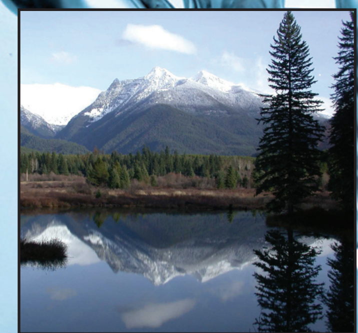
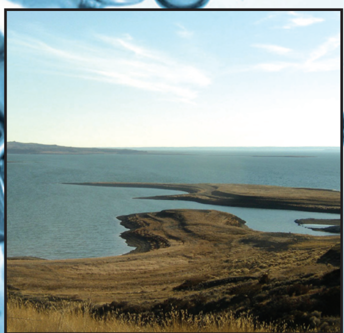
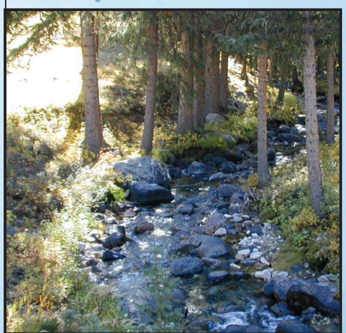
H_2O

MONTANA WATERCOURSE

Volunteer Water Monitoring

GUIDEBOOK



Produced by
Montana Watercourse of the Montana Water Center

Graphic Design
Emily Harrington, Kestrel Designs

Editor
Savannah Barnes

Advisory Committee
Janet Bender-Keigley, Montana Watercourse
Mark Bostrom, Montana Department of Environmental Quality
Tammy Crone, Gallatin County Local Water Quality District
Dave Feldman, Montana Department of Environmental Quality
Frances Graham, Montana Watercourse
Rai Hahn, Fairfield Middle School
Mark Holston, Flathead Basin Commission
Andrew Jakes, Montana Department of Environmental Quality
Tina Laidlaw, Environmental Protection Agency
Mike Philbin, Bureau of Land Management
Tom Pick, Natural Resources Conservation Service
Robert Ray, Montana Department of Environmental Quality
Alan Rollo, Sun and Teton Watershed Groups
Rosie Sada, Montana Department of Environmental Quality
Ted Sedell, Montana Watercourse
Sean Sullivan, Rithron Associates
Debbie Zarnt, Montana Watercourse

Funded by
The Montana Department of Environmental Quality and the Environmental Protection Agency from the Federal Clean Water Act 319 grant program.

To request additional copies
Montana Watercourse
(406) 994-6671
mtwatercourse@montana.edu

To obtain an electronic copy, please access our web site at www.mtwatercourse.org.

MONTANA STATE UNIVERSITY
THE MONTANA WATERCOURSE
Montana Department of Environmental Quality
MONTANA University System WATER CENTER

Table of Contents

THE MONTANA WATERCOURSE

Who are we?

The Montana Watercourse is a water education program whose mission is to foster lifelong stewardship of Montana's water by providing education, information, and resources for all water users.

The aim of the Montana Watercourse's Volunteer Water Monitoring (VWM) program is to promote knowledge and stewardship of aquatic resources by teaching local citizen volunteers the skills needed to gather accurate, non biased water quality information.

Purpose of this guidebook

The Volunteer Water Monitoring program (VWM) was launched in November 1996 with a grant from the Montana Department of Environmental Quality and the Environmental Protection Agency. Through funding resources, a guidebook was developed by Montana Watercourse. With additional support from the Department of Environmental Quality and support from an advisory committee, the guidebook has been revised in this Ninth Edition to reflect the most current water quality science and collection techniques. It has been reformatted and designed to serve both community and educational groups who are either initiating volunteer monitoring programs or expanding a well-established program.

This guidebook is designed to serve both community and educational groups who are either initiating volunteer monitoring programs or expanding a well-established program.

The Montana VWM program employs a non advocacy approach in teaching water quality and water monitoring procedures, focusing on providing citizens with tools and training so that they may make informed decisions regarding local water quality issues. Participants are encouraged to collaborate with other groups in order to form working partnerships in their communities whenever possible. The information gathered by participants is intended to increase awareness and enhance stewardship of Montana's water resources. Additionally, it is a starting point for individuals to gather baseline information about their streams and rivers.

By becoming more knowledgeable about the complex world of water quality, a constituency of educated stewards becomes an essential component in the management and protection of Montana's water resources.

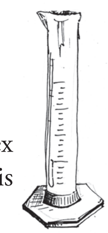
What is monitoring and why should I do it?

Do I have to be a scientist to monitor a stream?

Monitoring is the gathering of information or data on a regular basis. The data gathered can be analyzed and serve as an indication of the stream's health, used to educate the community on the impacts of human activities (positive and negative), make important watershed management decisions, and help understand the effects of these decisions. A greater understanding of the stream ecosystem and an active community are necessary elements of a healthy, productive watershed, as they often serve as building blocks for stream improvement and protection projects.

Stream monitoring activities can range from a simple visual observation to collecting complex chemical, physical, and biological attributes.

simple ←→ complex
visual observations — chemical, physical, and biological analysis



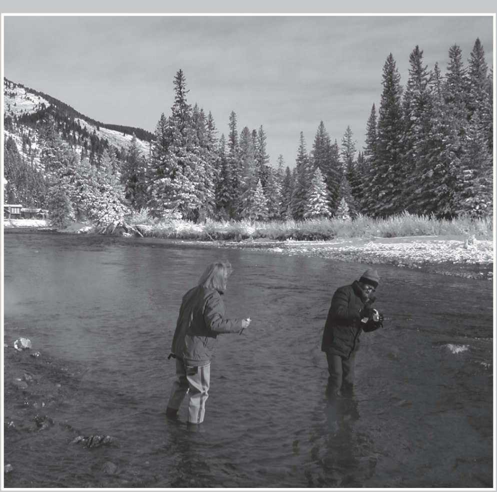
The activities your community or school group conducts will depend on the **goals of your program**. It is important to establish the goals of your monitoring program at the beginning as they will affect its structure.

Communities monitor the health of their streams for a variety of reasons, which can be general:
- Increase education and awareness
- Foster community involvement
- Collect baseline data

Goals can also be more specific:
- Collect information to guide watershed management to understand what community actions need to be taken to improve watershed health
- Collect data for regulatory purposes

BLUE WATER TASK FORCE

COMMUNITY ACTION



In 1999 concern over potential water quality threats on the Gallatin River inspired several citizens to start a volunteer water quality monitoring program. Workshops were held at Montana State University to teach interested citizens about the techniques used to collect and analyze river samples for water chemistry, aquatic insects, and periphyton. Volunteers from these workshops began collecting water quality data in May 2000 and data was collected through January 2004. With this baseline data, continued quarterly data sampling, public education and community outreach, the Blue Water Task Force aims to protect and preserve the health of the Gallatin River Watershed.

Trainings offered

Overview

The Montana Watercourse's Volunteer Monitoring Program trains educators, students, communities, watershed councils, and interested persons in developing and maintaining a monitoring program, including water quality data collection and data management. There are three levels to the Volunteer Water Monitoring Program designed to address the diverse needs of Montana's volunteer monitoring communities:

Level 1: Education and Awareness
Level 2: Continuous Record
Level 3: Problem Investigation / Certification

EDUCATION AND AWARENESS

Level 1

This level is appropriate for groups that would like **an introduction to water quality monitoring** or have had previous training and need a refresher. Community groups, educators, school groups, or individuals will benefit from level one training. Specifically, this training provides an introduction to: starting a program, designing a monitoring plan, water quality monitoring basics, data management, and program sustainability. A typical training involves some classroom time to become familiar with water quality concepts and monitoring protocol. The majority of time will be spent in the field measuring various aspects of the river: water flow, physical shape of stream, biological communities, and water chemistry using simple testing kits.

CONTINUOUS RECORD

Level 2

This level is appropriate for community and school groups with **some experience in water quality monitoring**. Groups collecting data that will be used for investigation of a water quality problem, for educating local decision makers, or for a continuous record will benefit from this training. The training is similar to level one, but the water quality monitoring methods are more advanced or may include additional parameters. Methods may use water quality probes or other advanced technology. At this level the group will also learn how to develop a detailed monitoring plan.

PROBLEM INVESTIGATION / CERTIFICATION

Level 3

This level is appropriate for groups that have **ample experience in water quality monitoring and want to collect data that can be submitted to federal or state agencies**. The group will coordinate closely with the Department of Environmental Quality (DEQ) to ensure that appropriate methods and parameters will be measured. Contact Montana Watercourse if you are interested in the Volunteer Monitoring Certification process.

Six steps to starting your program

If you are interested in starting a water quality monitoring program, the Montana Watercourse is available to assist in numerous ways. Following are a few suggestions to get you started:

Can I get help?

1 Read through this guidebook to gain a better understanding of what is involved in volunteer monitoring and identify which level your group would be.

2 Contact individuals and organizations in your community to find people who are interested in participating in a volunteer monitoring program. Some groups or organizations that might have an interest in monitoring:

- Conservation districts
- Watershed groups
- Civic groups
- School, Girl/Boy Scouts or 4-H
- Local government officials
- Fishing, canoeing, or kayaking clubs
- Local health officials
- University clubs
- Professionals

3 Arrange a meeting with local stakeholders, interested citizens, local officials, agency representatives, and potential volunteers to educate everyone on volunteer monitoring and give them a chance to ask questions.

4 Design a river monitoring study (further detail in Chapter 4).

5 Conduct monitoring at regular, consistent intervals.

6 Once you've got a program started, there are a few vital steps in keeping the program sustainable:

- Designate one person to serve as a leader of the program
- Have regular meetings
- Keep track of and maintain equipment
- Manage and report the data collected
- Evaluate lessons learned

Once the program is organized, these responsibilities can be delegated so that one person isn't doing everything. It is very important that volunteer monitoring programs have a designated leader to ensure that the data is being collected as planned. *The Montana Watercourse can assist leaders with keeping the program sustainable by providing training on data management, equipment care, and data collection.*

☞ The Montana Watercourse can help you with your first community meeting to explain the process of starting and improving your volunteer monitoring program. Contact us at: (406) 994-6671 or e-mail: mtwatercourse@montana.edu.

Wide world of water cycling

What is a hydrologic cycle?

The water you see in the rivers, lakes, and oceans is the same water that has always been on the earth. Water never goes away—it is just in a continuous cycle of change. The term for this cycle of change is the **hydrologic cycle** (also known as the hydrologic system). This cycle is the path water takes as it moves through its three states—vapor, liquid, and solid.

A common misconception is that water travels in a circle. Rather, water can transform and travel throughout different places on Earth and in the atmosphere. For example, the energy that the sun provides heats up the water causing it to evaporate from the surface and travel to the atmosphere. Water molecules condense into clouds and when enough air pressure builds, the water molecules may precipitate back to the earth in the form of rain, sleet, hail, or snow. Water can also accumulate in snowpacks in the mountains, infiltrate into the ground replenishing aquifers, or runoff into rivers. Finally, water is also found in living plants and animals. All of these elements working together are commonly known as the hydrologic cycle.

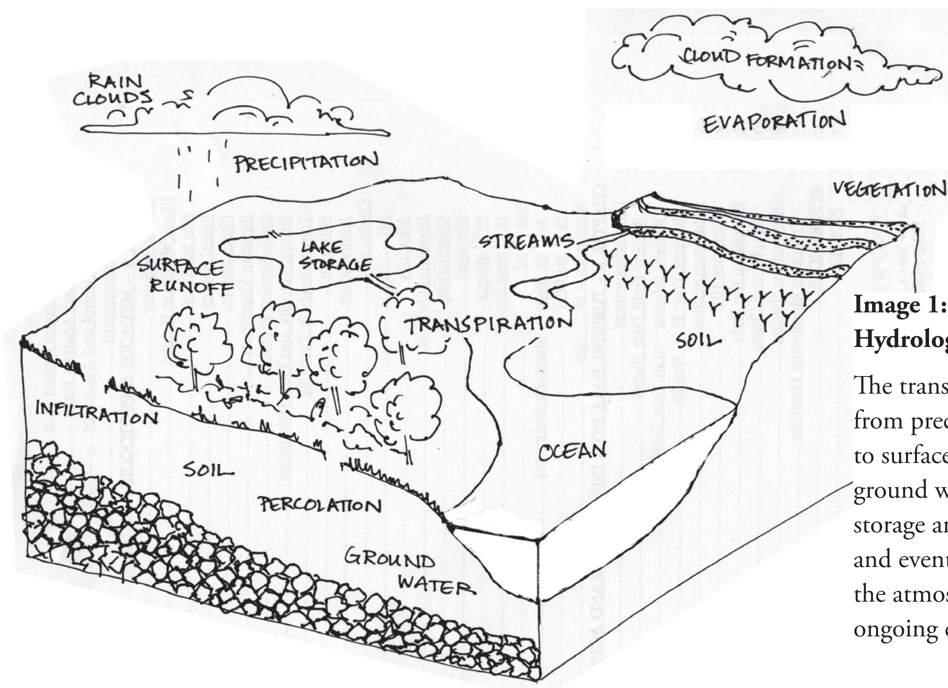
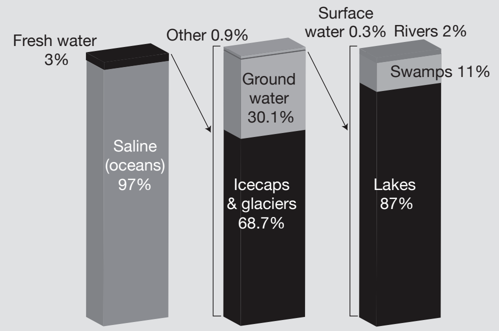


Image 1: The Hydrologic Cycle

The transfer of water from precipitation to surface water and ground water to storage and runoff and eventually back to the atmosphere is an ongoing cycle.

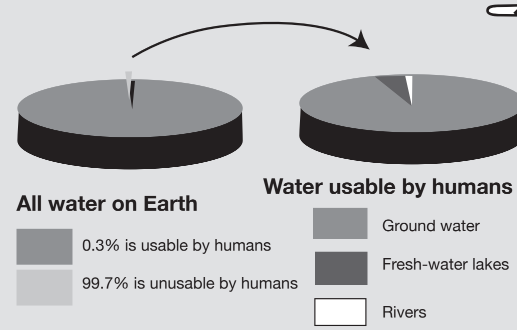
Some interesting water facts

Image 2: Distribution of Earth's Water



On Earth:

- Only 3% of our water is fresh water.
- Icecaps and glacieres store 68% of all fresh water.
- Ground water makes up almost 30% of our fresh water.



Q: How much of the human body is water?

A: *Two-thirds. Without it we would die in three days.*

The fuss about water

What is so special about it anyway? When you consider that our bodies are two-thirds water, without it we would die in three days, and all life on earth depends on water, the answer to this question becomes obvious.

As you probably already know, water's chemical description is H_2O. Water is comprised of two hydrogen molecules (H_2) and one oxygen molecule (O). The hydrogen molecule has a positive charge that attracts the negative charge of the oxygen molecule. This gives the water molecule some very unique properties and characteristics.

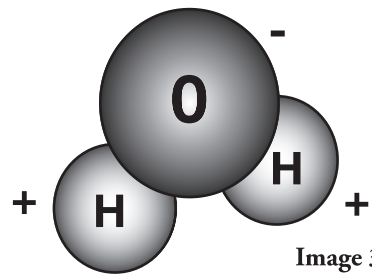


Image 3: Water Molecule

Q: What is specific heat?

A: *The specific heat of a substance is defined as the amount of heat that must be absorbed or lost for 1 g of that substance to change its temperature by 1° C.*

THE PROPERTIES OF WATER *(Chaplin, 2006)*

- Water is the "universal solvent," which means that more substances can be dissolved in water than any other solvent. This is an important characteristic. Water can transport many different substances in runoff across the ground, through infiltration into the ground, and ultimately, in the movement of ground water.
- Water is the only natural substance that is found in all three physical states: liquid, solid, and gas.
- The Celsius scale is based on the freezing (0 degrees) and boiling (100 degrees) points of water.
- Pure water has a neutral pH (7 on a scale of 1 to 14).
- Water has a high specific heat and can therefore stabilize temperature well.By warming up only a few degrees, a large body of water can absorb and store a huge amount of heat from the sun in the daytime and during summer. At night and during winter, the gradual cooling of water can warm the air. This is the reason coastal areas generally have milder climates than inland regions. Also, because organisms are made primarily of water, they are more flexible to environmental temperature changes.
- Water molecules are attracted to other water molecules (**cohesion**), as well as other materials (**adhesion**). The attraction between water molecules at the surface of a liquid is known as **surface tension**. Surface tension creates a membrane on the surface of the water that allows certain aquatic species to survive.
- Water is the second most common molecule in the universe (hydrogen is the first) and is fundamental to star formation.

WHAT IS WATER QUALITY?

How do you define water quality?

Water quality is a term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose. Although scientific measurements are used to define water's quality, it's not as simple as saying "this water is good" or "this water is bad." After all, water that is perfectly good to wash a car with may not be good enough to serve as drinking water at a dinner party for the President *(USGS, 2006)*.

What are the sources of pollution?

The quality of water can be degraded by pollution that enters the stream from both human activities and natural causes.

SOURCES OF STREAM POLLUTION *(US EPA, 1996)*

POINT SOURCE POLLUTION

Pollution that comes from a distinct source such as:

- factories
- wastewater
- treatment plants
- illegal straight pipes from homes and businesses

NONPOINT SOURCE POLLUTION

Pollution from a broad area that can be difficult to identify:

- surface runoff
- agricultural runoff
- mine drainage
- construction site runoff
- runoff from city streets and parking lots

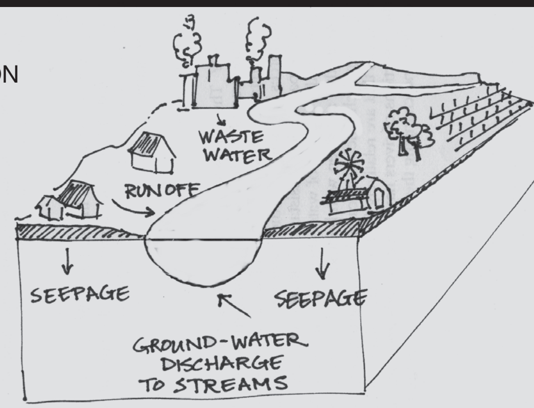


Image 4: Examples of Pollution Points

Water quality can be related to water quantity as concentrations of pollutants are influenced by stream flow. In larger volumes of faster-moving water, a pollutant will be more diluted and flushed out more quickly. In comparison, an equal amount of pollutant in a smaller volume of slower-moving water will be more concentrated.

LOOK DEEPER—GROUND WATER

Where is water stored?

Ground water is water that is contained underground in the air spaces between soil particles (sand, gravel, or clay) and in the cracks and fissures of bedrock. An **aquifer** is an underground geologic formation that contains ground water in sufficient quantities to be potentially used for drinking water supply, commercial, industrial, or agricultural purposes. The soil, sediments, or bedrock above an aquifer where the air spaces are not completely filled with water is called the **unsaturated zone**. The boundary between the unsaturated zone and the top of the aquifer is called the **water table**. Ground water is affected by rain, snow melt, rivers, streams, wetlands, and lakes. The water table boundary fluctuates with the amount of **recharge** from precipitation and snowmelt, seasonal changes, drought, or excessive pumping of ground water via wells. The response of the water table to these changes may take months or years depending on how far beneath the surface the aquifer is. Ground water is a very important component of the water cycle.

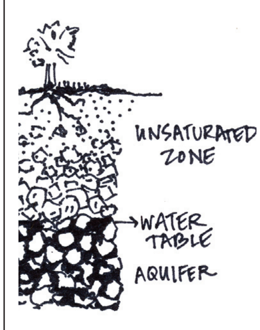


Image 5: Underground Layers

What is an aquifer?

HWHP Educator's Guide, p. 187

Going Underground

AQUIFERS

Unconfined aquifers are directly connected to the water on the ground above and are recharged directly from the infiltration of precipitation. That is, there are no geologic materials that isolate it from the ground above. These types of aquifers are vulnerable to contamination from activities on the land surface.

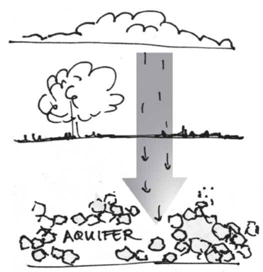
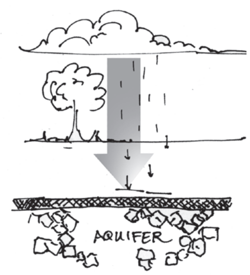


Image 6a: Unconfined Aquifer

A **confined aquifer** is covered by a layer(s) of geologic material (usually clay) that impedes the movement of water into the aquifer from above. Confined aquifers are not directly recharged by infiltration from the above land surface—they must be connected to an unconfined aquifer for recharge to occur. Confined aquifers are somewhat isolated from contaminants from overlying unconfined aquifers; however, if they do become contaminated it can be extremely difficult and costly to restore.



6b: Confined Aquifer

Q: Where does the water in our streams and rivers come from in mid-summer after the mountain snowpack is gone?

A: *This is ground water! Ground water provides the baseflow for our rivers. This is why snowpack in the mountains is crucial to the flows of our rivers in the summer.*

GROUND WATER AND SURFACE WATER INTERACTION

Ground water can be (and often is) connected to surface water. Some ground water may be recharged by leakage through rivers, streams, wetlands, and lakes. When a river or stream loses water to the ground, it is called a **losing stream**. Conversely, if a stream or river receives water into the channel from the ground-water system, it is called a **gaining stream**. A stream or river system can have multiple reaches that are "gaining" or "losing." In Montana, spring runoff provides high flows to our rivers and streams.

Pumping ground water from a well can effect surface water levels. Some of the factors include proximity of the well to the stream, size, and depth of the well, and the volume of water being pumped, as well as length of time the well is pumped. Also, multiple wells in an area (large or small) potentially have a huge impact on a nearby water source.

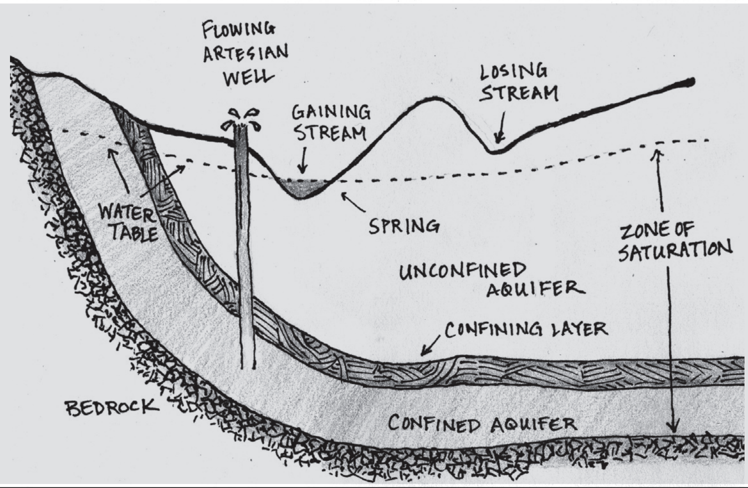
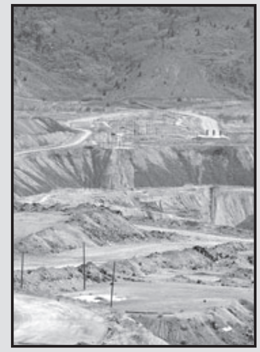


Image 7: Ground-Water Related Features and Terminology

Ground water elevation along the stream corridor can vary significantly over short distances, depending on subsurface characteristics.

WATER ISN'T JUST FOR THE AQUIFERS

Rivers and streams play an essential role in our lives: we use these waters to irrigate the crops we eat and to satisfy our domestic and industrial needs; we recreate in them, and we use them for transportation purposes. Rivers have many important uses for Montana's residents.



River genesis

Where do rivers start?

The **headwaters** (where rivers begin) are often located in the mountains or topographically higher areas. Snowpack, lakes, springs, ground water, and precipitation provide sources of water that flow down the mountain or higher area due to the forces of gravity. As the water travels, it collects and erodes a channel that follows the path of least resistance. Rivers will vary in size, shape, and slope depending on the amount of water they carry, the local geology, and the type of soils. Areas that are steep with bedrock, such as mountain streams, will have relatively straight channels that carry fast moving water, while rivers or streams in valleys (areas that are relatively flat) will have channels that are **sinuous** and dynamic. These sections of rivers are highly susceptible to flooding and changing the locations of their channels *(Dunne & Leopold, 1978)*.

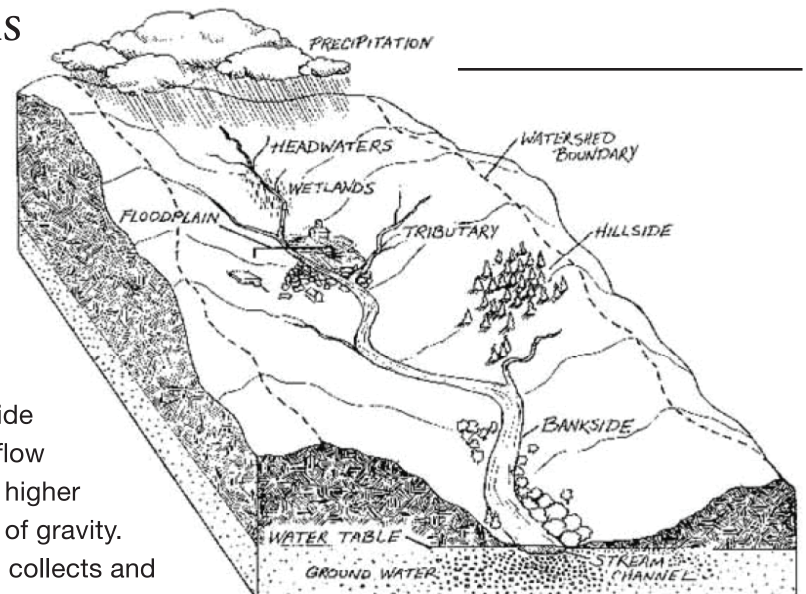


Image 8: Cross Section of a Watershed

Stream channels are formed by the flow of water and the load of sediment they carry. The amount of water and sediment moving through a watershed depends on climate and geology.

IMPACTS OF CLIMATE *(MT DEQ, 2006)*

- Amount of rain and snow, and the timing of runoff
- Rate of evaporation
- Type of vegetation
- Rate of ground-water recharge
- Rate of erosion
- How quickly bedrock weathers to soil

IMPACTS OF GEOLOGY *(MT DEQ, 2006)*

- Rate of erosion
- Potential for sedimentation
- Stream bank material
- Permeability and porosity of soils
- Aquifer depth and recharge rate
- Water chemistry and biological productivity

Montana streams

SEASONS FOR WATER

Peak flow, the greatest flow in a stream, typically occurs in western Montana during late spring and early summer when snow melts in the mountains. In eastern Montana some streams experience high flows after intense rainstorms in spring and summer.

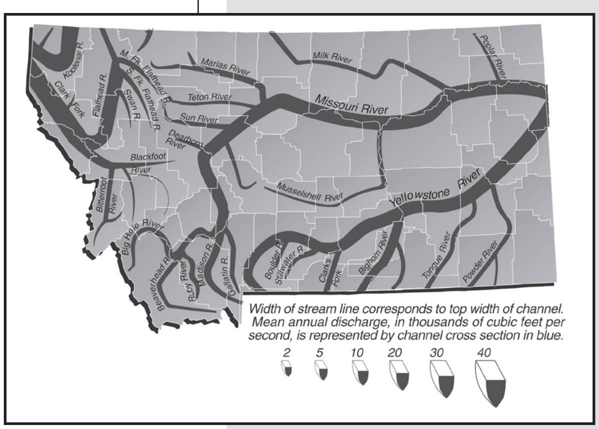
Base flow, the lowest flow in a stream, typically occurs in western Montana from late summer through the winter. Flows may go entirely below ground during dry periods—sometimes drying up or leaving stagnant pools.

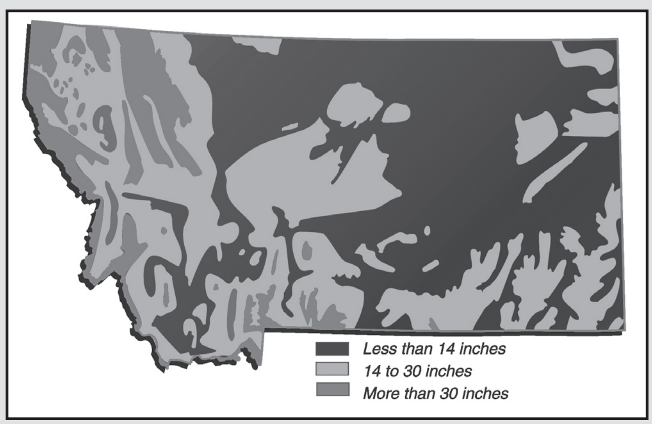
How much rain does your community get?

IT'S RAINING IN MONTANA

Precipitation in Montana falls unevenly—most falls in the western third of the state, west of the Continental Divide. Because of this, *more water flows out of the state in the Clark Fork River than in the Missouri River, which collects water from the eastern two-thirds of the state.*

Forested mountainous watersheds in northwestern Montana receive sixty to one hundred inches of precipitation per year and have more perennial streams. Grassy plains watersheds of eastern Montana, which receive eight to twelve inches of precipitation, have more intermittent and ephemeral streams.





Images 9a, b: Average Annual Runoff (L) and Average Annual Precipitation (R). ©2006 mediaworksmt.com

Which stream looks like yours?

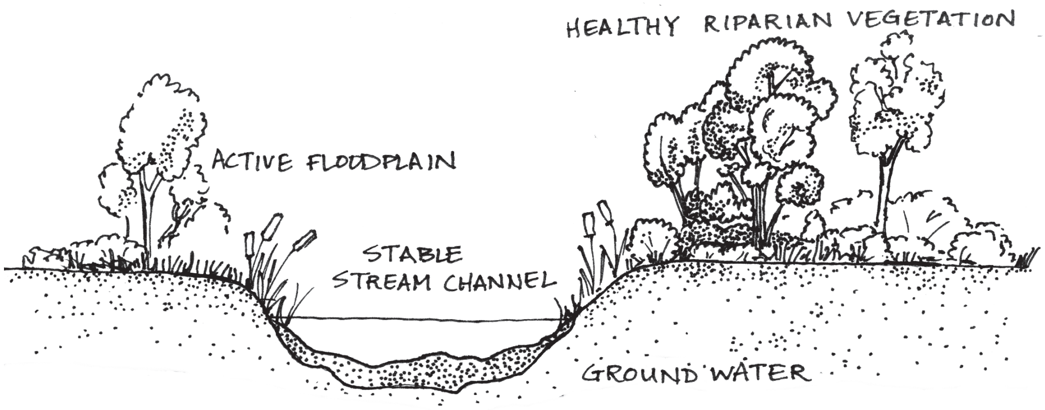
MONTANA DIVERSITY

Montana's streams are as diverse as the landscapes through which they flow. When a stream flows through a steep, narrow valley, it runs relatively straight and fast, cascading and scouring out pools.

Some streams flow slowly through wide, flat valleys. Wetlands and riparian areas form along the banks and occupy floodplains, creating rich streamside habitat. Stream banks are of finer-textured soils, hold more water, and may support a greater diversity of vegetation than high mountain streams.

Stream ecology

Image 10: Components of a Healthy Stream System



FLOODPLAINS

Flooding is a natural stream process and floodplains are an essential part of river and stream ecosystems. During spring melt or heavy, prolonged rain events, the water level will rise and sometimes flow over the riverbanks. If streamflow spills over from the channel onto the floodplain, excess flows will be dissipated because of riparian and floodplain vegetation, minimizing flood damage downstream. If a river is channelized or contains too much rip-rap (a loose assemblage of broken stones erected in water or on soft ground as a foundation or for erosion control), excess flows will accumulate. The energy of the flowing water will also accumulate, eroding or incising the channel. Additionally, downstream flooding will be more intensified if streamflow is prevented from accessing the floodplain upstream.

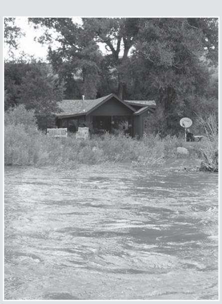
The probability of a certain size flood occurring is determined by first examining past occurrences of flooding events, and then analyzing **recurrence intervals** of historical events. Recurrence intervals are return times or past occurrence of random events. These are plotted on a graph and then extrapolated to estimate the size and probability of occurrence. Finally, the data can be used to determine future probabilities of floods *(USGS, 2005)*.

Q: What is the role of floodplains?

A:

- *Spread out and slow floodwaters, reducing their erosive force*
- *Slow water enough so it can seep into soil, recharge aquifers, and slowly return to stream*
- *Filter sediment that settles from the water, building deep, fertile soils*

COSTS AND BENEFITS OF FLOODING



Floods may be frightening events and can cause serious damage. Each year, flood damage costs the United States two billion dollars *(USGS, 2005)*. For this reason, local governments place restrictions on building homes in the floodplain. Check with your county to understand your local floodplain regulations. Although floods may cause damage to structures or roads built in the floodplain, they are essential for the ecosystem of the river and beneficial for many reasons. The floodwaters themselves replenish the aquifers that supply our drinking water. They also deposit food for wildlife, return nutrients to the soil, and replenish the water in adjacent wetlands. Additionally, allowing floodwaters to dissipate upstream will reduce flood damage downstream.

RIPARIAN AREAS

In a healthy riparian area, there is an interrelationship between vegetation, pools and riffles, and fish. Working together, these components produce a healthy environment for aquatic species and protect water quality.

Riparian vegetation:
- Provides cover and food for fish and other aquatic species
- Cools stream temperature
- Provides bank stability
- Contributes organic debris used by macroinvertebrates

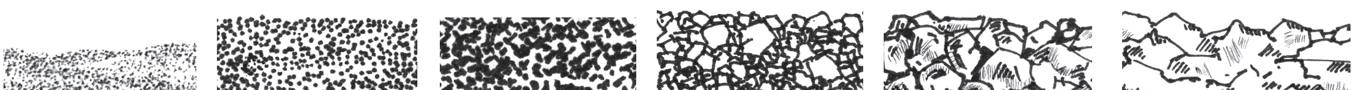
Can you match the pictures with the substrate of your stream?

STREAM CHARACTERISTICS *(MT DEQ, 2006)*

Streams are not all alike, but they do share many of the same characteristics. These characteristics include: Substrate (channel and bank materials), Sinuosity, Gradient, Floodplain, and Channel Shape. Climate and geology, which have already been discussed, also help shape the overall characteristics of a stream or river.

Substrate is the underlying layer of a stream. The most common materials that form the channel and bank include silt/clay, sand, gravel, cobble, boulders, and bedrock.

Image 11: Various Sizes of Substrate



silt/clay *sand* *gravel* *cobble* *boulders* *bedrock*

Substrate impacts:
- Amount of channel “roughness” to slow streamflow and reduce stream energy
- Sensitivity to disturbance and potential erosion
- Ability to support vegetation

Sinuosity refers to the amount of curvature in a stream channel. The increased length of a highly sinuous channel helps dissipate stream energy. Shorter and straighter channels possess more stream energy, therefore increasing erosion potential.

Gradient is the vertical distance over a set distance. The steeper the channel gradient, the greater the water velocity and potential for erosion.

Image 12 a: Common Stream Shapes

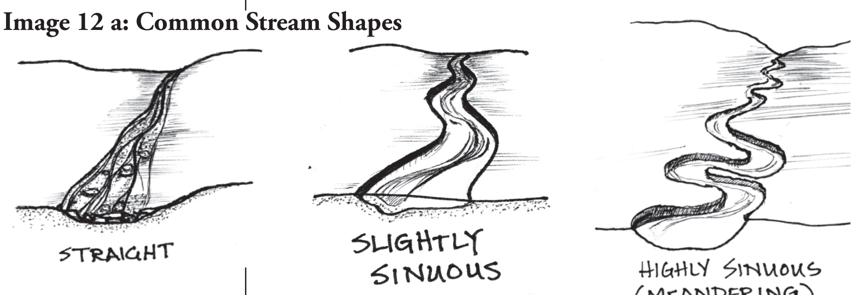
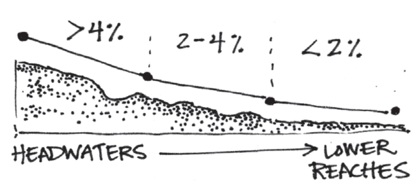
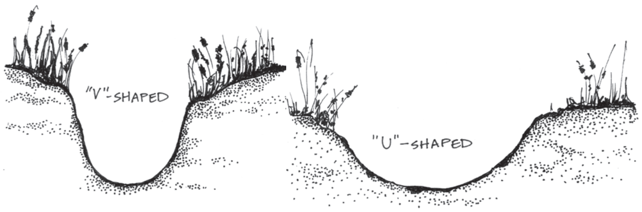


Image 12 b: Gradient from Headwaters to Lower Reaches



Channel shape is mostly influenced by: quantity of water, sediment load, type of substrate, gradient/valley slope, amount and type of vegetation, and human activities that directly alter the channel or watershed.



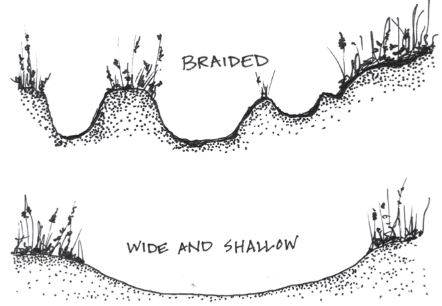


Image 13: Common Channel Shapes

Classifying Streams & Rivers

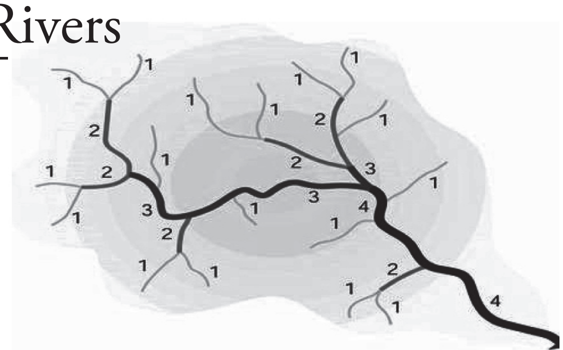


Image 14: Stream Order

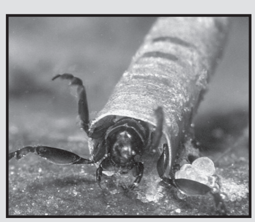
As streams flow downhill and meet other streams in the watershed, a branching network is formed. When observed from the air, this network resembles a tree; the largest river in the watershed is like the trunk, while the tributaries are like the branches. The "tipmost" branches are the headwater streams. This network of flowing water from the headwater streams to the mouth of the largest river is called the river system. A simple method of categorizing the streams in the river system has been developed: Streams that have no tributaries flowing into them are called first-order streams; streams that receive only first-order streams are called second-order streams; when two second-order streams meet, the combined flow becomes a third-order stream, and so on *(Strahler, 1957)*.

Does your stream overflow its banks every few years?

If not, the stream may be changing because of alterations in the watershed. Without a floodplain, the stream's energy is concentrated in the channel during flood flows. This increased energy may either downcut the channel or erode the banks.

THE LIVING STREAM

Macrophyte (aquatic plant)



Caddisfly larvae

Cutthroat trout

A healthy stream is a busy place. Wildlife and birds find shelter and food near and in its waters. Vegetation grows along its banks, shading the stream, slowing its flow in rainstorms, filtering pollutants before they enter the stream, and sheltering animals. Within the stream itself are fish and a myriad of insects and other tiny creatures with very particular needs. For example, stream dwellers need dissolved oxygen to breathe; rocks, overhanging tree limbs, logs, and roots for shelter; vegetation and other tiny animals to eat; and special places to breed and hatch their young. For many of these activities, they might also need water of specific velocity, depth, and temperature *(EPA, 1996)*.

River Continuum Concept

What is dynamic equilibrium?

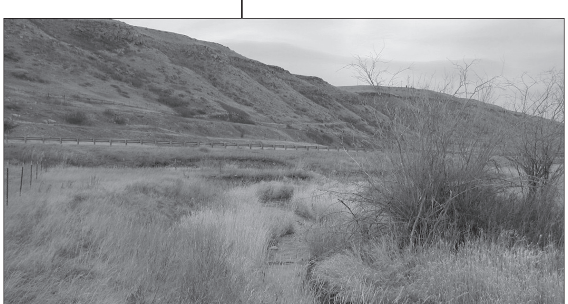
The **River Continuum Concept** (RCC) is a theory developed by Vannote and others in 1980 and is used to describe physical, chemical, and biological changes that occur on a longitudinal gradient from the headwaters to the lower reaches of a stream/river system. It is based on the concept of **dynamic equilibrium**: the stream system forms a balance among physical parameters, such as width, depth, velocity, and sediment load, and biological factors such as benthic macroinvertebrate communities. As stream size increases, the influence of the surrounding ecosystems decreases.

The river continuum concept provides predictions of the way that biological communities might change from headwater streams to larger rivers. Although there is really no such thing as a typical river system, the river continuum concept provides a general model that many rivers exemplify.

THE HEADWATERS

A headwater stream is a first- or second-order stream, generally no wider than a few feet. They have a fairly steep gradient, or vertical drop, over a set distance. They usually start as a spring or overflow from a lake. Logs and boulders create deep plunge pools and waterfalls. Boulders, cobble, and gravel form the substrate, or stream bottom. The stream valley contains a relatively straight channel that is narrow and "V"-shaped.

Oftentimes, very little sunlight reaches the stream due to close proximity of riparian vegetation, which reduces primary production from aquatic vegetation and phytoplankton. Instead, energy is created from the breakdown of organic and woody debris (leaves, twigs, etc.), also called **Coarse Particulate Organic Matter (CPOM)**, from the riparian zone *(Murdoch and Cheo, 1996)*.



Eastern Headwaters

THE MIDDLE REACH

Downstream, the middle reaches of the river system are deeper, wider, warmer, and lower in elevation. Usually a third- or fourth-order stream, the channel widens into a "U"-shape and a floodplain, a lateral flat area along its stream banks, is detectable. The stream begins to access the floodplain and meanders or curves are created.

The gradient of the stream decreases. The stream still retains logs, but they are farther apart and are usually accompanied by deeper areas of water called **pools**. In between the pools are shallower areas of faster-moving water called **riffles**. The bottom substrate is composed of mostly gravel and cobble.

The riparian zone is also wider apart and the canopy no longer reaches across the whole stream. Primary production from algae, phytoplankton, and macrophytes (aquatic plants) use photosynthesis to become part of the food base or energy source and can be reduced to **Fine Particulate Organic Matter (FPOM)**. The composition of the food base changes and hosts a slightly different community of organisms than in the headwaters *(Murdoch and Cheo, 1996)*.

THE LOWER REACH

After many more tributaries have entered and added more flow to the stream on its way to the mouth, the lower reach is often referred to as the mainstem river. The wider, deeper channel reflects an older, mature stage. The river flows in big, arcing meanders through a flat floodplain and broad valley.

The substrate of the river consists mainly of gravel, sand, and mud. Although the river is mostly unshaded, increasing **turbidity** from suspended sediments prevent sunlight from reaching very far into the water column. Fine particles replace organic debris and algae as the food source for primary consumers *(Murdoch and Cheo, 1996)*.

What is FPOM and CPOM?

Fine Particulate Organic Matter and Coarse Particulate Organic Matter

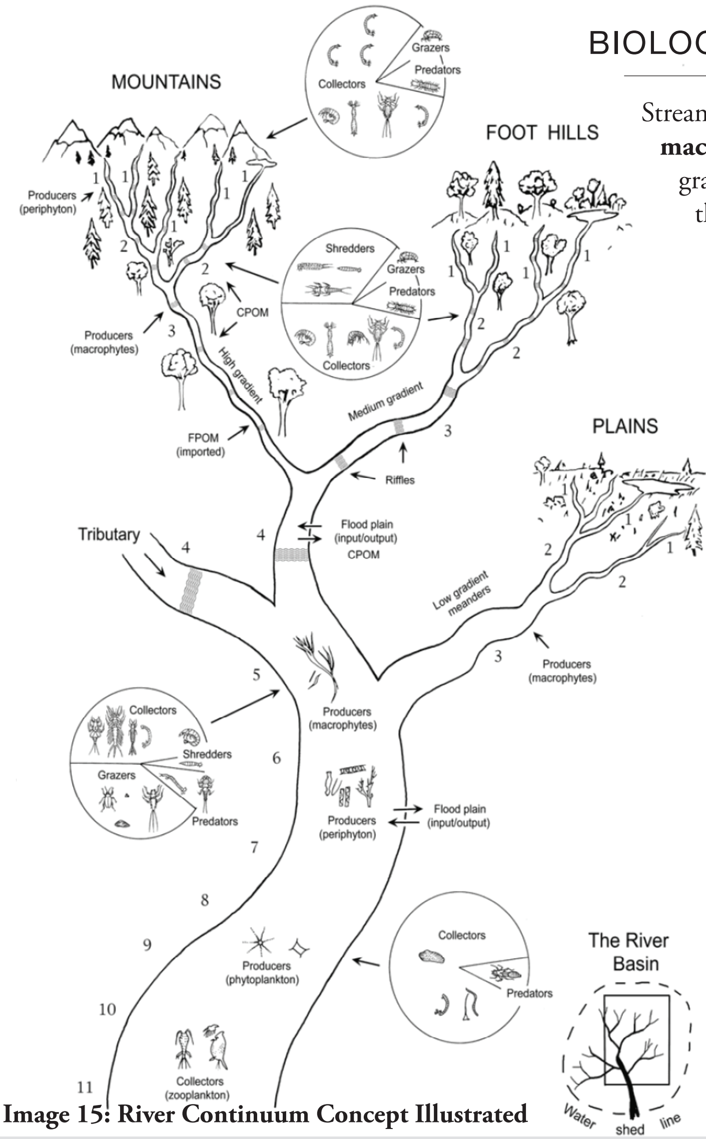


Image 15: River Continuum Concept Illustrated

BIOLOGICAL COMMUNITIES

Stream invertebrates, also called **benthic macroinvertebrates**, respond to the longitudinal gradient from the headwaters to the lower reaches of the river in community types that reflect the food availability in the different parts of the stream/river. The macroinvertebrates are classified according to Merritt and Cummins general feeding groups: shredders, collectors (gatherers and filterers), grazers (new name is scrapers), and predators. Shredders feed on CPOM, collectors filter or gather FPOM, and grazers (scrapers) mostly shear attached algae from surfaces. Predators eat grazers, collectors, and shredders.

Shredders and collectors dominate the headwaters in response to the CPOM derived from the riparian zone. Shredders are replaced by grazers in the mid-reaches (algae), while collectors are still abundant. Most invertebrates in the lower reaches are collectors due to the predominance of FPOM. The abundance of predators changes relatively little along the length of the entire stream.

Fish populations change from cool water species (trout) in the headwaters to warm water species (perch) in the lower reaches. Most headwater fishes feed on invertebrates, while in the mid to lower reaches, **piscivorous** (fish-eating) species are abundant and **planktivorous** (plankton-eating) species may be present *(Vannote et al., 1980)*.

Benthic macroinvertebrates are bottom-dwelling creatures that are visible to the naked eye and have no backbone. Certain macroinvertebrates can be used as indicator species of good water quality, including a mayfly, stonefly, and caddisfly, which are more sensitive to water quality conditions.

The Watershed

A **watershed** is an area of land where all the streamflow, ground water, and precipitation drains to a common point such as a lake, stream, river, or ocean. The watershed includes all of the land, animals, plants, and human development surrounding the common drainage. Watersheds can be as large as thousands of square miles or as small as a bowl depending on how you want to define them. The terms **drainage basin** or **catchment** are interchangeable with watershed. The boundaries of a watershed are between the highest points of land from where the water drains into one watershed or another.

The Continental Divide is the boundary that separates the United States' eastern- and western-flowing streams. The easterly rivers eventually flow to the Atlantic Ocean or the Gulf of Mexico, while the westerly rivers eventually reach the Pacific Ocean. On a big picture scale, this would be considered two watersheds: the Atlantic and the Pacific. Hundreds of smaller watersheds are then included in those two large watersheds.

Why is this concept important? The water that drains off of the land area in the watershed directly affects water quality of local streams, rivers, lakes, ground water, wetlands, estuaries, and the oceans. How the land is utilized and managed affects the water resources within the watershed. Land use practices in one area of the watershed can affect the quality of water in a different part of the watershed. Therefore, before designing your study it is important to get to know all aspects of your watershed.

How do scientists draw boundaries between watersheds?

Montana is headwaters to three major bodies of water: Hudson Bay, Gulf of Mexico and Pacific Ocean.

Which watershed(s) do you live in?

Image 16: Headwaters to a Continent

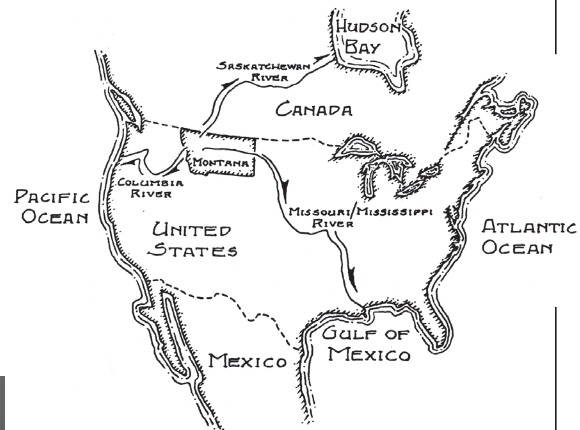


Image 17: Montana's Major Watersheds

Q: Which three major continental watersheds have their headwaters in Montana?

A: *The Missouri River (which flows to the Atlantic Ocean), the Columbia River (which flows to the Pacific Ocean), and the St. Mary River (which flows to Hudson Bay).*

Get to know your watershed

When you get to know someone for the first time you may ask where they live, where they work or go to school, or what they like to do on the weekends. When thinking on a watershed level, you can also ask a few important questions such as:

- Where are the boundaries?
- What is the spatial scale?
- What are the land use activities?
- How much rain or snow falls in a year?
- What kind of soils and geology are common to the area?
- What are the major streams and tributaries in the watershed?

Getting to know your watershed can be an excellent, hands-on educational exercise in either the classroom or on a field trip, incorporating geography and science topics.

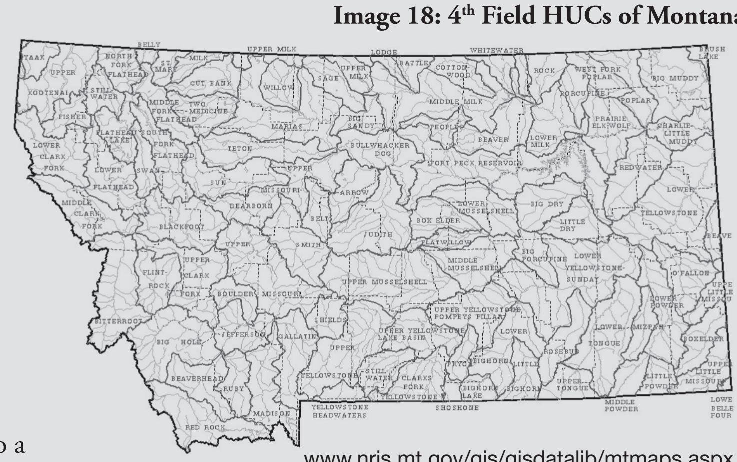
STEP 1: TOPOGRAPHICAL MAPS

The first step in getting to know your watershed is by obtaining a topographical map of the area and defining the watershed boundaries. Identify the major land and water features in the watershed. Watershed maps can be obtained from the Natural Resource Inventory System (NRIS) website http://nris.mt.gov/GIS/. The USGS and land management agencies in the area, such as the US Forest Service, Bureau of Land Management, and the National Park Service, also provide maps.

What is your watershed's address?

HUC CODE

Image 18: 4^{th} Field HUCs of Montana



www.nris.mt.gov/gis/gisdatalib/mtmaps.aspx

Your watershed has an address—well maybe not a postal address like you are familiar with, but an address nonetheless. Your watershed's address is called a HUC code, which stands for Hydrologic Unit Code. The USGS has delineated the country's basins according to a system that divides the watershed boundaries into four levels: regions, sub-regions, accounting units, and cataloging units. There are 21 regions, 222 sub-regions, 352 accounting units, and 2150 cataloging units in the country. The HUC is a string of eight numbers, two numbers representing each of the four levels. For example, the Madison River below Hebgen Lake has a HUC code of 06038500.

After you know your watershed address, you can access historical streamflow records and water quality data on the USGS website. The USGS has an easy to follow tutorial to walk you through the steps of accessing water data that has been collected on your river: www.water.usgs.gov. Also, when reporting your data (covered in chapter 6), you will need to know which HUC you are monitoring.

STEP 2: CLIMATE & WATER DATA

> Having students download and analyze stream data provides learning activities that meet both science and math learning objectives. Watershed coordinators can learn about historical and current conditions of the river and be able to educate members of their community with this information.

Watershed precipitation levels directly influence both surface water and ground water levels. Together, this information is a valuable asset in learning more about characteristics of a particular watershed. The United States Geological Survey (USGS) collects and stores this data that can be accessed by anyone. In order to find out how much precipitation your watershed receives and if there is a USGS gauging station in your area, you can log on to the USGS website (http://mt.water.usgs.gov/) where climate and streamflow data on many of Montana's Watersheds is available. Here, you will also be able to access flood frequency data, surface water data, and basin characteristics, such as area, slope, and precipitation.

> Log onto http://mt.water.usgs.gov/ for valuable climate and water data that can be accessed by anyone.

STEP 3: WATERSHED INVENTORY

(Modified from Crighton's Hoosier Riverwatch Manual, *Crighton and Hosier, 2005)*

Where can you find watershed information?

Watershed inventories provide valuable insight into what is affecting your local rivers. A land use inventory can be conducted by two means: research and field investigation.

Research

What to do? Find existing reports on your watershed. Gather maps and aerial photographs. Identify your local water resources and note any special attributes or threats that may exist. Go out in the community and ask questions. Find out what the local citizens are doing to protect their water supply. Contact the local municipalities who manage the watershed. These agencies will have resources available to answer your questions.

Local Water Quality Districts. If you live in Gallatin, Missoula, Lewis and Clark, or Butte-Silver Bow County, contact the local water quality district to find out what information and resources they have available.

> *HWHP Educator's Guide, p. 55*
> *Multiple Perspectives*

- USGS has information from stream gage stations across the state.
- Montana Department of Environmental Quality's website (www.deq.mt.gov) has information on water quality and also posts Total Maximum Daily Load (TMDL) reports.

Field Inventory

Although research is very important, one of the best ways to understand what is happening in your watershed is by getting out there and seeing for yourself what is going on. Take some time to visit special places in your watershed (respecting private property of course). Look for anything that may be affecting the river or stream you will be monitoring, such as excessive bank erosion or pollution sources.

Below is a checklist of some common land uses that influence the watershed. While this is not a complete list, it will help you get a big picture idea of what activities are occurring in your watershed.

What are potential impacts on your watershed?

HWHP Educator's Guide, p. 182
Picking Up the Pieces

- ❒ **Agriculture Crops / Fields**—are there conservation buffers?
- ❒ **Livestock / Pasture**—are grazing management Best Management Practices (BMP) in place?
- ❒ **Logging**—are there clear cuts or selective cuts?
- ❒ **Mining**—what kind of mining and is it abandoned or reclaimed?
- ❒ **Waste disposal—**are there landfills, septic systems, sewers, pet waste?
- ❒ **Construction areas**—are they using best management practices?
- ❒ **Residential / suburban**—are these impacts from storm drains, lawns, commercial businesses?
- ❒ **Urban—**are there drinking water / waste water facilities, factories?
- ❒ **Recreation areas**—are there forests, preserves, parks, campgrounds, trails, fishing areas, boating areas, public land access points?

Data Objectives: Looking Back, Looking Forward

After doing your inventory of the water information that has already been compiled on your watershed, examine this information with the intention of designing your monitoring program to build and expand upon past studies. Building on past work is an important component of scientific investigation. By considering what has already been done, your program will be more relevant and the data will more likely be useful for the community. You may find a report that will help answer some important questions that you have, as well as save you a lot of time.

SUN RIVER WATERSHED GROUP

Courtesy of Alan Rollo, Watershed Coordinator

SUCCESS STORY

Results of project actions and progress are monitored through multiple means. Monitoring at USGS gaging stations, water quality grab sample stations, photo points, station transects, as well as public opinion are used to ensure that actions are on track with established goals. Documented achievements are : 1) stabilized 20 miles of a 40 mile stream segment considered the worst nonpoint source issue in the state by reducing the sediment load by 80% (from 200,000 ton/year to 30,000); 2) restored four miles of primary fishery and spawning habitat on the Sun River and tributaries with designs prepared for an additional 30 miles; 3) implemented grazing management prescriptions on 50,000 acres of rangeland; 4) released thousands of insects for the control of noxious weeds; 5) cooperatively installed AgriMet stations to improve irrigation efficiency and reduce irrigation water consumption; 6) lined 800 feet of irrigation canals; and 7) automated numerous canal gates to improve water control and improve efficiency.

Scientific method

When water quality problems occur, the cause is not always apparent. Watersheds are large complex systems with many different types of activities occurring. Finding causes of problems or knowing there is no problem empowers communities to act proactively to restore or protect the health of their water. In order to do so, they must conduct a scientific investigation using the scientific method.

The scientific method is a process with objectives to construct an accurate, reliable, and consistent representation of the world. Since personal and cultural beliefs influence both perceptions and interpretations of the natural world, scientists and citizens alike should try to minimize these influences by using standard procedures and criteria. Repeating the same steps, in the same order, and using the same method is crucial to obtaining reliable, useful data.

There are five steps to the scientific method. Here are the steps with an example for a water quality study:

Why do we need the scientific method?

HWHP Educator's Guide, p. 42
Carts and Horses

5 Steps of the Scientific Method

	SCIENTIFIC METHOD STEP	EXAMPLE
1	**Observe and describe water quality.**	*There are large mats of algae floating in the river.*
2	**Formulate a hypothesis to explain the observation.**	*There is excess sewage seeping into the river from the treatment plant.*
3	**Use the hypothesis to predict the results of observations.**	*On days when the sewage treatment plant is not emitting, the nutrient levels are normal, whereas on days when it is emitting, the levels are elevated.*
4	**Design experimental tests to prove or disprove predictions.**	*Monitor nutrient levels on days when sewage treatment plant is and is not emitting.*
5	**Evaluate/Analyze and re-evaluate the hypothesis.**	*Is the data conclusive and does it support the original hypothesis?*

HWHP Educator's Guide, p. 70

Water Quality Monitoring From Design to Data

Designing a monitoring program

(Adapted from US EPA Volunteer Stream Monitoring—A Methods Manual*, 1996)*

Before jumping head first into volunteer monitoring, take some time to carefully plan your study or program. In order to make your efforts worthwhile, you must answer a set of questions that will help you identify the goals of the program and the methods you will employ. This guidebook presents the basic questions which you will need to address. The time you invest in preparing for the monitoring will be well worthwhile. Don't feel like you have to do this alone—enlist help from scientific advisors, data users, volunteers, and other monitoring groups or educators to assist you with addressing the questions in the study design level.

Why?

WHY WILL YOU MONITOR?

Essentially, you need to address the goals of your program. What exactly would you like to accomplish? Different monitoring goals will require different monitoring protocols, methods, and standards. The methods and standards used for management or regulatory decisions are more rigorous than for education and awareness purposes.

The following are examples of volunteer monitoring program goals:

- Educate the community about certain water quality issues to encourage pollution prevention.
- Collect baseline data.
- Document changes in water quality over time.
- Teach the scientific method.
- Collect data to guide watershed management decisions.
- Answer specific questions about local water quality issues to improve management decisions at the community level.
- Provide state agencies with data for river protection and improvement strategies.
- Determine compliance with regulations.
- Teach science and math through hands-on, interdisciplinary means.

Take time to write out your program goals so that you and the volunteers, whether students or community members, have a document that represents everyone's understanding of why they are monitoring and who will be responsible for which aspect.

Who?

WHO WILL DO THE MONITORING?

You will need to decide who will be conducting the monitoring. Will there be students involved? What age group? How will community members come together for the project? Will both students and community members work together to monitor? The methods you use may depend on the population that is doing the sampling. Some methods are appropriate for both student and community groups, while others may not be.

WHAT WILL YOU MONITOR?

What?

Monitoring parameters fall under three categories: physical, chemical, and biological. Since it will be impossible to monitor everything, you will need to decide what water quality parameters are most important and relevant to monitor based on your background research, land use inventory, skill level of the monitors, issues or concerns, and goals of monitoring. With this in mind, the group needs to decide which parameters are most important to monitor.

> This guidebook provides a description of the key methods for evaluating the three categories of water quality monitoring parameters: physical, chemical, and biological and how to choose which ones are most appropriate to monitor.

Monitoring **physical characteristics** of the river will require the least amount of training, equipment, and time. These measurements will help you to understand basic hydrology and changes in the watershed over time. Physical measurements include stream channel profile, flow/discharge, and streambed/substrate composition.

> Volunteer or student biological monitoring is a great exercise to get participants in the stream exploring the river ecosystem and observing the effects of watershed management on the river.

Chemical measurements involve using testing kits and meters and will require some time for training and equipment maintenance. These measurements provide a snapshot of information on what is happening at a specific time and place in the river. This type of data is useful for tracking changes over time by taking direct measurements that are easily compared to past data. A caution for using chemical measurements is that pollution may only be physically present in the stream for a limited time, but will have lasting effects on the river's biological community. Examples of chemical measurements include nutrients, such as nitrogen, phosphorous, sulfur, pH, dissolved oxygen, and conductivity.

Biological monitoring involves some training in proper methods, equipment, and interpretation of biologic indices. Samples collected for management or regulatory purposes will need to be sent to a lab for analysis. The type, number, and variety of **benthic macroinvertebrates** (bottom dwelling creatures that are big enough to see with the naked eye and don't have a backbone) in a stream reflects an integration of stream conditions (water chemistry, habitat, pollution levels, streamflow volume, and velocity) that occur over the life span of the biological community. For this reason, some macroinvertebrates are actually **indicator species** of good water quality.

Q: What is an indicator species?

A: *A sensitive species that indicates an ecosystem is intact and healthy.*

CHOOSING WHICH PARAMETERS TO MONITOR

What? (More)

Step 1: Refer to your watershed inventory and list stressors and sources of pollution in your watershed.

Step 2: Identify your monitoring goals, such as the following:

a. **Education and Awareness**. Choose a variety of monitoring parameters that encompass physical, chemical, and biological aspects of rivers.

b. **Condition and trend assessment**. Choose parameters that you can reliably monitor on a long-term basis (5-10 years) and that represent different aspects of the watershed ecosystem.

c. **Impact assessment**. Choose monitoring parameters that are most sensitive to the particular sources and causes of pollution. The time frame may be short, but if you do a restoration project or need to conduct effectiveness monitoring in the future, choose indicators that you can continue to monitor throughout the assessment.

d. **Use Support Assessment**. Montana DEQ determines the criteria for Use Support Assessment. Find out which parameters you will need to monitor from DEQ.

e. **Effectiveness Assessment**. The monitoring parameters you choose for this type of assessment will depend on the nature of the restoration project or protection measures that were implemented. Select parameters that would be affected by new threats or a reduction in impacts.

Step 3: Choose which parameters you will monitor based on your goals from Step 2. Parameters include but are not limited to the following:

Work with a water monitoring professional to decide which parameters are right for your program.

Physical:
- Habitat assessment
- Cross section
- Pebble count
- Streamflow
- Turbidity
- Temperature

Chemical:
- pH
- Dissolved Oxygen
- Nitrogen
- Phosphorous

Biological:
- Macroinvertebrate inventory

Where?

WHERE WILL YOU MONITOR?

Your program goals, along with the information you have from your watershed inventory will help you determine where you should monitor. For example, if you are interested in raising awareness for the community, choose an easily accessible and public site. If you want to answer specific questions, such as concerns over the sewage treatment facility, monitor above and below the facility. If you would like to get general baseline data, choose sites that provide a representative sample of the different stream types in your watershed.

When selecting monitoring sites, ask the following questions:

- ❒ Are other groups (local, state, or federal agencies; volunteer groups; schools or colleges) already monitoring sites in this watershed? Does this selection duplicate or enhance that data?
- ❒ Can you identify the site on a map and on the ground?
- ❒ Is the site representative of all or part of the watershed?
- ❒ Is there water in the site during the times of year that monitoring will take place?
- ❒ Is there safe, convenient access to the site (including adequate parking) and a way to safely sample a flowing section of the stream? Is there year-round access?
- ❒ Can you acquire landowner permission? Do you need to?
- ❒ Is the site large enough to accommodate all the volunteers without damaging the site?
- ❒ Can you perform all the monitoring activities and tests that are planned at this site?
- ❒ Is the site far enough downstream of drains or tributaries? Is the site near tributary inflows, dams, bridges, or other structures that may affect the results?
- ❒ Have you selected enough sites for the study you want to do?

Based on the answers, you may need to eliminate some sites or select alternative locations that meet your criteria. Once you have selected the monitoring sites, you should be able to identify them by latitude and longitude on a GPS unit. This location information is necessary if your data will potentially be used in Geographical Information Systems (GIS) or in sophisticated data management systems *(EPA, 1996)*.

WHEN WILL YOU MONITOR?

When?

Design a sampling schedule. Based on the goals for monitoring, the program should address these three questions:

- What time of day is best for sampling?
- What time of year is best for sampling?
- How frequently should monitoring take place?

Take into account the number of volunteers, number of sites, time of the year, and if it is feasible to sample year-round. Some streams do not flow year-round and some flood during spring runoff; both cases would make it challenging, unsafe or not possible to monitor at that time. When designing your plan, remember to consider how long each sample will take to collect and other time constraints.

Monitoring at the same time of day and at regular intervals (e.g., at 2:00 p.m. every 30 days) helps ensure comparability of data over time.

In general, monthly chemical sampling and twice yearly biological sampling are considered adequate to identify water quality changes over time. Some groups monitor at least four times a year to obtain a representative sample during the different flow conditions. It is also wise to sample after a storm event to gage impacts from storm-water runoff. (Biological sampling should be conducted at the same time each year because natural variations in aquatic insect population and streamside vegetation occur as seasons change.)

HOW WILL YOU MONITOR?

How?

The procedures presented in this guidebook are on a basic level. Most volunteers do not have access to expensive equipment or laboratories. The procedures are designed to be carried out in the field with relatively inexpensive, easily obtainable, or homemade equipment. For example, collecting benthic macroinvertebrates requires the use of a kicknet and an ice cube tray. Measuring pH and dissolved oxygen can be done with $40.00 field testing kits instead of expensive meters.

Once you have delved into the world of stream monitoring, you may decide you are ready for a higher level of analysis. You may decide to monitor fecal bacteria, which requires the use of a laboratory incubator. Or, you may decide to analyze your stream's macroinvertebrate population in more detail and need a stereoscope in your lab.

Try not to let funding issues keep you from reaching your goals. There are ways to gain access to high tech equipment and laboratories that do not require capital investment, such as creating partnerships with schools, agencies, or universities that already have the resources you need.

Ensuring quality data collection

DEVELOP A QUALITY ASSURANCE PLAN

Volunteer monitoring groups are encouraged to develop a Quality Assurance Project Plan (QAPP) or a Sample Analysis Plan (SAP)

No matter what parameters you measure and what procedures you follow, the best way to ensure the quality of your data is to develop a quality assurance project plan (QAPP). A QAPP documents the answers to all the questions you considered in designing your stream monitoring program. It is a blueprint that lists your goals and what parameters you are monitoring. It outlines your methods, the type of equipment you are using, where and when you are collecting information, as well as who is conducting the monitoring. It also documents how you calibrate your equipment, a procedure used to ensure accuracy.

Volunteers are encouraged to construct a thorough quality assurance project plan. Having a QAPP will make it easy to train new people joining your water monitoring group. Using a systematic approach will reduce the chances of errors and increase the validity of your data. With credible information and data on hand, you will be able to influence decision makers to correct problems you discover in your stream *(US EPA, 1996)*. Visit http://www.epa.gov/owow/monitoring/volunteer/qappcovr.htm to view an abbreviated EPA QAPP outline.

SAMPLING ANALYSIS PLAN

Sampling Analysis Plans (SAPs) are planning documents describing a particular study or data collection effort to support broader program (or project) objectives. If specific information (e.g., project organization, site background, standard operating procedures, etc.) relating to the present study is included in an existing QAPP, these can be referenced or cited in the SAP. The "meat and potatoes" of the SAP are, as the title implies, the field collection methods and sample analysis. Please see Appendix G for an SAP outline.

STUDY DESIGN OUTLINE

Development of QAPPs and SAPs are required for a level 3 certification and can be a seemingly daunting task. However, all volunteer monitoring programs are encouraged to outline their project goals and develop a monitoring plan. It does not have to be very detailed, but at the very least it should serve as a project road map. Below is a list of things to consider when planning your monitoring program and can be the foundation of your plan.

Background
- What do you know about your watershed?
- What do you want to or need to know?
- What are your goals?
- What can you do?
- Who can you partner with?

Why monitor?
- What questions do you want to answer?
- What type of data and information will be produced?

Information goals
- Who will get the information gathered and for what purpose?

What will you monitor?
- Physical, chemical, biological?
- Rivers/streams, lakes/ponds, ground water, riparian/wetland?
- Stressor, exposure, response?

When will you monitor (frequency)?
- Seasonal, monthly, after a hydrological event?

How will you monitor?
- What equipment will you need?

Where will you monitor?
- Upstream/downstream, mixing zones (tributaries, storm-water outlets), watershed?

Who will do what?
- Identify who will do what within monitoring design, level of responsibility, and authority.
- Choose a leader.
- Have a plan on who makes final decisions and how they are made.

Data quality objectives, assurance, and control
- How good does the data have to be?
- Consider: Precision, accuracy, comparability, reproducibility, consistency.

Data analysis plan
- How will the data be analyzed?
- Consider statistics, graphs, tables, presentation.

Data management plan
- How does the data need to be managed to produce the information?
- Consider data entry, storage, retrieval, analysis and reporting needs.

Reporting / Information utilization
- How does the information need to be reported?
- Consider the audience and format.

Documentation
- Write down a plan to document monitoring design components.

QUALITY CONTROL AND ASSURANCE *(Adapted from International Project WET's* Healthy Water, Healthy People Testing Kit Manual*, 2002 and Crighton's* Hoosier Riverwatch Manual*, 2005)*

Do you have both quality assurance and quality control?

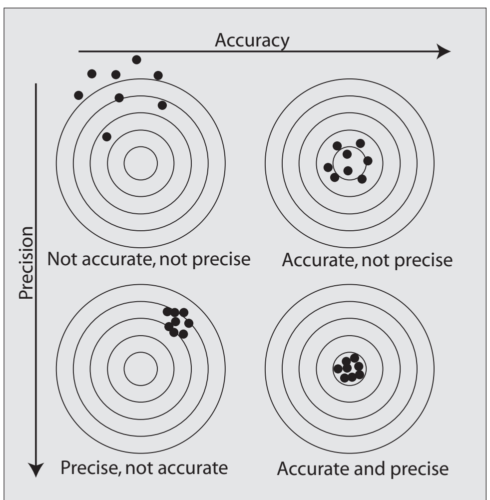
HWHP Educator's Guide, p. 49

Hitting the Mark

Quality assurance (QA) and **quality control** (QC) are often spoken as a single expression, but they are actually two distinct concepts. **Quality assurance** is defined as the procedures within a system that are implemented before monitoring is complete to ensure it meets requirements (e.g., project planning, evaluation of field crews, data management). **Quality controls** are procedures intended to ensure monitoring adheres to a set of quality criteria of requirements during data collection (e.g., method blanks, duplicates).

As an example, the selection of a particular method that is sensitive, accurate, and precise during project planning would be a QA activity. Likewise, the plan to evaluate the data after it is returned from the lab constitutes a QA activity. However, the criteria (operational controls) used to determine if the method remained in control while the results were being generated are quality controls (QC).

Image 19: Accuracy and Precision Target



The combination of QA and QC ensures that the appropriate methods for obtaining data are selected, the application of the method is evaluated, and the evaluation has a defined set of criteria to assess controls for comparison.

Precision and **bias** are the most common terms describing data's accuracy for a particular purpose. That is, data with good precision that is free from bias is typically fit for use in decision-making as originally planned. However, data that appears to have precision issues may be reflecting a natural phenomenon of the media being sampled. Further, very precise data may have a bias that would lead to decision error if taken at face value.

Taking **repeated measurements** is as important as conducting accurate tests. Water flowing past a certain point constantly changes. Taking multiple measurements and averaging these values may be necessary to represent actual "average" conditions. Averages, also called **arithmetic means,** should be used with caution. A single extreme value may skew the average and misrepresent the "average" condition.

Follow these steps to increase the quality of your data

- Collect samples as directed in the standard procedure
- Rinse sample collection bottles and tubes with sample water before collecting the sample and decontaminate with distilled water after completing the test
- Perform tests within the recommended holding time
- Execute careful use and maintenance of testing equipment
- Follow the specific directions of a testing protocol exactly as described
- Repeat measurements to check for precision and to identify any sources of error
- Minimize contamination of stock chemicals and equipment
- Store sampling and testing kits away from heat and sunlight
- Check expiration dates on chemicals and replace them before they expire
- Check to be sure the results submitted to the database are the same as those recorded on the field data sheets

Repeated measurements increase the likelihood of obtaining an extreme (**outlier**) value. However, in a large data set, extreme values are easier to recognize and can be dealt with by selecting other measures of the "average" condition, such as the **median value**, the middle value of the highest and lowest data points.

Quality control samples—standards, blanks, duplicates, and splits are the physical samples that are used to assess quality control. A **standard** is a sample of known concentration. A **blank** is a sample free from the target analysis and is used to determine if the method is contaminated (typically deionized or distilled water). By testing standards and blanks, volunteers can check for bad reagents and equipment contamination.
A **duplicate** is a repeated measure of the same sample to determine if the method is reproducible. A **split** is a sample divided in half and sent to different laboratories to determine if there are intra-laboratory differences.

The Montana Watercourse can help you. Contact us at (406) 994-6671 or e-mail mtwatercourse@montana.edu.

DATA MANAGEMENT *(US EPA, 1996)*

The volunteer program coordinator should have a clear plan for dealing with the data collected each year. Field and lab data sheets should be checked for completeness, data should be screened for outliers, and a database should be developed or adapted to store and manipulate the data. The elements of such a database should be clearly explained in order to allow users to interpret the data accurately and with confidence.

The website for the Montana Volunteer Monitoring Project is accessed on the web at http://water.montana.edu/vwm/login.php. Volunteer monitoring groups can register for access to the online database where water quality data can be uploaded or downloaded. Field data sheets are available and will assist groups in collecting data in a format that will make it easy to upload data to the database.

Program coordinators will also have to decide how they want to present data results, not only to the general public and to specific data users, but also to the volunteers themselves. Different levels of analysis might be needed for different audiences. Data management is further discussed in Chapter 6.

YELLOWSTONE RIVER WATCH

EDUCATION SUCCESS STORY

The main goal of Yellowstone River Watch is to increase students' awareness, knowledge, and appreciation of Montana's river systems through field study, data collection, and data analysis. Billings science teachers John Miller, Marvin Forquer, and Dean Smith founded the Yellowstone River Watch in 1993. Their dedication to watershed education, coupled with financial and coordinating assistance from Montana Fish, Wildlife and Parks, the Montana Watercourse, and Project WET Montana, has led Yellowstone River Watch from humble beginnings to a watershed-wide water quality education initiative. Yellowstone River Watch has been responsible for introducing hundreds of students to river systems and ecological concepts in real-world scenarios.

Your safety is most important and can never be overemphasized. If you ever feel uncomfortable about the water conditions or surroundings or if you or someone else could be put in danger, please stop sampling.

PFD: *Personal floatation devices. A "life jacket" will not save lives if not worn properly.*

Before all else—safety

Collecting water samples in a safe manner requires an awareness of the surrounding environment, knowledge of the equipment and chemicals being used, and personal responsibility. The Montana Watercourse recommends that you familiarize yourself with the methods and equipment prior to collecting samples in the field and that you dispose of the chemicals in an environmentally sound manner (some require disposal through a lab). These instructions will be included with the chemical kits.

The following are some basic **common sense safety** rules:

1. Always monitor with at least one partner. Teams of three or four people are best. Always let someone else know where you are, when you intend to return, and what to do if you don't come back at the appointed time.
2. Develop a safety plan. Find out the location and telephone number of the nearest telephone and write it down. Locate the nearest medical center and write down directions on how to get from the center to your site(s) so you can direct emergency personnel. Put this info in your first aid kit.
3. Have a first aid kit handy (see box on next page). Have each member of the sampling team complete a medical form that includes emergency contacts, insurance information, and pertinent health information, such as allergies, diabetes, epilepsy, heart conditions, etc. It is best if at least one team member has First Aid/CPR training.
4. Listen to weather reports. Do not sample if severe weather is predicted or if a storm occurs while at the site.
5. Never wade into swift or high water. Do not monitor if the stream is at flood stage. Do not attempt to cross a stream that is swift and above the knee in depth.
6. 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.
7. 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.
8. Never cross private property without permission from the landowner. Better yet, sample only at public access points, such as bridge or road crossings or public parks. Take along a card identifying you as a volunteer monitor.
9. Confirm that you are at the proper site location by checking maps, GPS coordinates, site descriptions, or directions.
10. Watch for irate dogs, farm animals, wildlife (particularly snakes), and biting insects, such as ticks, hornets, and wasps. Have a plan if you or someone in your group gets bitten or stung.
11. Watch for poison ivy, poison oak, sumac, and other types of vegetation in your area that can cause rashes and irritation.

Watch for the characteristic three-leaf clusters of poison ivy

12 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.

13 Do not monitor if the stream is posted as unsafe for body contact. If the water appears to be severely polluted, contact your program coordinator or the appropriate agency representative. Wear waders and rubber gloves in streams suspected of having significant pollution problems.

14 Do not walk on unstable stream banks. Disturbing these banks can accelerate erosion and might prove dangerous if a bank collapses. Try not to disturb streamside vegetation.

15 Try to limit walking in the stream itself and when you do, be very careful. Rocky-bottom streams can be very slippery and have deep pools; muddy-bottom streams might also prove treacherous in areas where mud, silt, or sand has accumulated in sinkholes. 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.

16 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!

FIRST AID KIT

- ❒ Telephone numbers of emergency personnel, such as the police and an ambulance service
- ❒ Several band-aids for minor cuts
- ❒ Antibacterial or alcohol wipes
- ❒ First aid cream or ointment
- ❒ Several gauze pads 3 or 4 inches square for deep wounds with excessive bleeding
- ❒ Acetaminophen for relieving pain and reducing fever
- ❒ A needle for removing splinters
- ❒ A first aid manual that outlines diagnosis and treatment procedures
- ❒ A single-edged razor blade for minor surgery, cutting tape to size, and shaving hairy spots before taping
- ❒ A 2-inch roll of gauze bandage for large cuts
- ❒ A triangular bandage for large wounds
- ❒ A large compress bandage to hold dressings in place
- ❒ A 3-inch wide elastic bandage for sprains and applying pressure to bleeding wounds
- ❒ If a participant is sensitive to bee stings, include their doctor-prescribed antihistamine

Be sure to have emergency telephone numbers and medical information with you at the field site for everyone participating in fieldwork.

Always ask if someone is allergic to latex gloves

WHEN USING CHEMICALS:

- Know your equipment, sampling instructions, and procedures before going 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, eyes, nose, and mouth. Never use your fingers to stopper a sample bottle (e.g., when you are shaking a solution).
- Wear safety goggles and disposable gloves when performing any chemical test or handling preservatives.
- 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.
- Know how to use and store chemicals. Do not expose chemicals or equipment to temperature extremes or long-term direct light.

No matter what, do NOT pour the chemicals in the stream or on ground

DISPOSAL OF CHEMICALS

See specific instructions for each chemical test. Carry a plastic sealed bottle for chemicals that cannot be poured down the drain and follow the kit's instructions on disposal.

Each water quality Testing Kit includes a "Material Safety Data Sheet" (MSDS). Read this and have it accessible in the field. In the MSDS you will find:

a. **Product identification**—Chemical name, manufacturer name, and manufacturer address.

b. **Hazardous ingredients**—Identifies the hazardous material and the chemical concentration to which you can be safely exposed.

c. **Physical / chemical characteristics**—Chemical's appearance, odor, and characteristics. It includes storage instructions and precautions.

d. **Physical hazards**—Fire and explosion hazards and fire-fighting procedures.

e. **Health hazards**—Information on the doses that are harmful to your health. Symptoms of overexposure are described.

f. **Precautionary measures**—Precautions that need to be taken while handling the chemical.

g. **First aid**—Instructions on what to do if negatively exposed to the chemical.

h. **Spill and disposal procedures**—Instructions on what to do in case of a spill and how to dispose of the chemical in an environmentally sound manner.

i. **Transportation**—Instructions for the shipper for proper transportation of the chemical.

j. **References**—Federal Regulation Acts, Registers, and other safety information pertaining to the chemical.

Methods & Protocols

Now you are ready to get your feet wet and test the waters. Chapter 5 walks you through the methods and protocols for the most common water quality parameters collected from streams and rivers. This chapter is broken up into three sections: physical, chemical, and biological assessment. Each section describes the background, methods, and tools you can use to monitor and assess the condition of your stream.

physical habitat

chemical composition

biological communities

Physical stream habitat

Data Sheet p. 84

Physical habitat can be defined as micro (within the stream) or macro (stream reach, watershed, riparian zone, floodplain) to define scale. Physical habitat includes objective and subjective measurements, rankings, and observations of physical features in the stream ecosystem that provide habitat for macroinvertebrates, microorganisms, fish, plants and other animals.

How something or someone appears physically can give an indication of their overall health. For example, when someone is sick, they may look noticeably different with pale skin, tired eyes, and a rash. The physical aspects of streams and rivers (streamflow, channel shape, size of substrate, amount and type of vegetation) can give us important clues about the health of the stream. Physical habitat integrity can influence both biological communities and chemical concentrations. Physical habitat itself can be degraded beyond a point where it will no longer support aquatic life. It is an essential monitoring component to determine the health, or changes in the health, of a stream.

Any alterations to the stream channel, substrate, sinuosity, the frequency of pools or the riparian zone can affect biological or chemical components of the river ecosystem. Activities that change the amount or timing of flow, such as channelization, dewatering, diversion return flows, addition of flows from transmountain diversions, culverts, road crossings, and bridges, can influence physical stream habitat.

Expect changes in physical characteristics *(Horn and Dates, 2005)*

Daily—it is uncommon for physical parameters, such as channel width, depth, and substrate to change in a day. However, large flood events may cause a drastic change in the physical characteristics of a channel. Streamflow, wetted perimeter, and stream velocity can change daily. During snowmelt, streamflow will fluctuate due to changes in daily temperature that affect the amount of snow that melts.

Seasonally—some physical features such as flow and discharge and riffle/pool habitat change seasonally. In spring and early summer, flows increase from a melting snowpack which can move substrate around and scour out new pools. Conversely, in late summer through winter the flow levels drop and streams can potentially go dry, leaving only isolated pools.

River Continuum—the river continuum can be described as a change in physical habitat features that can be predicated in downstream direction, barring human disturbances or changes. For example, substrate changes in dominant size, stream width and depth increase, velocity decreases, and elevation decreases.

SITE SELECTION

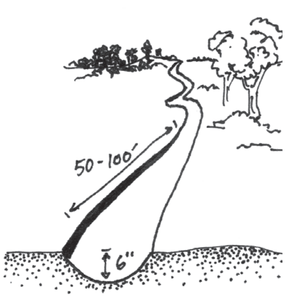


Image 20: Site Length

The selection of good measurement sites requires careful planning and evaluation. Choose a profile site that is easily accessible and safe. The stream reach should have the following characteristics:

- Preferably a 100-foot straight section (50 is fine, but longer is better)
- Relatively free from evident impacts and obstructions (roads, bridges, log jams, cattle…)
- Water depth greater than 6 inches
- Good bankfull indicators (see pg 40)

VISUAL SURVEY

Data Sheets
p. 85, 86

A visual survey characterizes the streamside, or riparian environment through which the stream or river flows, and develops observational skills.

Fill out the Site Information Data Sheet (see datasheets in Appendix) and include additional notes that help describe the stream, river, and riparian corridor. Include a sketch of each monitoring site. The site sketch is useful for assisting others in locating the site and is another visual document of change over time.

PHOTO SURVEY

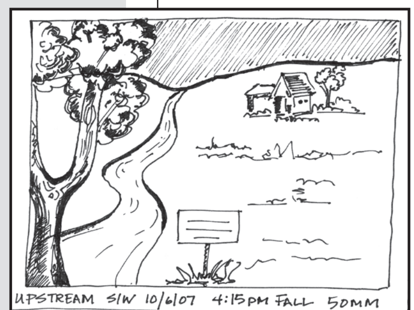


Image 21: Site Sketch

Does the above sketch have all the elements of a proper survey?

Completing a photographic record of your sampling station(s) could prove valuable in the future. A picture will be able to provide a clear representation of how the stream site has changed over time. It will also provide objective data that will be an important supplement to other water quality data.

When photographing the station, pick a specific location that can be used every time. Use an existing man-made structure or a distinctive tree to help mark your site and GPS this location. If these markers do not exist, mark the site with stakes or flags. From that location use a compass to find North, and take a North, East, South, and West, plus an upstream and downstream picture. Use the Photo Survey Data Sheet provided to document these.

A photo survey should be taken of your site every time you sample so you can document the current conditions. Include all of the following in your photo survey:

- A sign with the date, station name, and location in the picture
- Direction of photograph (upstream, downstream, facing North, East, South, and West)
- Date
- Time of day
- Time of year
- Focal length of lens (Ideally, use a 50mm lens, which is standard on most point-and-shoot cameras) for consistency

SURVEY OF RIPARIAN VEGETATION

Background: Riparian vegetation along the bank and transitioning into the upland ecosystem provides food and habitat for a variety of animals. It can also provide a migration corridor, soil stability, water quality filter, and buffer for the water body.

Methods: Describe the predominate vegetation type for each bank. You don't need to know the species, just the type—tree, grass, forbs (non-woody vegetation), or shrub/bush (woody vegetation)—and enter it on the Site Information data sheet. If you do know the species, document in the comments area. If there is no vegetation along the riparian zone, note "other" and describe in the space provided (i.e. pavement, dirt, etc.).

CROSS-SECTION PROFILE

Data Sheet p. 88

Background: The shape of a stream's cross-section profile is a reflection of current and recent flow conditions (e.g. **gradient, substrate, velocity, stream bank**). These conditions influence the streambed shape. Regular monitoring of a stream's cross-section profile allows you to document changes in stream conditions.

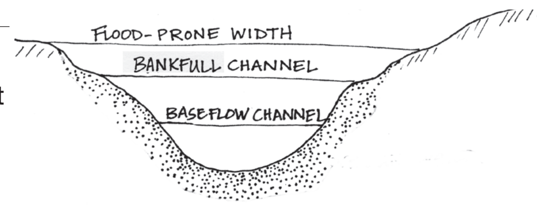
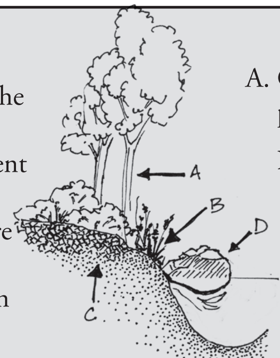


Image 22. Cross-section profile of a stream illustrating baseflow (the wetted portion of the channel, the bankfull, and the flood-prone channel)

What is bankfull level?

Bankfull level is also commonly known as 'high-water mark' or 'flood stage.' Bankfull is the level at which water completely fills the active channel and begins to overflow onto the adjacent floodplain. Identification of bankfull can be tricky, especially in high-gradient streams where no floodplain is present. In situations where bankfull level is not immediately evident, it can be distinguished by the following features:



A. Change in vegetation (the lower limit of perennial species)

B. Change in slope along the stream bank

C. Change in particle size of bank material (boundary between cobbles and silt/clay)

D. Color change, stain lines on the lower limit of lichens on streamside boulders

Image 23: Bankfull Indicators

NOTE: *You must be able to wade across the entire stream to accurately measure the discharge.*

Water that reaches over your knees becomes difficult to wade. Please consider safety first when collecting discharge measurements.

Methods: The cross-sectional area of a stream can be measured using a line level and tape measure to measure channel width and a yard stick to measure water depth.

1. At the upper reach of a straight section of the stream, stretch a length of string across the stream at bankfull level from the left to right. If possible, check with a line level.
2. Stretch the tape-measure across the same transect and secure on each bank. Record this measurement on the data sheet.
3. Start at the left bank facing upstream and, using the stadia rod or a yardstick, move along the tape measure. Stop at each one-foot interval to record the vertical distance from the streambed to the string level. Record these measurements on the data sheet as bankfull depth. When an interval has water in the channel, measure the vertical distance from the streambed to the water surface and record as water depth. It helps to have one person taking notes on the stream bank and one or two persons taking the measurements in the stream, calling out: "Bankfull 8 centimeters, Water depth 4 centimeters."
4. Be sure to record the horizontal distance to the left and right wetted edges of the channel on the data sheet (the wetted channel edge is where the water comes in contact with the bank). *Do not remove this cross-section if you plan to measure stream velocity.*

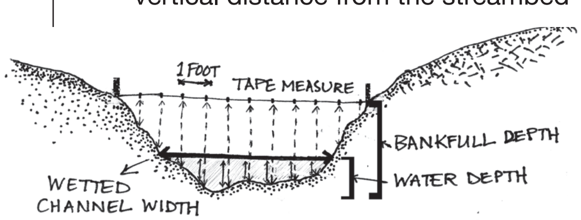


Image 24: Cross-Section Profile

STREAM FLOW (DISCHARGE)

Background: Stream flow, or discharge, is the rate at which a volume of water passes through a cross section per unit of time. In the United States, it is usually expressed in cubic feet per second (ft^3/sec) and commonly referred to as CFS. Discharge is an important component of the aquatic environment because it helps determine riparian and streambed habitats, temperature, the interaction between surface and ground water, species diversity, and the concentration of various chemical substances in water.

Data Sheet p. 89

Calculating Velocity

Methods: *Velocity* is the speed of water moving past a given point. You must determine velocity in order to calculate flow or discharge.

1. Repeat the cross-section profile for a downstream cross section (100 feet downstream).
2. Starting above the upstream cross section, have a participant hold a tennis ball just slightly above the cross-section rope. Situate the second participant downstream, at the end of the station, to catch the tennis ball as it crosses the lower cross section.

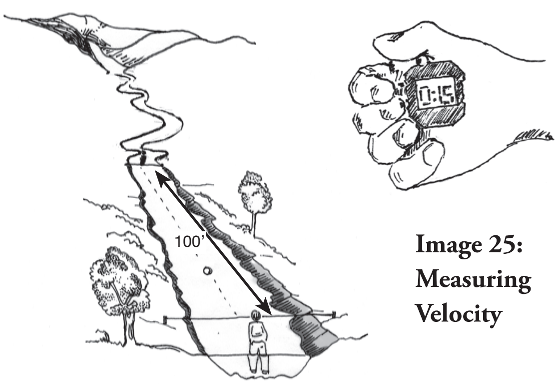


Image 25: Measuring Velocity

3. Have the upstream person gently release the ball at the surface of the water. Have another person call out when the ball crosses the line. One person records the time it takes the ball to pass from the upstream through the down-stream cross section. Capture the tennis ball and repeat this ten times. Record each trial on the data sheet.
4. Average the timed trials and record.
5. Calculate velocity by dividing the distance by the average time (feet/second). Multiply this value by the correction factor on the Stream Profile & Flow Data Sheet to get average corrected stream velocity. This correction is needed because the surface water where the tennis ball floats is actually faster than the average flow in the channel.

NOTE: *If there is not enough water to float the tennis ball, report the flow as less than 1 ft^3/sec and proceed with chemical and biological monitoring. If the tennis ball's movement is obstructed or impeded by branches, rocks, eddies, etc…do the trial over.*

Calculating Flow (Discharge)

Discharge can be calculated by measuring the average stream velocity and the area of the wetted stream cross section. Discharge is then calculated as:

Q=VA *Where:* ***Q*** *= discharge (ft3/sec),* ***V*** *= average velocity (ft/sec), and*
A *= cross-sectional area of the water (ft2)*

Using the Stream Profile & Flow data sheet, compute the cross-section area of the wetted stream. Since we measured water depth at one-foot intervals, this is simply the sum of the water depths for each cross section. Next, calculate the average cross-sectional area for the two profiles. Multiply this value with the average corrected velocity to get discharge.

Confused?

The data sheet on page 89 helps you through each step.

TRANSPARENCY & TURBIDITY

Data Sheet p. 87

HWHP Educator's Guide, p. 83
Turbidity or Not Turbidity

HWHP Field Monitoring Guide, p. 49
Turbidity / Transparency

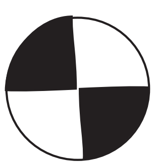
Background: Transparency is an indicator of how well light passes directly through water from the surface down. A measure of the transparency of the water is a general reflection of the water's turbidity. **Turbidity** is the cloudy appearance of water. Technically, turbidity is an optical property based on light scattered by the water. Dissolved chemicals, organic materials, sediment, and suspended particles in water can cause light to be scattered, reflected, or absorbed, thereby decreasing the transparency and the clarity of water. The more material suspended in the water, the lower the transparency. Conversely, the more material suspended in water, the higher the turbidity. Both transparency and turbidity can be quickly measured by a transparency or turbidity tube. Transparency is measured in centimeters and turbidity is measured in NTUs (Nephelometric Turbidity Units).

Particles and dissolved materials in water that lead to lower transparency may occur naturally.

Some of the nutrients attached to the sediments are necessary for plant growth. Streams will also have a natural change in transparency and suspended material across seasons. During spring snowmelt, higher flows tend to carry more material, therefore having a naturally lower transparency. During this time of year, it is also natural for algae to be scoured off of rocks and sediment to be transported downstream.

Excessive or unnatural levels of dissolved and suspended materials in the water can lead to impacts, such as:

- limiting the amount of light reaching plants, therefore decreasing photosynthesis;
- contributing to increased water temperatures because suspended particles can absorb light (similar to how someone wearing a black shirt standing next to someone in a white shirt may get warmer faster);
- filling in spaces between rocks as small suspended particles settle out of the water column. These spaces are necessary habitat for macroinvertebrates, fish eggs, and fish fry; and
- suspending solids that can harbor bacteria and viruses and make chemical disinfection more difficult.



The Secchi disk is at the bottom of the tube and is composed of two white and two black quadrants

Methods: Transparency or Turbidity Tube

1. If it is safe to get into the stream, fill your tube directly with water from mid-stream. If you need to use a bucket, fill the bucket with water, swirl thoroughly and pour the water into the tube.

Image 26: Water Collection

2. With your back to the sun, look directly down the top of the tube.
3. Have someone slowly let water out through a hole in the bottom of the tube until you can just make out the black and white Secchi disk on the bottom of the tube.
4. Record the height of the water column from the marks on the side of the tube in centimeters or NTUs (depending on which tube you are using).

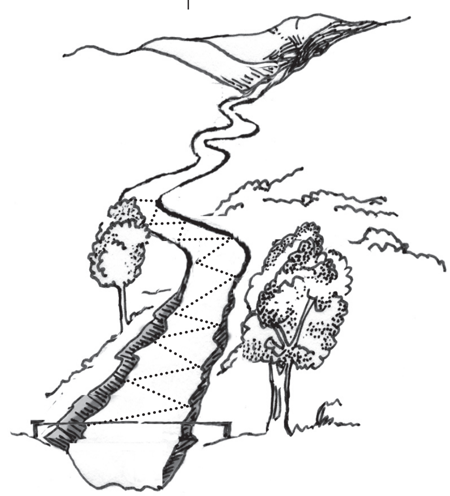
NOTE: *If you can see the quadrants of the Secchi disk when the tube is completely full, record the water level as greater than the highest cm or NTU marking on the side of the tube. For example: > 60cm*

SUBSTRATE COMPOSITION (PEBBLE COUNTS)

Data Sheet
p. 90

Background: Bed and bank materials of a stream are key elements in the formation and maintenance of channel morphology. These materials influence channel stability and provide resistance to scour during high flow events. The frequency of bed load transport can be critically important to fish spawning and other aquatic organisms that use the substrate for cover. The Wolman pebble count procedure was originally designed to quantify streambed substrate without having to collect substrate samples and take them back to the lab for sieve analysis. The procedure requires taking measurements of substrate on an increment within the bankfull channel.

Image 27: Follow a zig-zag pattern to collect substrate



Methods: The Wolman Pebble Count

1. The substrate particles are measured between the cross-section tapes and across the channel from bankfull to bankfull using the "zig-zag" method. Start at one end of the downstream cross section picking up pebbles moving across the stream channel. Then start picking up pebbles moving upstream and back across the stream channel. And back again until 100 particles are collected.
2. Without looking directly at the substrate of your sample location, step forward bringing your meter stick lightly down to touch the substrate. Reach down to the tip of the meter stick and pick up the first substrate that you touch. DO NOT LOOK while you are selecting the substrate to ensure a random sample is collected.
3. Measure the substrate along the intermediate axis with a ruler (scale = mm). The intermediate axis is the median side (B axis) of the rock; it is not the longest axis (length-wise, A) or the shortest axis (thickness, C) of the rock. Visualize the B axis as the smallest width of a hole that the particle could pass through.

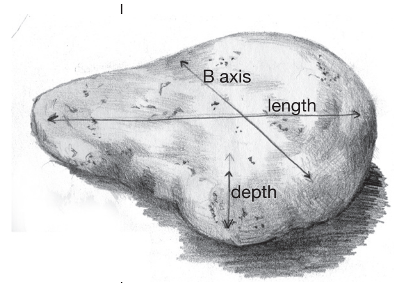


Image 28: How to Measure a Rock

4. Record the substrate as follows:

smooth dirt-feel	<2 mm gritty	>2 mm	>4096mm could park a car on it
↓	↓	↓	↓
Silt	**Sand**	**Record exact value**	**Bedrock**

NOTE:

- *On larger boulders, you may have to use a field tape or flip the ruler end-over-end several times to get a measurement.*
- *If rocks are embedded, you may have to feel for the intermediate axis with your hand and use your fingers as calibers to measure against.*

7. Enter all data on the Substrate data form. Write each measurement in the appropriate blank.

TEMPERATURE

Data Sheet p. 87

HWHP Field Monitoring Guide, p. 41
Temperature

Background: Temperature refers to the warmness or coldness of water. Cool water can hold more oxygen than warm water, because gases like oxygen are more easily dissolved in cool water.

Temperature varies seasonally and throughout the day so sampling at the same time and season each year is important for consistency. Temperature is influenced by:

- Summer urban runoff
- Stream depth
- Point sources of pollution
- Shading
- Amount of ground-water flow
- Soil temperature
- Ambient air temperature
- Stream orientation (N/S or E/W)

Why is temperature important?

Temperature is critical because it affects:

- The amount of oxygen that can be dissolved in the water
- The rate of photosynthesis by algae and larger aquatic plants
- The rates of growth, decomposition, digestion, etc., in aquatic life
- The sensitivity of organisms to toxic wastes, parasites, and diseases

Methods: Using a Celsius Thermometer

1. Rinse the thermometer with the stream water.
2. While at the sampling site, take the water temperature with your thermometer by submerging it in the water for one minute (or when temperature stabilizes). Attaching a string to the thermometer helps when the water is cold.
3. Record the temperature (in Celsius) on the Water Quality Data Sheet. There is a Celsius/Fahrenheit conversion chart in Appendix I.

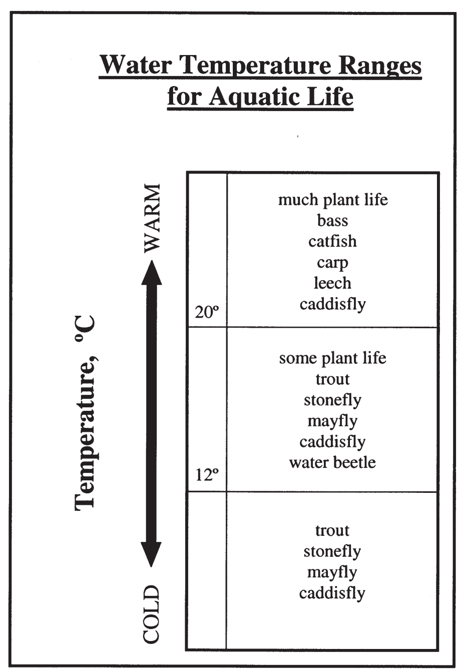


Image 29: Water Temperature Ranges

Testing the water's chemicals

The chemical makeup of water plays an important role in the health, abundance, and diversity of aquatic life. Chemical constituents also determine how suitable water is for drinking water supplies or for industrial uses. Excessive amounts of some constituents, such as nutrients, or the lack of others, including dissolved oxygen, can result in imbalances in aquatic ecosystems. Periodic or prolonged imbalances can degrade aquatic conditions and harm aquatic life. Pollution from human induced or naturally occurring chemical constituents can also make water unsuitable for human consumption, as well as greatly increase the cost of water treatment before it can be used.

NOTE: *Water chemistry methods described in this guidebook are for Hach Co. Chemistry Kits*

Expect changes in the water's chemical composition *(Horn and Dates, 2005)*

Daily —The chemical composition of the stream can fluctuate depending on the parameter measured. For example, temperature and dissolved oxygen often fluctuate throughout the day. Because dissolved oxygen (DO) is correlated directly with temperature, DO would increase as stream temperature decreased.

Seasonally — Water levels fluctuate throughout the year, causing high flows to occur during the spring melt-off and low flows at the end of summer. Temperature, dissolved oxygen, and pH can also change depending on the time of year.

River Continuum —The river continuum is described as a change in features that can be predicted in downstream direction, barring human disturbances or changes. For example, increases in nutrient loading, such as nitrogen and phosphorous levels, increase the further you move downstream.

PH

Background: Water (H_2O) contains both hydrogen (H^+) ions and hydroxyl (OH^-) ions. The pH test measures the H^+ ion concentration of liquids and substances. Each measured liquid or substance is given a pH value on a scale that ranges from 0 to 14. If the sample being measured has more H^+ than OH^- ions, it is considered acidic and has a pH less than 7. If the sample contains more OH^- ions, it is considered basic (alkaline) with a pH greater than 7. Pure, deionized water contains equal numbers of H^+ and OH^- ions and is considered neutral (pH 7), neither acidic nor basic.

Data Sheet p. 87

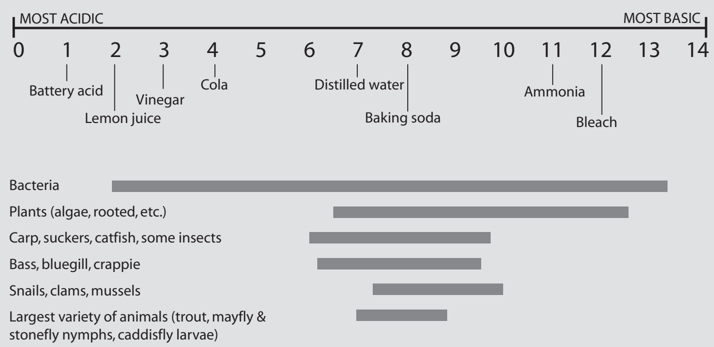
HWHP Field Monitoring Guide, p. 30
pH

0	7	14
← more H^+ ions	H^+ ions = OH^- ions	more OH^- ions →
ACIDIC	NEUTRAL	BASIC

pH is measured in pH standard units (s.u.) on a logarithmic scale. A logarithmic scale equates every one-unit change on the pH scale to approximately a ten-fold change in how acidic or basic the sample is. For example, the average pH of rainfall over much of the northeastern United States is 4.3 s.u. or roughly 10 times more acidic than normal rainfall of 5.3 s.u. The difference between pH readings of 5 and 6 s.u. is 10, between 5 and 7 s.u. is 100, between 5 and 8 s.u. is 1000.

NOTE:
For typical parameters, go to Appendix E, p. 77

Image 30: pH Ranges that Support Aquatic Life



Changes in the pH value of water are important to many organisms. Most organisms have adapted to life in water of a specific pH and may die if the pH changes even slightly. Unpolluted rainwater and snow both have a pH of roughly 5.5. During snowmelt in spring, lakes can drop below 5.0 endangering aquatic populations. Immature stages of aquatic insects and immature fish are extremely sensitive to pH values below 4.5.

In the United States, the pH of most surface water ranges between 6.5 and 8.5 s.u., although variations can occur. pH may fluctuate throughout the year and throughout the day because of changing physical, chemical, or biological conditions. The biggest daily change will likely occur in mid-summer because that is when the rate of photosynthesis and decomposition are greatest and these processes affect pH *(Stapp and Mitchell, 2000)*.

Possible influences on surface water pH:

- Natural changes due to local geology (limestone neutralizes the pH of stream water)
- Acid mine drainages (main cause of low pH in Montana)
- Acid rain from car exhaust and coal plant emissions

Methods:

How to calibrate the Hach pH Pocket Pal:

1. Before using the pH meter, you must calibrate it. Using a known pH solution of 7 (Hach has packets for easy use), insert thermometer and uncapped pH meter in the solution.
2. After the pH meter stabilizes, use a paper clip or small screwdriver to adjust the black button at the back of the meter to a 7.00 reading (be sure to do this on the side that says pH 7).
3. Repeat for either a known pH solution of 4 or 10 using the other dial.
4. Use the temperature chart on the back of the calibration solution to make any further adjustments.
5. Dispose calibration liquid into waste bottle.

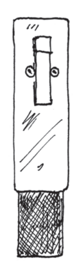


Image 31 b

Image 31 a, b: pH Pocket Pal (a) Front and (b) Back

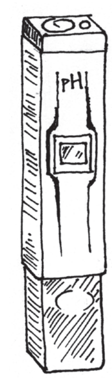


Image 31 a

How to use the Hach pH Pocket Pal:

1. Push black button on the top to "on" (a number will appear in the front window).
2. Remove the black protective cap from the bottom.
3. Immerse the bottom of the Pocket Pal 2" into the water (to the cap line). Hold for 5 seconds.
4. When the digital display stabilizes, read the pH value (while still holding in the water to avoid changes due to exposure to air).
5. Record the pH on your Water Quality Data Sheet. Repeat 2 more times. *Because pH is measured on a logarithmic scale, values can NOT be averaged.*
6. Rinse bottom of the Pocket Pal with distilled water. Replace protective cap.

Store pH meter (without cap) in a jar with 1-2 inches of water. You can also place several drops of water in the protective cap to prevent the glass bulb from drying out. Or, place a small piece of sponge in the bottom of the cap and keep it wet. This will provide a faster response time and a longer pH Pocket Pal life.

Battery Replacement:

1. Remove the case top from the Pocket Pal. Caution: do not overextend the attached wires!
2. Replace batteries with Eveready E675E, Duracell RM 675 or equivalent.

ALKALINITY *(Horn and Dates, 2005)*

Data Sheet p. 87

HWHP Field Monitoring Guide, p. 1 Alkalinity

Background: Alkalinity is a measure of the capacity of water to neutralize acids. Alkalinity of water is due primarily to the presence of bicarbonate, carbonate, and hydroxide ions. Salts of weak acids, such as borates, silicates, and phosphates, may also contribute to changes in alkalinity. Salts of certain organic acids may contribute to alkalinity in polluted or anaerobic water, but their contribution usually is negligible. Bicarbonate is the major form of alkalinity. Carbonates and hydroxide may be significant when algal activity is high, as well as certain industrial water and wastewater, such as boiler water.

Alkalinity is the balance of carbon dioxide in the river. Specifically, alkalinity is the amount of bicarbonates (HCO_3^-) and carbonates (CO_3^{2-}) present. It is measured in mg/L of calcium bicarbonate ($CaCO_3$) and influenced by:

1. **Watershed geology:** Variations in alkalinity can be attributed to the substrate and soils the water runs over and through. Limestone has high alkaline waters, while granite does not.

2. **Climate and precipitation:** Wetter and warmer climates have different soil types, and thus different vegetation. Likewise, alkalinity will vary among warmer and cooler climates, areas that freeze and have snow versus those that receive primary precipitation via rain.

3. **Land use activities:** Land use activities that disturb enough soil to make its way to the surface or ground water can increase alkalinity concentrations. Examples of how alkalinity can be increased include: a) the return of flood irrigation water to the stream; b) as the water flows over the land, it can pick up increased amounts of alkali; c) certain industrial processes; and d) ground water pumped and applied on land for which excess quantities flow into surface waters.

Image 32: Steps for Alkalinity Test

Methods: *Alkalinity test using Hach Test Kit*

High Range (20-400 mg/L as $CaCO_3$)

1. Fill the plastic tube (5.83 ml) with sample.
2. Wearing gloves, pour the contents of the tube into the square mixing bottle.
3. Add the contents of one Phenolphthalein Indicator Powder Pillow to the mixing bottle.
4. Swirl to mix. If the water remains colorless, the phenolphthalein alkalinity is zero. In this case, proceed to step 7.
5. If the sample turns pink, add Sulfuric Acid Standard Solution one drop at a time, counting each drop as you go and swirling the mixing bottle after each drop is added. Continue to add drops until the sample turns colorless.
6. Multiply the number of drops of Sulfuric Acid Standard Solution used by 20. This is the mg/L of phenolphthalein alkalinity as calcium carbonate ($CaCO_3$).
7. Add the contents of Green-Methyl Red Indicator Powder Pillow to the mixing bottle. Swirl to mix.
8. Add Sulfuric Acid Standard Solution one drop at a time, counting as you go and swirling the mixing bottle after each drop is added. Add drops until the sample turns pink.
9. Multiply total number of drops used in both steps 5 and 9 by 20. This is the total mg/L of methyl orange alkalinity as calcium carbonate ($CaCO_3$).

Low Range (5-100 mg/L as CaCO3)

1. Fill the square mixing bottle to the 23 mL mark with the sample water.
2. Wearing gloves, add the contents of one Phenolphthalein Indicator Powder Pillow.
3. Swirl to mix. If the water remains colorless, the phenolphthalein alkalinity is zero. In this case, proceed to step 6.
4. If the sample turns pink, add Sulfuric Acid Standard Solution one drop at a time, counting each drop and swirling the mixing bottle after each drop is added. Add drops until the sample turns colorless.
5. Multiply the number of drops of Sulfuric Acid Standard Solution used by 5. This is the mg/L of phenolphthalein alkalinity as calcium carbonate (CaCO3).
6. Add the contents of Green-Methyl Red Indicator Powder Pillow to the mixing bottle. Swirl to mix.
7. Add Sulfuric Acid Standard Solution one drop at a time, counting each drop, and swirling the mixing bottle after each drop is added. Add drops until the sample turns pink.
8. Multiply the total number of drops used in both steps 4 and 8 by 5. This is the total mg/L of methyl orange alkalinity as calcium carbonate (CaCO3).

DISSOLVED OXYGEN

Data Sheet p. 87

Background: Dissolved oxygen (DO) simply means oxygen dissolved in water. All aquatic organisms rely on DO to function, thus monitoring its levels is important. Fast-flowing, cold, mountain streams generally have high concentrations of dissolved oxygen. When dissolved oxygen concentrations drop to very low levels due to higher temperatures and slower moving water, such as in swamps or bogs, the community of organisms will be made up of those species which can tolerate low dissolved oxygen levels.

Some forms of pollution can lower dissolved oxygen levels. Adding nutrients to water may stimulate the growth of plants, which consumes oxygen in water when they decompose. Therefore, excess nutrients, such as nitrogen and phosphorus, can result in lowered dissolved oxygen levels critical for certain aquatic species.

HWHP Field Monitoring Guide, p. 15
Dissolved Oxygen

Dissolved oxygen varies throughout the day because temperature varies (which changes the amount of oxygen water can hold) and because the balance between **photosynthesis** (which puts oxygen into water) and **decomposition** (which uses oxygen) constantly changes over the day and throughout the year. Oxygen is most likely to be low during the predawn hours when little photosynthesis is occurring.

Most aquatic plants and animals need a certain level of oxygen dissolved in the water for survival (see chart below). Fish and some aquatic insects have gills to extract life-giving oxygen from the water. Some aquatic organisms like pike and trout require medium-to-high levels of dissolved oxygen. Other aquatic organisms like carp and catfish flourish in waters with low dissolved oxygen *(Stapp and Mitchell, 2000)*.

Dissolved oxygen is influenced by:

- Changes in temperatures seasonally and throughout the day.
- Atmospheric pressure (higher elevations have greater amounts of pressure).
- Organic wastes from waste water treatment, industry and runoff. Aquatic bacteria consume oxygen while decomposing organic material.
- Plant or vegetative die off.
- Deep, stagnant pools in slow moving streams and ponds can result in lower dissolved oxygen levels.

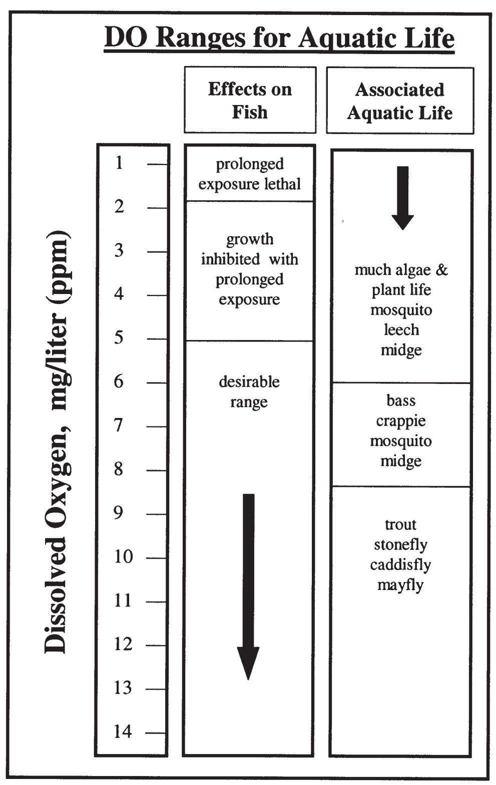


Image 33: Dissolved Oxygen Ranges for Aquatic Life

Image 34: Dissolved Oxygen Procedures

Be sure to fill measuring tube with sample before pouring into square mixing bottle

Methods: *Dissolved Oxygen Test Using Hach Test Kit model OX-2P*

High Range Test:

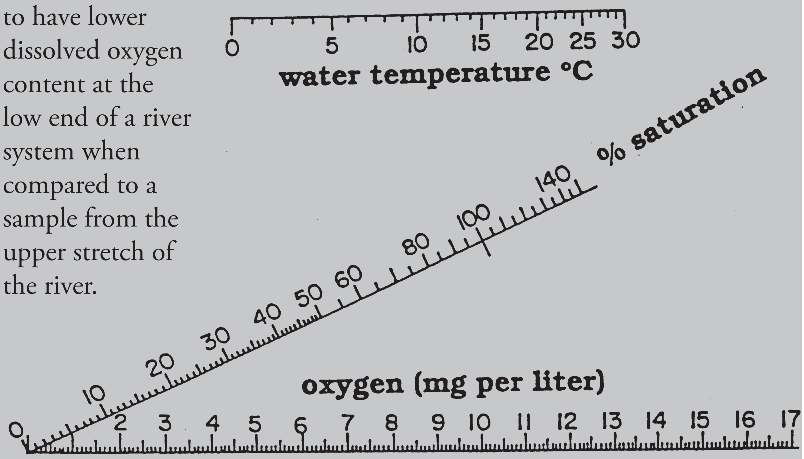
1. Using your Water Quality Data Sheet, complete the information at the top of the page.
2. Rinse the dissolved oxygen bottle (with river water) three times and dispose into waste bottle before collecting a sample. Fill the dissolved oxygen bottle (round bottle with glass stopper) with the water to be tested by allowing the water to overflow the bottle. To avoid trapping air bubbles in the bottle, incline the bottle slightly and insert the stopper with a quick thrust. This will force the air bubbles out. After inserting the stopper, DO NOT pour off the extra water; you will need it for the next step. If bubbles become trapped in the bottle in steps 2 or 4, the sample should be discarded before repeating the test.
3. Wearing glasses and gloves, use clippers to open one Dissolved Oxygen 1 Reagent powder pillow and one Dissolved Oxygen 2 Reagent powder pillow. Add the contents of each of the pillows to the bottle. Stopper the bottle carefully to exclude air bubbles. *No air bubbles can be present in the bottle, as it will affect your measurement.* Grip the bottle and stopper firmly; shake vigorously to mix (shake from shoulder to hip to be consistent). A **flocculent** (floc) precipitate will be formed. If oxygen is present in the sample, the precipitate will be brownish-orange in color. A small amount of powdered reagent may remain stuck to the bottom of the bottle. This will not affect the test results. (During this stage, oxygen is literally being pulled apart from the hydrogen).
4. Allow the sample to stand until the floc has settled below the line halfway in the bottle, leaving the upper half of the bottle clear. Shake the bottle again. Again, let it stand until the upper half of the sample is clear. *NOTE: the floc will not settle in samples with high concentration of chloride, such as seawater. No interference with the test results will occur as long as the sample is allowed to stand for four or five minutes*.
5. Use the clippers to open one Dissolved Oxygen 3 Reagent Powder pillow. Remove the stopper from the bottle and add the contents of the pillow. Carefully re-stopper the bottle and shake to mix (shoulder to hip). The floc will dissolve and a yellow color will develop if oxygen is present.
6. Fill the small plastic measuring tube level full of the sample prepared in steps 1 through 5. Pour the sample into the square mixing bottle.
7. Add Sodium Thiosulfate Standard Solution drop by drop to the mixing bottle, swirling to mix after each drop. Hold the dropper vertically above the bottle and count each drop as it is added (if the dropper is tilted, it will produce varying sizes of drops). Swirl the contents to mix after each drop. Continue to add drops until the sample changes from yellow to colorless.

8. Each drop used to bring about the color change in step 7 is equal to 1mg/L of dissolved oxygen (DO). Record the total number of drops used on the Water Quality Data Sheet. This is equal to the total mg/L of dissolved oxygen.
9. Calculate percent saturation using the chart provided on the right. If dissolved oxygen is less than or equal to 3 mg/L, go on to step ten.

Repeat test three times to get a precise reading. Record all three tests and the average on your Water Quality Data Sheet.

Remember, it is not unusual to have lower dissolved oxygen content at the low end of a river system when compared to a sample from the upper stretch of the river.

Image 35: Oxygen Saturation Chart



Low Range Test: If the results of step 8 are very low, 3 mg/L or less, a more sensitive test might be helpful.

10. Use the prepared sample left from step 4 in the High Range Test. Pour off the contents of the DO bottle (use your waste jug) until the bottle level just reaches the 30 ml mark on the bottle.
11. Add Sodium Thiosulfate Standard Solution drop by drop directly to the DO bottle. Count each drop as it is added and swirl the bottle constantly to mix while adding the Sodium Thiosulfate Standard Solution. Continue to add drops until the samples change from yellow to colorless.
12. Each drop of Sodium Thiosulfate Standard Solution used to bring about the color change in step 7 is equal to 0.2 mg/L dissolved oxygen.
13. Record the number of drops used and multiply by 0.2 mg/L. Record the result on your Water Quality Data Sheet.

Calculating Percent Saturation of Dissolved Oxygen

The dissolved oxygen test you conducted resulted in a number that was in mg/L (or ppm). However, since the solubility of oxygen is directly related to temperature, it is useful to express the amount of dissolved oxygen (DO) as a percent (%) of the maximum the water could hold.

Using the diagram above, find the stream or river temperature on the top scale and your corrected dissolved oxygen on the bottom scale. Draw a straight line (or use a straight edge) between the water temperature and dissolved oxygen measurement. Read the saturation percentage at the intercept on the sloping scale where your straight line crosses it. Record the result on the Water Quality Data Sheet.

What is saturation?

Saturation is the maximum level of dissolved oxygen that would be present in the water at a specific temperature in the absence of other influences. Rivers with a 90-100 percent dissolved oxygen saturation value have high dissolved oxygen saturation. Rivers below 90 percent saturation may have large amounts of oxygen-demanding materials (organic wastes).

Q: Does temperature affect conductivity?

A: *Yes, conductivity is affected by temperature. The warmer the water, the higher the conductivity. For this reason, conductivity is reported as specific conductivity at 25° Centigrade and is measured as micro Siemens per centimeter (_S/cm).*

CONDUCTIVITY

Background: Conductivity is a measure water's ability to pass an electrical current. This ability depends on temperature and the presence of ions. Conductivity is useful as a general measure of water quality. It does not identify or measure specific compounds in the water, as, for example, the test for nitrates does. Yet each river or stream tends to have a relatively consistent range of conductivity that can be used as a baseline for comparison with regular measurement of conductivity. A significant change in conductivity could be an indicator that some type of discharge or pollution has entered the water.

Conductivity in rivers and streams is affected primarily by the geology of the area through which the water flows and the presence of naturally occurring electrolytes, such as salts. High conductivity is created by the presence of inorganic dissolved solids, such as chloride, nitrate, sulfate, and phosphate **anions** (ions that carry a negative charge), or sodium, magnesium, calcium, iron, and aluminum **cations** (positively charged ions). Organic compounds like oil, phenol, alcohol, and sugar do not conduct electrical current very well; therefore, they have a low conductivity when in water.

Rivers running through areas with granite bedrock tend to have lower conductivity because granite is composed of more inert materials that do not become electrolytes when washed into the water. On the other hand, rivers that run through areas of clay soils and limestone tend to have higher conductivity due to the presence of materials that ionize when washed into the river *(Stapp and Mitchell, 2000)*.

Methods: Conductivity is measured using a meter and a probe containing two electrodes (or a conductivity pen). A voltage is applied between the electrodes. The voltage drop caused by the resistance of the solution is used to calculate its conductivity per centimeter.

How to calibrate the Hach Conductivity Pocket Pal:

1. Before using the Conductivity meter, you must calibrate it. Using a known electrolyte solution (Hach has packets for easy use), insert thermometer and uncapped Conductivity meter into the solution.
2. After the Conductivity meter stabilizes, use a paper clip or very small screwdriver in the hole in the back of the meter to adjust.
3. Repeat for a known Conductivity solution.
4. Use the temperature chart on the back of the solution packet to make any further adjustments.
5. Your meter is now calibrated. Dispose calibration liquids into waste bottle.

How to use the Conductivity Pocket Pal:

1. Push black button on the top to "on" (a number will appear in the window on the front).
2. Remove protective cap from the bottom.
3. Immerse the bottom of the Pocket Pal 2" into the water (to the cap line). Hold for 5 seconds.
4. When the digital display stabilizes, read the Conductivity value (while still holding in the water to avoid changes due to exposure to air).
5. Record on Water Quality Data Sheet.
6. Rinse bottom of the Pocket Pal with distilled water and replace protective cap.

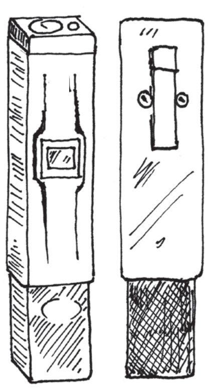


Image 36: Hach Conductivity Pocket Pal (front and back)

NITROGEN *(Horn and Dates, 2005)*

Data Sheet p. 87

HWHP Field Monitoring Guide, p. 25
Nitrate

Background: Gaseous nitrogen (N_2) forms the major portion of the earth's atmosphere (about 80 percent). Nitrogen can be found in water in several different combinations with oxygen. The ones that are important measurements of water quality and stream health are ammonia (NH_3), nitrite (NO_2^-), and nitrate (NO_3^-).

Nitrogen is necessary for all forms of life. Its electronic configuration makes it uniquely suited to form the long chain-like structures of proteins and nucleic acids. Proteins make up the building blocks for all cell structure and enzymes that carry on energy transformations within cells. Proteins also comprise the mass of muscle tissue that allows animals to carry out movement. Nucleic acids carry the genetic information, or genetic code, from generation to generation for making of all these proteins.

Gaseous nitrogen is not available for most living organisms to take up and use. Some microorganisms are able to chemically transform it and incorporate it into living cells to build proteins. The series of nitrogen transformations that bacteria carries out in soil and water is called the "nitrogen cycle."

During the nitrogen cycle, plants take up the nitrate bacteria and assimilate it into their tissue. Animals must obtain their nitrogen from either plants or consumption of other animals, and they excrete nitrogen in their waste through various forms.

Cells must also have an effective manner to get rid of nitrogen wastes (mainly ammonia) after the breakdown of old and replaced cell components. Too much ammonia in the bloodstream causes brain damage. In fish, ammonia is carried either free or as a complex to the gills where it is swept away by water. High concentrations of ammonia in water inhibit fishes' ability to excrete their own ammonia. Most terrestrial vertebrates convert ammonia to urea in the liver and then excrete it by means of the kidneys in urine. Birds and snakes excrete ammonia wastes as uric acid—a compound with four nitrogen molecules.

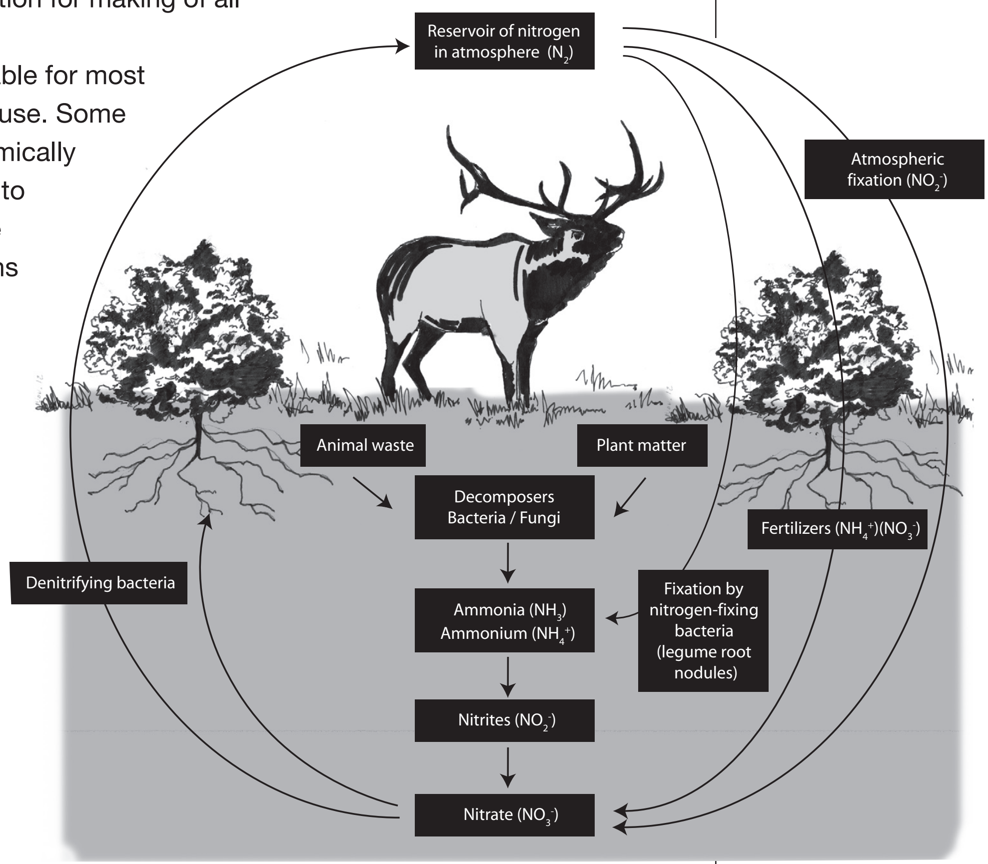


Image 37: Nitrogen Cycle, Hach Co.

High concentrations of nitrite and nitrate in water can cause oxidation of the iron molecule in the hemoglobin, especially in human infants by preventing the uptake of oxygen by red blood cells.

NOTE: *Nitrate testing using the Hach Nitrogen Test Kit creates a toxic cadmium by-product and the test is not sensitive enough to measure the trace amount of nitrates in most MT streams. Please weigh the pros and cons of performing this test. If test is carried out, please properly dispose of the cadmium waste.*

How do you choose between Low Range test and High Range tests?

When testing for nutrients (Nitrogen or Phosphorous), always start with the Low Range test procedures first. If the sample results are too high or inconclusive, try using the Mid or High Range testing procedures.

Methods: *Nitrate test using Hach Nitrogen Test Kit, model NI-14*

Nitrate, Low Range (0-1 mg/L as Nitrate Nitrogen)

1. Fill the color viewing tube to the 5-mL mark with sample. Stopper the tube and shake vigorously.
2. Empty the tube into a waste bottle and repeat step 1.
3. Fill the color viewing tube to the 5-mL mark with sample.
4. Open one NitraVer®5 nitrate Reagent Powder Pillow. Add the contents to the sample in the tube.
5. Stopper the tube and shake vigorously for three minutes. Allow the sample to stand undisturbed for thirty seconds. Unoxidized particles of cadmium metal will remain in the sample and settle to the bottom of the tube.
6. Carefully pour the prepared sample into a second viewing tube so that the cadmium particles remain in the first tube.
7. Open one NitriVer®3 Nitrite Reagent Powder Pillow. Add the contents to the sample in the tube.
8. Stopper the tube and shake vigorously for thirty seconds. A pink color will develop if nitrate is present. Allow at least ten minutes, but no more than twenty minutes before completing steps 9 through 11.
9. Insert the tube of the prepared sample into the color comparator.
10. Rinse the unoxidized cadmium metal from the color viewing tube used in step 3 and dispose in proper waste bottle. Fill to the 5-mL mark with the original water sample and place in the left top opening of the comparator.
11. Put the color disc in comparator. Orient the comparator with the tube tops pointing to a window or light source. View through the openings in the front of the comparator. Use care not to spill samples from unstoppered tubes.
12. Rotate the disc to obtain a color match. Read the mg/L nitrate-nitrogen through the scale window.
13. Multiply the reading from the scale window by 4.4 to obtain the mg/L nitrate (NO_3).
14. Record on data sheet.

Nitrate, Medium Range (0-10 mg/L as Nitrate Nitrogen)

1. Fill the color viewing tube to the 5-mL mark with deionized water. Stopper the tube and shake vigorously.
2. Empty the tube into a waste bottle and repeat step 1.
3. Rinse a plastic eye-dropper with the sample and fill to the 0.5-mL mark. Add contents of the dropper to the rinsed color viewing tube.
4. Fill the color viewing tube with the sample to the 5-mL mark with deionized water.
5. Open one NitraVer®6 nitrate Reagent Powder Pillow. Add the contents to the sample in the tube.
6. Stopper the tube and shake vigorously for three minutes. Allow the sample to stand undisturbed for thirty seconds.

Unoxidized particles of cadmium metal will remain in the sample and settle to the bottom of the tube.

7. Carefully pour the prepared sample into a second viewing tube so the cadmium particles remain in the first tube.
8. Open one NitriVer®3 Nitrite Reagent Powder Pillow. Add the contents to the sample in the tube.
9. Stopper the tube and shake vigorously for thirty seconds. A pink color will develop if nitrate is present. Allow at least ten minutes, but no more than twenty minutes before completing steps 10 through 12.
10. Insert the tube of the prepared sample into the color comparator.
11. Rinse the unoxidized cadmium metal from the color viewing tube used in step 3 and dispose of into a proper waste bottle. Fill to the 5-mL mark with the original water sample and place in the left top opening of the comparator.
12. Put the color disk into the comparator. Orient the comparator with the tube tops pointing to a window or light source. View through the openings in the front of the comparator. Use care not to spill samples from unstoppered tubes.
13. Rotate the disc to obtain a color match. Read the mg/L nitrate-nitrogen through the scale window.
14. Multiply the reading from the scale window by 4.4 to obtain the mg/L nitrate (NO_3).
15. Record on data sheet.

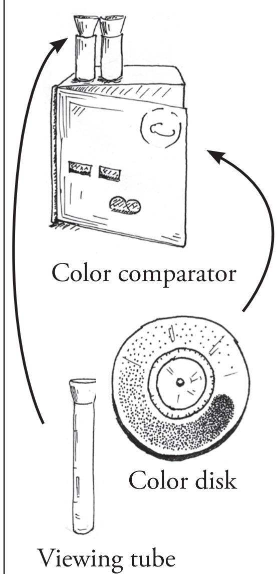


Image 38: Materials in Nitrogen test kit

PHOSPHORUS

Data Sheet p. 87

HWHP Field Monitoring Guide, p. 35
Phosphate

Background: Like nitrogen, **phosphorus** is an essential nutrient for plants and animals, but in excess allows algal blooms that decrease dissoved oxygen levels. Living cells require phosphorus for nucleic acid production and energy transformations. Adenosine triphosphate (ATP) is the major compound in cells that stores energy in molecular bonds. When these high-energy bonds are broken, other cellular compounds can be built up. Phosphorus is the major limiting element in water for algal growth. In standing waters where phosphorus accumulates, algal blooms proliferate and reduce the concentrations of dissolved oxygen. As oxygen concentrations decrease, less desirable organisms flourish.

The same samples that are preserved with sulfuric acid for nitrogen analyses are used to quantify total phosphorus.

The water is digested with concentrated acids and high temperatures to break down all forms of phosphorus into its simplest form (PO_4^{3-}). A soluble form of the element molybdenum (Mo) is added which combines with the phosphate to produce a yellow color. This color is converted to a blue color by the addition of ascorbic acid (vitamin C). The amount of light that is absorbed by the blue color is measured by a spectrophotometer. This is directly proportional to the amount of total phosphorus in the solution in mg/L.

Influences on phosphorus levels:

- Domestic wastewater containing phosphate detergents
- Fertilizers
- Irrigation runoff
- Soil type

Methods: *Phosphorous test using Hach Phosphate Test Kit model PO-19*

Orthophosphate (Low Range, 0-1 mg/L Phosphate)

1. Pre-rinse the square mixing bottle with sample water.
2. Fill the square mixing bottle to the 20-mL mark with the water to be tested.
3. Open one PhosVer®3 Phosphate Reagent Powder Pillow. Add the contents of the pillow to the bottle and swirl to mix.
4. Allow at least two, but not more than ten minutes for color development. If phosphate is present, a blue-violet color will develop.
5. Insert the lengthwise viewing adapter into the comparator.
6. Fill one sample tube to the line underlining "Cat. 1730-00" with the prepared sample (if not using 1730-00 tubes, the line is approx. 1 inch below the top of the tube). Insert it into the top right opening of the color comparator.
7. Fill a second sample tube with untreated water to the line as described in step 6. Insert it into the top left opening of the color comparator.
8. Put the color disk in comparator. Orient the comparator with the tube tops pointing to a window of light source. View through the openings in front of the comparator. Use care not to spill samples from unstoppered tubes.
9. Rotate the disc to obtain a color match. Read the concentration of the measured parameter through the scale window.
10. Divide the reading from the scale window by 50 to obtain the mg/L phosphate (PO_4). To obtain the value as mg/L phosphorus (P), divide the PO_4 value by 3.
11. Record the result on the data sheet.
12. Dispose treated sample water into a waste bottle.

Orthophosphate (Medium Range, 0-5 mg/L Phosphate)

1. Pre-rinse the square mixing bottle with sample water.
2. Fill the square mixing bottle to the 20-mL mark with the water to be tested.
3. Open one PhosVer®3 Phosphate Reagent Powder Pillow. Add the contents of the pillow to the bottle and swirl to mix.
4. Allow at least two, but not more than ten minutes for color development. If phosphate is present, a blue-violet color will develop.
5. Fill one sample tube to the lowest mark with the prepared sample (approx. 5 mL). Insert it into the top right opening of the color comparator.
6. Fill a second sample tube to the lowest mark with the untreated sample (approx. 5 mL). Insert it into the top left opening of the color comparator.
7. Put the color disk in comparator. Orient the comparator with the tube tops pointing to a window of light source. View through the openings in front of the comparator. Use care not to spill samples from unstoppered tubes.
8. Rotate the disc to obtain a color match. Read the concentration of the measured parameter through the scale window.
9. Divide the reading from the scale window by 10 to obtain the mg/L phosphate (PO4). To obtain the value as mg/L phosphorus (P), divide the PO4 value by 3.
10. Record the result on data sheet.
11. Dispose treated sample into a waste bottle.

HARDNESS *(Horn and Dates, 2005)*

Background: Hardness is a measure of calcium (Ca^{2+}) and magnesium (Mg^{2+}) **polyvalent cations** (ions with a positive charge greater than +1). Calcium and magnesium are the most common polyvalent cations in fresh water. Aquatic systems with hard water generally have more biological productivity, greater species diversity, and more cations and anions, as well as produce more biomass. Hard water leaves a crust or white film when it evaporates (sometimes found around faucets). Soft water is less productive in terms of primary productivity, species diversity and total biomass.

Hardness is measured in mg/L calcium carbonate (CaCO3) (similar to alkalinity). This unit provides a common language to compare hardness and alkalinity results across waterbodies.

Levels of Water Hardness mg/L CaCO3
Soft 0-60
Moderate 61-120
Hard 121-180
Very Hard ≥ 181

Influences on hardness of water:

- Watershed geology: Variations in hardness can be attributed to the substrate and soils the water runs over and through.
- Climate and precipitation: Wetter and warmer climates have different soil types and thus different vegetation. In addition, hardness will vary among warmer areas (that receive primary precipitation via rain) and cooler ones (that freeze and have snow).
- Land use activities: Land use activities that disturb enough soil that makes its way to the surface or ground water can increase hardness concentrations. For example, when water is applied to land, via flood irrigation, hardness can artificially increase in waterways through irrigation return flows. Certain industrial processes could also increase hardness. Ground water pumped and applied on land where excess quantities of water overflow into surface waters can increase hardness.

When fish reside in high hardness waters, they can withstand higher concentrations of metals compared to in a low hardness environment. The hardness appears to "protect" fish from the effects of elevated metals. It is not known exactly how hardness mitigates toxic impacts from elevated metals. It is thought that the available Ca^{2+} and Mg^{2+} outcompete the dissolved metals, such as Cd^{2+} or Fe^{2+} on the gills of fish. Gills are physically damaged and also functionally impaired in water with elevated metals. The more calcium and magnesium present, the better the odds of those ions being on the gill uptake sites than a harming metal. It is the dissolved or free form of the metal that harms aquatic life. In sum, hardness is inversely related to metal toxicity.

Q: What are water "softeners"?

A: *Hard water makes using soap difficult because it won't lather. Water softeners make hard water functional or able to lather up and clean our bodies, clothes, or cars. In general, water softeners work by replacing calcium and magnesium with sodium (Na^{+}) and potassium (K^{+}) ions.*

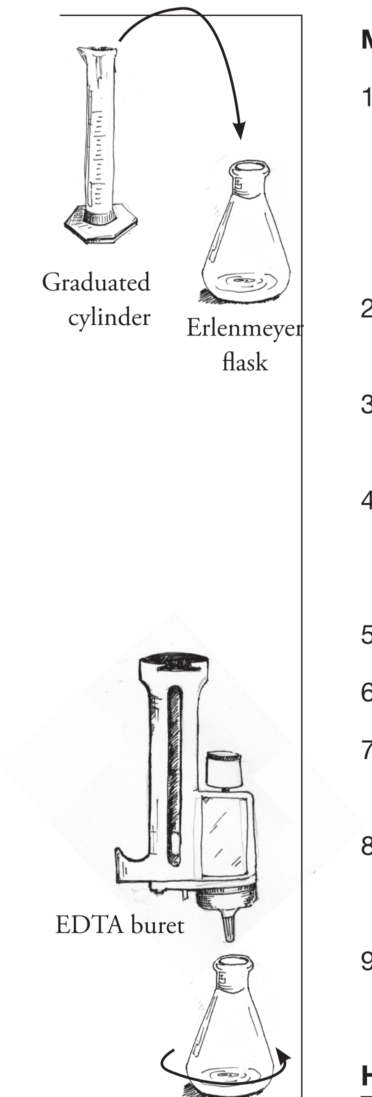


Image 39: Hardness Test Procedures

Methods: Hardness test using Hach Digital Titrator Kit

1. Select a sample size and an EDTA Titration Cartridge corresponding to the expected amount of calcium as calcium carbonate ($CaCO_3$) concentration. Use the table for the concentrations in mg/L.

> EDTA: ethylenediaminetetraacedic acid

2. Insert a clean delivery tube into the titration cartridge and attach the cartridge to the titrator body.
3. Turn the delivery knob to eject a few drops of titrant and reset the counter to zero and wipe off the tip.
4. Use a graduated cylinder or pipette to measure the sample volume from the table below. Transfer the sample into a clean 250-mL Erlenmeyer flask and dilute to about the 100-mL mark with deionized water.
5. Add two mL of 8 N Potassium Hydroxide Standard Solution and swirl to mix.
6. Add the contents of one CalVer®2 Calcium Indicator Powder Pillow and swirl to mix.
7. Place the delivery tube tip into the solution and swirl the flask while titrating with EDTA turning the solution from pink to blue. Record the number of digits required.
8. Calculate the sample concentration using the formula:

   Total Digits Required x Digit Multiplier (from table) = mg/L Calcium Hardness

9. Record on the data sheet.

Hardness Table

Range (mg/L as $CaCO_3$)	Sample Volume (mL)	Titration Cartridge (MEDTA)	Digit Multiplier
10-40	100	0.0800	0.1
40-160	25	0.0800	0.4
100-400	100	0.800	1.0
200-800	50	0.800	2.0
500-2000	20	0.800	5.0
1000-4000	10	0.800	10.0

Biological

MACROINVERTEBRATES

(Adapted from Crighton's Hoosier Riverwatch Manual*, Creighton and Hosier, 2005)*

Background: The diversity and abundance of aquatic organisms in a stream are indicators of the water quality. By sampling aquatic insects, we can evaluate whether the stream is providing the habitat and water quality necessary for certain species to thrive. The presence or absence of certain aquatic insects tells us a lot about the stream. **Benthic** (bottom-dwelling) **macroinvertebrates** (animals without backbones and visible to the naked eye) have been used for years as an indication of water quality. Diversity measures are founded on the concept that higher quality waters generally support a greater diversity of organisms than poor quality waters where pollution sensitive species cannot live.

Macroinvertebrates are usually easy to find and collect. Many have a one- or two-year life cycle, and are therefore continuous monitors of water quality. Unlike fish, many macroinvertebrates are not mobile enough to move in and out of an area if there is an intermittent pollution problem. Macroinvertebrate communities often contain many species, each with its own preferred environmental conditions and life histories, creating a complex and often diverse community.

One advantage of biological sampling is that it enables us to look at indicators of environmental conditions which are present in the stream over a period of time, thus being able to make chemical hypotheses based on the species present, rather than just a snapshot in time, such as a dissolved oxygen or pH measurement.

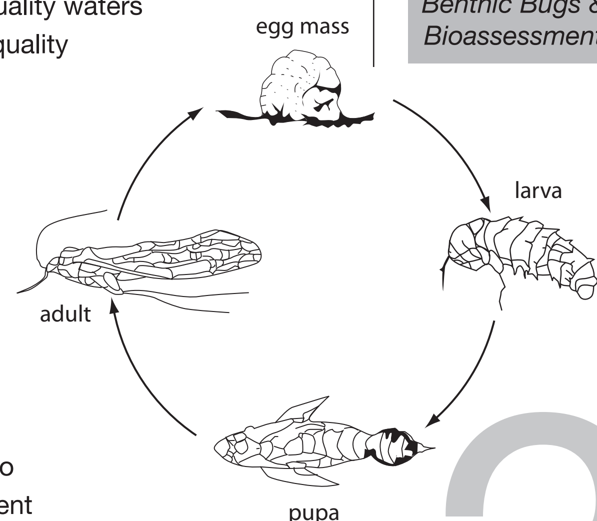


Image 40: Life Cycle of Aquatic Insect

Macroinvertebrate Resources:

- *A Guide to Common Freshwater Invertebrates of North America,* Voshell, Jr., J. Reese. 2002.
- *Key to Macroinvertebrate Life in the River and Ponds,* University of Wisconsin Extension and Wisconsin Department of Natural Resources. Available on Montana Watercourse website mtwatercourse.org.
- *Stream Bugs as Biomonitors—A Guide to Pacific Northwest Macroinvertebrate Monitoring and Identification*, Adams, Jeff & Vaughan, Mace. Xerces Society. 2007. www.xerces.org/aquatic.
- *Aquatic Entomology: The Fishermen's & Ecologist's Illustrated Guide to Insects & their Relatives*. McCafferty, Patrick. Purdue University. 1998.
- Macroinvertebrate key, see Appendix F, p. 78.

Data Sheet p. 91, 92

HWHP Educator's Guide, p. 155

Benthic Bugs & Bioassessment

Q: How many different species of macroinvertebrates are there in Montana streams and lakes?

A: *Nearly 500. You will most certainly become an expert with the benthic macroinvertebrates commonly found at your sampling site (ranging from 5-20 different major groups).*

Macroinvertebrates vary with the season. They emerge at different times of the year filling a variety of niches. Because of seasonal variations, you should sample twice a year.

If you are a level one or two monitor, you may not need to collect 300 bugs—check with Montana Watercourse.

Methods:

1. Use a D-Net to collect sample. One kick per collection sample unless you composite several samples in one.
2. In a riffle area and facing downstream, place the net in front of you so the bag is resting on the bottom of the stream. Vigorously kick and disturb the substrate (bottom material of the stream) walking diagonally up the stream (back and forth on small streams) traveling twenty feet and for one minute. It is helpful to have a partner act as a timekeeper and call out "fifteen seconds," "thirty seconds," "forty-five seconds," and "stop." Make sure the kicking lasts one minute for consistency. For safety reasons, DO NOT sample where the stream is above your knees. Confine your sampling to the shallows.
3. Carefully rinse net into a dishpan or cooler with 1″- 2″ of stream water in it.
4. Pick macroinvertebrates at random until you have 300 (plus or minus 10%) individuals selected.
5. Sort by major groups (e.g. mayflies, stoneflies, leeches, etc.) into ice cube trays.
6. Compute the percent composition of each major group by counting the total number (out of the 300 bugs in your sample). Record your numbers on Macroinvertebrate Data Sheet 1. Does one major group dominate? Are the "EPT" Orders [Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly)] well represented? If not, why? In mountain streams, EPT insects are indicators of clean, oxygenated, cold water. There are other macroinvertebrate taxa that indicate high water quality in prairie streams. These can range from Coleoptera (beetles), to Odonata (dragonflies and damselflies).
7. If you are making a reference collection, store the bugs in 70 percent denatured ethyl alcohol (ethanol).

Optional: *Compute a Pollution Tolerance Index on the data sheet provided in the Appendix.*

Optional: *Identification can be taken a step further by completing the trophic level (functional feeding analysis). If the bugs are identified to the family level, the trophic level (functional feeding group) can be determined. Functional feeding group or trophic level refers to how a bug "captures" its food, for example shredding detritus, filtering the water, gathering detritus, or preying on other bugs.* The Streamkeeper's Field Guide *is an excellent resource for determining functional feeding groups.* NOTE: *You will have to preserve the bugs in alcohol and examine them under a scope to do this. This cannot be done in the field.*

What does it all mean?

After you become familiar with protocols, equipment, and what to monitor and why, you might wonder what all the results mean. Monitoring activities generate data, numbers, ratings, descriptions and the like, but do not necessarily produce information. In addition to identifying your monitoring questions and data user/use endpoints, turn data into information through some version of the following process:

1. Determine findings and analyze (objective analysis, such as summary statistics, comparison to criteria, benchmarks, pre/post event or historic conditions).
2. Interpretation and conclusions from the findings and analyses (can be subjective).
3. Make recommendations and/or take action.
4. Data utility, reporting or delivery to the identified decision-makers. An effective study design would have planned these steps in the best way possible based on the needs of the target data users with consideration for the uses of the data and the identified monitoring objectives.

HELPFUL TIPS

1 Know what you are monitoring or measuring. What is dissolved oxygen? What is alkalinity? What is physical habitat substrates ecological contribution? What are macroinvertebrates?

2 Know how your variable is "supposed" to behave daily, seasonally, upstream to downstream (river continuum concept), with the ground water, with the flood plain, etc.

3 Know why you care about this variable. What is the ecological contribution and associated monitoring question?

4 Remember the triangle relationship between physical, chemical, and biological attributes of a stream? For example, how do the physical parameters affect chemical and biological parameters?

5 Employ criteria and or benchmarks for comparison. These can be in the form of Clean Water Act Stream standards, biological or toxicity thresholds, historic data, pre/post event, upstream / downstream (control, impact, recovery zones), and reference or least impacted sites.

6 What other variables might influence this parameter and was it measured? For example, dissolved oxygen fluctuates with temperature, or discharge can dilute or concentrate some nutrients. There will be a better story to tell if both parameters are monitored in each example.

7 Land or water uses, precipitation, geology, stream morphology, hydrological modifications and natural events can influence results. Where are point sources and nonpoint sources of pollutants in your watershed?

8 What are you measuring: stressors (chemical variables for example), response (macroinvertebrate assemblages), or exposure? Are you trying to make an interpretation about the response community based on stressor data or visa versa?

Data Management

Do the numbers have anything to do with reality?

DECIPHERING THE DATA

Analysis involves looking at data and trying to explain or understand what you've found. Often, collection of data over time reveals patterns and trends that are extremely useful in data analysis. Using graphs may help you see and understand these patterns. Tips on creating graphs are provided on pages 65-66.

It is important to remember that the data you have collected is interrelated—for example, habitat evaluation helps to explain macroinvertebrate presence, which depends upon chemical parameters. A simple, but important question is: Do my results make sense? If not, what does not fit? How can this be explained? The following are useful questions to ask during data analysis:

- Are there any noticeable patterns?
- How do my results compare to the Montana average values and typical ranges?
- What does macroinvertebrate sampling reveal that is not reflected in chemical testing?
- Do the results indicate sources of pollution in the watershed?
- Do the test results seem to correlate to land use?

TURNING DATA INTO ACTION

What are some actions that you could immediately take?

1. List any problems that you discovered during sampling. You may decide that you want to help resolve a problem that you have identified. First, you must define who or what is affected by the problem. For example, E. coli bacteria contamination impacts the stream community and is a threat to human health.
2. Second, determine the possible actions that you could take. You may choose to:
   - Educate others (speaking to neighbors, at school, or write to the newspaper).
   - Take political action (speak at a public meeting or write / visit public officials).
   - Take direct action by making lifestyle changes, organize a stream cleanup, or plant vegetation to stabilize stream banks.
3. Third, create an action plan comprised of the actions you feel will best help solve the problem. Your plan needs to be realistic and achievable with available information and a designated time frame, yet still be challenging and interesting to you and your group. Work locally with people in your community.
4. Finally, implement your plan. Divide tasks among group members and interested participants and set timelines for each step, as well as an overall deadline. Record meetings and monitor your progress. We encourage volunteers to use their data to take action at a local level.

EVALUATE THE PROGRAM PLAN

Evaluation of your river study is important, as it helps to identify successes and improve future monitoring efforts. Consider whether or not you were able to meet the goals you set prior to beginning stream monitoring. Was time a major limitation? Did you take on too many sampling sites? Did you feel comfortable using the equipment or would another Montana Watercourse Water Monitoring training workshop be helpful? What did you learn? If you developed an action plan, was it successful?

In evaluating your stream or river study, you will likely come up with additional questions. Feel free to contact the Montana Watercourse, as we want to help with the continued success of your volunteer monitoring project and the statewide volunteer stream monitoring program.

Did you feel comfortable using the equipment or would another Montana Watercourse Water Monitoring training workshop be helpful?

STATISTICS 101

(Adapted from the Vermont Volunteer Surface Water Monitoring Guide*, Picotte and Boudette, 2005)*

There are many different ways to look at the values you obtained while measuring water quality. If you have a large data set or data from several years, presenting all of this can be cumbersome and your story can be buried amidst the numbers. Using some simple statistics can reduce the volume of data to relatively few numbers that summarize the data set. Commonly used statistics include averages, geometric means, medians, and quartiles. Be aware that these summaries become highly unrepresentative of your data if you use only a few data points. A minimum of five data points is recommended to calculate any of the statistical summaries.

Average (arithmetic mean): The average is calculated by adding all the values and dividing by the number of the values. Averages are representative or typical of all the sample observations. A problem can occur when you have a few very high or very low numbers that distort results. The term mean also refers to the average.

Example: 6 + 6.5 + 6.8 + 7.0 + 7.5 + 7.5 + 8 + 9 + 9 + 9.5 + 10 + 10 = 96.9
96.9/12 = **8.1**

Remember, some results cannot be averaged (eg. pH), so the median value may be more useful.

Median: The median is the value that divides the distribution of the data into two halves. In other words, 50 percent of the values are above the median and 50 percent below. Medians are meant to be a value representative or typical of the dataset. The median is not affected by outliers (values that are extremely high or low) and is frequently more representative of data than the average. This is particularly true when the dataset contains only a few very high or very low numbers.

Example: *Put values in numerical order from lowest to highest:*
6 6.5 6.8 7 7.5 7.5 8 9 9 9.5 10 10
7.5 + 8 = 15.5
15.5/2 = **7.75**

Since there is an even number of values, the median is the average of the two middle values. If there were an odd number of values the median would be the middle value.

Quartiles and the Interquartile Range: Quartiles are the values below which lie 25%, 50%, and 75% of the values in a dataset. Another way to look at the quartiles is that 50% of your data, or the interquartile range, lies between the 25% and the 75% quartiles. If these quartiles are far apart, it means there is a lot of variability in your data. If they are close together, it means your dataset is relatively consistent and is clustered about the median.

Example: 6 6.5 6.8 | 7 7.5 7.5 | 8 9 9 | 9.5 10 10

Quartile 1 (25%) (6.8 + 7)/2 = 6.9

Median

Quartile 3 (75%) (9 + 9.5)/2 = 9.25

Standard deviation: Standard deviation (SD) describes the variability of the datapoints around the average. For a normally distributed population, the average plus or minus one standard deviation represents a 66% confidence interval. Confidence intervals and standard deviations will be larger when there is a lot of variability. Most scientific calculators have a function for calculating standard deviation and some will perform confidence intervals.

Confidence interval: Confidence interval is a group of continuous values that tends to include the true value a predetermined portion of the time. For example, if we say that the 95% confidence interval for parameter "y" is 6 to 26, that means we are confident that 95% of the time the true value of parameter "y" is between 6 and 26. You may not be able to establish accurate confidence intervals until several years of data have been accumulated.

Geometric Mean: The geometric mean reduces the influence of very high and very low numbers on the dataset. The geometric mean is commonly used to summarize bacteria data, since the values can fluctuate from single digits into the thousands. There are several ways to calculate a geometric mean.

The Geometric Mean can be calculated using the following equation:

GM = (r1 x r2 x r3…rN)1/N

Where: R = the value for samples 1, 2, 3 through the Nth sample.

N = the total number of samples collected

Using an example data set for E. coli (where bacteria is measured in cfu/100mL = colony forming units per 100 milliliters of water), the calculation looks like this:

GM = (22 x 234 x 17 x 36 x 188 x 77 x 89) = 4,059,088,697,664

(4,059,088,697,664)1/7 = 63 cfu/100mL

It may be easier to convert the fraction (in this case 1/7) into a decimal for calculations.

In general, it is recommended to use the median instead of the average, particularly if you have atypically high or low numbers. If you do not have atypically high or low numbers, then the median may be the same as the average. For temperature and dissolved oxygen, we suggest that you calculate seasonal medians because these vary naturally with the seasons. For example, if you are sampling during the fall and spring, you should calculate separate summaries for each. The geometric mean is most often used for bacteria, and the interquartile range can be used by all data sets when spread would be useful to see.

Presenting the data

(Adapted from the US EPA Volunteer Stream Monitoring: Methods Manual*, 1996)*

Analyzing and presenting numerical data is very difficult using tables filled with numbers. Graphs and charts are one of the best ways to summarize your findings and show the bottom line for each site (i.e., is it good or bad) and seasonal and year to year trends.

How will your audience best understand what you've found?

GRAPHS AND CHARTS

Graphs can be used to display the summarized results of large data sets and to simplify complicated issues and findings. The three basic types of graphs that are typically used to present volunteer monitoring data are: bar graph, line graph, and pie charts. Bar and line graphs are typically used to show results along a vertical or y-axis for a corresponding variable on a horizontal or x-axis. For example, the x-axis could be the date or time of day and the y-axis could be the parameter measured, such as pH. These types of graphs can also have two vertical axes, one on each side, with two sets of results shown in relation to each other and to the variable along the x-axis.

Bar Graph – A bar graph uses columns with heights that represent the value of the data point for the parameter being plotted. Figure (a) is an example using fictional data from Volunteer Creek.

Line Graph – A line graph is constructed by connecting the data points with a line. It can be effectively used for depicting changes over time or space. This type of graph places more emphasis on trends and the relationship among data points and less emphasis on any particular data point. Figure (b) is an example of a line graph again using fictional data from Volunteer Creek.

Pie Chart – Pie charts are used to compare categories within the data set to the whole. The proportion of each category is represented by the size of the wedge. Pie charts like Figure (c) are popular due to their simplicity and clarity, but are not very useful in conveying complex scientific data.

Image #41: Types of Graphs

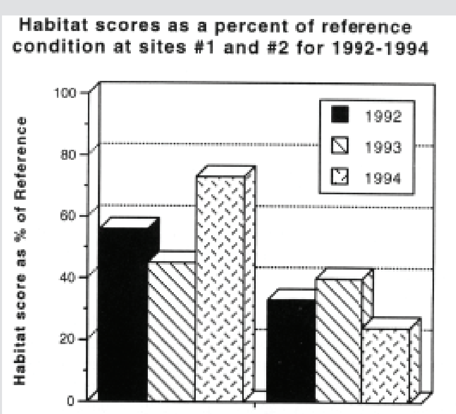


Figure a. Bar graph displaying habitat data.

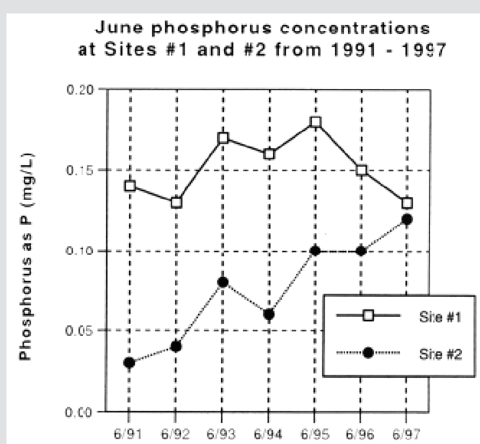


Figure b. Line graph.

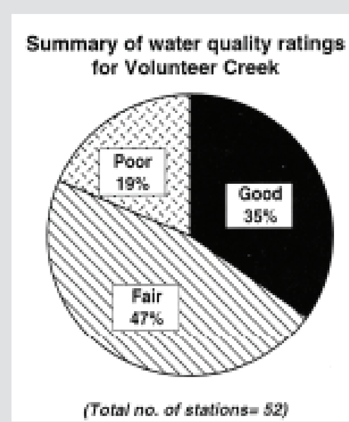


Figure c. Pie chart summarizing water quality ratings

GRAPHING TIPS

Regardless of which graphic style you choose, follow these tips to ensure you use them most effectively:

- Each graph should have a clear purpose. The graph should be easy to interpret on its own and should relate directly to the content of the text of a document or the script of a presentation.
- The data points on a graph should be proportional to the actual values to avoid distorting the meaning of the graph. Labeling should be clear and accurate and the data values should be easily interpreted from the scales. Do not overcrowd the points or values along the axes. If there is a possibility of misinterpretation, accompany the graph with a table of the data.
- Keep it simple. The more complex the graph, the greater the possibility for misinterpretation.
- Limit the number of elements. Pie charts should be limited to five or six wedges, the bars in a bar graph should fit easily, and the lines in a line graph should be limited to three or less.
- Consider the proportions of the graph and expand the elements to fill the dimensions, thereby creating a balanced effect. Often, a horizontal format is more visually appealing and makes labeling easier. Try not to use abbreviations that are not obvious to someone who is unfamiliar with the program.
- Create titles that are simple, yet adequately describe the information portrayed in the graph.
- Use a legend to describe the categories within the graph. Accompanying captions may also be needed to provide an adequate description of the elements.

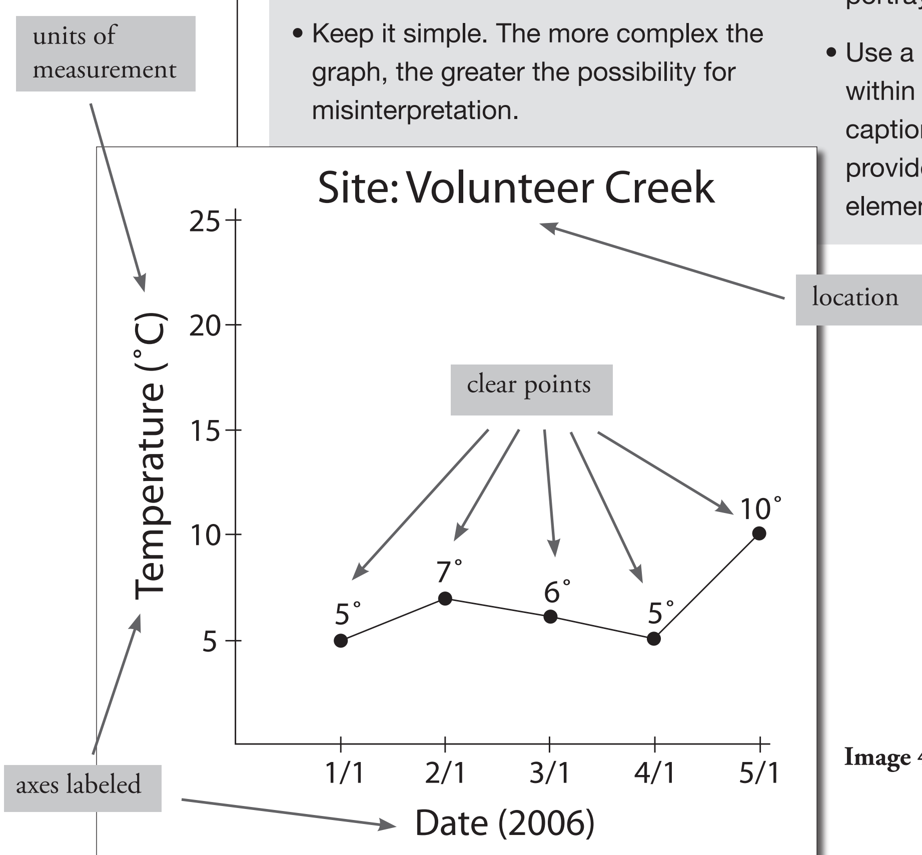


Image 42: Key Elements of a Graph

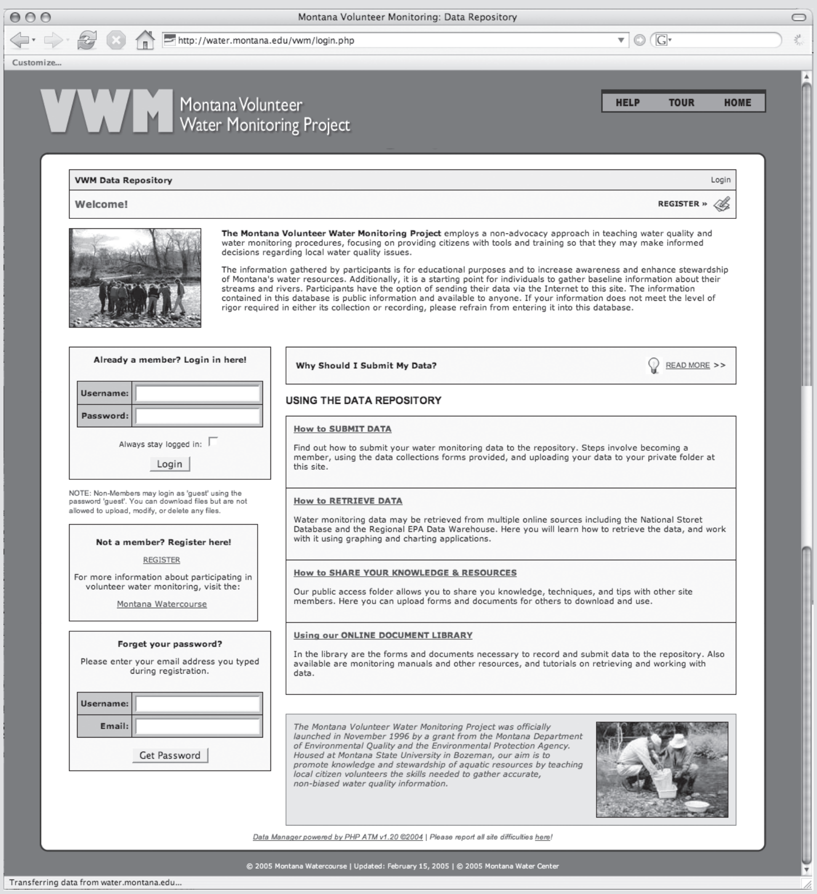
Data Reporting

VOLUNTEER STREAM MONITORING INTERNET DATABASE

Montana Watercourse encourages you to share your data by entering it online at http://water.montana.edu/vwm/login.php.

This database is yours, giving you a location to store and retrieve your data. Entry in this database also makes your data accessible to the general public, other volunteers, agencies, and anyone else interested in Montana's water quality.

To enter your stream data, you first need to register yourself or your group and your stream site through the database. Please take the tour of the database on the website to get yourself acquainted with the process.



Volunteers are strongly encouraged to enter their data through this system.

If you don't have a computer or Internet access at home, most libraries have public Internet access. Another option is to partner with a school or another organization (Conservation Districts or Watershed Councils) that might have a computer with Internet access. Or, you can send your hard copies to Montana Watercourse.

Call or e-mail Montana Watercourse for help.

Photos courtesy of:

Laura Alvey	Irrigation	13
Frances Graham	Mountain Stream	14
	Physical and Chemical	37
istockphoto.com	Water drops	Cover
Stuart Jennings	Mining	13
Montana Water Center	Fort Peck Reservoir	Cover
	West Gallatin River	Cover
	Blue Water Task Force	6
	Biological	37
Montana Watercourse	Headwater Stream	Cover
	Plains Stream	14
	Caddisfly, Macrophyte	17
	Eastern Headwaters	18
Montana Wetlands Legacy	Bull River	Cover
Ted Sedell	Cutthroat trout	17, 57
Debbie Zarnt:	Recreation	13
	Flooding	15

Images courtesy of:

Images courtesy of	Image #	Title	Page #
EPA	8	Cross Section of a Watershed	13
	41	Types of Graphs	65
Federal Interagency Stream Restoration Working Group	14	Stream Order	17
Hach, Co.	19	Accuracy and Precision Target	32
	37	Nitrogen Cycle	53
Emily Harrington (Kestrel Designs)	1	Hydrologic Cycle	9
	3	Water Molecule	10
	4	Example of Pollution Points (Adapted from USGS)	11
	5	Ground Layers	11
	6a, b	Unconfined, Confined Aquifer	12
	7	Ground Water Features (Adapted from FISRWG)	12
	10	Components of a Healthy Stream System	15
	11	Examples of Substrate Material	16
	12a	Common Stream Shapes	16
	12b	Gradient from Headwaters to Lower Reaches	16
	13	Common Channel Shapes	17
	20	Site Length	38
	21	Site Sketch	39
	22	Cross-Section Profile	40
	23	Bankfull Indicators	40
	24	Cross-Section Profile Measurements	40
	25	Measuring Velocity	41
	26	Water Collection	42
	27	Substrate Collection	43
	28	How to Measure a Rock	43
	31a,b	pH Pocket Pal	46
	32	Steps for Alkalinity Test	48
	34	DO Test Procedures	50
	36a, b	Conductivity Pocket Pal	52
	38	Materials in Nitrogen Test Kit	54
	39	Hardness Test Procedure	58
	40	Macroinvertebrate Life Cycle	59
	42	Key Elements of a Graph	66
Montana DEQ & Mediaworks, 2006	9a	Average Annual Runoff	14
	9b	Average Annual Precipitation	14
Montana Water Center	16	Headwaters to a Continent	21
NRIS	17	Montana's Major Watersheds	21
	18	4th Field HUCs of Montana	22
Stapp and Mitchell	29	Water Temperature Ranges	44
	30	pH Ranges that Support Aquatic Life	46
	33	Dissolved Oxygen Ranges for Aquatic Life	49
	35	Oxygen Saturation Chart	51
United States Geological Survey, 2006	2	Distribution of Earth's Water	9
Vannote, et al	15	River Continuum Concept	19

Behar, S. (1997). *Testing the waters: Chemical & physical vital signs of a river*. Portland, OR: The River Network.

Chaplin, M., PhD. (2006). *Water structure and behavior.* Retrieved 15 Aug. 2006 from <www.lsbu.ac.uk/water/chaplin.html>.

Crighton, L., and J. Hosier. (2005). *Volunteer stream monitoring training manual*. Indianapolis, IN: Hoosier Riverwatch.

Dunne, T., and L. B. Leopold. (1978). *Water in environmental planning*. San Francisco, CA: W.H. Freeman and Company.

Federal Interagency Stream Restoration Working Group. (1998). *Stream corridor restoration: Principles, processes, and practices*. Washington, DC: Government Printing Office.

International Project WET. (2002). *Healthy water, healthy people testing kit manual*. Bozeman, MT.

Horn, B. and G. Dates. (2005). *Watershed monitoring and assessment design workbook*. Denver, CO: The Rocky Mountain Watershed Network.

Mitchell, M., and W. Stapp. (2000). *Field manual for water quality monitoring,* (12th ed.). Dubuque, IA: Kendall/ Hunt Publishing Company.

Montana Department of Environmental Quality. (2006). *Montana stream management guide*. Helena, MT: Montana Department of Environmental Quality.

Murdoch, T., and M. Cheo. (1996). *Streamkeeper's field guide: Watershed inventory and stream monitoring methods*. Everett, WA: Adopt-A-Stream foundation.

Picotte, A., and L. Boudette. (2005). *Vermont volunteer surface water monitoring guide*. Waterbury, VT: Vermont Dept. of Environmental Conservation.

Strahler, A.N. (1957). *Quantitative analysis of watershed geomorphology*. American Geophysical Union Transactions 38: 913-920.

Strapp, W., and M. Mitchell. (1995). *Field manual for global low-cost water quality monitoring.* (1st ed.). Dexter, MI: Thomson-Shore Printers.

US EPA. (1996). *Volunteer stream monitoring, a methods manual*. Washington, DC: US Environmental Protection Agency.

US EPA. (1996). *The volunteer monitor's guide to quality assurance project plans*. Washington, DC: US Environmental Protection Agency.

US Geological Survey. (2006). *Water science for schools*. Retrieved 15 Aug. 2006 from <http://ga.water.usgs.gov/edu/index.html>.

US Geological Survey. (2005). *The 100-year flood.* Fact Sheet 229-96. Retrieved 15 Aug. 2006 from <http://pubs.usgs.gov/fs/FS-229-96/>.

Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell, and C. E. Cushing. (1980). *The river continuum concept.* Can. J. Fish. Aquatic. Sci. 37:130–137.

Water Quality Association. (2000). *Water hardness classifications*. Retrieved 14 Aug. 2006 from <http://www.wqa.org/sitelogic.cfm?ID=362>.

Accuracy: A data quality indicator used to show the extent of agreement between an observed value (the sample) and the accepted value of the parameter being measured.

Adhesion: Water molecules that stick to other substances, such as wood or rocks.

Algae: A primitive plant ranging from one to many cells in size that lives in fresh or salt water.

Alkalinity: The capacity of water to neutralize acid.

Anion: An ion that has a negative electric charge.

Aquatic insect: Insect species that spends at least part of its life in water (often the juvenile life stages of flying insects).

Aquifer: An underground geological formation containing water; may be unconfined (water must flow) or confined (not permeable, very slow recharge).

Arithmetic mean: The average, or mean, and is calculated by adding all the values and dividing by the number of the values.

Bankfull: Bankfull is the level at which water completely fills the active channel and begins to overflow onto the adjacent floodplain.

Baseflow: The lowest flow in a stream.

Bedrock: Unbroken solid rock, overlain in most places by soil or sediment.

Benthic: Bottom-dwelling. The plant and animal life whose habitat is the bottom of a sea, lake, or river.

Bias: A prejudice, usually in the sense of having a preference for one particular viewpoint or perspective.

Biological monitoring: The use of biological entity as a detector and its response as a measure to determine environmental conditions.

Blank: A “clean” sample (e.g., distilled water) that is otherwise treated the same as other samples taken from the field.

Catchment (also drainage basin or watershed): The land area draining into a body of water.

Cation: An ion that has a positive electric charge.

Channelization: The straightening and deepening of streams. Channelization increases bed and bank erosion, reduces the ability of the stream to assimilate waste, and destroys habitat of fish and other aquatic life.

Chemical measurements: Measurements of the chemical properties of water, such as pH, dissolved oxygen, or nutrients.

Coarse Particulate Organic Matter (CPOM): Organic and woody debris, such as leaves and twigs.

Cohesion: Water molecules are attracted to other water molecules.

Conductivity: A measure of the water’s ability to conduct an electric current, directly related to dissolved ions in the water.

Confidence interval: A group of continuous values that tends to include the true value a predetermined portion of the time.

Confined aquifer: A layer of geologic material (usually clay) that impedes the movement of water into the aquifer from above.

Conifer: A type of cone-bearing tree or shrub (a pine or fir tree, for example).

Cover: Overhanging or instream structures (such as tree roots, undercut streambanks, or boulders) that offer protection from predators, shelter from strong currents, and/or shading.

Cubic Feet per Second: The rate of discharge representing a volume of one cubic foot passing a given point during one second (ft^3/s or CFS).

Current: The velocity (speed) of the flow of water.

Deciduous: A type of tree that sheds its foliage at the end of the growing season.

Decomposition: To break down organic matter from a complex to a simpler form.

Discharge: The rate at which a volume of water passes through a certain place per unit of time.

Dissolved Oxygen (DO): The amount of oxygen dissolved in water. Generally, proportionately higher amounts of oxygen can be dissolved in colder waters than in warmer waters.

Drainage basin (also watershed): The land area draining into a body of water.

Duplicate: A repeated measure of the same sample to determine if the method is reproducible.

Ecosystem: The interacting system of a biological community (plants, animals) and its non living environment (land, air, water, rock, solar energy).

Effluent: The wastewater from a municipal or industrial source that is discharged.

EPT Index: (Ephemeroptera, Plecoptera, Trichoptera) summarizes the species richness within the insect groups that are considered sensitive.

Erosion: The wearing away of the land surface by wind or water.

Fine Particulate Organic Matter (FPOM): Fine organic debris that is derived from aquatic insects, animal (fish, amphibian) tissue, and leaves.

Flocculent (floc): An aggregation of suspended particles formed in a fluid.

Floodplain: An area on both sides of a stream or river where flood waters spread out during high rains and rapid snowmelt. The surface may appear dry for most of the year, but is commonly occupied by plants that are adapted to moist soil.

Gaining stream: When a stream or river receives water into its channel from a ground-water source.

Geometric mean: An average or mean that reduces the influence of very high and very low numbers in a dataset.

Global Positioning System (GPS): A satellite-based navigation system in which the user has a receiver that calculates the exact latitude and longitude of a given location.

Gradient: The slope or steepness of the stream.

Groundwater: The supply of freshwater under the earth's surface in an aquifer or soil.

Habitat: The specific environment in which an organism lives and depends on for food and shelter.

Hardness: A measure of calcium and magnesium ions in water. Hard water makes using soap difficult because it won't lather.

Headwaters: The start of a stream. Often, creeks at the uppermost end of a stream system found in the mountains that contribute to larger creeks and rivers. Sometimes lakes and ponds are "headwaters" to a stream.

Hydrologic cycle: The transfer of water from precipitation to surface water and ground water to storage and runoff and eventually back to the atmosphere in an ongoing cycle.

Indicator species: Animals or plants that are unique environmental indicators as they offer a signal of the biological condition in a watershed.

Intermittent stream: A watercourse that flows only at certain times of the year.

Invertebrate: An organism without a backbone.

Losing stream: When a river or stream loses water to the ground.

Macroinvertebrates: Animals that do not have backbones and are visible to the naked eye.

Macrophytes: Rooted aquatic plants that grow in or on the water. They have true roots, flowers, and leaves.

Median: The middle value in between the highest and lowest data points.

Monitor: To measure a characteristic, such as streambank condition, dissolved oxygen, or fish population, over a period of time using evaluation methods to measure change.

Nephelometric Turbidity Units (NTU): A unit of measurement commonly used in electronic turbidity meters that indicate how far light can penetrate into a water sample before the cloudiness of the sample cuts into the light.

Nitrogen cycle: The transfer of nitrogen from bacteria to plants to animals and back to the soil in an ongoing cycle.

Non point source pollution: Pollution generated from large areas with no particular point of pollutant origin, but rather from many individual places. Urban and agricultural areas generate non point source pollutants. The source of pollution that may be unknown.

Nutrient: Any substance, such as fertilizer, phosphorous, and nitrogen compounds, which enhances the growth of plants and animals.

Outlier: a value or number that is far away from the rest of the values.

Peak flow: The greatest flow in a stream.

Perennial stream: A watercourse that flows continuously throughout the year.

pH: The measurement of acidity or alkalinity on a scale of 0-14. A pH of 7 is neutral, less than 7 is acidic, and more than 7 is alkaline or basic.

Phosphorus: An essential plant nutrient that, in excessive quantities, can contribute to the pollution of water bodies.

Photosynthesis: A process by which green plants and other organisms produce simple carbohydrates from carbon dioxide and hydrogen, using energy from the sun.

Physical characteristic: The physical aspects of streams and rivers that include streamflow, channel shape, size of substrate, and type of vegetation.

Phytoplankton: Small, free-floating aquatic plants.

Piscivorous: Fish-eating, feeding habitually or mainly on fish.

Planktivorous: Plankton-eating, feeding primarily on phytoplankton.

Point source pollution: A known discharge of pollution via an identifiable pipe, vent, or culvert.

Pool: An area of relatively deep, slow running water in a stream.

Pond: A body of freshwater, smaller than a lake.

Precision: A data quality indicator that measures the level of agreement or variability among a set of repeated measurements, obtained under similar conditions.

Primary production: The production of organic compounds from atmospheric or aquatic carbon dioxide, usually through the process of photosynthesis.

Quality Assurance (QA): Assessing the quality of data—its accuracy, precision, completeness, representativeness, and comparability. QA asks if we are doing the right things.

Quality Assurance Project Plan (QAPP): A formal written document (plan) that will be followed to achieve a specific project's data quality requirements.

Quality Control (QC): Using standard acceptable methods. The system of checks that are used to generate excellence, or quality, in a program. QC asks if we are doing things right.

Quartile: Are the values below which lie 25%, 50%, and 75% of the values in a set of numbers.

Reach: A stream section with fairly homogeneous characteristics.

Recharge: To replenish water either by rainfall or a melting snowpack.

Riffle: A shallow, gravel area of streambed with swift current. Riffles are aquatic insect habitat and are used for spawning by salmonids and other fishes.

Riprap: A retaining wall usually built of rocks or concrete.

Riparian area: The land adjacent to and along a watercourse that is the transition zone between the water and the uplands.

Run: A stretch of fast, smooth current, deeper than a riffle.

Runoff: The portion of rainfall, melted snow, or irrigation water that flows across ground surface and eventually returns to streams. Runoff can pick up pollutants from the air or the land and carry them to streams, lakes, and oceans.

Sampling Analysis Plan (SAP): Planning documents describing a particular study or data collection effort to support broader program (or project) objectives.

Scientific method: A process with objectives to construct an accurate, reliable, and consistent representation of the world.

Secchi disk: A black and white disk used to measure water transparency.

Sediment: Fine soil or mineral particles that settle to the bottom of or are suspended in the water.

Silt: Fine particles of soil or rock that can be picked up by air or water and deposited as sediment.

Sinuous: The amount of curvature in a stream channel.

Solvent: The ability to dissolve substances; water is a solvent.

Specific heat: The amount of heat that must be absorbed or lost for 1 g of that substance to change its temperature by 1° C. The specific heat of water is 1.00 cal/g °C. Compared with most other substances, water has an unusually high specific heat.

Split sample: A sample that has been equally divided into two or more subsamples and submitted to different analysts or laboratories. Used to measure the precision of analytical methods.

Standard: A sample of known concentration.

Standard deviation: Used to determine precision. The most common calculation used to measure the range of variation among repeated measurements.

Storm water runoff: Water that washes off the land after a rainstorm. In developed watersheds it flows off pavement into storm drains which may feed directly into the stream; often carries concentrated pollutants.

Stream corridor: A perennial or intermittent stream, its lower and upper banks.

Stream flow: The amount of water moving in a stream in a given amount of time.

Stream mouth: The section of a stream where it empties into a lake, ocean, or another stream.

Substrate: The material that makes up the bottom layer of the stream, such as gravel, sand, or bedrock.

Suspended sediments: Fine material or soil particles that remain suspended by the current until deposited in areas of weaker current. They create turbidity that can be measured in a laboratory as “Total Suspended Solids” (TSS).

Topography: The configuration of a surface area including its relief, or relative elevations, and the position of its natural and man-made features.

Topographic map: A map representing surface features of a particular area.

Total Maximum Daily Load (TMDL): Refers to the Clean Water Act’s Section 303(d) requirements. A calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards.

Transparency: An indicator of how well light passes directly through water from the surface down.

Turbidity: The cloudiness in water caused by suspended sediments.

Turbidity tube: A tube with a Secchi disk attached to the bottom to measure the turbidity of the water.

Unconfined aquifer: An aquifer that is directly connected to the water on the ground above and is recharged directly from the infiltration of precipitation.

Unsaturated zone: The soil, sediments, or bedrock above an aquifer where the air spaces are not completely filled with water.

Velocity: A measure of the rate of speed and direction.

Watershed: The entire surface drainage area that contributes water to a stream or river. Many watersheds which drain into a common river make a drainage basin.

Water quality: The condition of the water with regard to the presence or absence of pollution.

Water table: The boundary between the unsaturated zone and the top of the aquifer.

Wetlands: Lands where saturation with water is the dominant factor determining the nature of soil development. They also can be identified by unique plants which have adapted to oxygen-deficient (anaerobic) soils. Wetlands influence stream flows and water quality.

Width/Depth ratio: The maximum depth of your stream divided by the width of your stream. It gives you a profile of your stream over time.

Zone: To designate, by ordinances, areas of land reserved and regulated for specific uses, such as residential, industrial, or open space.

B APPENDIX
Acronyms

BMP	Best Management Practice
BWTF	Blue Water Task Force
cfs	cubic feet per second
CPOM	Coarse Particulate Organic Matter
CWA	Clean Water Act
DO	Dissolved Oxygen
EPT	Ephemeroptera, Plecoptera, Tricoptera
FPOM	Fine Particulate Organic Matter
GIS	Geographical Information Systems
GPS	Global Positioning System
HUC	Hydrologic Unit Code
L	Liter
μS	microSeimen
mg	milligram
MSDS	Material Safety Data Sheet
MSU	Montana State University
MT DEQ	Montana Department of Environmental Quality
MT FWP	Montana Fish, Wildlife, and Parks
NRIS	Natural Resources Information System
NTU	Nephelometric Turbidity Units
PFD	Personal Flotation Device
PTI	Pollution Tolerance Index
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
RCC	River Continuum Concept
SAP	Sample Analysis Plan
STORET	Storage and Retrieval (EPA's Database)
TMDL	Total Maximum Daily Load
U.S. EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VWM	Volunteer Water Monitoring

GENERAL

- ❑ Montana Volunteer Water Monitoring Training Handbook
- ❑ Data sheets (in Appendix)
- ❑ Clipboard / pen or pencil
- ❑ Waders or water shoes
- ❑ First aid kit
- ❑ GPS unit
- ❑ Topographic map
- ❑ Phone for emergencies

VISUAL & PHOTO SURVEY

- ❑ Visual Survey & Photo Survey data sheets
- ❑ Camera w/ film

CHEMICAL

- ❑ Water quality data sheet
- ❑ Water quality testing kit(s)
- ❑ Thermometer
- ❑ Disposable latex or nitrile gloves
- ❑ Glasses or goggles
- ❑ Waste bucket w/ lid (for example, milk jug)
- ❑ Distilled or deionized water for rinsing
- ❑ Timer or wristwatch
- ❑ Plastic beaker
- ❑ Rinse bottle

PHYSICAL

- ❑ Stream Profile & Flow Data Sheets
- ❑ 100-foot tape measure
- ❑ Yardstick
- ❑ Stakes (4) or flagging to mark site (optional)
- ❑ Tennis ball
- ❑ Twine or rope
- ❑ Line level
- ❑ Stopwatch or wristwatch with second hand
- ❑ Transparency or Turbidity tube (or both)

BIOLOGICAL

- ❑ Macroinvertebrate data sheets
- ❑ D-net or kicknet
- ❑ White plastic dishpan or tray
- ❑ White ice cube trays
- ❑ Plastic petri dishes
- ❑ Plastic pipettes
- ❑ Plastic spoons
- ❑ Forceps or tweezers
- ❑ Stopwatch or wristwatch w/ secondhand
- ❑ Hand lens or microscope

Resources for Monitoring

- **Cooperative State Research, Education, and Extension Service (CSREES)** www.usawaterquality.org
  This site is designed for scientists, instructors, and extension educators to learn about successful water quality improvement programs across the nation by linking to Regional Water Coordination Programs or browsing through content of the national topical themes, accomplishments, and success stories.

- **Hoosier Riverwatch (Indiana)** www.in.gov/dnr/riverwatch
  An Indiana state-sponsored water quality monitoring program website.

- **Montana Department of Environmental Quality (DEQ)** www.deq.state.mt.us/wqinfo/index.asp
  This website is designed to provide access to organizational information, laws, rules, permitting information, standards, and bulletins related to water quality in Montana.

- **Montana NRIS Water Information** nris.mt.gov/wi.asp
  A great starting point for locating water resources information in Montana, such as data on surface water, groundwater, water quality, riparian areas, water rights, climate data, and more.

- **Montana Watercourse** www.mtwatercourse.org
  A statewide water education program that supports water resource decision-making and stewardship by providing unbiased information, resources, tools and education to all water users.

- **Montana Volunteer Water Monitoring Project** water.montana.edu/vwm/login.php
  The Montana Watercourse's online Volunteer Water Monitoring data repository for volunteer monitoring groups to share their data. The information gathered by participants is for educational purposes, increasing awareness, and enhancing stewardship of Montana's water resources.

- **River Network** www.riverwatch.org
  The nation's leader in supporting grassroots river and watershed conservation groups, this site is designed to link people with river information, resources, and services.

- **Rocky Mountain Watershed Network (RMWN)** www.rmwn.org
  The Rocky Mountain Watershed Network (RMWN) promotes and supports volunteer monitoring programs at the regional, state, and watershed levels.

- **US Environment Protection Agency QAPP Guidelines** www.epa.gov/owow/monitoring/volunteer/qappcovr.htm
  This website outlines the procedures for those who conduct a monitoring project to ensure that the data they collect and analyze meets project requirements. This document is designed to encourage and facilitate the development of volunteer QAPPs by clearly presenting explanations and examples.

- **US Environmental Protection Agency (EPA)** www.epa.gov/owow/monitoring/vol.html
  Volunteer Monitoring: This website contains resources and information for establishing a volunteer monitoring program with topics that include, project design, methods, and data management.

- **US Geological Survey Water Resources** water.usgs.gov
  Provides water resources and information such as publications, data, maps, and applications software for the entire United States.

Typical Values of Chemical Parameters Found in Healthy Streams

This table presents typical values for your parameters in healthy streams. Use this, as well as the state water quality standards, to evaluate trouble spots.

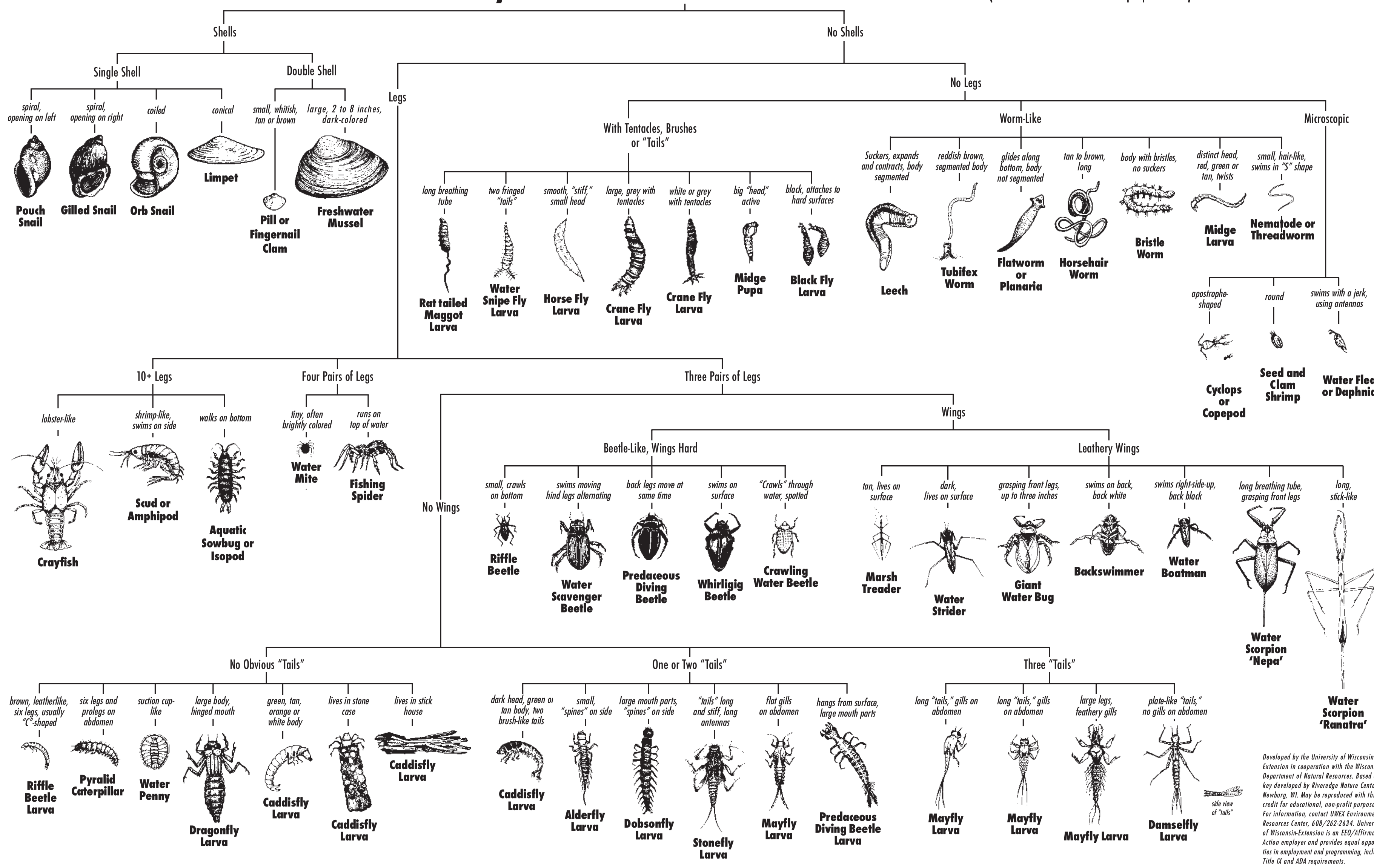
Chemical Parameter	Typical Value
DISSOLVED OXYGEN	Since values are temperature-dependent, it is best to look at % saturation to determine if oxygen levels are adequate. Generally speaking, oxygen levels rarely dip below 9 ppm under healthy conditions.
TEMPERATURE	Most warm water aquatic systems cannot thrive at temperatures much above 80-85 degrees F (27-29 degrees C) for extended periods. Cold water fisheries have very sensitive fauna and flora that cannot thrive much above 60-65 degrees F (15-19 degrees C).
% SATURATION OXYGEN	Values of percent saturation of oxygen generally fall between 80% and 120%. Anything above or below that range is cause for concern.
pH	Although some streams are naturally acidic, anything below 6 or above 8.5 is not considered typical.
ALKALINITY	Any stream with less than 20 mg/l (ppm) of alkalinity has little buffering capacity and is at risk for impact from acidic deposition.
NITRATES	Typical values in non-impacted streams are below 1 mg/L.
ORTHOPHOSPHATES	Typical values in non-impacted streams are below 0.01 mg/L (ppm). Levels of greater than 0.1 mg/L are cause for concern.
TURBIDITY	Turbidity values of greater than 50 NTUs are considered turbid. A 10–day average of greater than 10 NTUs is problematic for trout waters and greater than 25 NTUs for non-trout waters.

HWHP Field MonitoringGuide, Appendix 1

Interpreting Your Water Quality Data

Key to Macroinvertebrate Life in the River

(Sizes of illustrations are not proportional.)



Developed by the University of Wisconsin-Extension in cooperation with the Wisconsin Department of Natural Resources. Based on a key developed by Riveredge Nature Center, Newburg, WI. May be reproduced with this credit for educational, non-profit purposes. For information, contact UWEX Environmental Resources Center, 608/262-2634. University of Wisconsin-Extension is an EEO/Affirmative Action employer and provides equal opportunities in employment and programming, including Title IX and ADA requirements.

Sampling Analysis Plan

Volunteer monitoring groups are encouraged to develop QAPPs and SAPs. To be eligible for MT DEQ and EPA certification groups must have a completed QAPP or SAP. Sampling Analysis Plans will be reviewed for these basic elements. For assistance, please contact Montana Watercourse.

1. Introduction and Background Information
- Site history (reference from QAPP or provide details if QAPP doesn't address this site)
- Regulatory framework or action levels (e.g., DEQ-7, ARM, Reference Conditions)
- Summary of previous investigations and conclusions (if any)
- Location and characteristics of any known pollution sources at the site or in the area
- Site location map showing relevant features of the surrounding area

2. Objectives and Design of the Investigation
- Objectives of this study (describe how they support the QAPP's goals and objectives)
- Provide the study design (i.e., sample characteristics, spatial/temporal limits, and the smallest subpopulation, area, volume, or time frame for which separate decisions must be made)
- Sampling station locations
- Rationale for station selection
- Site map(s) showing sampling stations and other pertinent features
- Proposed reference sites (if not previously established)
- Table showing the water depth or flow at each proposed station (if known)

3. Field Sampling Methods
- Sampling methods (can be cited from DEQ, EPA, USGS, etc.)
- Sampling equipment, including field instruments
- Consider representativeness of sample collection methods (e.g., compositing strategy)
- Sample containers and decontamination procedures
- Field documentation and sample labeling procedures
- Procedures for disposal of contaminated sediments

4. Sample Handling Procedures
- Sample storage requirements (e.g., conditions, maximum holding times)
- Chain-of-custody procedures
- Delivery of samples to analytical laboratories

5. Laboratory Analytical Methods
- Chemical analyses, methods, and target detection limits
- Biological analyses
- Corrective actions

6. Quality Assurance and Quality Control Requirements
- QA/QC for chemical analyses (precision, accuracy, reproducibility)
- QA/QC for biological analysis
- Data quality assurance review procedures

7. Data Analysis, Record Keeping, and Reporting Requirements
- Data interpretation including limits for decision error relative to the consequences.
- Record-keeping procedures
- Reporting procedures (e.g., hardcopy, STORET deliverable)

8. Schedule
- Table or figure showing key project milestones

9. Project Team and Responsibilities
- Sampling personnel (if different than shown in QAPP)
- Identify project team responsibilities

10. References
- List of references (include reference to QAPP)

Montana Volunteer Water Monitoring Project Information Sheet

If you desire to have your project data in the national EPA database and contributing to the general, publicly available water quality knowledge in your area, please work with Montana Watercourse staff to answer these questions. Following the rules makes database searches possible. Montana Watercourse will keep a copy on file to assist in data sharing efforts.

▲ This symbol indicates information that links your data to your project and stations in the database. It will need to be repeated **EXACTLY**.

Organization: MTVOLWQM (Montana Volunteer Water Quality monitoring)

FOR MTVOL PROJECT SPREADSHEET:

▲ Project ID (up to 8 characters, must be unique): ______________________

Project Name (up to 60 characters): ______________________

Project Start date (MM/DD/YYYY): ______________________

Planned project duration (up to 15 characters): ______________________

Project Description (reasons why you started): ______________________

____

____

Contact Name for the stations listed below: ______________________

FOR MTVOL STATION SPREADSHEET:

Use one line on the Excel spreadsheet for each station you sample. Latitude, longitude, method of determination, waterbody type, county and watershed code will also be required.

▲ Station ID (up to 10 characters): ______________________
(3 from your project ID, 2 first letters of your town, 2 about waterbody and up to 3 characters of your own choosing)

Station name (up to 60 characters): ______________________
(water body name first, qualifiers such as "west fork" next)

▲ Station ID (up to 10 characters): ______________________
(3 from your project ID, 2 first letters of your town, 2 about waterbody and up to 3 characters of your own choosing)

Station name (up to 60 characters): ______________________
(water body name first, qualifiers such as "west fork" next)

▲ Station ID (up to 10 characters): ______________________
(3 from your project ID, 2 first letters of your town, 2 about waterbody and up to 3 characters of your own choosing)

Station name (up to 60 characters): ______________________
(water body name first, qualifiers such as "west fork" next)

Celsius to Fahrenheit Conversion Chart

°C	°F	°C	°F	°C	°F	°C	°F
50	122.0	27	80.6	4	39.2	-19	-2.2
49	120.2	26	78.8	3	37.4	-20	-4.0
48	118.4	25	77.0	2	35.6	-21	-5.8
47	116.6	24	75.2	1	33.8	-22	-7.6
46	114.8	23	73.4	0	32.0	-23	-9.4
45	113.0	22	71.6	-1	30.2	-24	-11.2
44	111.2	21	69.8	-2	28.4	-25	-13.0
43	109.4	20	68.0	-3	26.6	-26	-14.8
42	107.6	19	66.2	-4	24.8	-27	-16.6
41	105.8	18	64.4	-5	23.0	-28	-18.4
40	104.0	17	62.6	-6	21.2	-29	-20.2
39	102.2	16	60.8	-7	19.4	-30	-22.0
38	100.4	15	59.0	-8	17.6	-31	-23.8
37	98.6	14	57.2	-9	15.8	-32	-25.6
36	96.8	13	55.4	-10	14.0	-33	-27.4
35	95.0	12	53.6	-11	12.2	-34	-29.2
34	93.2	11	51.8	-12	10.4	-35	-31.0
33	91.4	10	50.0	-13	8.6	-36	-32.8
32	89.6	9	48.2	-14	6.8	-37	-34.6
31	87.8	8	46.4	-15	5.0	-38	-36.4
30	86.0	7	44.6	-16	3.2	-39	-38.2
29	84.2	6	42.8	-17	1.4	-40	-40.0
28	82.4	5	41.0	-18	-0.4	-	-

°C = temperature in degrees Celsius, °F = temperature in degrees Fahrenheit

For greater accuracy use formula below:

To convert from Celsius to Fahrenheit:
$°F = (9/5)\ °C + 32$

To convert from Fahrenheit to Celsius:
$°C = (5/9) \times (°F - 32)$

Concept	VWMG Page	Healthy Water Healthy People—Educator's Guide	Healthy Water Healthy People—Field Monitoring Manual
Temperature	12	Going Underground p. 187	
Perspectives of Water Users	23	Multiple Perspectives p. 55	
Land Use and Watershed Health	24	Picking up the Pieces p. 182	
Scientific Method	25	Carts and Horses p. 42	
Creating a Study Design / Data Interpretation	26	Water Quality Monitoring—From Design to Data p. 70	
Accuracy and Precision in Data Collection	32	Hitting the Mark p. 49	
Turbidity	42	Turbidity or not Turbidity—That is the Question p. 83	Turbidity pg.49
Temperature	44		Temperature pg. 41
pH	45	From H to OH p. 15	pH p. 30
Alkalinity	47		Alkalinity p. 1
Dissolved Oxygen	49		Dissolved Oxygen p. 15
Conductivity	52		Conductivity p. 11
Hardness	57		Hardness p. 20
Nitrate	53		Nitrate p. 25
Phosphate	55		Phosphate p. 35
Macroinverte-brates	59	Benthic Bugs and Bioassessment p. 155	

Montana Volunteer Water Monitoring Site Information Sheet

For each site that you sample, please record the information below.
You only need to this once of each site you intend to survey.

Site ID	Must be unique in the database (10 characters)- work with Montana Watercourse to establish	
Site Name	Limit 60 characters - Waterbody Name First - (follow with qualifiers like West Fork or Lower) - then brief location description	
Description	Detailed site description	
Primary Type	Stream/river, wetland, canal, lake, pond	
Secondary Type	Required if Primary type is a canal, wetland or facility. Otherwise use "**None**"	
Latitude Degrees	Latitude in Decimal Degrees	
Longitude Degrees	Longitude in Decimal Degrees	
Geopositioning Method	Most common is GPS Code Standard Position Off - 016	
Geopositioning Datum	NAD27, NAD83, or WGS84	
Map Scale	For lat/long by map interpolation, map scale is required. (Ex: 1:2400). Otherwise leave blank.	
Ecoregion Name	Mountains, Foothiils valley, Plains , or Prairie	
State	2 character state code (MT for Montana)	
County	County the stream site is in	
Hydrologic Unit Code (HUC) or River Basin Name	8 digit Hydrologic Unit Code or Write down the major river basin name (Ex. Bozeman Creek is in the Gallatin River basin)	

9/20/2007. Montana Volunteer Water Monitoring Datasheet: Please return to Montana Watercourse, P.O. Box 170575, Bozeman, MT 59717 or call (406) 994.6671

Site Information & Summary Data Sheet

Project ID:	DATE: / / TIME:
Site ID:	Surveyors:
Stream/River:	GPS Coordinates:
Organization/School:	Site Description:

Current Weather Conditions (circle one)	Present Flow Characteristics (check one)
Cloud cover: < 5% 5 - 25% 25 - 75% 75 - 100%	☐ Perennial (flows year round)
Precipitation: None Light Moderate Heavy	☐ Intermittent (pools only, no flowing water)
Past Precip. (last 24 hr): None Light Moderate Heavy	☐ Ephemeral (dry channel, only flows after extreme storms)
Air Temp (C or F): ______.____ @ ___________ Hours	☐ Seep or spring-fed (headwater channel is less than 2 feet wide)

Stream Channel & Riparian Vegetation Summary

Presence of streamside shrubs/trees:

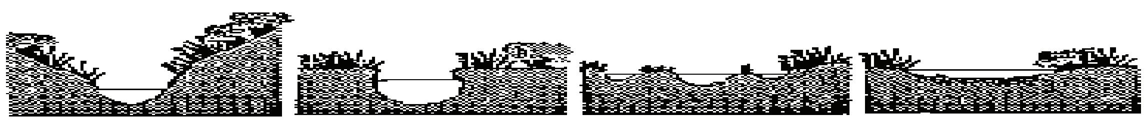
☐ All grass/no shrubs or trees ☐ All young shrubs/trees ☐ All mature shrubs & trees ☐ Mixed ages

Browsing/grazing on riparian shrubs:

☐ None/slight ☐ Some/moderate ☐ Severely used ☐ Widely spaced & mostly dead

Stream channel morphology:

☐ Steep and Narrow ☐ U-shaped ☐ Wide & Braided ☐ Wide & Shallow



Floodplain land use (check all that apply):

☐ Industrial ☐ Commercial ☐ Residental ☐ Pasture

☐ Cropland ☐ Forest ☐ Developed Park ☐ Other (specify):

Comments:

Page 39 in the VWM Guidebook

9/20/2007. Montana Volunteer Water Monitoring Datasheet: Please return to Montana Watercourse, P.O. Box 170575, Bozeman, MT 59717 or call (406) 994.6671

Site Map Drawing

Draw a map of the stream reach you are sampling. Note features that affect the stream habitat such as riffles, pools, ditches, wetlands, dams, roads, bridges, rip rap, log jams, gravel bars, vegetation and other landscape features.

Page 39 in the VWM Guidebook

9/20/2007. Montana Volunteer Water Monitoring Datasheet: Please return to Montana Watercourse, P.O. Box 170575, Bozeman, MT 59717 or call (406) 994.6671

Photographic Data Sheet

Project ID:						Surveyors:
Stream/River:						Organization/School:
		GPS Coordinates (decimal degrees)		PHOTO		
DATE	**SITE #**	**Latitude**	**Longitude**	**jpeg #**	**Time**	**COMMENTS** (Photo description, direction, conditions, etc.)

Page 39 in the VWM Guidebook

9/20/2007. Montana Volunteer Water Monitoring Datasheet: Please return to Montana Watercourse, P.O. Box 170575, Bozeman, MT 59717 or call (406) 994.6671

Water Quality Data Sheet

Project ID:	Surveyors:
Site ID:	GPS Coordinates:
Stream/River:	Site Description:
Organization/School:	

Methods and protocols for testing basic water chemistry parameters are located on pages 44 - 56 in the VWM Guidebook.

Date	Time	Air Temp.	Water Temp.	Specific Cond.	pH 1	pH 2	pH 3	Alkalinity	DO #1	DO #2	DO #3	Avg. DO	% DO Sat.	Turbidity	Nitrate	Phosphate
		C	C	uS/cm				mg/L	mg/L	mg/L	mg/L	mg/L	%	NTU or cm	mg/L	mg/L

Comments:

9/20/2007. Montana Volunteer Water Monitoring Datasheet: Please return to Montana Watercourse, P.O. Box 170575, Bozeman, MT 59717 or call (406) 994.6671

Cross Section Data Sheet

Project ID:	DATE: / / TIME:
Site ID:	Surveyors:
Stream/River:	GPS Coordinates:
Organization/School:	Site Description:

Set up the cross section by stretching a tape measure across the stream channel at bankfull level (high water mark). Facing upstream, measure cross section depths in intervals (and can be adjusted according to the width of the stream, but need at least 10 measurements) from left to right across the stream. To determine the interval, divide the cross section width (from bankful pin to bankful pin) and divide by 10. For larger streams, divide the cross-section width by 20. **Page 40 in the VWM Guidebook.**

Distance Between Cross Sections (example: 100 ft):

Measurement Intervals (example: 0.5', 1', or 2' minimum of 10 intervals):

Cross Section #1 - Interval Depths

Interval #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Sum
Bankfull Depth (ft)																										
Water Depth (ft)																										

Cross Section #2 - Interval Depths

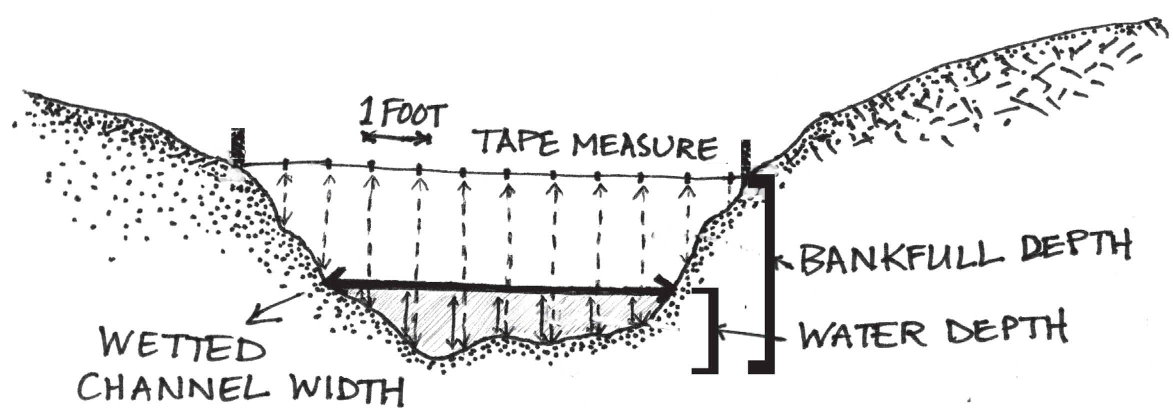
Measurement Intervals (example: 0.5', 1', or 2' minimum of 10 intervals):

Interval #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Sum
Bankfull Depth (ft)																										
Water Depth (ft)																										

Horizontal Distance

	Left Bank (bankfull)	Left Wetted Edge	Right Wetted Edge	Right Bank (bankfull)
Cross Section 1	0 ft			
Cross Section 2	0 ft			

Comments:



9/20/2007. Montana Volunteer Water Monitoring Datasheet: Please return to Montana Watercourse, P.O. Box 170575, Bozeman, MT 59717 or call (406) 994.6671

Stream Velocity Data Sheet

Project ID:	DATE: / / TIME:
Site ID:	Surveyors:
Stream/River:	GPS Coordinates:
Organization/School:	Site Description:

Measure the time it takes for a float (tennis ball) to travel downstream from cross section #1 to cross section #2. Divide the average time of ten trials by the distance between cross-sections to get average float velocity. Multiply by the correction factor (0.8) to get average stream velocity. **Page 41 in VWM Guidebook.**

Velocity Float Trials:

Trial #	1	2	3	4	5	6	7	8	9	10	Total time / # of trials
Time											

Distance: ________ **Avg Time:** ________ **Velocity = Distance / Time:** ________

Calculation of Discharge

Cross Sectional Area #1 = ________ (Sum of water depth Cross Section #1) ÷ ________ (Number of water depth measurements (wetted channel)) = ______ft (Avg. Depth) x ________ft (Wetted Width) = ________ft^2 (Area #1)

Cross Sectional Area #2 = ________ (Sum of water depth Cross Section #2) ÷ ________ (Number of water depth measurements (wetted channel)) = ______ft (Avg. Depth) x ________ft (Wetted Width) = ________ft^2 (Area #2)

Average Cross Sectional Area = ________ft^2 (Area #1) + ________ft^2 (Area #2) = ________ft^2 (Sum Areas) ÷ 2 = ________ft^2 (Avg. Cross Sectional Area)

Avg. Surface Velocity = ________ (Distance) ÷ ________ (Avg. time) = ________ (Velocity Ft/sec) x (0.8) (Correction Factor) = ________ (Avg. Corrected Velocity (ft/sec))

Flow = ________ft/sec. (Avg. Corr. Velocity) X ________ft^2 (Avg. Cross Sectional Area) = ________CFS (Cubic Feet per Second)

Substrate Composition (Pebble Count) Data Sheet

Project ID:	DATE: / / TIME:
Site ID:	Surveyors:
Stream/River:	GPS Coordinates:
Organization/School:	Site Description:

Measure a minimum of 100 substrate particles along the Intermediate axis (B axis, which is the thickness of the rock) between the two cross sections using the "zig-zag" method, crossing back and forth acroos the stream channel in an upstream fashion. Measurements are in millimeters (mm). Determine & record the percent substrate composition at the bottom of the data sheet. **Page 43 in VWM Guidebook.**

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100	101	102	103	104	105

General Particle Size Class:		**Percent Substrate Composition:**	
Bedrock =	> 4085 mm	Bedrock =	
Boulders (Large) =	509 - 4084 mm	Boulders (Large) =	
Boulders (Small) =	255 - 508 mm	Boulders (Small) =	
Cobble =	64 - 254 mm	Cobble =	
Gravel =	2.1 - 63 mm	Gravel =	
Sand (gritty) =	< 2.0 mm	Sand (gritty) =	

To determine the percent of substrate composition: 1) determine size class for each of the rocks measured. 2) Divide the number rocks in each size class by the total number of rocks measured.

Example, 100 rocks were measured throughout the monitoring site: 12 Large boulders (12/100 = .12 = 12%), 4 Small boulders (4/100 = .04 = 4%), 54 Cobble (54/100 = .54 = 54%), 27 Gravel (27/100 = .27 = 27%), and 3 Sand (3/100 = .03 = 3%).

9/20/2007. Montana Volunteer Water Monitoring Datasheet: Please return to Montana Watercourse, P.O. Box 170575, Bozeman, MT 59717 or call (406) 994.6671

Macroinvertebrate Data Sheet

Project ID:	DATES: / / TIMES:
Site ID:	Surveyors:
Stream/River:	GPS Coordinates:
Organization/School:	Station Description:

Percent Composition of Major Groups:

1. This measure provides information about the relative abundance of different groups of organisms within a sample. This is an excellent measure for developing charts or graphs.

2. Sort organisms from your sample into ice cube trays to major groups. Count the number of organisms in each of the major groups and calculate the percent composition.

3. Enter your final score on the Summary Data Sheet.

Percent Composition = Number of organisms in each group / Total number of organisms

See Page 59 in the VWM Guidebook

TAXA (ORDER OR MAJOR GROUP)	SAMPLE 1	TOTAL	%	TAXA (ORDER OR MAJOR GROUP)	SAMPLE 1	TOTAL	%
Mayflies (Order Ephemeroptera)				Crayfish (Order Decapoda)			
Stoneflies (Order Plecoptera)				Gilled Snails (Class Gastropoda, Order Prosobranchia)			
Caddisflies (Order Trichoptera)				Snails- other (Class Gastropoda, Order Pulmonata)			
Blood Midges (Order Diptera, Family				Clams (Class Pelecypoda)			
Midges- other (Order Diptera, Family				Aquatic worms (Class Oligochaeta)			
Craneflies (Order Diptera, Family Tipulidae)				Leaches (Class Hirudinea)			
Snipeflies (Order Diptera, Family Athericidae)				Alderflies (Order Megaloptera, Family Sialidae)			
Dragonflies (Order Odonata)				Other:			
Riffle Beetles (Order Coleoptera, Family				Other:			
Beetles- other (Order Coleoptera)				Other:			
Scuds (Order Amphipoda)				**TOTAL NUMBER OF ORGANISMS**			

Comments:

9/20/2007. Montana Volunteer Water Monitoring Datasheet: Please return to Montana Watercourse, P.O. Box 170575, Bozeman, MT 59717 or call (406) 994.6671

Macroinvertebrate Pollution Tolerance Index

Project ID:	DATES: / / TIMES:
Site ID:	Surveyors:
Stream/River:	GPS Coordinates:
Organization/School:	Station Description:

See page 59 in the VWM Guidebook

Pollution Tolerance Index

Put a check next to each taxa which is present in your macroinvertebrate sample. Complete the remainder of the chart. Fill out one of these for each sample.

GROUP 1 TAXA *Intolerant*		GROUP 2 TAXA *Moderately Intolerant*		GROUP 3 TAXA *Fairly Intolerant*		GROUP 4 TAXA *Very Tolerant*	
	Stonefly Nymph		Dameselfly Nymph		Black fly Larva		Segmented worms (aquatic)
	Caddisfly Larva		Dragonfly Larva		Midge Larva (excluding blood midges)		Rat-tailed Maggot
	Mayfly Nymph		Sowbug		Planaria		Left-handed snail
	Dobsonfly Larva		Scud		Leech		Blood midge (red)
	Riffle beetle		Crayfish				
	Water Penny		Cranefly Larva				
	Right-handed Snail		Clam/Mussel				
			Gilled snail				
# of taxa =		# of taxa =		# of taxa =		# of taxa =	
	x 4		x 3		x 2		x 1
Group Score =		Group Score =		Group Score =		Group Score =	

Total of all group scores = ______

Your Stream Quality Assessment:

Assessment:

23 and above	Potentially Excellent Water Quality
17 to 22	Potentially Good Water Quality
11 to 16	Potentially Fair Water Quality
10 or less	Potentially Poor Water Quality

Comments:

9/20/2007. Montana Volunteer Water Monitoring Datasheet: Please return to Montana Watercourse, P.O. Box 170575, Bozeman, MT 59717 or call (406) 994.6671

Montana Water Law and Regulations

MONTANA'S WATER RESOURCE AGENCIES

Montana's water resources are managed by these agencies:

- Montana Department of Natural Resources and Conservation (DNRC) http://dnrc.mt.gov/
- Montana Water Court http://courts.mt.gov/water/
- Montana Department of Environmental Quality (DEQ) http://www.deq.state.mt.us/

MONTANA WATER OWNERSHIP

from Water Rights in Montana February 2006 *published by the Montana Water Center*

Montana waters, in all its varied forms and locations, belong to the state. This ownership, however, exists on behalf of all state citizens. The **Montana Constitution** states that:

> *"All surface, underground, flood, and atmospheric waters within the boundaries of the state are the property of the state for the use of its people…"* (ARTICLE IX, SECTION 3(3))

Because Montana waters belong to the state, water rights holders do not own the water itself. Instead, they possess a right to use the water, within state guidelines. Accordingly, Montana law notes:

> *"A 'water right' means the right to use water…"* (SECTION 85-2-422, MCA)

Water rights in Montana are guided by the prior appropriation doctrine, that is, first in time is first in right. A person's right to use a specific quantity of water depends on when the use of water began.

Montana has closed some of its river basins to certain types of new water appropriations because of water availability problems, overappropriation, and concern for protecting existing water rights.

WATER QUALITY REGULATIONS

from A Guide to Montana Water Quality Regulation *published by the Montana Water Center*

The Montana Legislature passed its first water quality law in 1907, responding to typhoid outbreaks in the Milk River Basin. The law required treatment of all sewage discharge into public water supplies. This legislation became the first in a series leading to our current water quality statutes, collectively known as the Montana Water Quality Act (WQA).

The WQA incorporates both national and state policy by integrating the directives of the federal Clean Water Act (CWA) while also codifying the priorities of the Montana Constitution's environmental quality clauses.

Essentially, the WQA provides guidelines to prevent, abate, and control the pollution of Montana waters in a manner consistent with national standards.

While the Environmental Protection Agency (EPA) administers the CWA, Montana is delegated by that authority to implement certain CWA programs. The EPA still is involved by providing support and oversight and retaining ultimate authority to administer aspects of the CWA on a case by case basis.

The Department of Environmental Quality (DEQ) is the state agency that administers water quality law in Montana. Their activities include (but are not limited to): data collection, research, development of pollution prevention plans, and water quality monitoring.

To implement water quality laws, the Board of Environmental Review (a seven-member body appointed by the Governor to provide policy guidance) adopts classification of state waters, water quality standards, and the non-degradation policy.

Surface and ground water are classified according to the beneficial uses supported by each water body/segment.

The board formulates and adopts water quality standards specifying maximum allowable levels of alteration during use of state waters. Water quality standards are both numeric and narrative.

CLASS	BENEFICIAL USE
A-Closed	• Suitable for drinking, culinary, and food processing purposes after simple disinfection; swimming and recreation; and growth and propagation of fishes and associated aquatic life, although access restrictions to protect public health may limit actual use of these waters.
A-1	• Suitable for drinking, culinary, and food processing purposes after conventional treatment for removal of naturally present impurities; bathing, swimming, and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl, and furbearers; and agricultural and industrial water supply.
B-1	• Suitable for drinking, culinary, and food processing purposes after conventional treatment; bathing, swimming, and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl, and furbearers; and agricultural and industrial water supply.
B-2	• Suitable for drinking, culinary, and food processing purposes after conventional treatment; bathing, swimming, and recreation; growth and marginal propagation of salmonid fishes and associated aquatic life, waterfowl, and furbearers; and agricultural and industrial water supply.
B-3	• Suitable for drinking, culinary, and food processing purposes after conventional treatment; bathing, swimming, and recreation; growth and propagation of nonsalmonid fishes and associated aquatic life, waterfowl, and furbearers; and agricultural and industrial water supply.
C-1	• Suitable for bathing, swimming, and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl, and furbearers; and agricultural and industrial water supply.
C-2	• Suitable for bathing, swimming, and recreation; growth and marginal propagation of salmonid fishes and associated aquatic life, waterfowl, and furbearers; and agricultural and industrial water supply.
C-3	• Suitable for bathing, swimming, and recreation; and growth and propagation of nonsalmonid fishes and associated aquatic life, waterfowl, and furbearers. The quality of these waters is naturally marginal for drinking, culinary, and food processing purposes, agriculture, and industrial water supply.
I	• The goal of the State of Montana is to have these waters fully support the following uses: drinking, culinary, and food processing purposes after conventional treatment; bathing, swimming, and recreation; growth and propagation of fishes and associated aquatic life, waterfowl, and furbearers; and agricultural and industrial water supply.

Surface Water Classification

CLASS	BENEFICIAL USE	SPECIFIC CONDUCTANCE (microSiemens/cm at 25° C)
I	• Suitable for public and private water supplies, food processing, irrigation, etc., with little or no treatment required.	less than 1,000
II	• May be used for public and private water supplies where better quality water is not available. The primary use is for irrigation, stock water, and industrial purposes.	1,000-2,500
III	• Used primarily for stock water and industrial purposes.	2,500-15,000
IV	• Used primarily for industrial purposes.	greater than 15,000

Ground water classification.

Montana is fortunate to contain an abundance of clean water. To protect these waters, the state adopted the nondegradation policy that applies to all new or increased discharges after April 1993. There are three levels of water protection, stipulating what degradation, if any is allowable in each level. The highest level of protection pertains to the outstanding resource waters, prohibiting “to the greatest extent practicable, changes to existing water quality of those waters” (section *75-5-315(1), MCA*). The middle tier of protection applies to high quality waters. The state may authorize degradation of high-quality waters up to but not exceeding water quality standards (*sections 75-5-303(2) and (3)(c), MCA*). The lowest level of protection is for waters classified neither as ORW nor high quality waters. There is no nondegradation review requirement to discharge into these waters, but water quality standards and discharge permit conditions still apply.