

WATER QUALITY MONITORING

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Significant interest in “water quality monitoring” within the rangeland community reflects an awareness of nonpoint source pollution (NPS) water quality issues by ranchers and rangeland managers. This chapter familiarizes ranchers and range managers with basic monitoring methods and concepts. For most ranchers, getting in the stream and obtaining water samples may not be the best use of time and resources. Before monitoring water quality, you should have a complete record of grazing utilization, photo monitoring, changes in upstream land use, and observations of fish and other aquatic life. Your water samples can augment samples by agencies, but they need to conform to scientific design described in this chapter. Random samples will not provide complete information for decision making. Water quality monitoring may help to “keep others honest”, as the data can be used to enhance, refute, or otherwise impact their sampling and interpretations.

Unless a water quality monitoring program addresses specific objectives, a lot of money and time can be spent with little return to the investment. Potential errors must be minimized during design and recognized during data interpretation. Properly designed rangeland water quality monitoring incorporates the concepts of NPS.



Initiation of erosional adjustments in a tributary subsequent to main channel entrenchment of Long Valley Creek.

Important Concepts of Non Point Source Pollution

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Nonpoint source pollution is driven by meteorological and hydrological events on a watershed. Excess nonpoint source pollution is caused by human activity that alters natural processes. The occurrence and magnitude of nonpoint source pollution is directly linked to the hydrologic cycle. These facts lead to four basic concepts that must be considered when developing or evaluating a NPS monitoring program.

1. Because nutrient cycling and erosion are natural processes, there is some “background” level or natural nonpoint source “pollution” for each watershed. Background levels vary from watershed to watershed based upon unique climatic, hydrologic, geologic or soil and ecological factors that are almost always unknown. The potential exists for background levels to exceed water quality standards during rare storm flow events such as 10-, 25-, and 100- year storms. If water quality standards have not been adjusted to reflect natural variation among watersheds, non-compliance may be caused by large storms.
2. The watershed is the basic land unit of the hydrologic cycle and thus is the source of nonpoint pollution generation and transport. Water quality at any point along a stream reflects all pollutants from all sources in the watershed above that point (natural geological processes, grazed uplands, roads, housing developments, channel erosion, wildlife activities, campers, etc.).
3. The amount of nonpoint source pollution from rangelands depends on storm intensity. Most nonpoint source pollution will be generated and transported during high-flow storm events, which represents a short period (hours to days) of high stream flow. In general, concentrations of nonpoint source pollutants such as suspended sediment, nitrogen, phosphorus and pathogens increase as storm flow increases. However, pollutants such as Ca, Mg, and pH that are controlled by ground water discharge from springs and seeps to streams often decrease during a storm because ground water inflows are being diluted by the higher stream flows.
4. Nonpoint source pollution generation and transport are unpredictable because they are driven by rainfall and depend on individual watershed characteristics. Interacting climatic, hydrologic, geologic or soil, vegetation, and land-use factors cause a high level of natural variability in NPS generation and transport through time (duration of rainfall) and space (size of watershed).

Developing a Monitoring Program

Realistic Expectations

Many ranchers as well as technical specialists over estimate the importance and capabilities of water quality monitoring to address complex questions which are, in actuality, research hypotheses. Do not expect poorly planned and implemented monitoring to answer cause-and-effect questions (i.e., a road crossing caused increased nitrate concentrations). Without a valid experimental design and statistical principles early in the development of a monitoring plan, it is difficult to identify cause and effect. If the monitoring objective is to identify cause and effect, monitoring will certainly be more time consuming and expensive. In most cases, monitoring simply represents observation of water quality variables over time.

Even with the “best” techniques and designs, detecting changes in nonpoint source pollution is difficult. Spooner et al. (1987) evaluated the sensitivity of grab sample-based NPS monitoring programs. They determined that a 30 to 60 percent increase or decrease in the average pollutant concentration over a five year period is required to document a significant change in water quality caused by management changes.

Types of Monitoring

There are many types of monitoring, but two basic approaches are often used in water quality monitoring. Thinking through which approach you want to use can help you to develop your monitoring program.

Cause-and-effect tries to prove or disprove a cause-and-effect relationship between a specific land activity and water quality degradation. There are three basic cause-and-effect designs for documenting water quality problems or changes in water quality due to changes in land use or management (Spooner et al. 1985, USEPA 1993). These designs attempt to separate natural geologic, weather, or upstream impacts from land management impacts.

For instance, the question might be: Does fencing the riparian zone on Ranch X reduce suspended sediment concentrations in the stream? Remember that suspended sediment concentration depends on stream flow. How are the following two scenarios interpreted?



1. The stream is fenced. For the next four years rainfall is low, and, thus, stream flow and sediment concentration are below normal. Was the reduced sediment concentration due to the fence or the low rainfall?
2. The stream is fenced. The next four years rainfall is high, and stream flow and sediment concentrations are above normal. Was the fence ineffective or was the increased sediment concentration due to the high rainfalls?

Without some method to quantify the effect of natural weather and stream flow variation, there is no way to determine the effectiveness of the fencing practice on Ranch X.

The key to cause-and-effect monitoring design is adequate baseline or control information and an understanding and application of experimental design and statistical principles. If you do not understand these basic principles, you may not want to start cause-and-effect monitoring. However, it is a good idea to at least have an awareness that these methods exist.

The **before-and-after** design incorporates water quality monitoring before and after a change in management to determine if the change alters water quality. Without associated long-term

monitoring of water quality, weather, and stream flow, this method will provide little insight. Of the three, this method is the least useful for determining cause and effect.

The **above-and-below** design involves sampling water quality over time immediately above and below a potential source of nonpoint source pollution, such as monitoring immediately above and below where a road crosses a stream. The primary advantage of this design over the before-and-after design is that it allows for separation of nonpoint source pollutants contributed upstream above your ranch. This advantage can be lost if the monitoring sites do not isolate the source of interest from other inputs to the stream. Also, changes to the channel may cause changes to upstream reaches. For example, a poorly designed bridge could cause bank erosion upstream.

The **paired watersheds** design involves monitoring water quality on two or more watersheds over time. The watersheds are initially under the same management. After a sufficient pretreatment time period (several years as a minimum), one watershed is selected as a control and the others are treated. The control watershed measures the year-to-year and seasonal climatic variation. The design is the most useful of the three methods for establishing cause-and-effect relationships. It is also the most technical and expensive method. Using this design to answer a question represents water quality research.

Compliance monitoring evaluates whether water quality parameters are within (complying) set minimum or maximum chemical values. State and/or regional boards have set water quality standards based on “beneficial use categories” for each stream, river, and lake. “Beneficial use” is a term used by the EPA (Environmental Protection Agency) to describe different functions of water. Most waters support several beneficial uses. The rationale for public regulation of water quality is to protect the existing and designated beneficial uses of water (Monitoring Guidelines, EPA publication #910/9-91/001 May 1991). Although the specific designated uses vary from state to state, they generally include agricultural use, industrial use, domestic water supplies, recreational use, and the propagation of fish and wildlife. Each state determines which use(s) should be applied to the water bodies within the state. The numeric parameters for water quality are assigned to each beneficial use and then become minimum criteria for water quality. The specific water quality parameters to monitor will depend on the beneficial uses of the water.

Important Questions

There are several basic questions, which if specifically addressed will help begin the process of identifying objectives and guiding the development of a meaningful nonpoint source pollution monitoring program.

Why Monitor Water Quality

The most important step in developing a meaningful nonpoint source pollution monitoring plan is to establish clear, explicit and realistic objectives.

What questions about water quality do you need to answer?

What do you intend to do with the information you obtain from this monitoring?

How confident do you need to be in the accuracy and precision of this information?

Vague or unrealistic objectives are likely to result in monitoring that collects unnecessary or insufficient data and cannot answer pertinent management questions. Once the monitoring objectives (or why) have been established, the who, what, where, when and for how long questions can be systematically answered. The “best “ monitoring program for each watershed and monitoring objective is unique. The objectives and the watershed set the protocol. Because it is impossible to monitor everything, everywhere, all the time, experience and judgement must be used to select the appropriate type and intensity of monitoring. Your objectives will not only help you define the type of monitoring to use, but also the level and intensity of monitoring.

When to Sample

When during the day and also during the year with regard to stream flow will water quality be monitored, and what relation does the timing of sampling have to the monitoring objective?

The proper time to sample water depends on the monitoring objectives. The time of year, time of day, and flow conditions are major considerations. For certain water quality properties, such as dissolved oxygen, temperature, and bacteria/pathogen levels, the time of day water is sampled can affect the results. Temperature, dissolved oxygen, and bacteria/pathogen levels are often most critical during low flows

Suspended sediments or turbidity sampling results depend on timing and frequency of sampling in relation to the stream flow. Figure 1 illustrates the general relationship between suspended sediment concentration and stream flow during a single storm event on a headwater’s stream. Suspended sediment is the major NPS pollutant on rangelands and is used as an example. Most other nonpoint source pollutants on rangelands have a similar if not more complex relationship with flow.

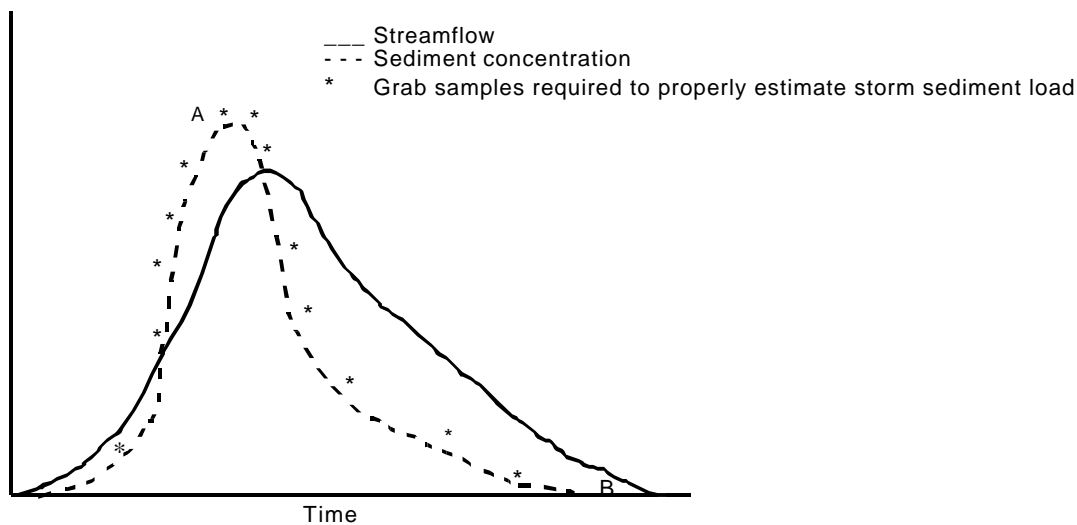


Figure 14.1. General relationship between streamflow and suspended sediment concentrations during a stormflow event.

In headwater streams, suspended sediment concentration increases rapidly with stream flow and typically peaks before stream flow does (Figure 1). Erosion is usually highest at the start of a runoff event when sediments are readily available for transport by overland flow to the stream channel. Sediment concentrations drop rapidly as the supply of readily eroded sediment is diminished. Note the timing and frequency of grab samples required to adequately estimate total storm sediment load.

The relationship in Figure 1 will repeat throughout a wet season as storms come and go and stream flow rises and falls. The amount of suspended sediment per storm will be reduced throughout the season, as the readily available sediment supply in the watershed is depleted, but the relationship of suspended sediment concentration to flow will remain the same. There will be brief periods of sediment loading (high sediment concentrations and high flow). Each storm event would have to be sampled with a timing and frequency similar to that illustrated in Figure 1 to properly estimate the total NPS loads in the stream. These events often occur at inopportune times for sampling, such as late at night or when other activities are just too pressing.

A grab sample represents nonpoint pollution transport only at the time of sampling. For proper interpretation, each water sample should be accompanied by a stream flow measurement and an indication of whether the sample represents rising, peak or falling flow.

What to monitor

What water quality variables will be monitored, and what relation do the variables have to the monitoring objective?

Table 1

Relative Sensitivity and Cost of Water Quality Monitoring Parameters			
	Sensitivity *	Equipment Costs	Analysis Costs
Temperature	2	L	L
pH	3	L	L
Conductivity	3	L	L
Dissolved Oxygen	1	L-M	L
Nitrogen	1	L	M
Phosphorous	1	L	M

* Sensitivity of monitoring grazing management activity 1= high 3=slight

Costs: L= low M= moderate

From: Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams, EPA 10/9-91-001 May 1991

If you have trouble setting objectives that help you determine what to monitor, you may want to consider the structure of compliance monitoring (Table 2). Determine the beneficial use on or downstream from your ranch. Once you have determined which beneficial uses fit your situation, you can review the EPA monitoring suggestions. These are simply suggestions. What you decide to monitor must be based on your specific monitoring objectives.

Table 2

BENEFICIAL USES				
ITEMS SUGGESTED BY EPA TO MONITOR	Warm/Cold Fishery	Domestic Water Supply	Recreation	Hydroelectric
		Temperature	Sediment	Bacteria
	Dissolved oxygen	Bacteria/Pathogen	Pathogen	Flow Rate
	Turbidity	Nitrate	Sediment	
	Channel Characteristics		Nitrogen	
	Nitrogen		Phosphorous	
	Phosphorous		Flow rate	
	Stream flow			
	BOD(biochemical oxygen demand)			

Source: (EPA Monitoring Guidelines, publication # 910/9-91/001 May 1991)

Where to Monitor

Where will water quality be monitored, and what relationship does the location have to the monitoring objective?

This variability can be introduced into the data by where you collect samples along with the stream reach (i.e. pool vs. riffle) as well as within the stream cross-section (bottom vs. top).

1. Where Along the Stream

The section of the stream sampled is very crucial and depends on the monitoring design. Consider impacts of inflows such as tributaries, springs, seeps, or irrigation return flows when selecting sampling sites. Make sure you sample where the waters are well mixed; not from a pool or in the middle of a riffle area, but somewhere in between. Never sample stagnant water.

2. Where in Stream Cross Section

Sample more than one spot in the stream cross section. Integrate water collection from the top to the bottom of the stream and across the stream. In general, collect samples in the main current away from the riverbank. Try to stay away from pool areas, riffle areas, and rock dams. In shallow stretches, carefully wade into the center current to collect the sample. If wading is not possible, tape your sample bottle to an extension pole or use a boat.

Boat. Try to maneuver the boat into the center of the main current to collect the water sample on the upstream side of the boat. Reach out from the boat as far as safely possible.

Wading. Try not to disturb the bottom sediment and do **not** collect water that contains **bottom sediment**. Face upstream and collect the water sample in front of you.

Who Will Monitor

Who will conduct the monitoring, and what is their understanding of water quality monitoring and data interpretation?

Because timing is an important part of water quality monitoring, the best person to collect water samples may be the rancher as he/she can usually respond to weather changes faster than a hired expert or agency. A sampling station can be programmed to sample on an hourly, daily, or whatever frequency you desire but such stations are expensive and can take only a limited number of samples.

How Long to Monitor

How long will the monitoring last, and how will you know when it is time to stop?

The more years you study an area the more accurately you can evaluate the situation with varying rainfall intensities and timing. The length of a study will also depend on how often you sample during the season.

How to Collect Samples and Related Information

Stream Flow

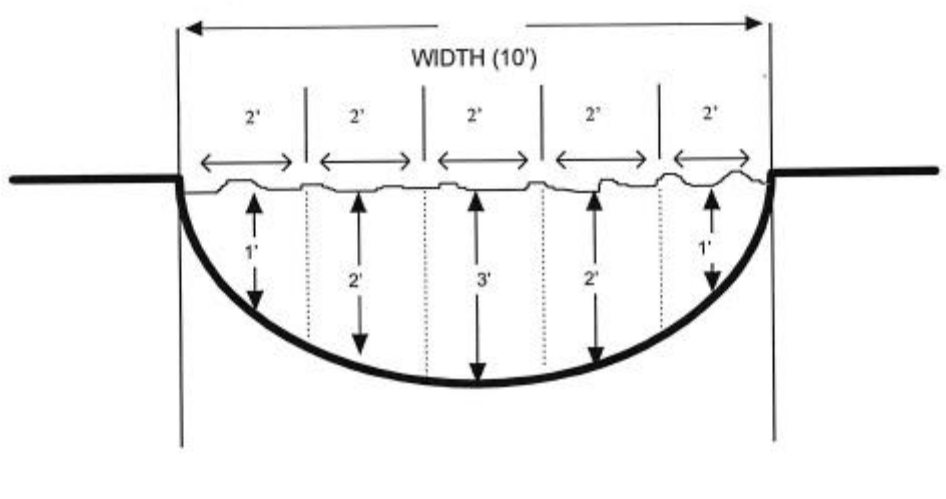
You must have the stream flow amount to determine pollutant load. The pollutant load is calculated by the pollutant concentration (from the lab report) multiplied by the stream flow amount. Some streams have a United States Geological Service (USGS) gauging station that records flow volumes. You can obtain this information from the USGS Internet web site (<http://h2o.usgs.gov/>) or from the California Department of Water Resources. The data may be miles away from your property and other streams may add or a diversion may subtract flow volume by the time the stream reaches your property. Although the flow measurements may not be exact, they will allow you to estimate flow data for your stream.

Because stream flow is simply the volume of water passing a point on a stream per unit time (ft^3/sec), you can estimate stream flow as the area of water within a cross section of the stream channel multiplied by the current velocity. Stream flow is usually expressed as cubic feet per second (ft^3/sec). One ft^3/sec equals 7.5 gallons per second.

$$\text{Stream flow (ft}^3/\text{s)} = \text{Cross-section Area (ft}^2\text{)} * \text{Average Velocity (ft/s)}$$

Figure 2

Calculating the Area for a Channel Cross-Section



$$\text{Average Depth} = \frac{1' + 2' + 3' + 2' + 1'}{5 \text{ measurements}}$$

$$\text{Area} = \text{Width} \times \text{Average Depth}$$
$$18 \text{ sq. ft} = 10' \times 1.8'$$

1. Calculating the Area of a Channel Cross Section

Figure 2 illustrates the partition of a stream channel cross section into five divisions and the estimation of area within each division. The number of divisions in a cross section depends on the characteristics of the cross section. The more irregular (rough) the cross section, the more divisions required.

2. A Simple Method to Determine Stream Velocity

Velocity is a measure of how fast something moves. Water velocity can be measured by timing how fast a floating object travels 50 feet in a stream deep enough to float the object. Wind can be a factor, so use an object that floats low in the water, such as an orange, fishing bobber, or stick. Calculate the velocity using the formula below.

The average of three to five trials will give a good velocity figure.

$$V = 50 \text{ ft.} \div X \text{ sec.}$$

Where: X is the number of seconds it takes the object to float 50 ft.

V = Velocity.

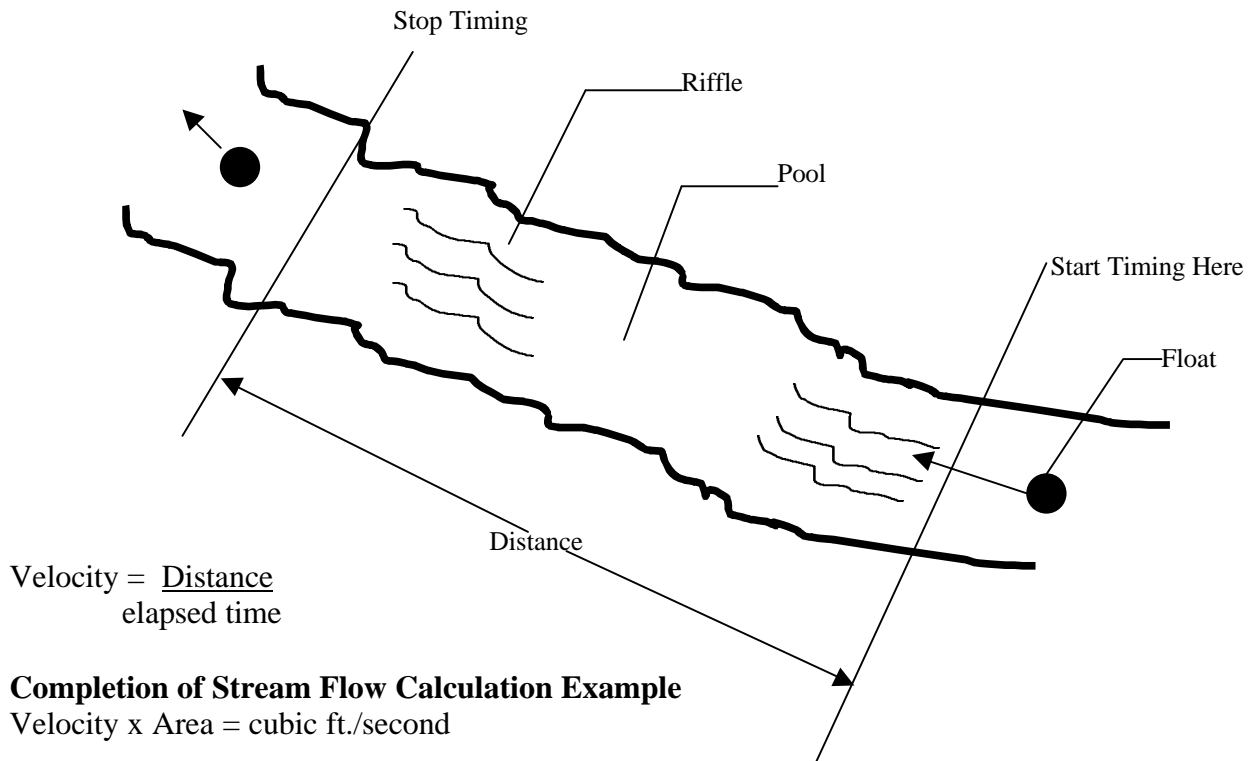
Example: If your object floats 50 feet in 25 seconds, velocity is:

$$V = 50 \text{ ft.} \div 25 \text{ sec.}$$

$$V = 2 \text{ ft./sec.}$$

Figure 3 A Simple Method to Determine Stream Velocity

The velocity can be measured by a velocity meter (pygmy) or by timing a floating object between two points.



2 ft./sec. X 1.8 square feet = 3.6 cubic ft./sec.

Calculation of load

Concentration x stream flow = Load

10 oz of sediment/cubic ft. x 3.6 cubic ft./sec. = 36 ounces of sediment/second

Collecting and Preservation of Samples

Prior to sampling, contact a lab that has a Quality Assurance Quality Control (QA/QC) state certification and request collection bottles and sampling and handling procedure information. The certification assures that the lab complies with state procedure standards. When sampling, make sure that your hands do not touch the lip of the bottle. You should also pay special care and attention to handling the bottle cap to prevent contamination. Ask the laboratory to explain the proper way to place the water sample into the bottle. Use an ice chest to keep the water samples below stream temperature during transportation. Try to get the samples to the lab within 24 hours. In general, the shorter the time between collection of a sample and its analysis, the more reliable the results. Table 5 (see the end of this chapter) shows the maximum storage times for various samples.

Water Sample Containers

- Label the bag or bottle with the site number, date, and time.

- Fill in the bag or bottle number and/or site number on the appropriate field data sheet. This is important. It is the only way the lab coordinator will know which bottle goes with which site.

1. **Whirl-pak® Bags** (If not supplied by the lab, see Table 6 for supplier.)

- A. Just prior to sampling, tear off the top of the bag along the perforation above the wire tab. Avoid touching the inside of the bag. If you accidentally touch the inside of the bag, use another one.
- B. Hold the two white pull tabs in each hand and lower the bag into the water on your upstream side with the opening facing upstream. Open the bag midway between the surface and the bottom by pulling the white pull tabs. The bag should begin to fill with water. You may need to “scoop” water into the bag by drawing it through the water upstream and away from you. Fill the bag no more than 3/4 full!
- C. Lift the bag out of the water. Pour out excess water. Pull on the wire tabs to close the bag. Continue holding the wire tabs and flip the bag over at least 4-5 times quickly to seal the bag. Do not try to squeeze the air out of the top of the bag. Fold the ends of the wire tabs together at the top of the bag, being careful not to puncture the bag. Twist them together, forming a loop.

2. **Screw-cap Bottles**

- A. Remove the cap from the bottle just prior to sampling. Avoid touching the inside of the bottle or the cap. If you accidentally touch the inside of the bottle, use another one.
- B. Hold the bottle near its base and plunge it (opening downward) below the water surface. If you are using an extension pole, remove the cap, turn the bottle upside down, and plunge it into the water facing upstream. Collect a water sample 8 to 12 inches beneath the surface or mid-way between the surface and the bottom if the water is shallow.
- C. Turn the bottle underwater into the current and away from you. In slow-moving river reaches, push the bottle underneath the surface and away from you in an upstream direction.
- D. Leave a 1-inch air space (Except for DO and BOD samples). 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.

3. **General Precautions**

Failure to follow proper field handling protocol and laboratory techniques (see Table 5) can also be a source of error. Obtain a sample that meets the requirements of the sampling program and handle it in such a way that it does not deteriorate or become contaminated before it reaches the lab. Make a record of every sample collected and identify every bottle, preferably by attaching an appropriately inscribed tag or label. Record sufficient information to provide positive sample identification at a later date. Include the name of the collector, date, hour, exact location, water temperature, and any other data that may be needed for correlation, such as weather conditions, water level, and stream flow. You should always determine stream flow even if it is only an estimate. Fix sampling points by detailed description, by maps, or with the aid of stakes, buoys, global positioning system (GPS) or landmarks in a manner that will permit their identification by other persons without reliance on memory or personal guidance.

4. Quantity of Sample

For most chemical or physical analyses, a two quart or smaller sample should be sufficient. In some cases larger samples may be required. Often more than one type of bottle will be needed. Table 4 shows the volumes required for different types of analyses. The lab you plan to send your samples to should be able to tell you how much water to collect for each analysis as well as provide you with the bottles you will need.

Specific Water Quality Variables

Water Temperature

Water temperature can be the most limiting factor for fish production, as it greatly affects the amount of dissolved oxygen available in water. Most aquatic organisms take on the temperature of the water that surrounds them. Their metabolic rates are controlled by water. Trout generally need 50° to 60°F for normal production. Temperatures above 78°F can be lethal. Temperature ranges for several species are shown in Table 3.

Table 3 Maximum weekly average temperatures for growth and short-term maximum temperatures for the following fish (°F)

Species	Growth	Maximum	Spawning*	Embryo Survival**
Bluegill	(90)	(95)	(77)	(93)
Trout	(66)	(75)	(48)	(55)
Channel catfish	(90)	(95)	(81)	(84)
Largemouth bass	(90)	(93)	(70)	(81)
Smallmouth bass	(84)	(63)		

*The optimum or mean of the range of spawning temperatures reported for the species (ERL-Duluth, 1976)
**The upper temperature for successful incubation and hatching reported for the species (ERL-Duluth, 1976)

Source USEPA 1984

There are four things to consider in temperature monitoring:

1. **Time of Day** The time of day samples are collected can greatly impact measurements. Water temperatures will be impacted by air temperature. The amount of daily stream temperature will vary with the stream size, shape, and amount of shade provided by the vegetation. Monitoring in the afternoon period if a critical maximum temperature is of concern.
2. **Frequency** Water temperature sampling frequency depends on the goals established prior to monitoring. If you are trying to determine whether the stream is providing proper fish habitat, you would want to sample when temperatures are at the highest or lowest.

3. **Location** Sampling site location can greatly influence temperature readings. For a typical stretch of stream, select sites from shaded pools and open water for water temperature sampling. Stream characteristics can greatly influence water temperature. During midsummer, shade provided by plants and close overhanging banks can keep a stream 7-12°F cooler than one exposed to direct sunlight.

Water in a stream mixes with air through exposure and turbulence at the surface, and is influenced by the air temperature. Because of larger surface area, a wide, shallow stream will heat more rapidly than a deep, narrow stream. Color and composition of a streambed also affects how rapidly stream temperature rises. A dark bedrock channel will gain and pass to the stream more heat from solar radiation than a lighter colored channel. Similarly, solid rock absorbs more heat than gravel.

The stream flow, or volume of water in a stream also influences temperature. The larger a body of water, the slower it will heat. Rivers and large streams have more constant temperatures than smaller streams.

The direction a stream flows also affects how much solar radiation it will collect. Southerly flowing streams receive more direct sunlight than streams flowing north, because of the angle of the sun's rays. Eastward or westward flowing streams may receive shading from adjacent ridges, trees and riparian vegetation.

4. **Equipment used** Water temperature thermometers come in two types. One type is a red alcohol-filled thermometer. You or your neighbor may have one in your artificial insemination equipment kit or an outside weather thermometer. This is a cheap, simple, but labor intensive method of monitoring temperature. If you are interested in less labor intensive and more frequent monitoring samples, sophisticated electronic temperature recorders can automatically take up to several thousand readings. These devices can be placed in several sites in the stream and monitor temperature throughout the season. Data can easily be down-loaded into a computer. See Table 4 at the end of the chapter for more information on available devices.

Dissolved Oxygen

Dissolved oxygen controls aquatic organism growth and development. It concerns most fish biologists. You could monitor dissolved oxygen if there is a concern about the lack of stream vegetation, possible manure inflows, or high temperatures. Dissolved oxygen (DO) is measured in parts per million of oxygen to water.

DO levels are impacted by:

- Water temperature
- Altitude
- Water agitation
- Types and numbers of aquatic plants
- Light penetration
- Amounts of dissolved or suspended solids that use oxygen, such as organic matter
- Salinity

The capacity of water to hold oxygen in solution (dissolved oxygen) is directly related to water temperature. Oxygen is more soluble at lower temperatures, thus dissolved oxygen decreases as temperature increases. At higher altitudes (elevation) the dissolved oxygen saturation point is lower than under the same conditions at lower altitudes.

Trout prefer having the dissolved oxygen near saturation. Water absorbs oxygen from the atmosphere as it contacts air at rapids, riffles or waterfalls, in a stream. Oxygen can also be added to water by plant photosynthesis.

Dissolved oxygen can be measured in the field with an electric meter with a membrane sensor or a kit that can be purchased for approximately \$44.00 from the Hach Company (see Table 6). For laboratory analysis you need to collect the water samples and transport them to the laboratory within one hour, as the dissolved oxygen concentration changes with time.

1. If you are taking samples for a laboratory, take two water samples at each site. No air should be in the bottle. Sample by pointing the bottle downstream, within 2-1/2 inches of the stream surface, at least 6 inches from the stream bank, and in water moving at the average velocity for the stream.
2. Fill the bottle gradually and cap underwater when full.
3. Measure the temperature of the water.

Biochemical Oxygen Demand

Biochemical oxygen demand (BOD) measures the amount of oxygen required to decompose and oxidize organic and certain inorganic substances in water. BOD is important because it predicts oxygen consumption in a body of water. High BOD limits aquatic organism function by lowering dissolved oxygen.

BOD can be impacted by the following variables:

- Temperature
- pH
- Microorganisms present
- Type of material in the water

Two samples are required per site. One is tested for dissolved oxygen, the second is incubated in the dark at 20°C for 5 days and then tested for the remaining dissolved oxygen to indicate BOD. Record the water temperature at the time of sampling.

Sediment and Turbidity

Often turbidity is measured because it is easier and faster than measuring suspended sediment. Turbidity refers to the amount of light that is scattered or absorbed by a fluid. Turbidity is actually an optical property of the fluid. An increase in turbidity is visually described as an increase in cloudiness. Turbidity in streams is usually caused by suspended particles of silt and clay (eroded soils), but other materials such as colored organic compounds and microorganisms can add turbidity.

High sediment levels adversely affect fish. Very high concentrations of suspended sediments can irritate and actually clog gill filaments, causing fish to suffocate. Bedload sediments, such as gravel, create beds used by fish for spawning. Increased sediment can reduce the amount of suitable spawning habitat. It fills the spaces between the rocks where the eggs can be deposited or covers deposited eggs, which reduces the amount of oxygen available by blocking water circulation, and traps fry in the gravel. Sediment caused changes in plant and insect composition can also reduce amount and types of food needed during different stages of fish development.

Turbidity can be measured by either purchasing a turbid meter (which is very expensive) or by collecting a sample and taking it to a laboratory to be analyzed. The sample needs to be kept in a cool dark place until it can be delivered to the lab. The sample should be delivered to the lab within 24 hours of collection.

Phosphorous (P)

Phosphorous may be of interest if erosion or sediment are of concern. It may also be measured if fecal contamination or applied phosphorus fertilizers are of concern. Phosphorous is usually measured as total phosphorous and orthophosphates. Orthophosphate is a chemistry-based term that refers to the phosphate molecule by itself. Total phosphorous measures orthophosphates, condensed phosphate (inorganic), and organic phosphate. Phosphorous can negatively affect water quality, as it is one of the most important limiting nutrients for algae growth. When algae grow, respire, die and decay, they lower dissolved oxygen levels. The analysis for phosphorous can be done in the field using a Hach kit or sent to a laboratory. Phosphorus concentrations vary with the time of day due to fluctuations in temperature and biological activity.

Sample containers need to be glass, acid washed plastic, or disposable Whirl-pak® bags. The EPA analysis procedures are outlined in Table 5.

Nitrogen (N)

Nitrogen may be of interest when erosion or sediment are of concern. Nitrates are usually a major concern in excess amounts, along with phosphorus, because they can increase algae's growth that will ultimately decrease dissolved oxygen. Nitrogen may also be important if fecal contamination or applied nitrogen fertilizers are of concern. Analyses that are used for nitrogen are generally nitrates (NO₃), ammonia, and total N.

Nitrogen is found in the following forms:

- Ammonium (NH (+3))
- Nitrates (NO (-3))
- Nitrates (NO (-2))

Total N includes these forms and the nitrogen bound into organic matter.

The natural levels of nitrate are typically low, less than milligrams/liter. Unless you have expensive equipment (nitrate electrodes and meters can cost \$700-\$1,200), nitrogen must be measured in a laboratory. Delayed or warm transport of samples can alter nitrogen levels.

Electrical Conductivity (Nitrogen & Phosphorus)

Electrical conductivity is a measure of the ability of water to pass an electric current. The basic unit of measurement of conductivity is micromhos/centimeter (**mmhos/cm**), or microsiemens/centimeter (*ms/cm*). Distilled water has a conductivity and a range of 0.5-3 **mmhos/cm**. Rivers generally range from 50-1500**mmhos/cm**. Streams that support fish range between 500-1500**mmhos/cm**.

Conductivity in water is affected by the presence of inorganic dissolved solids, such as salts, nitrates and phosphates. Conductivity is also affected by temperature; the warmer the water the higher the conductivity. For this reason, conductivity is reported as conductivity at 25°C. Analysis of a sample can be done either in the field or the lab by measuring conductivity with a probe and meter. The drop in voltage between two electrodes of a probe immersed in the water sample determines conductivity. Some conductivity meters can also be used for total dissolved solids and salinity. Suitable conductivity meters cost about \$350.

Bacteria/Pathogen

Contamination of streams by warm-blooded animals with microorganisms is monitored by measuring fecal coliform (FC) and fecal streptococci (FS) concentrations in the water. Fecal coliform and fecal streptococci are often referred to as “indicator bacteria”. FC and FS do not generally cause disease themselves, but they may indicate the possible presence of other disease causing bacteria and protozoans. The sources of FC and FS are from warm-blooded animals including wildlife, domestic animals, and humans. As a consequence, a sample of water that tests positive for FC and FS does not clearly identify which mammal, including humans, contaminated the water. Additional tests, which identify the species of origin are costly and usually not very precise.

You should obtain bottles from the lab and chill them immediately after sampling in the field. Allowing your water samples to reach warmer temperatures may increase the bacterial counts and misrepresent the real situation in the stream. Along with chilling, it is extremely important that you get the samples to the lab immediately. The laboratory needs to process the samples within 30 hours of sampling. Bacteria can either be measured with a simple field kit called TBC (Total Bacterial Count) or through laboratory analysis. The field kit will give you a general idea of the number of bacteria present. For a more specific analysis take samples to a laboratory.

Cryptosporidia is also an important pathogen that can be checked, but testing water for this pathogen is very costly.

It is also important to recognize natural background levels and their fluctuations by monitoring above and below the grazing area. Recording your pasture use by cattle can be combined with water quality monitoring to help clarify the impact of grazing management practices on bacteria and pathogen levels.

Definitions

Water quality reflects the composition and characteristics of water as affected by natural causes and man's activities, expressed in measurable terms and related to intended use of the water.

Water quality monitoring is the quantifiable measurement of water quality variables such as suspended sediments, temperature, nutrients and pathogens in a stream over time.

Pollutant concentration is the amount of pollutant per volume of water often expressed as milligrams per liter (mg/L). Concentration may also be reported as parts per million (PPM). For most purposes it can be assumed that mg/L=PPM.

Pollutant load is the amount (weight) of pollutant passing a point along a stream over a specific time period. Common time periods of interest are total storm load, total daily load, and annual load. Load is calculated as concentration (mg/L) per unit time multiplied by flow volume (L) for the same unit time.

Table 4 Water Quality parameters for Fish (Oregon Dept. Of Environmental Quality)

	General	Salmonids	Warm water fish
Dissolved Oxygen (Minimum)	6 mg/l	7 mg/l	6 mg/l
Conductivity (Maximum)	300 umos/cm	300 umos/cm	500 umos/cm
Phosphorus*	50 (ppb)	50 (ppb)	50 (ppb)
Nitrogen (Maximum)	300 (ppb)	300 (ppb)	300 (ppb)

* Values used by Oregon DEQ may not be universally appropriate, check with a local source.

Source - Oregon Cooperative Extension - Klamath County, 1995

References

Field Manual for Water Quality Monitoring, 8th Ed. M. Mitchell and W. Stapp, 2050 Delaware, Ave., Ann Arbor, Michigan 48103, fax (313) 761-4951.

Monitoring Guidelines. EPA publication # 910/9-91-001 (May 1991). Region 10, NPS section(WD-139), 1200 Sixth Ave., Seattle, WA. 98101

Spooner, J., R.P. Maas, S.A. Dressing, M.D. Smolen, and F.J. Humenic. 1985. Appropriate designs for documenting water quality improvements from agricultural NPS control programs. In: Perspectives on nonpoint source pollution. USEPA 440/5-85-001. P.30-34.

Spooner, J., R.P. Maas, M.D. Smolen, and C.A. Jamieson. 1987. Increasing the sensitivity of nonpoint source control monitoring programs. Symposium on Monitoring Modeling and Mediating Water Quality. American Water Resources Association.

Standard Methods for the Examination of Water and Wastewater, 18th Ed. American Public Health Association (APHA), Washington, D.C.

The Stream Scene. Oregon Dept. of Fish and Game, P.O. Box 59, Portland, OR 97207, (503) 229-5400, ext. 432

USEPA. 1993. Paired watershed design. 841-F-93-009.

Table 5

SUMMARY OF SPECIAL SAMPLING OR HANDLING REQUIREMENTS

Determination	Container	Minimum Sample Size ml	Preservation	Maximum Storage Recommended/Regulatory*	Method	Location (lab or field)
Biological Oxygen Demand	P,G	1000	Refrigerate	6h / 48hrs	Winkler meter 1st part 2nd part	either lab
Nitrate	P,G	100	Add H ₂ SO ₄ to pH <2, refrigerate	48h / 48 hrs	Cadmium reduction w/ - compactor	either
Nitrate + nitrite	P,G	200	Analyze as soon as possible or refrigerate; or freeze at - 68°F	none / 48 hrs		
Total Solids			Measure within 24 hrs.		-oven drying -meter	lab either
Oxygen, dissolved:	G, BOD bottle	300	Analyze immediately	0.5h / 1 hr	meter Winkler	either either
			Titration may be delayed after acidification	8h / 8 hrs	-	lab
Phosphate	G(A)	100	For dissolved phosphate filter immediately; refrigerate; or freeze at -50°F	48h / 48 hrs	Ascorbic acid w/ - color comparator -spectrophotometer	either lab
Temperature		-----	Measure in the stream		thermometer or recording thermistor	field
Turbidity	P,G	-----	Analyze same day; store in dark up to 24h	24h/48 hrs	meter secchi disk	either field

Refrigerate = storage at 4°C, in the dark.

P = plastic (polyethylene or equivalent)

G = glass

G(B) = glass,
borosilicate

G(S) = glass, rinsed with organic solvents

* = EPA handling guidelines

References

- Volunteer Stream Monitoring: A Methods Manual
April 1995, U.S. EPA, Office of Water, Washington D.C. 20460, Pub. # EPA 841 D 95-001, pg. 111.

- Standard Methods for the Examination of Water and Wastewater, 18th Ed.
American Public Health Association (APHA), Washington, D.C.

Table 6

This is a partial list of chemical and scientific equipment supply companies from which to purchase equipment for water quality monitoring.

Fisher Scientific

711 Forbes Ave.
Pittsburgh, PA 15219-4785
(800) 766-7000

Hach Company

P.O. Box 389
Loveland, CO 80539
(800) 525-5940

Hydrolab Corporation

P.O. Box 50116
Austin, TX 78763
(512) 255-8841

LaMotte Chemical Products

P.O. Box 329
Chestertown, MD 21620
(800) 344-3100

Millipore Corporation

397 Williams Street
Marlborough, MA 01752
(800) 225-1380

Thomas Scientific

99 High Hill Road at I-295
P.O. Box 99
Swedesboro, NJ 08085-0099

Carolina Biological Supply Company

2700 York Court
Burlington, NC 27215-3398
(800) 334-5551

VWR Scientific

P.O. Box 2643
Irving, TX 75061
(800) 527-1576

Wildlife Supply Company

301 Cass Street
Saginaw, MI 48602
(517) 799-8100

Onset Instrument*

P.O. Box 2450
Pocasset, MA 02559-3450
tel. (508) 563-9000
fax (508) 563-9477

YSI Incorporated

1725 Brannum Lane
Yellow Springs, Ohio 45387
(513) 767-7241

* Manufacturer of the temperature monitor