 times as acidic as one with a pH of 6.0, and a pH of 4.0 is 100 times as acidic as a pH of 6.0.

pH Scale Showing the Value of Some Common Substances



Source: U.S. Fish and Wildlife Service

Importance of pH

pH affects many chemical and biological processes in the water. For example, different organisms flourish within different ranges of pH. The largest variety of aquatic animals prefers a range of 6.5-8.0. pH outside this range reduces the diversity in the stream because it stresses the physiological systems of most organisms and can reduce reproduction. Low pH can also allow toxic elements and compounds to become mobile and "available" for uptake by aquatic plants and animals. This can produce conditions that are toxic to aquatic life, particularly to sensitive species like rainbow trout. Changes in acidity can be caused by atmospheric deposition (acid rain), surrounding rock, and certain wastewater discharges.

Input of basic or acidic substances (man-made or natural)

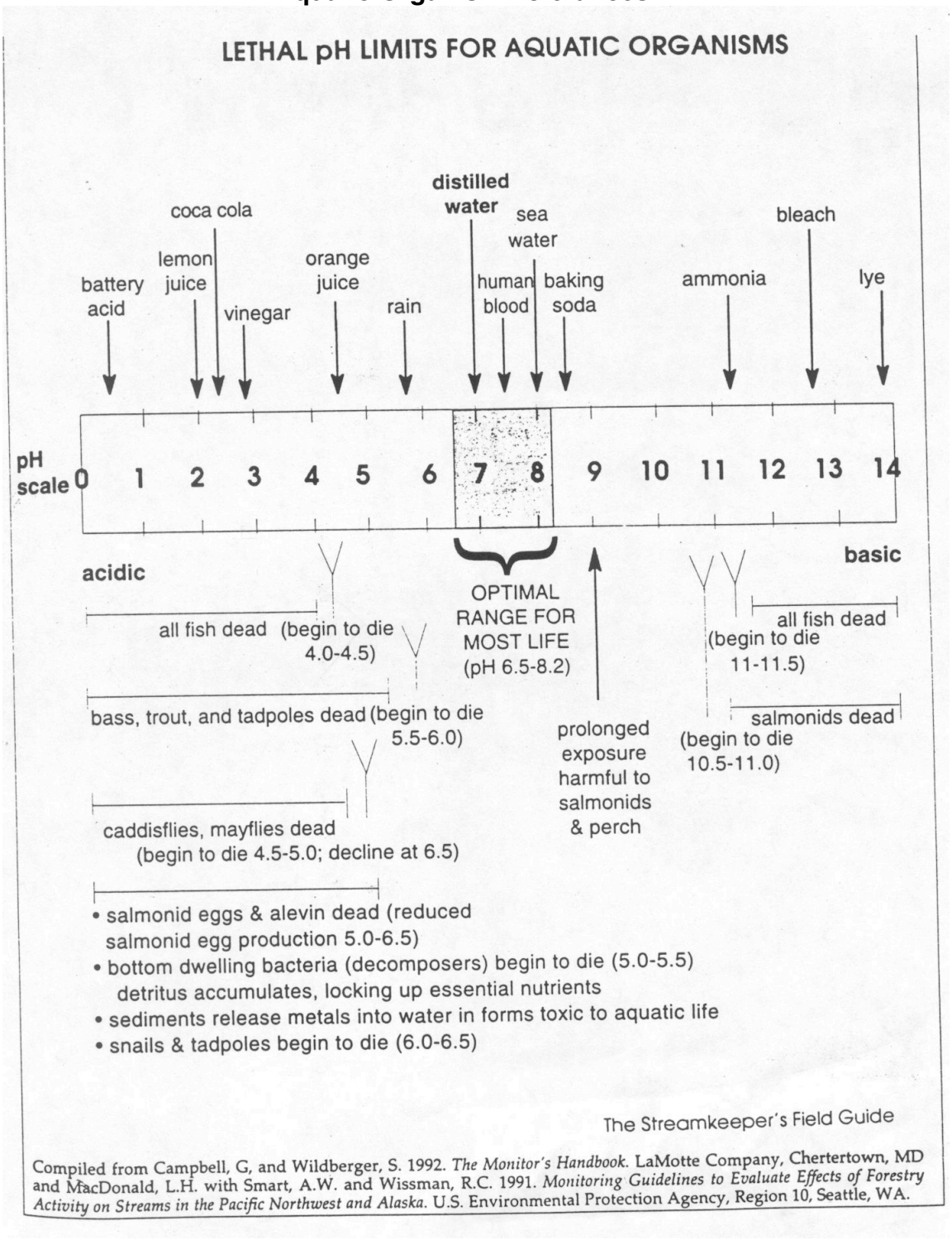
pH can change because of external inputs. You might measure a difference in pH along a stream due to:

- Changes in tree types surrounding the water, for example conifer needles are acidic and maple leaves are basic
- Changes in adjacent soils or rock types and erosion events
- Changes in the stream bottom material, for example the difference between gravel, silt, and bedrock
- Large changes in temperature affecting the CO_2/O_2 (carbonic acid) cycle in the water.
- Changes in human activity affecting the stream.

<u>Other Factors</u>

- In fresh water, increasing temperature decreases pH.
- Waters with high algal growth can show a diurnal change in pH. When algae grow and reproduce they use carbon dioxide. This reduction causes the pH to increase. Therefore, if conditions are favorable for algal growth (sunlight, warm temperatures), the water will be more alkaline. Maximum pH usually occurs in late afternoon, pH will decline at night. Because algal growth is restricted to light penetrating zones, pH can vary with depth in lakes, estuaries, bays and ocean water.
- High levels of bacterial activity in sediments can cause associated water to become acidic.
- Manmade inputs that reduce pH include acid rain (from automobiles or industrial sources) and acid mine drainage. Nutrients con indirectly affect pH by stimulating algal growth.

Aquatic Organism Tolerances



Compiled from Campbell, G, and Wildberger, S. 1992. *The Monitor's Handbook*. LaMotte Company, Chertertown, MD and MacDonald, L.H. with Smart, A.W. and Wissman, R.C. 1991. *Monitoring Guidelines to Evaluate Effects of Forestry Activity on Streams in the Pacific Northwest and Alaska*. U.S. Environmental Protection Agency, Region 10, Seattle, WA.

How to Measure pH

(Take 3 to 5 measurements)

The same meter is used to test both water temperature and pH. It is a red meter that reads both parameters on the LCD display. This meter reads more accurately when presoaked in 1" of water. Information about pH follows this section.

Step 1: **Presoak:**
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Step 5: **To turn the meter off:**
While in normal mode, press the MODE button. OFF will appear on the secondary display. Release the button. Store the meter upright with the electrode in a drop of water in the cap.

4. Conductivity

Conductivity is the ability of water to conduct an electrical current. Dissolved ions in the water are conductors. The major positively charged ions are sodium (Na^+) calcium (Ca^{2+}), potassium (K^+) and magnesium (Mg^{2+}). The major negatively charged ions are chloride (Cl^-), sulfate (SO_4-2), carbonate (CO_3-2), and bicarbonate (HCO_3-). Nitrates (NO_3-2) and phosphates (PO_4-3) are minor contributors to conductivity, although very important biologically.

Salinity is a measure of the amount of salts or ions in the water. Because dissolved ions increase salinity as well as conductivity, the two values are related. The salts in sea water are primarily sodium chloride (NaCl). However, other saline waters, such as Mono Lake, owe their high salinity to a combination of dissolved ions including sodium, chloride, carbonate and sulfate.

Importance of Conductivity (TDS)

Conductivity can affect the quality of water used for irrigation or drinking. Most aquatic biota tolerate a range of conductivity. However, the ionic composition of the water can be critical. For example, cladocerans (water fleas) are far more sensitive to potassium chloride than sodium chloride at the same concentration.

Conductivity will vary with water source such as ground water, water drained from agricultural fields, municipal wastewater and rainfall. Therefore, conductivity can indicate groundwater seepage or a sewage leak.

What Affects Conductivity of Water

- Soil and rocks release ions into the waters that flow through or over them. The geology of a certain area will determine the amount and type of ions.
- Salinity and conductivity of coastal rivers is influenced by tides. Sea spray can carry salts into the air that then fall back into the rivers with rainfall.
- De-icing salt used on roads and driveways can easily end up in nearby streams and affect salinity until diluted by large volumes of low salinity water.
- Flow of rivers into estuaries can greatly affect salinity as well as the location of the estuarine mixing zone. This is very important to the survival of estuarine organisms.
- Fresh water lost by evaporation will increase the conductivity and salinity of the waterbody. Warm weather can increase ocean salinity.

- As temperature increases, conductivity increases. Salinity is the amount of salt actually present in the water; therefore, it is not dependent on temperature.

Acceptable Conductivity Ranges

Here are some values of conductivity and salinity to give you an idea of possible data ranges you might encounter in the field. Waters that might have higher conductivity than reported here are rivers or drainage ditches dominated by subsurface agricultural return flows; ephemeral streams or pools late in the season; tidally influenced coastal waters; and naturally saline lakes or ponds.

Conductivity of Water

Water Type	**Conductivity** (mhos/cm or ?S)
Distilled Water	0.5 - 3.0
Melted snow	2 - 42
Potable water in U.S.	30 - 1500
Irrigation Supply Water	< 750

How to Measure Conductivity

Step 1: **Presoak:**
First remove meter cap and presoak the TDS meter in 1" of river water, in the shade upright in a container for at least 10 minutes, with the **power off.** Be sure water level stays below the meter's buttons.

Step 2: **Take the measurements**:
Turn the meter on and dip the electrode into river water or sampling arm vessel. Do not wet above the cap line! Stir gently every few seconds, until the readings stabilize. The probe automatically compensates for temperature, so it may take a couple of minutes for the values to stabilize. Be patient. Record value in microsiemen (µS).

Step 3: **Turn off meter**.
Repeat twice more, turning meter on and off for triplicate readings. Be sure meter is off when all three readings are recorded.

5. Dissolved Oxygen (DO)

The amount of oxygen dissolved in water, and is measured in micrograms per liter or parts per million (ppm).

Importance of Dissolved Oxygen (DO)

The creek system both produces and consumes oxygen. It gains oxygen from the atmosphere and from plants as a result of photosynthesis. Running water, because of its churning, dissolves more oxygen than still water, such as that of a reservoir behind a dam. Most aquatic organisms need oxygen to survive and grow. Some species, such as trout and stoneflies require high levels of DO, while other species such as catfish, worms and dragonflies, do not.

If there is not enough oxygen in the water, the following may result: death of adults and juveniles; reduction in growth; failure of fish eggs/insect larvae to survive; change in species present; and/or growth of toxic or smothering bacteria, fungi, or algae.

Factors Affecting Dissolved Oxygen Levels in Water

<u>Pollution</u>
If organic material (e.g. algae) or waste (e.g. septic leaks) is present in water, bacteria quickly move in to decay the material. As they respire and feed on the decaying material, they use up oxygen and generate CO_2 in the water. Large algae blooms (caused by events like people dumping lawn clippings or leaves, or fertilizer runoff) can create near-zero oxygen conditions in creeks.

<u>Temperature</u>
As temperature increases, less oxygen can be dissolved in water. When water holds all the DO it can at a given temperature, it is said to be 100 percent saturated with oxygen. Water can be supersaturated with oxygen under certain conditions (e.g. below large dams where discharging flows are very turbulent).
The following table shows the concentration of dissolved oxygen that is equivalent to the 100 percent saturation for the noted temperature (and normal barometric pressure). For fresh water only!

Dissolved Oxygen 100% Saturation at Sea Level

Temperature (degrees Celsius)	Dissolved Oxygen (mg/L)	Temperature (degrees Celsius)	Dissolved Oxygen (mg/L)
0	14.6	16	9.9
1	14.2	17	9.7
2	13.8	18	9.6
3	13.5	19	9.3
4	13.1	20	9.1
5	12.8	21	8.9
6	12.5	22	8.7
7	12.1	23	8.6
8	11.8	24	8.4
9	11.6	25	8.3
10	11.3	26	8.1
11	11.0	27	8.0
12	10.8	28	7.8
13	10.5	29	7.7
14	10.3	30	7.6
15	10.1	31	7.5

Sources of Dissolved Oxygen (DO)

Oxygen is added to water by:

Re-aeration
Oxygen from air is dissolved in water at its surface, mostly through turbulence. Examples of this include water tumbling over rocks (rapids, riffles, curves in the waterway) and wave action.

Photosynthesis (during daylight)
Plants produce oxygen when they photosynthesize. DO is generally highest in the late afternoon, and lowest in the early morning hours before sunrise.

Consumption of Dissolved Oxygen (DO)

Dissolved oxygen is used in two major ways—both of which contribute to the Biological Oxygen Demand (BOD) of the creek system:

Respiration

- Aquatic organisms breathe and use oxygen.
- Large amounts of oxygen are consumed by algae and aquatic plants at night (when large masses of plants are present).
- Large amounts of oxygen are consumed by decomposing bacteria (when there are large amounts of dead material to be decomposed, there will be significant numbers of bacteria).

Substances

Examples of substances that breakdown and use oxygen in the process are generally biodegradable and include dead organic matter, algae, sewage/feed lot waste, yard clippings/yard waste, oil/grease, and fertilizer runoff.

Causes of Low Dissolved Oxygen (DO) Levels

- Increases in water temperature
- Algal blooms
- Human waste
- Animal waste (especially from feedlots/dairy farms)
- Depletion near the bottom of reservoirs by bacteria

Other Factors

- Altitude—water holds less oxygen at higher altitudes
- Salinity—dissolved oxygen decreases, as salinity increases
- Mineral content--dissolved oxygen decreases, as the mineral content and concentration of the water increases

Acceptable Dissolved Oxygen (DO) Ranges

The following table gives specific DO values for the survival of different species:

Biologic Effects of Decreasing Dissolved Oxygen (DO) Levels on Salmonids, Non-Salmonids Fish, and Aquatic Invertebrates

	DO (mg/mL)	
	Instream	Intergravel
I Salmonid waters		
A. Embryo and larval stages		
No production impairment	11	8
Slight production impairment	9	6
Moderate production impairment	8	5
Severe production impairment	7	4
Limit to avoid acute mortality	6	3
B. Other life stages		
No production impairment	8	
Slight production impairment	6	
Moderate production impairment	5	
Severe production impairment	4	
Limit to avoid acute mortality	3	
II. Non-Salmonid waters		
A. Early Life stages		
No production impairment	6.5	
Slight production impairment	5.5	
Moderate production impairment	5	
Severe production impairment	4.5	
Limit to **avoid** acute mortality	4	
B. Other life stages		
No production impairment	6	
Slight production impairment	5	
Moderate production impairment	4	
Severe production impairment	3.5	
Limit to avoid acute mortality	3	
III. Invertebrates		
No production impairment	8	
Some production impairment	5	
Limit to avoid acute mortality	4	

How to Measure Dissolved Oxygen

(Follow each step precisely and take 3 measurements)

Set up your test bottles in a shady, flat area. Once you collect your samples, it is very important that you **immediately** proceed through step #6 of the instructions in the Lamotte kit . If you let your sample sit for any period of time, the amount of dissolved oxygen in the water can change, giving you inaccurate readings.

Fixing your samples:

Step 1: Rinse the DO sampling bottle with creek or river water.

Step 2: It is important not to introduce air into the sample. Face upstream in the main current where there is no whitewater. Uncap sampling bottle and plunge underwater into the vertical center of water column. Tip and fill completely.

Step 3: Tap the sides of the bottle to dislodge any air bubbles. Be sure that no air bubbles are trapped inside. Cap bottle underwater.

Step 4: If you are using a sampling arm, remove the cap at the moment just before filling the bottle. Tilt the bottle and fill the sample bottle using the water taken with the arm. Do this slowly and fill bottle to the top (by tilting bottle up). Tap sides of bottle to remove any bubbles that appear in the bottle and cap bottle.

Step 5: Put on gloves.

Step 6: Using the Winkler method with the LaMotte Dissolved Oxygen Test Kit, Code 5860, add 8 drops of **Manganous Sulfate Solution** AND

Step 7: Add 8 drops of **Alkaline Potassium Iodide Azide**; some liquid will overflow out of the bottle. Be sure to hold bottles vertically and press drops out slowly. Cap the two chemical solution bottles.

Step 9: Cap the sample bottle and mix by inverting several times. A precipitate will form.

Step 10: Set sample bottle down for a few minutes and allow the cloudy precipitate to settle below the shoulder of the bottle.

Step 11: Immediately add 8 drops **Sulfuric Acid 1:1**.

Step 12: Cap and gently invert the bottle to mix the contents until the solid precipitate and the reagent have totally dissolved. The solution will be clear yellow to orange if the sample contains dissolved oxygen.

Step 13: ***Note: At this point the sample has been "fixed" and may be stored for days or weeks. *** Triplicate samples may be run together until this point, adding each treatment to all 3 bottles consecutively. After this point, titrate the samples separately. This is also the point at which you record for time of sample collection for D.O. on your data sheet.***

Titration:

Step 1: Fill the titration tube so that the meniscus of the liquid is at the 20 mL line with the fixed sample. (See picture of meniscus on clipboard). Cap the tube with its flat lid.

Step 2: Depress plunger of the Titrator.

Step 3: Insert the Titrator into the plug in the top of the **Sodium Thiosulfate, 0.025N** titrating solution.

Step 4: Invert the bottle and slowly withdraw the plunger until the shoulder of the plunger (the end in contact with the solution) is opposite the zero mark on the scale. ***Note: If small air bubbles appear in the Titrator barrel, expel them by partially filling the barrel and pumping the titration solution back into the reagent container, or you can tap the side of the barrel to remove bubbles. Repeat until bubble disappears***.

Step 5: Turn the bottle upright and remove the Titrator. Insert the tip of the Titrator into the opening of the titration tube cap.

Step 6: Slowly depress the plunger to dispense the titrating solution. After every two drops, swirl the solution to mix in the sodium thiosulfate. Titrate until the yellow-brown color changes to a very pale yellow. Hold sample against a white sheet of paper to see color changes more accurately.

Step 7: Tap the Titrator to remove any drops of solution on the end, and then carefully remove the Titrator and cap. Do not disturb the Titrator plunger.

Step 8: Add 8 drops of **Starch Indicator Solution** into the titration tube**.** Gently swirl to mix in starch to sample solution. The sample should turn blue.

Step 9: Cap the titration tube. Insert the tip of the Titrator into the opening of the titration tube cap.

Step 10: Continue titrating one drop at a time until the blue color disappears and the solution becomes colorless. Swirl after each drop is added. It usually only takes one or two drops of sodium thiosulfate to turn the blue solution to clear. ***Note: If the plunger tip reaches the bottom line on the scale (10ppm) before the endpoint color change occurs, refill the Titrator until completely full and continue the titration. Add the value of the original amount of reagent dispensed (10ppm) to the second volume when recording the test result.***

Step 11: Record the test result where the Titrator tip (where the plunger meets the solution inside the barrel) meets the scale. Have you partners check your reading so you all agree. Record as ppm Dissolved Oxygen. Each minor division on the Titrator scale equals 0.2 ppm. When testing is complete, discard titrating solution in Titrator into waste bottle.

Step 12: **Between samples, rinse titration tube with a small amount of the next sample to be tested. This avoids leaving trace amounts of sodium thiosulfate in the titration tube which could skew subsequent sample readings.**

6. Turbidity

Turbidity is a measure of water clarity and how much the material suspended in the water decreases the passage of light through the water. Suspended materials include soil particles (clay, silt, and sand), algae, plankton, microbes, and other substances. These materials are typically in the size range of 0.004 mm (clay) to 1.0 mm (sand). Turbidity can affect the color of the water. Higher turbidity increases water temperatures because suspended particles absorb more heat. This, in turn, reduces the concentration of dissolved oxygen (DO) because warm water holds less DO than cold. Higher turbidity also reduces the amount of light penetrating the water, which reduces photosynthesis and the production of DO. Suspended materials can clog fish gills, reducing the resistance to disease in fish, lowering growth rates, and affecting egg and larval development. As particles settle, they can blanket the stream bottom, especially in slower waters, and smother fish eggs and benthic macroinvertebrates.

Sources of Turbidity

- Soil erosion
- Waste discharge
- Urban runoff
- Eroding stream banks
- Large numbers of bottom feeders (such as carp), which stir up bottom sediments
- Excessive algal growth (e.g. phytoplankton)

Why Measure for Turbidity

Turbidity can be useful as an indicator of the effects of runoff from construction, agricultural practices, logging activity, discharges, and other sources. Turbidity often increases sharply during a rainfall, especially in developed watersheds, which typically have relatively high proportions of impervious surfaces. The flow of storm water runoff from impervious surfaces rapidly increases stream velocity, which increases the erosion rates of stream banks and channels. Turbidity can also rise sharply during dry weather if earth-disturbing activities are occurring in or near a creek without erosion control practices in place.

Regular monitoring of turbidity can help detect trends that might indicate increasing erosion in developing watersheds. However, turbidity is closely related to stream flow and velocity and should be correlated with these factors. Comparisons of the change in turbidity over time, therefore, should be made at the same point at the same flow.

Turbidity is not a measurement of the amount of suspended solids present or the rate of sedimentation of a stream since it measures only the amount of light that is scattered by suspended particles. Measurement of **Total Suspended Solids (TSS)** is a more direct measure of the amount of material suspended and dissolved in water.

How to Measure Turbidity

A turbidity meter consists of a light source that illuminates a water sample and a photoelectric cell that measures the intensity of light scattered at a 90 degree angle by the particles in the sample. It measures turbidity in formazine turbidity units (FTU). Meters can measure turbidity over a wide range from 0 to 1000 FTUs. A clear mountain stream might have a turbidity of around 1 FTU, whereas a large river like the Mississippi might have a dry-weather turbidity of around 10 FTUs. These values can jump into hundred of FTUs during runoff events.

How to collect a "grab" sample for turbidity

Step 1: Label the bottle with the site number, date, time and your name or initials. Use waterproof pen, if possible.

Step 2: Remove the cap from the bottle just before sampling. Avoid touching the inside of the bottle or the cap. In high flows, use a sampling pole. Rinse the sampling bottle on the pole 3 times prior to decanting water into sample bottle

Step 3: It is best to collect the sample while standing on a rock. If you need to wade, try to disturb as little bottom sediment as possible. Be careful not to collect water that contains bottom sediment. Stand facing upstream. Collect the water sample in front of you (upstream).

Step 4: Hold the bottle near its base and plunge it (opening downward) below the water surface. Collect a water sample 6 to 12 inches beneath the surface or mid-way between the surface and the bottom if the stream reach is shallow.

Step 5: Turn the bottle underwater into the current and away from you in an upstream direction.

Step 6: Leave a 1" air space, so that sample can be shaken before analysis.

Step 7: Check off the test on your appropriate field data sheet. This is important because it tells the monitoring coordinator which bottle goes with which site.

Step 8: **This turbidity sample does not need to be chilled**. It will be read using the Turbidimeter after you return from monitoring.

Turbidity Meter Procedure: HACH 2100P Turbidimeter

Samples must be read within 12 hours of collection. First, shake samples and allow to sit 20 minutes before taking readings. Samples should be at room temperature when read.

Wash hands before carrying out turbidity meter readings and wear at least one glove. When handling sample cells, never touch glass with an ungloved hand, as oily fingerprints will affect readings. Try to handle sample cells by cap only. If you must hold glass, make sure you do so with a glove.

Set out a clean towel to work on. Always set sample cells down on a towel. Begin by wiping down sample cells thoroughly with one drop of silicone oil and a lint-free cloth (black cloth in kit).

You will take three samples from each grab bottle (fill sample cells) and you will take one reading from each of the three samples. Record readings on turbidity reading log sheet.

Step 1: Begin by filling a clean sample cell up to the white line on the glass with the thoroughly agitated sample. Hold the sample cell with your gloved hand when you pour. Allow sufficient time for bubbles to escape before securing the cap—**do not over tighten the cap.**

Step2: Set the sample cell down on the towel in front of the meter.

Step 3: Turn the meter on by pressing the POWER key. The meter will carry out a self-test displaying a full set of figures. After the test, the LCD will change to the measurement mode.

When the LCD displays “0.0 NTU“ the meter is ready to measure.

Step 4: Wipe the sample cell thoroughly with a lint-free tissue before inserting into the measurement cell. The sample cell must be completely free of fingerprints and other oil or dirt, particularly in the area where the light goes through (approximately the bottom 2 cm/1 inch of the sample cell).

Step 5: Place the sample cell into the instrument cell compartment and check that the white “V” mark on the cell is positioned securely in front of the bar marking on the instrument housing. The mark on the sample cell should point towards the LCD.

Step 6: Press the READ key and the LCD will display a blinking “----NTU”. The turbidity value will appear after approximately 20 seconds.

Step 7: To turn off meter, press the POWER key.

7. Fecal Bacteria

Coliform bacteria are found in the environment, in soils, degrading leaves, and other sources, and is no longer commonly used as a water quality indicator. Fecal bacteria are used as indicators of possible sewage contamination because they are commonly found in human and animal feces. *E. coli* is a species of fecal coliform bacteria that is specific to fecal material from humans and other warm-blooded animals. Enterococcus is another fecal bacteria indicator (albeit not coliform) used to monitor water quality.

Importance of Bacteria

E.coli and Enterococcus bacteria are generally not harmful by themselves, but do indicate the possible presence of pathogenic (disease-causing) bacteria, viruses, and protozoans that also live in human and animal digestive systems. Elevated levels of these bacteria can cause health problems (including ear infections, stomach upset and urinary tract infections in women), cloudy water, unpleasant odors, and an increased oxygen demand (the amount of oxygen consumed by microorganisms in breaking down waste). The EPA recommends *E. coli* and Enterococcus as the best indicators of health risk from water contact in recreational waters.

Sources of Fecal Coliform

- Wastewater treatment plants
- On site septic systems
- Domestic and wild animal manure
- Storm runoff

Acceptable Fecal Bacteria Ranges

Coliform ranges typically found in surface water are <1 to 80,000 colonies per 100 mL, while coliform ranges typically found in fecal-contaminated surface water are 1,200 to >4,000,000 colonies per 100 mL.

The “advised safe level” for *E. coli* in freshwater used for bathing is a concentration of less than 126 *E. coli* per 100 mL.

The advised safe level for Enterococcus in freshwater is 61 Enterococci per 100 ml.

How to collect a "grab" sample for Fecal Bacteria

Step 1: Label the small bacteria bottle with the site number, date, time and your name or initials. Use waterproof pen, if possible.

Step 2: **<u>Put on gloves to prevent sample contamination and for your safety.</u>**

Step 3: Remove the cap from the bottle just before sampling. Avoid touching the inside of the bottle or the cap. If you accidentally touch the inside of the bottle, consider it contaminated. Use another one or discard sample.

Step 4: ***Our sterile bottles sometimes contain a pellet of sodium thiosulfate. This is for tap water samples, not river water samples. Either leave it or remove it. Its presence is not important.***

Step 5: Wading. Try to disturb as little bottom sediment as possible. In any case, be careful not to collect water that contains bottom sediment. Stand facing upstream. Collect the water sample in front of you (upstream).

Step 6: Hold the bottle near its base and plunge it (opening downward) below the water surface. Collect a water sample 6 to 12 inches beneath the surface or mid-way between the surface and the bottom if the stream reach is shallow.

Step 7: Turn the bottle underwater into the current and away from you in an upstream direction.

Step 8: Fill to 120 mL mark. Do not fill the bottle completely so that the sample can be shaken just before analysis. Recap the bottle carefully, remembering not to touch the inside.

Step 9: Circle the "yes" opposite "Bacteria Sample Collected" on your field data sheet.

Step 10: Place samples in your cooler for transport to your watershed coordinator and the lab.

Step 11: Discard gloves.

8. Metals

Metal ions area usually found in low concentration in fresh water. Metals to be tested in the Upper Mokelumne include zinc, arsenic and mercury.

Importance of Metals

Certain concentrations of metals are required for biological processes. If metal ion concentrations area too high, they become toxic.

Arsenic:
Arsenic is an element that is naturally –occurring in parts of our watershed. Its presence in waters is exacerbated by open mines and stock piles of tailings from hard rock mines. Runoff from such activities mobilizes this carcinogen into the waters.

Importance of Arsenic:
Arsenic is toxic at high levels and may lead to cancer at lower levels.

Arsenic in water is largely the result of mineral dissolving naturally from weathered rocks and soils. Mining accelerates this process.

Mercury:
Mercury is converted to methyl mercury by bacteria found in or attached to sediment. Methyl mercury is the form of mercury most readily incorporated into biological tissues and most toxic to humans. Mercury is typically found adsorbed to sediment or accumulating in the food web.

Mercury was used extensively for gold mining. Miners used mercury to recover gold. At hydraulic mines, placer ores were broken down with water cannons and the resulting slurry was directed through sluices and drainage tunnels where gold particles combined with liquid mercury to form gold-mercury amalgam. Loss of mercury in this process resulted in highly contaminated sediments at mine sites. These sediments are leaching mercury and themselves eroding into streams. The mercury gradually makes its way downstream in particulate and dissolved form, with the rate of movement and the chemical form dependent upon physical (flow) and chemical (e.g., pH) characteristics of the water. Mercury may also enter from contaminated groundwater adjacent to the water body and may pass back and forth between the benthic sediments and the water above.

Acceptable Ranges for Metals

The Environmental Protection Agency National Recommended Water Criteria for various metals are shown below.

The Criteria Maximum Concentration (CMC) represents an estimate of the highest concentration of the material in surface water to which an aquatic community can be exposed ***briefly*** without an unacceptable effect.

The Criterion Continuous Concentration (CCC) is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed ***indefinitely*** without an unacceptable effect.

	CMC (*µ*g/L)	**CCC (*µ*g/L)**
Zinc	120	120
Arsenic*	340	150
Mercury	1.4	0.77

The Environmental Protection Agency has recently lowered the maximum contaminant level of arsenic permitted in drinking water from 50 µg/L to 10 µg/L.

How to collect a "grab" sample for Metals

Step 1: Label the Metals bottle with the site number, date, time and your name. Use waterproof pen, if possible.

Step 2: Please follow the same procedures as for Turbidity and Bacteria samples. Remember to face upstream so as to not contaminate your sample. Leave a 1" space at the top of the bottle and keep it ***chilled*** until you return to you monitoring rendezvous site.

9. Nutrients (Total Nitrogen and Orthophosphate)

Nitrogen is a nutrient that is found in several different forms in terrestrial and aquatic ecosystems and is needed by all living plants and animals to build protein. Nitrogen is most commonly found in its molecular form (N_2) and makes up 79% of the air we breathe. However, this form is useless for most aquatic plant growth. Bacteria are able to use N_2 and convert it into forms of nitrogen that plants can take up through their roots and use for growth: ammonia and nitrate. Animals get their nitrate by eating aquatic plants or by eating animals that eat aquatic plants. When aquatic plants and animals die, bacteria break down large protein molecules into ammonia. Ammonia is then oxidized (combined with oxygen) by specialized bacteria to form nitrites and nitrates. Through decomposition of dead plants and animals and the excretions of living animals, nitrogen that was previously locked up is released.

Phosphate is a required macro-nutrient for green plants. It is often a limited resource, especially in fresh water systems. Orthophosphate is a form of phosphate readily taken up by plants.

Importance of Nitrates and phosphates

Nitrates and phosphates are essential plant nutrients, but in excess amounts they can cause significant water quality problems. When naturally-occurring levels become elevated, algal blooms can occur which may lead to oxygen depletion and to fish kills.

What Affects Nitrate and Phosphate Levels of Water

Possible sources of human activities include wastewater treatment plant discharges, runoff from fertilized lawns and cropland, failing on-site septic systems, runoff from animal manure storage areas, and industrial discharges that contain corrosion inhibitors. Pesticides commonly contain various orthophosphates, but elevated levels of orthophosphates can also be caused by lake turnover events

Nitrates from land sources end up in rivers and streams more quickly than other nutrients like phosphorus. This is because they dissolve in water more readily than phosphates, which have an attraction for soil particles. As a result, nitrates serve as a better indicator of the possibility of a source of sewage or manure pollution during dry weather.

Water that is polluted with nitrogen-rich organic matter might show low nitrate levels. Decomposition of the organic matter lowers the dissolved oxygen

level, which in turn slows the rate at which ammonia is oxidized to nitrite and then to nitrate. If unusual levels of total nitrogen are encountered, it might be necessary to also monitor for nitrites or ammonia, which are considerably more toxic to aquatic life than nitrate.

Acceptable Nitrate and Orthophosphate Ranges

The natural level of ammonia or nitrate in surface water is typically low (less than 1 mg/L or 1,000 ppm) while in the effluent of wastewater treatment plants, it can range up to 30 mg/L (30,000 ppm).

Total Nitrogen An unusual reading for most streams is one greater than 7 ppm

Phosphate (PO_4) An unusual reading for most streams is one greater than 0.2 mg/L. If the sampling site is less than 2 miles downstream of a wastewater treatment plant discharge, or the stream is very muddy, an unusual reading would be one greater than 4.0 mg/L.

Accuracy in Data Sheets

- ✓ Verify that the site number and location on your form are correct.
- ✓ Record each triplicate reading for each test in columns titles Sample 1, Sample 2, Sample 3. Sample 4 is for an extra measurement in case of error.
- ✓ Record the average time for each test in time column when recording data. For Dissolved Oxygen, record the time the sample is "Fixed".
- ✓ Record times and circle Yes/No for all Grab Samples.
- ✓ When your recordings are entered into the database, statistics will be automatically entered (mean, std deviation, FC).
- ✓ Please record each meter's ID number (shaded column) in each row, for each test. These numbers should be the same as your Bag List and the actual meter.
- ✓ Record your name, initials of partners if present, and the date.
- ✓ *****Most Important:***** Please hand the data sheet to your partner to double check that all the information is filled in accurately before leaving the field.

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