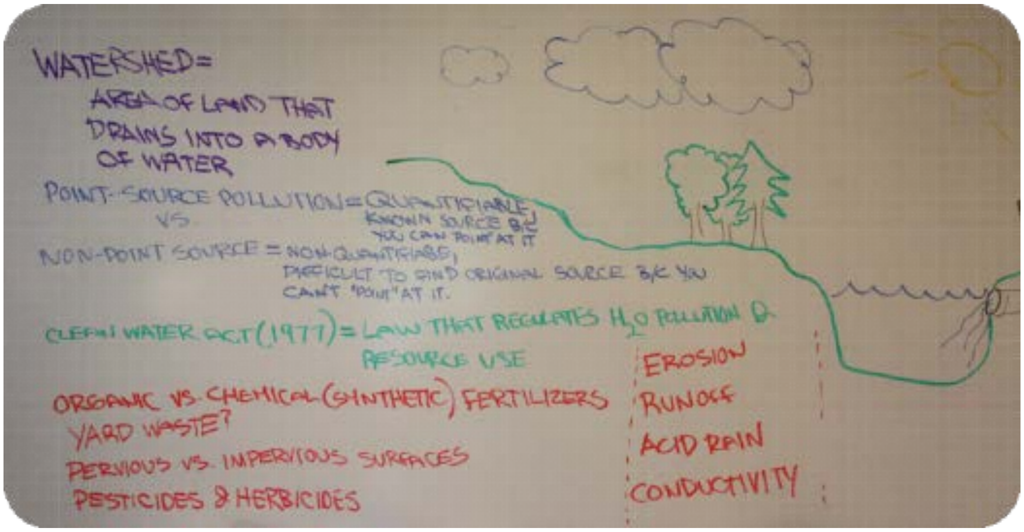

University of Vermont

Watershed Alliance

Stream Monitoring and Stewardship Program Handbook

Engaging Vermont's youth in their community as informed watershed citizens through hands-on, inquiry-based, educational programs

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INTRODUCTION

The University of Vermont Watershed Alliance (UVM WA) is a Lake Champlain Sea Grant (LCSG) program in partnership with UVM Extension and the Rubenstein School of Environment and Natural Resources (RSENR). UVM WA provides and supports statewide watershed education and water quality monitoring for Vermont middle and high school students and teachers, alternative education programs, and youth groups. The primary objective of UVM WA is to increase awareness and knowledge of watershed issues among Vermont youth. UVM WA provides curriculum, equipment, and instructors to schools and youth groups participating in our programs, as well as support and training to teachers who wish to integrate watershed education into their current curriculum. UVM WA seeks to engage program participants through interactive classroom instruction and hands-on field science. Learning in a real-world context empowers students to take action to increase community education and improve watershed health.

UVM WA has the knowledge and tools to engage students in the scientific process. Our three-dimensional watershed model, which is just one of the many resources available to your class, helps students visualize a watershed and understand how humans impact water quality. Students become citizen scientists as they learn about the scientific method and put their learning to practice in a local stream or lake/pond study. Students gain a better understanding of aquatic ecosystems as they test chemical, biological, and physical parameters of their local stream using kick nets, identification keys, chemical test kits, and digital meters. Lessons learned on watershed health are extended to the community through stewardship projects such as student presentations to planning commissions, local newspapers articles, presentations to younger students, and stream buffer plantings with local watershed associations.

Our instructors (Watershed Educators) are trained undergraduate and graduate students from colleges and universities in the Lake Champlain Basin studying environmental science and/or education and are looking to gain expertise in water resources and environmental education. Each semester, UVM WA provides paid internship opportunities for between five and eight students. Interns receive training in stream ecology, watershed science, classroom management and inquiry based science teaching pedagogies. Watershed Educators often work with UVM WA for subsequent semesters to refine their skills as educators, or to assist with curriculum development. Watershed Educator alumni rate this internship highly because it provides an opportunity to gain field based skills and directly apply the knowledge they are learning in their college coursework.

Stream Monitoring and Stewardship Program Overview

The Stream Monitoring and Stewardship Program can be divided into three main components: (1) Classroom Introduction, (2) Field Science Inquiry, and (3) Community Outreach and Stewardship. Although the time commitment for each component varies depending upon your specific program objectives, all three are integral to the overall success of the program. Below is a brief description of each component.

Classroom Introduction – *Pre-monitoring Activities*

The Classroom Introduction is designed to familiarize students with general watershed concepts, the scientific method, and stream monitoring. The length of this program component varies as there are several options for activities, but it is generally between 1 ½ - 2 hours in length. Investing this time in the classroom will better prepare students for their field experience and will provide a context for stream monitoring. Below is a brief description of the Watershed Model, a popular introductory activity, as well other optional activities. A detailed lesson plan for the Watershed Model begins on page 15.

Watershed Model (Length – 1 hour): This interactive table-top model by EnviroScape® is designed to introduce key watershed concepts such as the definition of watershed, types and sources of pollution, effects of pollution on humans and ecosystems, the differences between point and non-point source pollution, and best management practices.

Exploration Stations (Length – 30 minutes to 1 hour): With assistance from our Watershed Educators, students review key watershed concepts and are introduced to monitoring methods and equipment through self-guided stations that direct students to carry out specific tasks which include journaling, reviewing sampling methods, and using sampling tools such as identification keys, chemical test kits, or digital meters.

(Optional) Watershed Delineation (Length – 45 minutes to 1 hour): Using topographic maps, students will outline the area of a watershed by marking the highest places surrounding the waterway and connecting those areas via ridgelines. The area of the watershed can be calculated using the map's scale and overlaying a grid or determining the area of a similar shape (circle, rectangle, etc.).

Additional Suggested Activities:

"Water Quality Monitoring: From Design to Data" from *Healthy Water, Healthy People* (Length – 2 – 2 ½ hours or 2 to 3, 50 minute periods): Students create a study design, then analyze and interpret water quality data to model the process of water quality monitoring.

Field Science Inquiry - *Stream Monitoring*

Watershed educators and classroom teacher(s) lead students in the aquatic field study. Physical, chemical and or biological data is collected from 1 to 3 sites in order to answer the monitoring question identified previously during the classroom introduction. Depending upon the parameters monitored, processing samples can occur in the field or back in the classroom. Details are provided on sampling methods in subsequent chapters. The time needed for the field study varies, but generally ranges from 3 – 6 hours for data collection and 1+ hours for data analysis and interpretation.

Community Outreach and Stewardship – *Post-Monitoring Activities*

UVM Watershed Alliance emphasizes action based on unbiased scientific information. The Community Outreach component is a student centered project that allows students to utilize their creativity while they extend their scientific findings to their local community. Program participants have presented their findings to local planning commissions, school boards, watershed groups, and parents. Other Community Outreach projects have included the production of a series of public service announcements broadcasted on the radio, brochures, websites, and participant led lessons for younger students. Projects can also be directed more towards on-the-ground stewardship with riparian tree plantings, invasive species removal and clean-up days.

How to Use This Manual

This manual was designed to support our Stream Monitoring and Stewardship Program. It provides background information on water quality monitoring in an educational context, directions on how to design your monitoring program, pre- and post-field activities, sampling methods and datasheets, equipment information, and an overview of water quality monitoring in Vermont. In addition, the UVM WA Education and Outreach Coordinator will work with you to fine-tune your program in order to best integrate it into your classroom curricula. A description of each chapter is provided below.

Chapter 1: EDUCATIONAL MONITORING – Describes the importance of maintaining water quality, provides an overview of water quality monitoring. In future handbook updates we will list complementary standards from the Next Generation Science Standards that teachers can use.

Chapter 2: DESIGNING YOUR PROGRAM – Outlines the process of designing your monitoring program and answering the questions what, where, when, why, and how to monitor. Provides tips on how to facilitate this process with your students.

Chapter 3: PRE-MONITORING ACTIVITIES – Gives detailed lesson plans for several pre-monitoring activities that are options for implementation in the classroom prior to field sampling.

Chapter 4: FIELD PREPARATION – Covers topics including minimizing impacts to aquatic resources when sampling, safety, appropriate behavior and learning expectations of students, and quality assurance/quality control considerations and practices.

Chapter 5: PHYSICAL MONITORING – An overview of methods for monitoring physical characteristics of the river such as velocity, discharge, substrate, depth, and width.

Chapter 6: BIOLOGICAL MONITORING – An overview of methods and ecological context for monitoring benthic macroinvertebrates (BMIs), riparian vegetation, and coliform bacteria.

Chapter 7: CHEMICAL MONITORING – An overview of methods for chemical monitoring and various resources beneficial to carrying out a water chemistry unit.

Chapter 8: POST MONITORING ACTIVITIES– Provides ideas and resources for extending findings through a Community Outreach and Stewardship project.

Chapter 9: WATER QUALITY IN VERMONT – Gives an overview of how ambient waters are monitored in Vermont, relevant state and federal water quality regulations, and state agencies and watershed associations involved in watershed management.

Chapter 1: Educational Monitoring

Chapter Summary:

- Introduction
- Monitoring Components
- Learning Objectives
- Watershed Alliance Tier System
- Interdisciplinary Study Figure

Introduction

River monitoring is a systematic way to assess a waterway's ecological integrity and understand how humans may have impacted it. Through monitoring, we can compare the current state of the study area to that of a reference standard, condition, or site and therefore make predictions about the surrounding watershed's health. Knowing this, we can design solutions to water quality issues and advocate for better water quality management practices in and around the river. Furthermore, water monitoring allows students to make connections between humans and the environment helping to foster future generations of environmental stewards.

Monitoring Components

The health of a river system can by analyzed by looking at its physical, biological, and chemical characteristics. Therefore, UVM WA's Stream Monitoring and Stewardship Program (SMSP) targets each of these components and breaks them into separate stations for the stream monitoring exercise. WA encourages that these components then be analyzed together, as each piece is interconnected and plays an important role in telling the stream's story. Below, are tables that depict each parameter that is measured in WA's SMSP.

Physical Parameters	**Biological Parameters**	**Chemical Parameters**
Velocity Discharge Substrate Composition Embeddedness Width/Depth Turbidity Riparian Vegetation Temperature Canopy Cover	Benthic Macroinvertebrates (BMI) Coliform Bacteria	Dissolved Oxygen Phosphorus Nitrates pH Conductivity Alkalinity* Chloride* *not typically monitored

Monitoring the physical characteristics of a river can provide a context for evaluating chemical and biological parameters, and can be the simplest and most effective way of evaluating a river's health if time and resources are limited. Evaluating chemical indicators allows us to take a "snapshot" of the river at a specific moment in time. Results from one sample may be affected by present conditions such as a high rain event or a sewage leak. As such, it is useful to monitor chemical parameters over time to establish baseline conditions for the river, which allows one to track long-term changes. Finally, living organisms are dependent upon the chemical and physical conditions in the river over their lifespan. For example, benthic macroinvertebrates (BMIs) have specific habitat requirements that must be met over their lifespan in order to reproduce and thrive. Monitoring biological communities can be another cost-effective way of evaluating a river's health as they can give us the opportunity to look at the health of the river over a longer span of time.

Learning Objectives

Students will be able to:

- Accurately define the term "watershed."
- Name the basin and sub-basins where they live. Describe how basins and sub-basins are nested.
- Understand the differences between point source (PS) and non-point source (NPS) pollution.
- List potential sources and environmental impacts of the following pollutants: manure/animal feces, human feces, oil/automotive pollutants, salt, fertilizers, pesticides, and soil.
- List at least three BMPs students can follow to reduce their watershed impact.
- Know the largest threats to water quality and ecosystem health in the Lake Champlain Basin or Connecticut River Basin (based on students geographic location).
- Understand the reason why scientists monitor biological, chemical and physical characteristics of a river, and what each can tell us about river health.
- Know the scientific inquiry process in the context of river monitoring.
- Demonstrate competency using UVM WA stream monitoring methods and equipment. Demonstrate competency using at least one data analysis method.
- List at least one local stakeholder who may be interested in their river study. Demonstrate methods of sharing information with the community.

Watershed Alliance's Tiered System

Over the past 15 years UVM WA has worked with amazing schools and teachers in both formal and in formal education settings throughout Vermont and the Lake Champlain Basin. The veteran teachers of WA programs are one of our greatest assets, providing support to teachers in their school and/or district as well as sharing the success of the SMSP program and getting new teachers to sign up for WA programming. This has helped WA grow and expand our reach throughout the Basin tremendously over the last ten years. Last fall (2016) we worked with 15 schools and educated over 800 students between late August and early November.

As a result, we have seen an increase in requests for our services. In order to ensure that we are able to meet the needs of schools throughout the Basin and Vermont we instituted a tiered system of school program support in the spring of 2015. This tiered system seeks to differentiate the amount of support teachers receive through WA programming. Our tier 1 teachers are new to WA programming; therefore, they require more structured support. Our tier 2 teachers have participated in programming 1-4 years and till require support in the classroom. Lastly, our tier 3 teachers have participated in programming for more than 5 years and capable of leading this program on their own, WA can provide SMSP equipment and mild support.

Tier	Participation	Support
1	New to WA SMSP program	Full programmatic support
2	Have participated 1-4 years	Some programmatic support
3	Have participated 5 or more years	Mild programmatic support, access to rent SMSP equipment (free of charge)

Tier 3 schools with veteran teachers will need to be trained in our new curriculum (2017 revised handbook) and equipment rental procedures. Teachers and the WA Outreach & Education coordinator will work closely to guarantee the school feels comfortable with the curriculum, stream monitoring, and outreach and stewardship projects. WA will help the Tier 1 schools and teachers maintain or initiate relationships with community and watershed groups interested in the student work and actions.

If a school or teacher has any concerns, questions or suggestions please contact Ashley Eaton, Interim UVM WA Outreach & Education Coordinator at ashley.eaton@uvm.edu

Interdisciplinary Study

Adapted from: M.T. Denecour, “Interactive Lake Ecology”

Chapter 2: Designing Your Program

Chapter Summary:

- Monitoring Questions
- Monitoring Limitations
- Planning an Outreach/Stewardship Projects

Monitoring Questions

Answering what, where, when and how to monitor. In order to have a meaningful and successful monitoring program, it is essential to outline the reasons for it. Your river study objective could be to increase overall awareness of the river, to develop basic monitoring skills, or to answer specific questions about the river.

The most successful programs are student-centered, where students are involved throughout the study design process. Student-led projects often result in increased participation and investment. Guide your students in formulating specific questions about your river/watershed and designing the study around one or more of those questions: the question is then the basis for the investigation of the river(s) or stream(s). Inquiry-based river studies are the most educational, useful, and fun type of study, and leads to better contextual understanding of watersheds, the scientific process, and the roles we play as citizens and scientists.

A few guiding questions, and you are on your way to a successful program:

- Why are you monitoring?
- What will you monitor?
- What are your data goals?
- Where will you monitor?
- When will you monitor?
- What methods will you use?

The reason or objective for stream monitoring can be in the form of a **goal,** a **question,** or **hypothesis**. For example, your students may visit a river site that has been heavily eroded by a recent flood and they create a **goal** to perform a physical assessment to see where the river was damaged and where restoration efforts could be implemented. Or your students may go to a river site that looks polluted and ask the question **why** that is so and set out to complete a set of chemical tests to discover the answer. Or perhaps your students visit a river site that has uncharacteristically low fish populations and they make the **hypothesis** that perhaps there's a low density of their food source. Therefore, they set up a benthic macroinvertebrate abundance study to test their hypothesis.

As the instructor, you can begin by considering the current uses of the river and how changes in water quality may affect them. For instance, students may be interested in examining the water quality at a popular swimming hole. The monitoring question could be, "Is this swimming hole safe for swimmers according to VT state law?" Students would monitor bacteria in the river, and compare the results to the state standard (less than 77 E. coli colonies/100 ml water). Keep in mind that the current technology used to determine E. coli bacteria levels in streams requires 24+ hours to process. Streams are constantly flowing, and the water that was sampled yesterday is long gone today. Therefore, the information about bacteria levels is already outdated when you receive it, and the numbers are used only as a very general guide to the recreational suitability of the river.

Other options include **value-driven questions** or **current issues questions**. What value does this river have? Is it valued as habitat, for aesthetics, or for ecosystem services? What specific threats does the watershed face?
Are there potential issues with sedimentation, runoff, or loss of riparian vegetation? Uses, values, or issues can serve as potential drivers for the river study. Some common river monitoring questions are given below.

Sample Essential Questions:

- Does this stream meet VT water quality standards?
- Does this stream provide appropriate wildlife habitat (BMI's, birds, fish, etc.)?
- Is this stream negatively impacted by human development (leaking septic systems, erosion from construction, and discharge from industry, farm runoff, and removal of streamside buffers)?
- What sorts of benthic macroinvertebrates are found in this stream? Is the benthic macro invertebrate community healthy in this stream?
- Is this stream safe for swimming right now? What about after a significant rain event?
- Advanced: Have stream buffer plantings been effective in reducing erosion and providing flood water storage?

Monitoring Limitations

It is important to remember the scope and limitations of projects when planning your monitoring program, and analyzing the data. In particular:

- Rivers are ephemeral. While one may find elevated levels of phosphorus one minute, levels may be normal the next. The same is true with coliform and E. coli data. It is difficult to make inferences about the water quality of a river without long-term, consistent data. Some ways to increase the usefulness of your data:
- From year to year, always monitor at the same spot in the river. This will provide a baseline for analysis of long-term trends.
- If you have time, try scheduling your monitoring over an entire week. If possible, monitor in varying weather conditions. This may help to illustrate pollution from runoff sources.

It is key to remember that your time and resources will also play an integral role in how you answer the questions what, where, when, why, and how, which will guide your development of an educational monitoring program and ensure that it is well-suited to your class and curriculum.

Activity		Minimum Field Time Required	Min # of Persons Required
Physical	Habitat Assessments	60 Mins	3
Chemical	Dissolved Oxygen	20 Mins	2
	Phosphorous	15 Mins	1
	Conductivity	10 Mins	1
	pH	10 Mins	1
Biological	Streamside Survey (BMI's)	60 Mins	2
	Bacteria	10 Mins (24 – 48 hrs to process sample)	1

Planning Your Outreach and Service Project

The more directly you can link your outreach project to actual community needs and resources, the stronger the experience for your students and the greater impact the project will have. Before you begin your outreach or service project, be sure to answer these important questions that will help guide you in the planning process:

Please see Chapter 8 for additional resources.

Outreach Project

1. What are your goals and objectives?
2. How much time and resources do you have to invest?
3. Who is your target audience?
4. What is the take-home message?
5. What is the best way to communicate this message to your chosen audience?

Service/Stewardship Project

1. What are your goals and objectives?
2. What direct action needs have been identified by your monitoring results, town government or local conservation organizations?
3. How much time do you have to commit to carrying out the project?
4. What special equipment, tools, or other resources will you need?
5. What are the potential safety concerns?
6. Who can help you plan and implement your service/stewardship project

Outreach Project

1. What are your goals and objectives?
2. How much time and resources do you have to invest?
3. Who is your target audience?
4. What is the take-home message?
5. What is the best way to communicate this message to your chosen audience?

Stewardship Project

1. What are your goals and objectives?
2. What direct action needs have been identified by your monitoring results, town government or local conservation organizations?
3. How much time do you have to commit to carrying out the project?
4. What special equipment, tools, or other resources will you need?
5. What are the potential safety concerns?
6. Who can help you plan and implement your service/stewardship project

Chapter 3: Pre-Monitoring Activities

Chapter Summary:

- Introduction
- Learning Objectives
- Pre-Monitoring Activities
- List of Pre-Monitoring Resources

Introduction

There is a wealth of pre-monitoring activities available that provide students with a foundation in watershed concepts and enable them to carry out an effective stream monitoring program. In order for students to understand pertinent concepts associated with why and what they are monitoring, it is imperative that the students are adequately prepped in the classroom beforehand.

Learning Objectives

- After completing pre-monitoring activities students will be able to:
- Understand the concept of a watershed
- Define point and nonpoint source pollution
- Understand the common chemical parameters of water quality testing
- Know how to assess physical attributes of stream
- Identify common benthic macroinvertebrates
- Advanced: Draw approximate watershed boundaries

Pre-Monitoring Activities

With the right classroom introduction, students will not only be introduced to foundational concepts about watersheds, but will also go into the field with background knowledge about how human activities affect water quality. This knowledge will allow them to make more informed predictions about how development may have impacted the stream or river they are testing. Here are two of the pre-monitoring activities that WA routinely uses:

- Watershed Model Demonstration
- Exploration Stations

Other pre-monitoring lessons could include:

- Watershed Delineation
- "Build a Watershed" activity
- MacroMania game
- Aquatic Leaf Pack
- Pond and Stream Safari

See list of Pre-Monitoring Activities below for information about where to find these activities.

Watershed Model Demonstration

Our interactive tabletop watershed model, produced by EnviroScape (www.enviroscapes.com), is used in a demonstration that is approximately 1 hour in length and has two parts, How Water Pollution Occurs and Preventing Water Pollution, which serve as an introduction to basic watershed concepts. Below is an activity outline for use in preparing your class. For a vocabulary list see page 92.

How Water Pollution Occurs

1. Audience awareness: POLLUTION. What do you think of when you hear this word?

2. Watershed Discussion: What is a watershed? What is a waterbody? Everyone lives in a watershed.
    a. Discuss watershed scale and nested watersheds. Introduce model as a representative watershed.
    b. Discuss water cycle.

3. Sources of Water Pollution: two types—point and non-point.

Discuss and demonstrate examples of point source	Discuss Non Point-Source Pollution
Industrial plant	Farm (erosion, fertilizers and pesticides, manure)
Sewage treatment plant and combined sewer overflows	Residential area (pet waste, septic systems, household chemicals, lawn/garden fertilizers and pesticides
Storm drain	Golf course (fertilizers and pesticides)
	Forest (erosion)
	Roads (salt, automotive pollutants)
	Streambanks/lakeshore (erosion)

    a. Demonstrate non-point sources using props (soil, fertilizers, pesticides, oil, salt, manure

4. **Make it RAIN!** Discuss runoff.
    a. Why does runoff happen?

Type	Explanation
Construction site	No vegetation or no silt fencing to hold soil
Lawns and Golf Course:	too much pesticides and/or fertilizers used, not absorbed by plants Highways, Roads and Parking Lots: collect automotive pollutants and salt; impervious surfaces send pollutants to storm drain
Stream banks and Lakeshore:	lack of vegetation contributes to erosion
Forest Clearing:	lack of vegetation, heavy equipment, and steep slope accelerate erosion Plowed fields: disturbed soils are vulnerable to erosion
Crops	see lawn and golf course

5. Why is Pollution Harmful?
    a. Discuss the invisible components of runoff

Type	Explanation
Nutrients	Manure (animal and human) and fertilizers may contribute excess nutrients (phosphorus and nitrogen) to the ecosystem resulting in eutrophication.
Toxic Substances	Toxins are poisonous substances (oil, pesticides, and metals) and are harmful to animals and humans. Some toxins bioaccumulate (PCBs, mercury) and this has led to fish consumption advisories in many areas (including Lake Champlain).
Bacteria	Some species may cause diseases such as dysentery and typhoid fever. Bacteria can infect shellfish, which in turn can make consumers sick. Bacteria can also harm other aquatic organisms. E.coli is used as an indicator of fecal contaminator and indicates potential contamination of harmful bacteria. The VT state standard for recreational waters is less than 77 colonies E.coli/100 ml water.
Soil	Erosion contributes excess sediment to water bodies which may affect recreational use of water, cause flooding, kill fish, destroy habitat, and disrupt reproduction habits. May also increase eutrophication due to phosphorus adsorbed to soil particles.

6. Discuss home activities: how do we contribute to pollution in our daily lives?
    a. Examples of how we pollute at home:
        i. Improper use and disposal of household chemicals
        ii. Excessive use of water
        iii. Failure to maintain septic systems
        iv. Microplastics: facewash, toothpaste, microfibers from clothing
        v. Pet Waste: not picking up pet waste and letting it wash into nearby streams or storm drains
        vi. Pharmaceuticals: waste passed through our bodies or flushed down toilet
7. Review, summary and questions.
    a. Review and summarize point source (PS) and non-point source pollution (NPS).
        i. NPS contributes more than 50% of the total water pollution, and is the major source of pollution in Lake Champlain. Although it is such a large problem, NPS is unregulated, and pollution prevention (best management practices) is voluntary.
        ii. PS pollution has been regulated by the federal government since 1970 with the passage of the Clean Water Act (although there are non-compliance issues)

Preventing Water Pollution

1. Prepare model: drain lake, wipe off grime from first demonstration and refill lake.

2. Check audience awareness: ask for suggestions on how to prevent nonpoint source pollution and

write them down.

3. Introduce the phrase Best Management Practices (BMPs): systems, activities and structures that can prevent nonpoint source pollution.

    a. BMPs are not 100% capable of eliminating pollution, but each one helps to reduce and prevent pollution.
    b. BMP s can be site and pollutant specific; therefore, a single BMP may not be effective with all pollutants found at a single location.
4. Prepare and place the BMPs
    a. Make fence, place along stream next to cows to illustrate the practice of preventing them from entering stream.
    b. Make a small berm out of clay and place along plowed field next to lake.
    c. Place felt "grass" strips along edge of roadway next to lake, beside construction site, around lower
    d. half of clear-cut forest.
    e. Place felt "wetland" on area to right of plowed farm field.
    f. Place manure containment bin on grass next to road on the farm. Make any other BMPs audience suggests
5. Add "pollutants" to model as in previous demonstration
6. Demonstrate BMPs

Pollution Type	Primary BMP	Secondary BMP's
Construction site:	spray with rain, point out BMP (grass strip) and discuss. List other construction	BMPs (silt fencing, straw bales).
Lakeshore and streambanks:	spray with rain. Point out BMP (grass strip) and discuss.	Forest—see above. Other BMPs include selective cutting, erosion controls on logging roads
Farm area:	Spray with rain. Notice how berm prevents soil from entering waterbody. Notice how wetland filters sediments, nutrients, pesticides.	Other BMPs include contour plowing, conservation tilling, and vegetative filter strips. For crops, BMPs include appropriate use of fertilizers and pesticides, plant cover crops, rotate crops.
Driveways and highways:	Spray with rain. Discuss grass strips.	Other BMPS include permeable surfaces, good motorist habits including preventing oil leaks, recycling used oil.
Cows: Manure containment	Spray with rain and show that manure containment is important. Place manure in manure containment, spray with rain and observe how runoff is contained. Farmers still need to manage manure—manure can be applied to the ground as a fertilizer (do not	Other BMPs include fencing cows out of the stream is a BMP; however, it requires farmers to provide an alternative water source and shaded area, which can be costly.

	over apply or apply when ground is frozen).	
Lawns and Golf Courses	Spray with rain. Note that it is important to only use pesticides and fertilizers sparingly and follow label instructions.	Other BMP's include using alternative fertilizers like compost or leave grass clippings on lawns. Have soil tested to find out exactly what grass needs. Choose plants that are suited to the climate of your area to save on water, fertilizers and pesticides. Do not dispose of grass clippings or leaves down storm drains or in streams.
Household Activities	Be a smart shopper; read labels and buy the least toxic product that will do the job. Buy biodegradable, recyclable products whenever possible.	Use household chemicals properly. Never burn or bury leftover chemicals. Never flush chemicals down drain or pour into storm drains. Check with local solid waste managers for proper disposal of household chemicals.
Household Waste	Clean up after pets Use less water	Maintain septic tank properly
Household Landscaping	Reduce the use or eliminate the use of fertilizers and herbicides Plant native pollinators and native plants that increase bank stability if located near a waterbody	plant groundcover in your yard to prevent erosion Leave the lawn long, cutting only 1/3 of the grass height

Exploration Stations

This classroom activity was created by WA and is presented to students participating in WA's SMSP before starting their local stream monitoring study. It is designed as a thorough introductory lesson to **why** and **how** we monitor a stream's health. It involves a short PowerPoint presentation as well as hands-on activities with stream monitoring equipment to prepare students for the stream site visit.

For advice on how to prepare your own "Exploration Stations" activity, please contact the WA Outreach & Education Coordinator at 802-859-3086 ext.305 or at watershd@uvm.edu

Activity	Company	Phone	Website
Watershed Model	Eviroscape	(703) 631-8810	http://www.enviroscapes.com
MacroMania Game*	LaMotte	(410) 778-3100	http://www.lamotte.com/en/education
Aquatic Leaf Pack*	LaMotte	(410) 778-3100	http://www.lamotte.com/en/education
Watershed Delineation	Various sources	n/a	http://www.wvca.us/envirothon/pdf/Watershed_Delineation_2.pdf
Pond and Stream Safari*	Cornell Cooperative Extension	n/a	http://www.amazon.com/Pond-Stream-Safari-Invertebrates-Experience/dp/157753039X
"Build a Watershed Model"	Various Sources	n/a	http://www.iwla.org/index.php?ht=a/GetDocumentAction/i/2194

Note: Activities marked with an asterisk need to be purchased from their respective companies (or other sources). Those designated as having "various sources" can be located from various places online. Example sites are provided under "website"

Chapter 4: Field Preparation

Chapter Summary

- Sampling Safety
- Equipment

Sampling Safety Tips

There are a number of additional considerations to make when teaching students in an outdoor setting. Below are some guidelines to follow to ensure impacts on natural resources are kept to a minimum and that students enjoy a safe, positive learning experience.

We ask teachers to manage their class and (to the best of their ability) the sets of groups that are participating in stream monitoring. The UVM Watershed Alliance educators will also be attuned to students and the activities around the water, however, the educators cannot teach effectively while managing class safety. Please read the following tips before venturing out on your own stream monitoring or working with UVM Watershed Alliance.

Tips on Managing Class Safety

Closely manage your group in the field

- Set distinct boundaries for the group, and keep all group members within sight and hearing distance (be aware that the noise of the river may greatly limit your hearing distance).
- Make sure you are aware of any severe student allergies such as bee stings and know how to respond in case of an allergic reaction.
- Keep a first aid kit with you and accessible at all times.
- Maintain a student to adult ratio of at least 8:1.

Be aware of potential field hazards

- Wear appropriate clothing and footwear at all times.
- Visit the site prior to bringing your students and identify potential hazards such as high water, slippery rocks, poison ivy, steep banks, and downed trees. Discuss these hazards with your students before the field trip and what precautions they need to take to avoid them.
- Scout the area for any dangerous debris such as broken glass, wire, or other sharp objects; flag and avoid as needed.
- Never sample during a thunderstorm. Check the forecast and be aware of quickly changing conditions.

Follow safety guidelines for handling chemicals

- Wear proper personal protection such as goggles and gloves when using chemical test kits.
- Dispose of used chemicals in an environmentally sound manner.
- Avoid opening reagent packets under windy conditions as the chemicals can get blown onto skin or into eyes.
- Be sure to wash hands thoroughly after handling chemicals.

Limit your site impact

- Handle living organisms carefully and gently. Once they are collected in the net, quickly place them in the sorting tub or ice-cube tray, which should be filled with water in advance. Keep these in the shade to prevent them from heating up rapidly from the sun's energy.
- Replace rocks you have overturned.
- Encourage students to explore freely, but only collect organisms with a purpose. Despite careful efforts, collecting can cause stress.
- Stay off of unstable and easily eroded stream banks.
- Sweep the area for any items the group may have left behind before leaving the sampling site.
- Clean kick nets, sorting trays, boots and gloves with bleach and water solution.

Stream Monitoring Equipment

Each stream monitoring station has equipment that ranges from inexpensive to moderately priced. Some equipment may even be found for free and from your home. WA has compiled a list of equipment it uses to teach the Stream Monitoring & Stewardship Program. There is no need to purchase these materials, during the program WA will bring all equipment necessary.

However for their 3 teacher and teachers looking to expand the program on their own SMSP Teacher Kits, a set of all SMSP materials and equipment, are available to rent.

<table>
<tr><th>Biological Station</th><th>Chemical Station</th><th>Physical Station</th></tr>
<tr><td rowspan="3">• Rectangular net
• D-Net
• Storage Bins
• 5-Gallon Buckets
• Foreceps
• Ladle Spoons
• Hand Lenses
• Sieves
• Ice-Cube Sorting Tray
• BMI Investigation Kit
• BMI ID Guides
• Macro Mania Game
• Aqua Bug Kit
• BMI Flashcards
• Pond Safari Games Cards</td><td>• Phosphate Kit
• Dissolved Oxygen Hatch Kit
• Nitrate Hatch Kit
• Urban Waters Lamotte Kit
• Water Monitoring Kit</td><td rowspan="3">• Meter Stick
• Tape Measure
• Tennis Ball
• Stopwatch
• Turbidity Tube
• Rock Tray
• Quadrant</td></tr>
<tr><td>Watershed Model</td></tr>
<tr><td>• "Pollutants" (herbs, soy sauce, sprinkles, etc.)
• Spray bottles</td></tr>
</table>

If there are any items you would like to purchase on the list below that you cannot find please contact UVM Watershed Alliance and we can help locate the item through our retailers.

Chapter 5: Physical Monitoring

Chapter Summary

- Introduction
- Learning Objectives
- Monitoring Guidelines
  - Student Fieldwork Activities
  - Preparing for Fieldwork
- Stream Handbook
- Fieldwork Packet
  - Choose a Sampling Site
  - Field Sheets

Introduction

Monitoring the physical conditions in and along a stream – from streambed to stream flow to bank cover – can be an effective way to evaluate the stream's health. It is simple, inexpensive, and requires few supplies and little time. Most physical parameters can be assessed from the streambank and don't require getting into the water. Some, like velocity, are measured in the water.

The physical state of the stream can help investigators interpret the chemical and biological conditions found there. As an example, an eroding streambank (a physical indicator) adjacent to a cow pasture might help to explain a high level of phosphate in the water (a chemical indicator used to measure organic pollution). That is, the eroding streambank indicates that runoff from the pasture, with its load of cow manure, is flowing directly into the stream. Cow manure contains high levels of phosphorus and other pollutants that can cause organic pollution in the stream. Organic pollution contains excess nutrients that can cause aquatic algae to grow luxuriantly on the rocks, which supports a huge population of grazing organisms (a biological indicator).

Learning Objectives

After completing the physical assessments in this chapter, students will be able to:

- Measure various physical parameters in a stream Understand how physical parameters affect aquatic habitats
- Interpret physical assessment results and relate them to surrounding land use

Monitoring Guidelines

This section summarizes how to prepare for and carry out physical assessments at a suitable stream site. We encourage you to conduct stream assessments at regular intervals and to compile your datasets so that you can compare stream conditions over time. Do conditions stay the same? If your data consistently indicate good water quality, what can you and your students do to maintain it? If your data indicate worsening conditions, you and your students can begin to investigate land and water uses that might negatively impact the stream.

Regularly completed assessments that are compiled into a database form the foundation of a stream monitoring program. Your regular assessments can help you monitor your stream's health, design stewardship activities to improve water quality, and measure the effectiveness of your efforts.

Student Fieldwork Activities

The physical assessments in this chapter include:

Physical Parameters (canopy cover, water appearance, embeddedness, and transparency/turbidity) that

are recommended for all groups
Stream Habitat Assessments offered in three Tiers; you choose the Tier that is appropriate for your students (see below)
Stream Discharge for older and/or more experienced students
Land and Water Use Investigation for older and/or more experienced students

Instructions are provided below for completing each assessment using enclosed field sheets. (Note: Instructions are provided only for supplies and methods used by WA).

Preparing for Fieldwork

Step 1:
Familiarize yourself with the "Sampling Safety" section in Chapter 4 and with the instructions for each physical assessment that you will conduct.

Step 2:
Obtain the necessary supplies for the assessments you will conduct (see the **Supplies** List for each assessment below). These items can be acquired by participating in Watershed Alliance's Stream Monitoring and Stewardship Program (SMSP) or by borrowing them from WA.

Step 3:
Choose a suitable stream site using the criteria in the **FIELDWORK PACKET** below, and bring this information with you during fieldwork.

Step 4:
See **Student Fieldwork Activities** above, and read the assessment instructions and their field sheets in the
FIELDWORK PACKET. Then decide which assessments you will use with your students.

Stream Habitat Assessment Tiers

The Stream Habitat Assessment is used to indicate general physical conditions of the stream and its banks. This assessment can provide useful information about overall stream health and contribute to an understanding of chemical and biological water quality parameters. Each tier of the assessment generates a Stream Habitat Quality Score on a scale from Excellent to Poor.

Each sheet includes a set of parameters. For each parameter, students read a list of statements and choose the statement that best reflects their stream site. Then they look in the **Point Values** column to find the number of points associated with their choice, and write this number in the **Points Given** column. Finally, students add up all Points Given to produce an overall **Stream Habitat Quality Score**. In general, a high diversity of physical conditions supports a high diversity of aquatic organisms and contributes to a healthy stream. Healthy stream conditions usually correlate with high water quality.

Physical Assessment Fieldwork Packet

This packet contains information that will help you prepare for and carry out your fieldwork activities. It also contains field sheets for your students to complete. Please choose the field sheets that are appropriate for your students. Bring this fieldwork packet with you during fieldwork for reference.

Choosing a Sampling Site

1. **Find a streambank site that provides good access to the stream for your class. It should be big enough to allow all students to work comfortably and**
To move around safely.
2. **If you're planning to do the BMI assessment in chapter 6, please find a long riffle that can accommodate 3 replicate samples, or several riffles in the same region of the stream. (see chapter 6 fieldwork packet for more information on choosing a good BMI site.)**

Field Sheets

Physical Parameters Field Sheet – All Tiers

All students should assess the following Physical Parameters at their stream site. This activity will allow them to record features and conditions of their site, improve their observation skills, and help them understand how physical conditions in and along a stream affect chemical and biological conditions in the stream.

Weather – Have students record the weather that is occurring while they are at the stream as well as all-weather events that occurred over the last 48 hours. Precipitation, in particular, can dramatically affect stream conditions.

Site Description – Have students write some phrases and words that describe their site.

Surrounding Land Uses – The condition of the landscape around the stream and the human activities that take place within it can have a significant effect on stream health and water quality. In many cases, the results of a physical assessment of the stream can help to shed light on the health of this landscape.

Canopy Cover -- This is a measure of the shading of the stream, expressed as a percentage. *Supplies*: none. Stand in the middle of the stream and raise your arms until your hands point to the top of the vegetation along each stream bank. If both of your arms are straight up, there is 100% canopy cover. If not, estimate the angle of coverage based on the angle of your arms as a percentage of 180 degrees.

Embeddedness -- This is the percent surface area of larger particles (boulder, rubble, cobble, or gravel) surrounded or covered by sand or silt. Many benthic macroinvertebrates live in the spaces between particles on the streambed. When sediment settles between particles, these spaces are reduced or eliminated, and embeddedness increases.

1. Pick up 10 random rocks from the streambed. The bottom of the rock will usually be lighter in color than the rest, and there is often a "bathtub ring" that separates this lighter region below from the darker region above. The lighter part of the rock was embedded in sediment.
2. Estimate the percentage that each of the 10 rocks was embedded, record these percentages, and average the results.

Transparency / Turbidity — Turbidity is a measure of water clarity or, conversely, of the tiny materials

suspended in water. Such suspended materials may be soil particles, algae, plankton, microbes, and other substances. Higher turbidity increases water temperatures because suspended particles absorb more heat from the sun. This, in turn, reduces the concentration of dissolved oxygen (DO) because warm water holds less DO than cold water. High turbidity also reduces the light needed for photosynthesis and the suspended materials can clog the gills of fish and other aquatic organisms. If these particles settle, they can blanket the streambed, which increases embeddedness and smothers fish eggs and benthic macroinvertebrates.
Equipment: bucket, WA transparency tube

1. Enter the stream at your sampling spot, moving slowly and smoothly so as not to stir up sediment. Fill the bucket upstream of where you are standing; avoiding any sediment you may have stirred up.

2. Make sure that the release valve on the transparency tube is closed. Mix the bucket water well and pour it into the transparency tube. Fill the tube to the top mark.

3. At this point, two people need to work together to obtain a reading: the *Looker* and the *Valve Manager*. Have the Valve Manager practice opening and closing the valve before you complete this assessment.

Conduct either 3.a. or 3.b. below. Note: The Valve Manager is not needed for 3.a.

3.a. *Looker:* Look down the tube at the secchi disk on the bottom. **If you can see the secchi disk**, record the height of the water column in the tube as centimeters. (This is the top mark on the tube.) (The *Valve Manager* is not needed.)

3.b. *Looker:* Look down the tube at the secchi disk on the bottom. **If you cannot see the secchi disk**, ask your *Valve Manager* to get ready to release water until you can see the secchi disk.

Valve Manager: Open the valve carefully and slowly to release water from the tube at the bottom until the *Looker* can see the secchi disk at the bottom. Close the valve precisely at this point. Record the height of the water column in the tube as centimeters. *

Transparency Conversion Chart

Centimeters	Inches	Approximate NTU Value
<6.4	<2.5	>240
6.4 to 7.0	2.5 to 2.75	240
7.1 to 8.2	2.76 to 3.25	185
8.3 to 9.5	3.26 to 3.75	150
9.6 to 10.8	3.76 to 4.25	120
10.9 to 12.0	4.26 to 4.75	100
12.1 to 14.0	4.76 to 5.5	90
14.1 to 16.5	5.6 to 6.5	65
16.6 to 19.1	6.6 to 7.5	50
19.2 to 21.6	7.6 to 8.5	40
21.7 to 24.1	8.6 to 9.5	35
24.2 to 26.7	9.6 to 10.5	30
26.8 to 29.2	10.6 to 11.5	27
29.3 to 31.8	11.6 to 12.5	24
31.9 to 34.3	12.6 to 13.5	21
34.4 to 36.8	13.6 to 14.5	19
36.9 to 39.4	14.6 to 15.5	17
39.5 to 41.9	15.6 to 16.5	15
42.0 to 44.5	16.6 to 17.5	14
44.6 to 47.0	17.6 to 18.5	13
47.1 to 49.5	18.6 to 19.5	12
49.6 to 52.1	19.6 to 20.5	11
52.2 to 54.6	20.6 to 21.5	10
>54.7	>21.6	<10

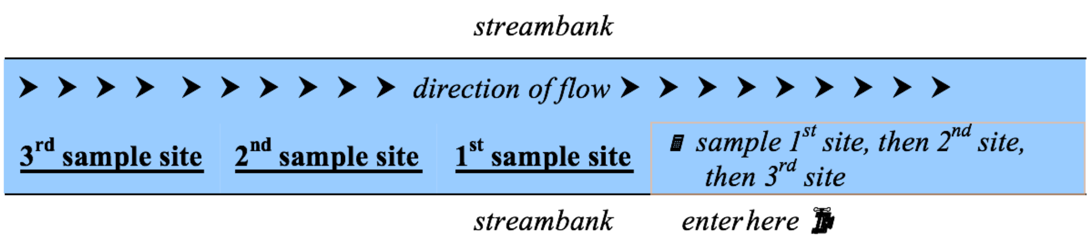
*Use the **Transparency Conversion Chart** to convert centimeters to Nephelometric Turbidity Units (NTUs).

Current Velocity – This is a fun activity for all ages! And it measures an important condition of streams: the rate at which water flows along. Velocity affects sediment types, dissolved oxygen levels, the transport of food particles, the flushing of pollutants, and other factors. Velocity changes dramatically along a stream and correspondingly affects the physical, chemical, and biological conditions there. Velocity is measured as distance traveled divided by time traveled (meters/second).
Equipment: tape measure for 10 meters, float (an orange or tennis ball), timer to record seconds, stakes or other markers for the "START" and "STOP" ends of your 10-meter section.

1. Choose two different 10-meter sections of the stream: one in fast current and one in slow current. Try to pick an open path for each, where the float will not encounter rocks or other stream obstructions.

2. At each section, measure 10 meters along the stream by standing in the stream and holding the tape or string above the water between two people. Mark the upstream end ("Start") and the downstream end ("Stop").
3. Choose 5 people to perform this test. Read the following descriptions of each role and position them as in the diagram below.
   - *Float Releaser:* Stand upstream of the *Starter* facing one of the banks. Hold the float 3/4 submerged in the water in front of you. Avoid placing the float in the "eddy" caused by your legs. Release the float.
   - *Starter:* Stand at upstream marker (0 meters). When the float reaches the 0-meter mark, say "START!" The *Timer* starts the clock and measures the number of seconds the float takes to travel the 10 meters.
   - *Stopper:* Stand downstream of the *Starter* at marker 10 meters. When the float reaches your mark, say "STOP!"
   - *Timer:* Stand on the bank with a stopwatch and stop the clock when "STOP" is heard.
   - *Float Catcher:* Stand downstream of the *Stopper* and nab the float when it travels past the *Stopper*.

Do this float test again and record the results from the first and second test on the field sheet, then average the two times. Complete the velocity formula (see page 26).



PHYSICAL PARAMETERS ASSESSMENT — ALL TIERS

FIELD SHEET

NAME:	**DATE:**	**TIME:**
STREAM OR RIVER NAME:		
WATERSHED NAME:	**TOWN:**	

WEATHER	**PRESENT** (CHECK ONE)	**PAST 48 HOURS** (CHECK ALL THAT OCCURRED)	**SITE DESCRIPTION**
CLEAR / SUNNY	❒	❒	
OVERCAST	❒	❒	
SHOWERS	❒	❒	
STEADY RAIN	❒	❒	
HEAVY RAIN	❒	❒	

SURROUNDING LAND USES

CHECK ALL THAT APPLY

❒ Farm ❒ Park ❒ Golf course ❒ Residential ❒ Factory

❒ Forest ❒ Crops ❒ Logging ❒ Road along bank ❒ Other ____________

❒ Road nearby ❒ Commercial

❒ **PIPES ENTERING STREAM** ❒ **WATER TREATMENT PLANT UPSTREAM**

CANOPY COVER

PUT AN X ON THE DASHED LINE BELOW TO INDICATE PERCENTAGE OF STREAM WIDTH COVERED BY OVERHANGING GRASSES, SHRUBS, AND TREES:

100% **75%** **50%** **25%** **0%**

WATER APPEARANCE & ODOR (CHECK ALL THAT APPLY)

❒ **CLEAR**	❒ **MILKY**	❒ **CLOUDY**	❒ **GREEN**	❒ **OILY SHEEN**
❒ **TEA-COLORED**	❒ **MUDDY**	❒ **FOAMY**	❒ **REDDISH**	❒ **OTHER ____**
❒ **FISHY ODOR**	❒ **OILY ODOR**	❒ **ROTTEN EGG ODOR**	❒ **SEWAGE ODOR**	❒ **CHLORINE ODOR**

PICK UP 10 RANDOM ROCKS AND LOOK FOR THE "BATHTUB RING" ON EACH, WHICH SHOWS HOW DEEP IT WAS EMBEDDED IN SEDIMENT. FOR EACH ROCK, ESTIMATE THE PERCENT EMBEDDEDNESS.

1ST ROCK ____%	2ND ROCK ____%	3RD ROCK ____%	4TH ROCK ____%	5TH ROCK ____%
6TH ROCK ____%	7TH ROCK ____%	8TH ROCK ____%	9TH ROCK ____%	10TH ROCK ___%

ADD ALL %'S, THEN DIVIDE BY 10 = ___________% AVERAGE EMBEDDEDNESS.

PUT AN X ON THE DASHED LINE BELOW TO INDICATE THE AVERAGE EMBEDDEDNESS.

100% 75% 50% 25% 0%

TRANSPARENCY / TURBIDITY

FOLLOW INSTRUCTIONS IN THE FIELDWORK PACKET TO CONDUCT THE TRANSPARENCY / TURBIDITY ASSESSMENT, AND COMPLETE THE BLANKS BELOW.

HEIGHT OF WATER COLUMN: _________ CM = NTU'S: ___________

CURRENT VELOCITY

FOLLOW INSTRUCTIONS IN THE FIELDWORK PACKET TO CONDUCT 2 TRIALS OF THE VELOCITY ASSESSMENT, THEN AVERAGE THE RESULTS.

TRIAL 1 VELOCITY: 10 METERS ÷ ______ SECONDS = _______ M / S

TRIAL 2 VELOCITY: 10 METERS ÷ ______ SECONDS = _______ M / S

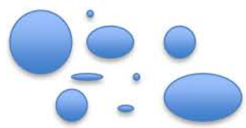
TRIAL 1 VELOCITY + TRIAL 2 VELOCITY ÷ 2 = _____ METERS/SEC | **AVERAGE VELOCITY:**

WRITE A PARAGRAPH THAT INCLUDES INFORMATION ABOUT EACH PARAMETER ABOVE TO DESCRIBE THE PHYSICAL CONDITIONS AT YOUR SITE.

Basic Stream Habitat Assessment — Tier 1

Field Sheet

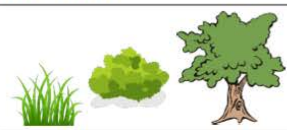
Name:	**Date:**	**Time:**
Stream or River Name:		
Watershed Name:	**Town:**	

Streambed – Check one:	**Point Values**	**Points Given**
❐ Big, medium, and small particles 	12	
❐ 2 sizes of particles	8	
❐ 1 size of particles	4	
❐ concrete	0	

Streambank Erosion – Check one:	**Point Values**	**Points Given**
❐ No erosion	12	
❐ A little erosion	8	
❐ Medium erosion	4	
❐ Lots of erosion	0	

Speed (Velocity) – Check one:	**Point Values**	**Points Given**
❐ All of these speeds:	12	
Fast (broken surface) 		
Medium (bumpy surface) 		
Low (smooth surface)		
❐ 2 speeds	8	
❐ 1 speed	4	
❐ No speed (still)	0	

Add the Points Given for Page 1:	

Streambank Plants (Riparian Vegetation) – Check one:	Point Values	Points Given
❒ Grasses, shrubs, and trees 	12	
❒ 2 kinds of plants	8	
❒ 1 kind of plant	4	
❒ No plants	0	

Streambank Plant Width – Check one:	Point Values	Points Given
❒ More than 20 paces (>20 paces) 	12	
❒ Between 10 and 20 paces	8	
❒ Between 10 and 2 paces	4	
❒ Less than 2 paces	0	

Add the Points Given for Page 2:	

Page 1 Points Given + Page 2 Points Given = (This is your Stream Habitat Quality Score)	

Stream Habitat Quality Score – Check one:	
❒ 50 to 60 points	Excellent habitat quality
❒ 40 to 49 points	Good habitat quality
❒ 30 to 39 points	Fair habitat quality
❒ Less than 29 points	Poor habitat quality

Intermediate Stream Habitat Assessment — Tier 2

(Adapted from Vermont Project WET)

Name:	Date:
Stream or River:	Town:

Streambed Composition. Large sediment types (cobbles and gravels) support a wider variety of organisms than smaller sediment types (sands and silts).

*Check **one** of the following and write its points in the shaded column.*	Point Values	Points Given
❒ mixture of cobbles, gravels, and sand	3	
❒ mixture of gravel and sand	2	
❒ mostly sand and silt	1	
❒ mostly silt	0	

Streambank Stability. Stream banks that are actively eroding generally have degraded habitats when compared to stable streams.

*Check **one** of the following and write its points in the shaded column.*	Point Values	Points Given
❒ banks appear stable (no signs of erosion)	2	
❒ moderately stable banks (some areas of erosion visible)	1	
❒ unstable banks (lots of erosion present)	0	

Depth and Velocity. High dissolved oxygen (DO) levels support a healthy, diverse aquatic community. Shallow streams have warmer water, which results in lower DO levels. Fast streams mix air into the water, which results in higher DO levels.

*Check **one** of the following **for each category** (Deepest Pool and Flow Types) and write its points in the shaded column.*	Point Values	Points Given
Deepest Pool is at least:		
❒ chest deep	3	
❒ waist deep	2	
❒ knee deep	1	
❒ ankle deep	0	
Velocity		
❒ very fast (hard to stand)	3	
❒ fast (quickly takes objects downstream)	2	
❒ moderately fast (slowly takes objects downstream)	1	
❒ slow (hardly any flow)	0	

Subtotal for Page 1	

Streambed Cover. A wide variety and/or abundance of submerged structures in the stream supports good aquatic habitat.		
*Check **as many as you see** and write a point for each checked item in the shaded column. Example: If you check all items, give 5 total points.*	**Point Values**	**Points Given**
❒ bed rock (Ex: rock ledges)	1	
❒ submerged logs, stumps, or tree roots	1	
❒ large rocks	1	
❒ artificial objects (Ex: bridge footing)	1	
❒ other (Ex: rip-rap)________________________________	1	

Riparian Vegetation. The root systems of plants growing along streambanks help hold soil in place and reduce the amount of erosion that is likely to occur.		
*Check **one** of the following and write its points in the shaded column.*	**Point Values**	**Points Given**
❒ mixture of trees, shrubs, and grasses	3	
❒ mixture of shrubs and grasses	2	
❒ mostly grasses	1	
❒ no vegetation	0	

Riparian Vegetative Zone Width. A vegetative zone serves as a buffer to pollutants entering the stream from runoff and helps to control erosion.		
*Check **one** of the following and write its points in the shaded column.*	**Point Values**	**Points Given**
❒ buffer zone is greater than 30.5 meters (100 ft)	3	
❒ buffer zone is between 15 meters (50 ft) and 30.5 meters (100 ft)	2	
❒ buffer zone is between 7.6 meters (25 ft) and 15 meters (50 ft)	1	
❒ no buffer zone	0	

Subtotal for Page 2	

Total Score:	Subtotal for Page 1 ________ + Subtotal for Page 2 _________	=	

Stream Habitat Assessment Rating. Check the rating that applies to your total score.			
❒ Excellent	22 to 18 total points	❒ Fair	10 to 6 total points
❒ Good	17 to 11 total points	❒ Poor	5 to 0 total points

ADVANCED HABITAT ASSESSMENT FIELD SHEET

TIER 3

FIELD SHEET

Names: **Date:**

Stream or River Name: **Town:**

1. Substrate Habitat Types

a. Check ALL substrate/cover types that are present and stable.

- ❒ trees that have fallen into river
- ❒ submerged logs
- ❒ undercut banks
- ❒ cobble or larger rocks
- ❒ other stable substrate materials

b. Check ONE category:	Points
❒ > 70% has mix of stable habitat types	8
❒ 40 to 70% has mix of stable habitat types	6
❒ 20 to 40% has mix of stable habitat types	4
❒ < 20% stable habitat; substrate unstable or absent	2
Score for Substrate Habitat Types:	

2. Embeddedness

Check ONE category:	Points
❒ 0 to 25% embedded; rocks easy to move	8
❒ 25 to 50% embedded; rocks more difficult to move	6
❒ 50 to 75% embedded; rocks are mostly buried	4
❒ 75 to 100% embedded; rocks cannot be moved	2
Score for Embeddedness:	

3. Sediment Deposition

Check ONE category:	Points
❒ < 5% of riverbed effected by deposition	8
❒ 5 to 30% of riverbed effected by new deposition	6
❒ 30 to 50% of riverbed effected by new deposition	4
❒ > 50% of riverbed changing frequently	2
Score for Sediment Deposition:	

4. Velocity / Depth Types

a. Check ALL velocity/depth types that are present:

- ❒ slow & deep
- ❒ slow & shallow
- ❒ fast & deep
- ❒ fast & shallow

(slow is < 0.3 meters/second; deep is > 0.5 meters)

b. Check ONE category:	Points
❒ All for velocity/depth types present	8
❒ 3 velocity/depth types present	6
❒ 2 velocity/depth types present	4
❒ 1 velocity/depth type present	2
Score for Velocity/Depth Types:	

5. Channel Flow Status

Check ONE category:	Points
❒ Water reaches from bank to bank; minimal substrate exposed.	8
❒ Water fills > 75% of channel; < 25% of substrate exposed.	6
❒ Water fills 25 to 75% of channel; < 0.5 meter deep.	2
❒ Very little water in channel; mostly present in standing pools.	1
Score for Channel Flow Status:	

Subtotal Page 1

Add scores for #1 + #2 + #3 + #4 + #5 =

Page 1 of 2

6. Channel Alteration		**7. Frequency of Riffles**	
Check ONE category:	Points	Check ONE category:	Points
❐ Alteration minimal; river with natural pattern	4	❐ Occurrence of riffles very frequent	4
❐ Some alteration present; usually near bridges	3	❐ Occurrence of riffles common	3
❐ Alteration extensive; 40 to 80% of area disrupted	2	❐ Occasional riffles	2
❐ Riverbanks artificially lined; > 80% disrupted	1	❐ Generally all flat water or shallow riffles	1
Score for Channel Alteration:		Score for Frequency of Riffles:	

8. Bank Stability – Score each bank, looking upstream			
LEFT Bank - Check ONE category:	Points	RIGHT Bank - Check ONE category:	Points
❐ Stable; < 5% eroded or collapsed	4	❐ Stable; < 5% eroded or collapsed	4
❐ Moderately stable; 5 to 30% eroded or collapsed	3	❐ Moderately stable; 5 to 30% eroded or collapsed	3
❐ Somewhat unstable; 30 to 60% eroded or collapsed	2	❐ Somewhat unstable; 30 to 60% eroded or collapsed	2
❐ Unstable; 60 to 100% eroded or collapsed	1	❐ Unstable; 60 to 100% eroded or collapsed	1
Score for Bank Stability – LEFT Bank:		Score for Bank Stability – RIGHT Bank:	

9. Riparian Vegetation – Score each bank, looking upstream			
LEFT Bank - Check ONE category:	Points	RIGHT Bank - Check ONE category:	Points
❐ > 90% covered by natural vegetation	4	❐ > 90% covered by natural vegetation	4
❐ 70 to 90% covered by natural vegetation	3	❐ 70 to 90% covered by natural vegetation	3
❐ 50 to 70% covered by natural vegetation	2	❐ 50 to 70% covered by natural vegetation	2
❐ < 50% covered by natural vegetation	1	❐ < 50% covered by natural vegetation	1
Score for Riverbank Vegetation – LEFT Bank:		Score for Riverbank Vegetation – RIGHT Bank:	

10. Riparian Zone Width – Score each bank, looking upstream			
LEFT Bank - Check ONE category:	Points	RIGHT Bank - Check ONE category:	Points
❐ Width > 18 meters; no human impact	4	❐ Width > 18 meters; no human impact	4
❐ Width 12 to 18 meters; minimal human impact	3	❐ Width 12 to 18 meters; minimal human impact	3
❐ Width 6 to 12 meters; much human impact	2	❐ Width 6 to 12 meters; much human impact	2
❐ Width < 6 meters; little or no riparian vegetation	1	❐ Width < 6 meters; little or no riparian vegetation	1
Score for Riparian Vegetation– LEFT Bank:		Score for Riparian Vegetation – LEFT Bank:	

TOTAL SCORE: Subtotal Page 1 (#1 + #2 + #3 + #4 + #5): ____ + Subtotal Page 2 (#6 + #7 + #8 + #9 + #10): ____ =

Good Habitat: Score of 80 to 60 ----- Fair Habitat: Score of 59 to 40 ----- Poor Habitat: Score of 39 to 0

Page 2 of 2

Chapter 6: Biological Monitoring

CHAPTER SUMMARY

- Introduction
- Learning Objectives
- Monitoring Guidelines
- BMI Assessment Tiers
- Fieldwork Packet
- Choosing a Sampling Site
- Collecting Your Sample Student Fieldwork Activities
- Sorting and Identifying BMIs
- Preparing for Fieldwork Field Sheets

Introduction

Stream organisms are often studied to generate information on stream health and water quality. While certain communities, such as fish and aquatic plants, are valuable ecological indicators, one community of aquatic organisms - macroinvertebrates – is an especially useful indicator in stream systems.

Macroinvertebrates are organisms without backbones (vertebrae) that are small yet big enough to see without magnification. Aquatic macroinvertebrates include insects, snails, worms, and crayfish. In the flowing water of a stream, most macroinvertebrates must attach to or hide under objects on the streambed to resist the pull of the current. Because they inhabit the "benthos" (streambed), they are called *benthic macroinvertebrates* (BMI).

- BMI's are excellent indicators of stream health and water quality for several reasons:
- Many groups are sensitive to changes in the physical, chemical, and/or biological conditions of the stream.
- Because they are small and can't move around easily in the current, they can't travel far to escape pollution events.
- They are critical components of the stream's food web.
- They are easy to collect with inexpensive equipment that can be used repeatedly.

Learning Objectives

After completing the benthic macroinvertebrate assessments in this chapter, students will be able to:

- Understand that a diverse community of BMIs, including sensitive ones, usually reflects good stream health
- Understand how to use BMIs as indicators of physical, chemical, and biological conditions in a stream
- Interpret BMI assessment results and relate them to stream health and water quality

Monitoring guidelines

This section summarizes how to prepare for and carry out BMI assessments at a suitable stream site. We encourage you to conduct BMI assessments at regular intervals and to compile your datasets so that you can compare stream conditions over time. Do conditions stay the same? If your data consistently indicate good water quality, what can you and your students do to maintain it? If your data indicate worsening conditions, you and your students can begin to investigate land and water uses that might negatively impact the stream.

Regularly completed assessments that are compiled into a database form the foundation of a *stream monitoring program.* Your regular assessments can help you monitor your stream's health, design stewardship activities to improve water quality, and measure the effectiveness of your efforts.

Student Fieldwork Activities

This chapter includes a **BMI Cover Sheet** that is appropriate for all grades and experience levels. Your students should complete it before collecting their BMIs.

There are three versions, or tiers, of the **BMI Assessment**. Please review each tier and choose the one that is appropriate for your students based on their grade and their level of experience with BMI work. See BMI ASSESSMENT TIERS below for guidance on choosing the tier that is right for you.

If you have high school students or students experienced in BMI studies, you may want to assemble a **BMI Reference Collection**. This is a collection of preserved organisms that are properly identified and labeled. It can be used as an aid in identification, a record of the types of organisms you collected, and a teaching and training tool. Please see **QUALITY ASSURANCE** below.

Preparing for Fieldwork

Step 1:
Familiarize yourself with the "Sampling Safety" section in Chapter 4 and with the instructions for the BMI assessment you will conduct.

Step 2:
Obtain the necessary supplies for your assessment (see the **Supplies** list for each assessment below). These items can be acquired by participating in Watershed Alliance's Stream Monitoring and Stewardship Program (SMSP) or by borrowing them from WA.

Step 3:
Choose a suitable **Sampling Site** using the criteria in the **FIELDWORK PACKET** below, and bring this information with you during fieldwork.

Step 4:
Review the three tiers for the BMI Assessment below and decide which one to use for best results with your students. We recommend that you also consider having students complete the Stream Habitat Assessment in Chapter 5, which will help you interpret your BMI results. For instance, a serious erosion problem that is causing heavy sedimentation on the streambed might help explain why your BMI collection lacks sensitive organisms that can't live in sediments.

Step 5:
Review the **Collecting Procedures** in the **FIELDWORK PACKET** below, and bring this information with you during fieldwork. *Please note: These procedures are designed for Tier 2: Intermediate BMI Assessment and Tier 3: Advanced BMI Assessment. For Tier 1: Basic BMI Assessment, have students focus on*

collecting as many different kinds of BMIs as possible; there is no specific collecting protocol for Tier 1.

Step 6:

Use keys and field guides to benthic macroinvertebrates to introduce your students to these organisms and help them learn to sort them, as needed, for the BMI Assessment you choose. Please see **SORTING AND IDENTIFYING BMIS** in the **FIELDWORK PACKET** below, and bring this information with you during fieldwork.

BMI assessment tiers

This chapter offers 3 Tiers, or levels, of BMI Assessment: Basic, Intermediate, and Advanced. (Please see Chapter 1 for more information on WA's Tier System for Stream Monitoring.) For each tier, students collect BMIs using a kick net or a dip net.

In general, high BMI diversity, including types of BMIs that are sensitive to pollution and degraded physical conditions, indicates a healthy stream. A healthy stream usually correlates with high water quality. Each tier in this chapter uses biodiversity as the overall indicator of water quality. Tier 2 and Tier 3 use a water quality formula as well that includes *weighting factors*, which value sensitive organisms more heavily than tolerant organisms.

Please review the **FIELDWORK PACKET** below to help you choose the tier (1, 2, or 3) that is right for your students.

Biological monitoring fieldwork packet

Choosing A Sampling Site – All Tiers

1. Find a streambank site that provides your students with good access to the stream. It should be big enough to allow all students to work comfortably and to move around safely.
2. Find a long riffle that can accommodate 3 replicate samples, or several riffles in the same region of the stream. A riffle is a shallow area with a gravelly or rocky bottom and turbulent (choppy) water. If the stream is healthy and water quality is high, a diverse community of benthic macroinvertebrates (BMIs) lives in the riffles of the stream. Some of these BMIs are sensitive to pollution and physical degradation, some are moderately sensitive, and some are tolerant of poor conditions
3. Please note: For Tier 1: Basic Assessment and Tier 2: Intermediate Assessment, have students collect from riffles as well as other habitats, like undercut banks; snags, tree roots, and submerged logs; and leaf packs. For Tier 3: Advanced Assessment, have students sample only in riffles. Please see the Instructions for each Tier for more information.
4. Look for a riffle that has cobbles on the streambed. Cobbles are rocks that are 5 to 25 centimeters (about 2 to 10 inches) in diameter. Ideal sampling sites consist of cobbles sitting on top of pebbles. Avoid streambed materials dominated by rocks larger than 50 centimeters (about 20 inches) in diameter.
5. The water at your sampling site should be knee-deep or shallower. Sample in the main channel, unless the water is too deep. Avoid areas along the margins that may be dry during low flows.
6. Avoid currents that are so fast that students must strain to stay upright while standing in them.
7. Avoid the transition zone from riffle to pool.
8. Avoid bridges and other large human-made structural features. If unavoidable, sample at least 50 meters (about 54 yards) upstream of a bridge or 200 meters (about 218 yards) or more downstream of a bridge.

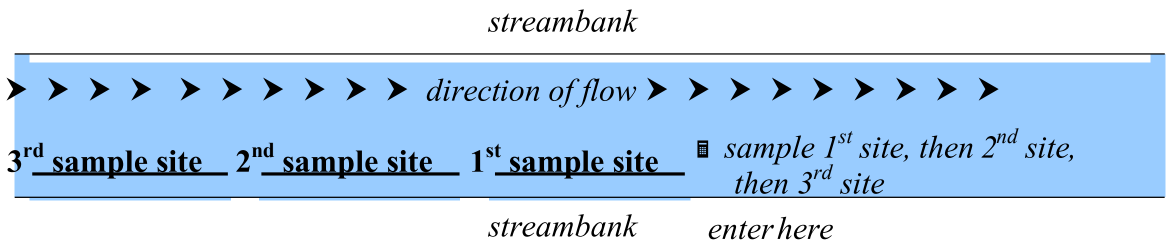
Collecting your sample -- tier 3

Using a Kick net

The kick net is 1 meter long and made of 500 to 600 micron mesh. Your goal is to disturb 1 square meter in front of the net to dislodge benthic macroinvertebrates that live there and allow the current to carry them into the net. Please note: use the procedure below to collect BMIs from 3 sampling spots in your riffle. Combine all BMIs caught to create one aggregate collection.

- Review the 3 sampling sites you have identified in your riffle(s).
- Choose 2 or 3 students to manage the net and collect the sample, as follows:
    - **Net Holder(s)** – If one holder: stand behind the net and brace both handles of the kick net in the water at a 45-degree angle. If two holders: stand on either side of the net; each of you holds one of the two handles. (In a fast current, it's much better to have two Net Holders.)
    - **Kicker** – When the kick net is in position, step in front of it and kick, roll, and otherwise disturb the rocks to dislodge BMIs living there. This person MUST have stiff, closed-toe shoes or boots so as not to damage their toes.

The Net Holder(s) and Kicker get the kick net and enter the stream downstream of your first sample spot, then walk upstream to the first sampling spot. (If you wade in upstream and walk down, every step you take disturbs the streambed and greatly reduces the accuracy of your results. See diagram below.)



]

- *Kicker:* In your mind, draw a 1-square-meter space in front of your net; this is the area you need to disturb in order to dislodge the BMIs that live there. Kick and roll the rocks in this square meter area. Pick up rocks and rub all of the debris off them in front of the net so the current carries all material into the net. If the streambed has soft substrate (like gravel or sand), dig down into the substrate to dislodge organisms that live within it.
- When you are finished disturbing the streambed in the 1 square meter in front of your net, remove the cobbles used to anchor it and rub them off in front of the net so that any clinging organisms are washed into the net.
- Remove the net carefully from the water so as not to lose any organisms, as follows:
  - *Net Holder(s):* Grab the top of the net handles.
  - *Kicker:* Grab the bottom of the net handles and the bottom edge of the net.
  - Together, lift the net out of the water by scooping it forward, into the current. Bring the two handles together and roll the net around them, being careful not to let any crawling organisms escape from the edges of the net.

Transferring Your Sample into a 5-Gallon Bucket

1. Put the bottom of your rolled-up net and the ends of the handles into the bucket so that the handles are vertical. Poor water down the net to rinse all materials into the bucket. If necessary, pick any clinging organisms from the net by hand and put them in the bucket.
2. Look through the material in the bucket and immediately return any fish, amphibians, or reptiles to the stream.
3. Carefully remove large pieces of debris (leaves, twigs, and rocks) from the sample. While holding the debris over the bucket, use forceps, spray bottle, and your hands to pick, rub, and rinse them to remove any attached organisms. When you are satisfied that the debris pieces are clean, discard them back into the stream.
4. Carefully pour the contents of the bucket through the net (or a sieve) into a second bucket (which has not yet been used and should be completely empty). The sample should be in the net or sieve. The water should be in the second bucket.
5. Use your spray bottle and forceps to remove all the material from bucket #1 and pour it onto the net or sieve. Carefully remove large pieces of debris (leaves, twigs, and rocks) from the sample.
6. As a final check, repeat the process above, but this time, pour bucket #2 over the net or sieve into bucket #1. Transfer any organisms on the net or sieve into the jar.

Swirling Your Collected Sample

This procedure uses gravity to separate the organisms and organic debris from the mineral debris like rocks, gravel, and sand.

1. Fill a 5-gallon bucket about 1/3 full of water, and place the sample into it. Swirl the water with your hand to create a whirlpool in the bucket. Organic debris and organisms will get caught in the whirlpool while the heavy particles will drop to the bottom.
2. Pour the water and organic debris into a #30 sieve, leaving the rocks, gravel and sand behind on the bottom of the bucket.
3. Fill about 1/3 of the bucket with water and repeat the swirling process 15 to 20 times until all that is left in the bucket is heavy particles, or until it has no debris in it.

Sorting and identifying BMI's – all tiers (especially tiers 2 and 3)

Rough Sorting by Physical Features

- Overall body shape (e.g. worm-like, segmented, round)
- Presence or absence of jointed legs (which are different than prolegs;

  see below) Presence or absence of antennae
- Presence or absence and

  location of gills Presence or

  absence of "tails"
- Presence or absence and location of prolegs, which are stubby, soft leg-like structures (they can be at the end of the abdomen, on each abdominal segment, below the head, etc.)
- Unusual appendages
- A clearly visible head capsule
- Type of movement (e.g.,

  swimming, crawling) Color and

  pattern (to some extent)

Major Groups of Benthic Macro Invertebrates

Scientific Names	Common Names
Order Ephemeroptera	Mayflies
Order Plecoptera	Stoneflies
Order Trichoptera	Caddisflies
Order Diptera	True Flies
Family Chironomidae	Midges
Family Tipulidae	Craneflies
Other Diptera families	Blackflies ,Horseflies etc.
Order Odonata	Dragonflies & Damselflies
Order Megaloptera	Fishflies, Dobsonflies
Order Coleoptera	Beetles
Order Amphipoda	Scuds
Order Isopoda	Sowbugs
Order Decapoda	Crayfish
Class Gastropoda	Snails
Class Pelecypoda	Clams
Class Oligochaeta	Bristle Worms
Class Hirudinea	Leeches

Quality assurance

The main quality assurance challenge is to make sure that all the organisms are correctly identified. This is particularly important when family identification is involved. To assure this, these measures are recommended:

- **Voucher Collection**: All processed samples should be saved for later verification by an expert. Samples should be stored in labeled vials filled with 90% ethyl alcohol with seals that prevent the alcohol from evaporating. Samples should be checked every few months and the alcohol replenished if needed.
- **Reference Collection:** Have an expert verify the identity of each family or major group in your sample. These examples should be stored in vials with a label that correctly identifies the organism. This collection can help to identify the unknown organisms from your river samples.

BMI Assessment Cover Sheet — All Tiers

Field Sheet

Name:	**Date:**	**Time:**
Stream or River Name:		
Watershed Name:	**Town:**	

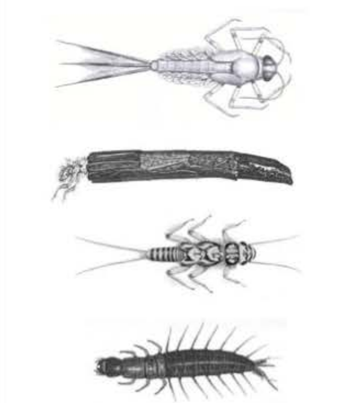
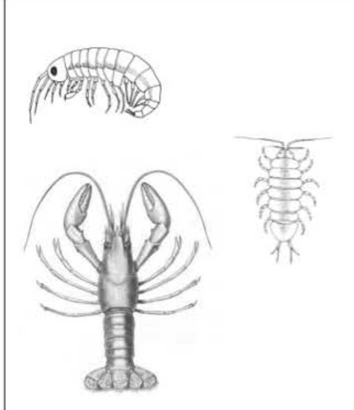
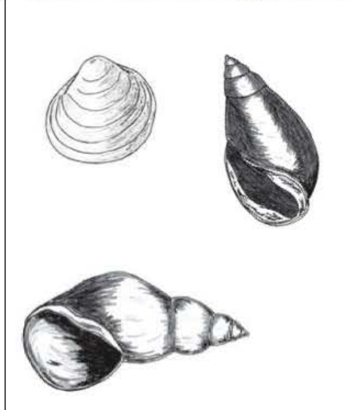
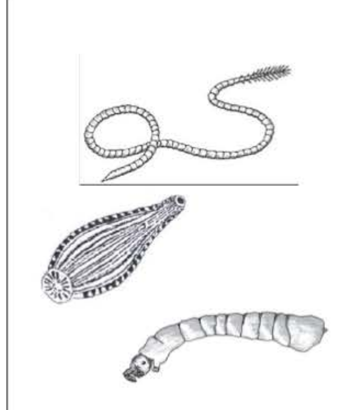
Weather	**Today (check one)**	**Past 48 Hours (check any that occurred)**	**Site Description:**
Clear / Sunny	☐	☐	
Overcast	☐	☐	
Showers	☐	☐	
Steady Rain	☐	☐	
Heavy Rain	☐	☐	

Site Sketch – Make a sketch of your site that includes the human activities along the stream vegetation or other items on the streambanks, the direction of water flow, features in the stream (large boulders, islands, bridges, etc.). When you choose your sampling spots (usually 3 spots in a riffle), note their location on your sketch.

Basic BMI Assessment
Field Sheet

Tier 1

Name:	Date: Time:
Stream or River Name:	Town:

Insect-like Animals ***Generally sensitive to pollution***	**Crayfish-like Animals** ***Generally sensitive to pollution***	**Shells** **both spiral and hinged shells** ***Sensitive to tolerant of pollution***	**Worm-like Animals** ***Generally tolerant of pollution***
			

Interpreting Your Results	
If you find:	**It suggests:**
Many kinds of animals, from sensitive to tolerant	Good water quality.
Only a few kinds of worm-like (tolerant) animals, but many individuals of these kinds	Severe organic pollution.
No animals	Toxic pollution.

POLLUTION TOLERANCE INDEX (PTI)

PT GROUP 1 *Intolerant*		PT GROUP 2 *Moderately Intolerant*		PT GROUP 3 *Fairly Tolerant*		PT GROUP 4 *Very Tolerant*	
Stonefly Nymph	________	Damselfly Nymph	________	Midges	________	Left-Handed Snail	________
Mayfly Nymph	________	Dragonfly Nymph	________	Black Fly Larvae	________	Aquatic Worms	________
Caddis Fly Larvae	________	Sowbug	________	Planaria	________	Blood Midge	________
Dobsonfly Larvae	________	Scud	________	Leech	________	Rat-tailed Maggot	________
Riffle Beetle	________	Crane Fly Larvae	________				
Water Penny	________	Clams/Mussels	________				
Right-Handed Snail	________	Crayfish	________				
# Of TAXA	________	**# Of TAXA**	________	**# Of TAXA**	________	**# Of TAXA**	________
Weighting Factors: **(x 4)**	________	**(x 3)**	________	**(x 2)**	________	**(x 1)**	________

"# of TAXA" refers to the number of *different types of BMI's in a PT Group*, i.e, if there are 4 stoneflies and 3 mayflies in PT Group 1, the **# of TAXA is 2, it is not 7, the total # of organisms**

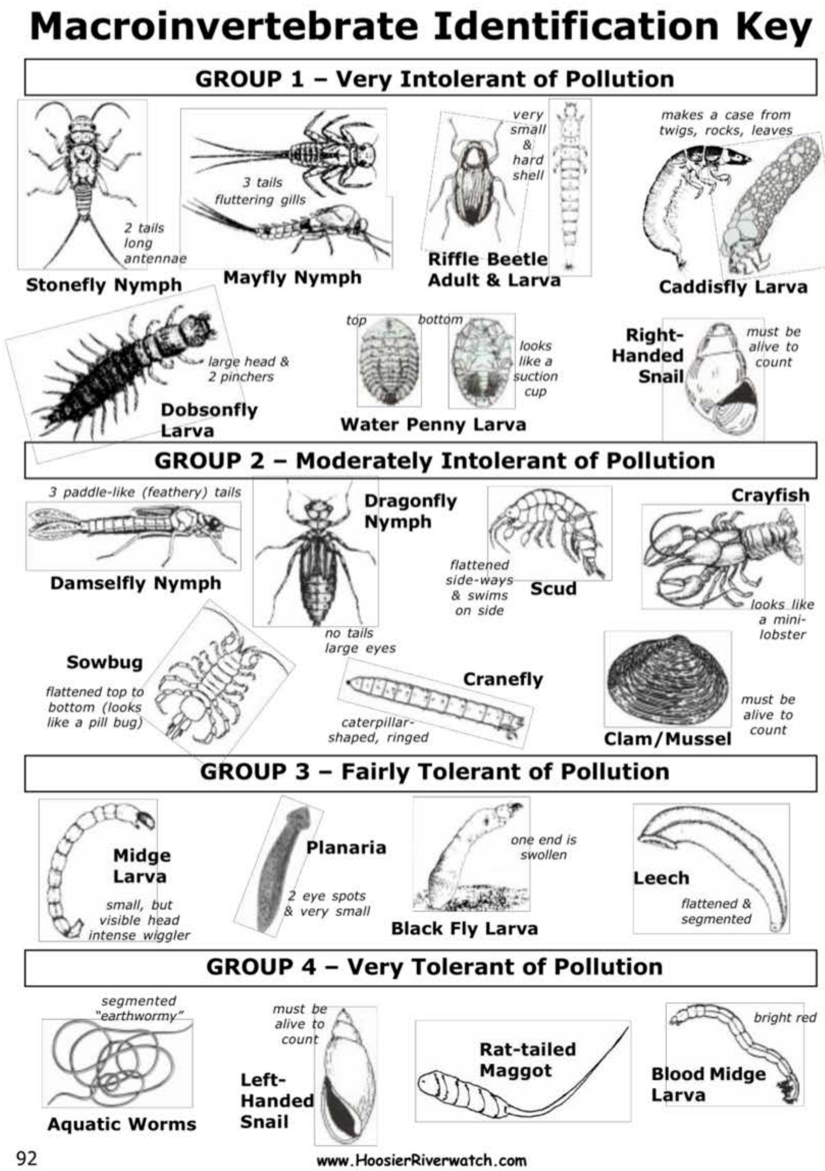
23 or More	**Excellent**
17 - 22	**Good**
11 - 16	**Fair**
10 or Less	**Poor**

POLLUTION TOLERANCE INDEX RATING ________

(Add the final index values for each group.)

Other Biological Indicators

☐ Native Mussels ☐ Zebra Mussels ☐ Rusty Crayfish ☐ Aquatic Plants _______ % Algae Cover _______ Diversity Index


Macroinvertebrate Identification Key
GROUP 1 – Very Intolerant of Pollution
2 tails
long
antennae
Stonefly Nymph
3 tails
fluttering gills
Mayfly Nymph
very
small
&
hard
shell
Riffle Beetle
Adult & Larva
makes a case from
twigs, rocks, leaves
Caddisfly Larva
large head &
2 pinchers
Dobsonfly
Larva
top
bottom
looks
like a
suction
cup
Water Penny Larva
Right-
Handed
Snail
must be
alive to
count
GROUP 2 – Moderately Intolerant of Pollution
3 paddle-like (feathery) tails
Damselfly Nymph
Dragonfly
Nymph
no tails
large eyes
flattened
side-ways
& swims
on side
Scud
Crayfish
looks like
a mini-
lobster
Sowbug
flattened top to
bottom (looks
like a pill bug)
Cranefly
caterpillar-
shaped, ringed
Clam/Mussel
must be
alive to
count
GROUP 3 – Fairly Tolerant of Pollution
Midge
Larva
small, but
visible head
intense wiggler
Planaria
2 eye spots
& very small
one end is
swollen
Black Fly Larva
Leech
flattened &
segmented
GROUP 4 – Very Tolerant of Pollution
segmented
"earthwormy"
Aquatic Worms
must be
alive to
count
Left-
Handed
Snail
Rat-tailed
Maggot
bright red
Blood Midge
Larva
92
www.HoosierRiverwatch.com

ADVANCED BMI ASSESSMENT – PART B (FIELD SHEET) TIER 3

NAME: ______________________________ **DATE:** __________ **TIME:** ________

STREAM OR RIVER NAME: ______________________________ **TOWN:** __________

1. Calculate the Index Value for each Group.

a. Look at the Sensitivity Groups on Page 1. In each Group box below, count the number of R's and write that number in the space to the left. Do the same for C's, then D's.

b. Multiply each number by its *Weighting Factor (WF).* Write that number to the right.

c. Add the numbers in the Value column on the right to get the Index Value for that Group.

Group I: Sensitive		**WF**		**Value for each Abund Code**	**Group II: Moderately Sensitive**		**WF**		**Value for each Abund Code**	**Group III: Tolerant**		**WF**		**Value for each Abund Code**
__ (# of R's)	X	5.0	=	______ +	__ (# of R's)	X	3.2	=	______ +	__ (# of R's)	X	1.2	=	______ +
__ (# of C's)	X	5.6	=	______ +	__ (# of C's)	X	3.4	=	______ +	__ (# of C's)	X	1.1	=	______ +
__ (# of D's)	X	5.3	=	______ ⇓	__ (# of D's)	X	3.0	=	______ ⇓	__ (# of D's)	X	1.0	=	______ ⇓
Group I Index Value:					**Group II Index Value:**					**Group III Index Value:**				

2. Calculate the Water Quality Score for the river site.

Add all Group Index Values together:

Group I Index Value ______ + Group II Index Value ______ + Group III Index Value ______ = **Water Quality Score** ________

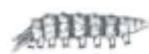
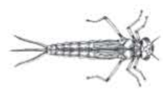
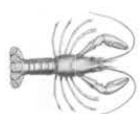
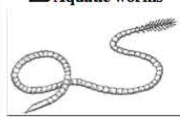
3. Compare this score to the following number ranges to determine the quality of your river site.

Water Quality Score	Check (▸) one box:	Explanation:
> 40	✕ Excellent water quality	No impairment of water quality
30 - 40	✕ Very good water quality	slight impairment of water quality
20 - 30	✕ Fair water quality	Moderate impairment of water quality
< 20	✕ Poor water quality	Significant impairment of water quality

Advanced BMI Assessment Field Sheet

Tier 3

Name   Date   Site Name

Group I: Sensitive	❑ **Caddisfly larvae** (except net spinners)  **Total Count** _______ **Abundance Code:** **R C D**	❑ **Mayfly larvae**  **Total Count** _______ **Abundance Code:** **R C D**	❑ **Stonefly larvae**  **Total Count** _______ **Abundance Code:** **R C D**	❑ **Water snipe fly larvae**  **Total Count** _______ **Abundance Code:** **R C D**	❑ **Water pennies**  **Total Count** _______ **Abundance Code:** **R C D**	❑ **Gilled snails**  **Total Count** _______ **Abundance Code:** **R C D**	❑ **Riffle Beetles**  **Total Count** _______ **Abundance Code:** **R C D**
Group II: Moderately Sensitive	❑ **Dragonfly larvae**  **Total Count** _______ **Abundance Code:** **R C D**	❑ **Damselfly larvae**  **Total Count** _______ **Abundance Code:** **R C D**	❑ **Sowbugs**  **Total Count** _______ **Abundance Code:** **R C D**	❑ **Alderfly larvae**  **Total Count** _______ **Abundance Code:** **R C D**	❑ **Fishfly and Dobsonfly larvae**  **Total Count** _______ **Abundance Code:** **R C D**	❑ **Scuds**  **Total Count** _______ **Abundance Code:** **R C D**	❑ **Beetle Larvae**  **Total Count** _______ **Abundance Code:** **R C D**
Group II: Moderately Sensitive	❑ **Crayfish**  **Total Count** _______ **Abundance Code:** **R C D**	❑ **Clams**  **Total Count** _______ **Abundance Code:** **R C D**	❑ **Mussels**  **Total Count** _______ **Abundance Code:** **R C D**	❑ **Cranefly larvae**  **Total Count** _______ **Abundance Code:** **R C D**	❑ **Net-spinning caddisfly larvae**  **Total Count** _______ **Abundance Code:** **R C D**		
Group III: Tolerant	❑ **Aquatic worms**  **Total Count** _______ **Abundance Code:** **R C D**	❑ **Blackfly larvae**  **Total Count** _______ **Abundance Code:** **R C D**	❑ **Midge larvae**  **Total Count** _______ **Abundance Code:** **R C D**	❑ **Leeches**  **Total Count** _______ **Abundance Code:** **R C D**	❑ **Lunged snails**  **Total Count** _______ **Abundance Code:** **R C D**		

Instructions

For each kind of organism you collect:

1. Check the box next to its name.
2. Count (or estimate) the number of individuals of this kind and enter this number in the "Total Count" space.
3. Circle Abundance Code R, C, or D for this kind.

Abundance Codes

1 to 9 organisms:	10 to 99 organisms:	over 100 organisms:
Rare (R)	Common (C)	Dominant (D)

Chapter 7: Chemical Monitoring

CHAPTER SUMMARY

- Introduction
- Fieldwork Packet
- Learning Objectives
- Choosing a Sampling Site
- Monitoring Guidelines
- Instructions for Data Collection
- Student Fieldwork Activities
- Interpreting Chemical Results
- Preparing for Fieldwork
- Field Sheets
- Chemical Assessment Tiers

Introduction

The water chemistry of a river system plays an important role in determining the health, abundance, and diversity of aquatic life found within it. By measuring chemical parameters, it becomes possible to ascertain how suitable the water is for aquatic life or whether it is an adequate drinking supply. Furthermore, by collecting and analyzing stream and river health we can make inferences about the watershed's surrounding land use, determine whether those land-uses are harmful or beneficial to the environment, and locate where better management practices could be implemented. We encourage the implementation of a stream chemistry unit at your local stream and will provide the materials and resources to make that possible.

It is important to note that stream environment conditions can dramatically change over months, weeks, and even over the course of a single day. Monitoring a stream site frequently and at regular intervals will ensure that average stream conditions can be quantified and that the data can be comparable over time, so please keep this in mind when planning our stream chemistry unit.

Learning objectives

After completing chemical monitoring students will be able to:

- Measure various water chemistry indicators
- Understand how chemical parameters affect aquatic life
- Interpret chemical test results and relate them to surrounding land uses

Monitoring guidelines

This section will summarize how to prepare for and carry out chemical monitoring at a suitable stream or river site. We encourage you to collect chemical data at regular intervals and to compile your datasets so that you can compare stream conditions over time. Regularly completed assessments that are compiled into a database form the foundation of a *stream monitoring program.* Your regular assessments can help you monitor your stream's health, design stewardship activities to improve water quality, and measure the effectiveness of your efforts.

Student Fieldwork Activities

This chapter provides **two,** unique water quality chemical assessments; each designed to target different ability levels. WA has also prepared a "fillable" chemical water monitoring scientific report (for advanced levels) for students to take notes during their time in the field. Please see **CHEMICAL ASSESSMENT TIERS** and **FIELDWORK PACKET** below for guidance on choosing the assessment that is best for you.

Preparing for Field Work

Step One:

Obtain one or more water quality test kits and other necessary equipment (see **FIELDWORK PACKET** below for a list of necessary materials).

Step Two:

Familiarize yourself with the "Sampling Safety" section in Chapter Four and with the instructions for using water-quality test kits in the Fieldwork Packet.

Step Three:

Prepare an introductory lesson to water quality chemical parameters. This lesson should include a discussion about **why** and **how** we test for these parameters. If you plan participate in WA's SMSP, this lesson will be covered in "Exploration Stations."

Step Four:

Choose a suitable stream site using the criteria in the **FIELDWORK PACKET** below, and bring this information with you during fieldwork. Be sure to double check that all necessary equipment is brought to the stream, including safety materials and kit instructions.

Chemical Assessment Tiers

This chapter offers three Tiers, or levels, of Chemical Assessment: Basic, Intermediate, and Advanced (see Chapter 1 for more information on WA's Tier System for Stream Monitoring). Please review each unique assessment in the **FIELDWORK PACKET** below to help you choose the tier (1, 2, or 3) that is right for your students.

The **basic** water chemistry assessment is designed to coincide with the use of LaMotte low-cost water quality test kits. These kits provide "healthy ranges" of the chemical parameter in a stream provided in parts per million (ppm). LaMotte kits are recommended for younger students because the methods for data collection are relatively simple and the chemicals aren't hazardous to human health. They are also biodegradable and can be disposed of directly down a drain at school.

The **basic** water chemistry assessment is designed to coincide with the use of LaMotte low-cost water quality test kits. These kits provide "healthy ranges" of the chemical parameter in a stream provided in parts per million (ppm). LaMotte kits are recommended for younger students because the methods for data collection are relatively simple and the chemicals aren't hazardous to human health. They are also

biodegradable and can be disposed of directly down a drain at school.

The **intermediate** assessment is designed to coincide with the use of Hach water chemistry test kits, which provide exact numbers of chemical parameters in mg/L. These kits involve a more challenging form of data collection, must be handled with safety glasses/gloves, and must be disposed of in an environmentally friendly manner.

The **advanced** assessment requires that students complete the intermediate assessment and prepare a scientific report of their findings. In this report students must pose a question, create a hypothesis, and test their hypothesis. If students are younger than high-school age and at this level, they can write a simple report rather than creating a genuine scientific report.

Chemical Assessment Fieldwork Packet

This packet contains information that will help you prepare for and carry out your fieldwork activities. It also contains field sheets for your students to complete. Please choose the field sheets that are appropriate for your students. Bring this fieldwork packet with you during fieldwork for reference.

Choosing A Sampling Site

1. Find a streambank site that provides good access to the stream for your class. It should be big enough to allow all students to work comfortably and to move around safely.
2. Locate a suitable spot for chemical data collection upstream of the physical and biological stations.
3. If you're planning to do a BMI assessment please find a long riffle that can accommodate 3 replicate samples, or several riffles in the same region of the stream (see chapter 6 fieldwork packet for more information on choosing a good BMI site).

Instructions For Data Collection

WA collects data for four chemical parameters in the stream - dissolved oxygen, total phosphorus, pH, and temperature.

Phosphorus Test

- Collect water sample from the middle of the stream.
- Follow instructions in manual for Hach Pocket II Colorimeter (located inside kit). Wipe off outside of bottle with Kimwipes prior to measuring with meter.
- Multiply number provided on meter by 0.326 to get total phosphorus. Dispose of liquid waste in a glass container labeled "PO_4".
- Dispose of solid waste (gloves and reagent packets) a plastic zip-lock bag.
- Rinse bottles and caps thoroughly with de-ionized water into liquid waste jar.

pH

Follow instructions on outside of bottle for pH test strips or the instructions with the pH meter. Dispose of pH strips in a plastic zip-lock bag.

Dissolved Oxygen Test

- **Wear lab glasses and gloves when performing this test.**
- Collect water sample from the middle of the stream.
- Follow instructions in manual for Hach Kit OX-2P (titration method).
- Squeeze dropper carefully so that only one drop of liquid is dispensed at a time; do not let

dropper touch liquid in bottle.

- Dispose of liquid waste in a glass container labeled "DO".
- Dispose of solid waste in a plastic zip-lock.
- Rinse bottles and caps thoroughly with de-ionized water into liquid waste jar

Temperature

- If possible, measure temperature in the main current, not along the bank. Place thermometer a few inches below the surface.
- Wait a few minutes for reading to stabilize, then read thermometer while the bulb is still in the water.

Equipment And Materials

This is a list of all the chemical test kits and equipment used during WA's stream monitoring program. Note: Some of these materials can be loaned out by WA to schools, but there will be a strict policy about returning and maintain the condition of this equipment (see Chapter 4 for biological and physical equipment list)

- Hach Dissolved Oxygen Kit Hach
- Phosphate Kit
- LaMotte Water Chemistry Kits (various)
- Safety Glasses
- Nitrile Gloves
- Mason Jars (for liquid chemical waste)
- 1 gallon plastic bags (for solid chemical waste)
- Deionized water (for cleaning water chemistry kit glass)
- Accuwipes
- Chemical Assessments (3)
- Chemistry Information Binders pH test strips
- pH test meter
- Thermometers

Interpreting Chemical Test Results

Below is a chart that depicts the healthy ranges of each chemical tested by WA. Use this chart in the field to make interpretations about the stream's health.

Dissolved Oxygen: 7 – 11 mg/L or 80 – 125% saturation

pH: 6.5 – 8.0

Phosphorus: < 0.05 mg/L (no impact), 0.05 – 0.10 mg/L (possible impacts), > 0.10 mg/L (impacted)

Conductivity: 150 – 500 µS/cm

E. coli: < 77 colonies per 100 ml (Vermont State Standard), < 235 colonies per 100 ml (EPA Standard)

Turbidity: 0 – 50 NTUs (no impact), 51 – 150 NTUs (possible impacts), > 150 NTUs (impacted)

The Hach dissolved oxygen kit

http://www.hwr.arizona.edu/globe/Hydro/kit_chem/hachdo.html

Equipment List

Chemicals
1) One bottle, Sodium Thiosulfate (0.0108N)
2) Dissolved oxygen reagent packet 1 (Manganous Sulfate>
3) Dissolved oxygen reagent packet 2 (LiOH, KI, Na-Azide)
4) Dissolved oxygen reagent packet 3 (Sulfamic Acid)

Glassware
1) One Hach Sampling bottle

2) One Hach mixing bottle
3) One Hach plastic measuring tube

To see exact amounts of chemicals necessary to make a kit of your own, click here

The Chemistry

Step 1.
Fill the Dissolved Oxygen bottle with the water to be tested by allowing the water to overflow the bottle for two or three minutes. This is to clear out the bottle and to make the sampling as uncontaminated as possible. To avoid trapping air bubbles in the bottle, incline the bottle slightly and insert the stopper with a quick thrust. Note the cone-shaped top which aides in forcing air bubbles out. If the bubbles become trapped in the bottle in Steps 2 or 4, the sample should be discarded before repeating the test.

This means... When you take a sample from your water source and cap it up, you begin the process of measuring the oxygen in your water by closing your sample off from the atmosphere. Inserting the stopper rapidly into your bottle forces air bubbles (containing oxygen) out. If these bubbles remain in the bottle, they may cause the test kit to indicate more oxygen is present than may actually be there.

Step 2.
Use the 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. Grip the bottle and stopper firmly; shake to mix. A side to side shaking motion works best. A flocculant (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 test results.
What is going on in this step:

- Reagent Powder Pillow #1 (Manganous Sulfate) $MnSO_4$

  This powder packet contains a powdered chemical called Manganous Sulfate which reacts with the oxygen present in the water. During the reaction, the oxygen is bound to the manganese (chemical element Mn), forming a brownish solid which settles to the bottom of the bottle (MnO_2). This process is called *fixing* the oxygen. In order for this fixation process to work however, the solution must be at high pH, so we need another reagent to make this occur...

- Reagent Powder Pillow #2 (LiOH, KI, Na-azide)

  If the Manganous Sulfate *fixes* the oxygen dissolved in the water, why do we need more chemicals? There are three specific chemicals present in packet #2 which are important to the *fixation* of the oxygen.

  - LiOH (Lithium Hydroxide) is a base, which means that in water it breaks up to form the OH^- ion, and the Li^+ ion. In this reaction, LiOH basically just functions as a catalyst to activate the binding process. The binding process involved with Manganous Sulfate requires a high pH to proceed. The addition of LiOH does just that.
  - KI (Potassium Iodide) is added to function as a dye, and will react with the sulfamic acid added, as explained below.

- NaN_3 (Sodium Azide) is an agent added which will not come into play until later in the reaction sequence. Because we will not come back to it, a quick explanation is appropriate. (For a more in-depth explanation, see the Winkler method titration page.) Basically during the final titration, Sodium Thiosulfate produces some nitrite (NO_2^-) which conflicts with the intended reaction. The addition of Sodium Azide prevents this conflictual reaction from occuring.

Step 3.
Allow the sample to stand until the floc has settled halfway in the bottle, leaving the upper half of the sample clear. Shake the bottle again. Again let it stand until the upper half of the sample is clear.

What is the story?

Allowing the floc time to settle in the bottle basically ensures that the chemical reaction occuring in the bottle has time to reach completion. If we proceded to step 4 before settling was complete, we might not get an accurate measurement of how much oxygen is actually dissolved in the water.

Step 4.
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 restopper the bottle and shake to mix. The floc will dissolve and a yellow color will appear if oxygen is present.

What is this mysterious reagent number 3?

- Reagent Powder Pillow #3 (Sulfamic Acid $C_6H_{13}O_3NS$) Upon addition of the Sulfamic Acid, the MnO_2 from above is reduced to Mn^{2+}, and the Iodine from the Potassium Iodide above is oxidized by the MnO_2 from I^- to I_2. This reaction step effectively causes the solution to take on a yellow-ish brown color proportional to the number of I_2 molecules present which in turn is proportional to the original amount of O_2 molecules in the water.

$$MnO_2 + 4H^+ + 2I^- = Mn^{2+} + I_2 + 2H_2O$$

  We say at this point, that the oxygen is *fixed*. This means that all of the oxygen from the original sample which was in solution has now been chemically modified to a form which won't change when exposed to the air. It is now in a stable form, and can be transported back to a classroom for analysis if necessary.

Step 5.
Fill the plastic measuring tube level full of the sample prepared in Steps 1 through 4. Pour the sample into the square mixing bottle.

Step 6.
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. Continue to add drops until the sample changes from yellow to colorless.

What does this do?

- Sodium Thiosulfate Standard Solution
  As drops of this chemical enter the solution, the Sodium separates from the thiosulfate ion. The thiosulfate then reacts with any Iodine (I_2) molecules available in the water. When the Iodine molecules react, they break up into I^- ions which are colorless.

$$2S_2O_3^{2-} + I_2 = 2S_4O_6^{2-} + 2I^-$$

What does this all tell us about the amount of oxygen in the water?

Stoichiometry (a fancy word meaning the chemical book keeping of the amount and concentration of chemicals in a reaction) tells us that 4 molecules of the Sodium Thiosulfate are required to change the color resulting from one molecule of O_2 in the original water. This clear definition allows us to get a very accurate estimate of the number of O_2 molecules in the original solution.

BASIC CHEMICAL ASSESSMENT — TIER 1

FIELD SHEET

This field sheet is designed to be used with LaMotte's Low-cost Water Quality Monitoring kit

Water Temperature

Dissolved Oxygen

Use the chart on the °C next page to determine % saturation from DO ppm and temperature readings

_____________**ppm**

_______________**% Saturation**

Phosphate

pH ___________**ppm**

Nitrate (optional)

_____________**ppm**

Use the chart below to calculate % saturation of dissolved oxygen in the river:

% saturation

Dissolved Oxygen

Temp°C	0 ppm	4 ppm	8 ppm
2	0	29	58
4	0	31	61
6	0	32	64
8	0	34	68
10	0	35	71
12	0	37	74
14	0	39	78
16	0	41	81
18	0	42	84
20	0	44	88
22	0	46	92
24	0	48	95
26	0	49	99
28	0	51	102
30	0	53	106

*Calculations based on solubility of oxygen in water at sea level, from Standard Methods for the Examination of Water & Wastewater, 18th edition.

INTERMEDIATE CHEMICAL ASSESSMENT — TIER 2

FIELD SHEET

This field sheet is designed to be used with Hach water quality monitoring kits

	Temperature (Varies with life stage and species) Example: Atlantic Salmon Max. for growth 23 C Opt. for spawning 5 C Embryo survival 7 C	**pH** 6.5-8.0 Average pH range for most aquatic life.	**Orthophosphate** **PO_4^{-3}** Multiply by 0.326 **No Impact** 0-0.05 mg/L of P **Likely Impact** 0.05-0.10 mg/L of P **Certain Impact** >0.1 mg/L of P	**Dissolved Oxygen** 4-7 mg/L of DO: low for cold fisheries, good for pond animals 7-11 mg/L of DO very good for most stream fish
Trial 1				
Trial 2				
Average				

Field Notes:

ADVANCED STREAM ANALYSIS AND LAB REPORT — TIER 3

FIELD SHEET

Use this form to take notes while in the field carrying out the intermediate chemical assessment. Take notes back school to type up a formal scientific report and give the final draft to your teacher.

Introduction

(This should include a question raised by the student after observing or assessing the stream or river. This question should then be followed by a hypothesis that guides the student into designing their stream study.)

Materials and Methods

(The materials and methods used to carry out the stream study should be listed out carefully, so that other individuals can imitate this study. Bulleted lists are acceptable for this section.)

Results

(This section should include all results retrieved by performing the stream study. Numerical data, graphs or tables are acceptable, as long as they are clearly explained.)

Discussion

(The final section should include interpretation of the results in paragraph format. The student could also provide management recommendations for the stream site based off of their findings.)

INTERMEDIATE CHEMICAL ASSESSMENT — TIER 3

FIELD SHEET

This field sheet is designed to be used with Hach water quality monitoring kits

	Temperature (Varies with life stage and species) Example: Atlantic Salmon Max. for growth 23 C Opt. for spawning 5 C Embryo survival 7 C	**pH** 6.5-8.0 Average pH range for most aquatic life.	**Orthophosphate** **PO_4^{-3}** Multiply by 0.326 **No Impact** 0-0.05 mg/L of P **Likely Impact** 0.05-0.10 mg/L of P **Certain Impact** >0.1 mg/L of P	**Dissolved Oxygen** 4-7 mg/L of DO: low for cold fisheries, good for pond animals 7-11 mg/L of DO very good for most stream fish
Trial 1				
Trial 2				
Average				

Field Notes:

Chapter 8: Post-Monitoring Activities

Community Outreach and Stream Stewardship

UVM Watershed Alliance requires that all groups participating in our Stream Monitoring and Stewardship Program complete a community outreach and/or stream stewardship project. We encourage groups to take action based on unbiased scientific information. Community outreach is an essential part of watershed education because it gives students the opportunity to apply information learned through the monitoring process and positively impact their community and their watershed. Students learn about civic participation and the importance of community involvement, and are often proud to share the results of their hard work with parents, peers, community members, and local officials.

UVM *Watershed Alliance* requires that all groups participating in our Stream Monitoring and Stewardship Program complete a community outreach and/or stream stewardship project. We encourage groups to take action based on unbiased scientific information. Community outreach is an essential part of watershed education because it gives students the opportunity to apply information learned through the monitoring process and positively impact their community and their watershed. Students learn about civic participation and the importance of community involvement, and are often proud to share the results of their hard work with parents, peers, community members, and local officials.

Ideas for outreach and stewardship projects

- Presentation of data/projects to a local conservation board/commission/district, town planners, local watershed organization, parents, peers, students in the same school, and/or students in a neighboring school
- Educational outreach and mentoring—hands on learning day with younger students
- Create a slide show (PowerPoint or photo) for presentation
- Create a video
- Produce a play
- Produce a radio ad and air it on local radio station
- Hold an informational poster campaign in school/community
- Hold a community watershed forum with speakers and open communication session
- Hold a watershed speaker series followed by presentation of student data/project
- Hold a watershed exposition at the school, library, or town green
- Work with local conservation district to plant trees and shrubs along riverbanks
- Organize a river/stream clean-up and invite the local paper

There are many options for outreach and stewardship projects, but we recommend you hold a brainstorming session to come up with student-led project ideas. Generally, it is best to decide on a project early in the planning phase, and before you begin your stream study. Additionally, it can be useful to alert the local press to your river study and outreach project. Many of our past participants have been featured in newspaper articles. Let's celebrate the students' learning and action.

Vignettes of Successful Stewardship Projects:

- Gay Craig and her Champlain Valley Union students (9/10th grade) present an annual report to the Lewis Creek Association (LCA). The students work closely with LCA to ensure that the data collected is useful to them.

- Websterville Baptist Christian School students, led by teacher Virginia Collins, produced an educational radio ad about their Winooski River study.

- During a UVM WA project, students in a local school discovered E.coli bacteria in the school. water and presented the data to town officials. This led to a "boil water" notice for the entire town, and the repair of the problem.

- Students at Danby's Currier Memorial School, led by Carrie Mauhs-Pugh, are working with local farmers on an on-going yearly study of a stream near the farm. The students plan to present the findings to the farmers along with suggested Best Management Practices.

- Ninth and tenth grade students at the SUCCESS School (an alternative school in Rutland) worked in conjunction with the VT Department of Environmental Conservation and the Rutland Natural Resource Conservation District on a study of the Moon Brook. The Moon Brook, located in Rutland city, is included on the state's 303d list of impaired waters. The Upper Otter Creek Watershed Council (UOCWC), a group of local officials, experts, watershed organizations, and concerned citizens formed to address issues in the upper Otter Creek watershed, is interested in the data the students collected.

- At U-32 High School in Montpelier, Brian Slopey's twelfth grade Environmental Science students. acted as educators and mentors to students from the middle school. Slopey's students designed hands-on projects that engaged the younger students as they taught them about watersheds and water quality. Slopey praised the students and the project, noting that his students benefited from the experience as much as those from the middle school did.

- Colchester and Essex High School Environmental Science classes are teaming up to study Indian Brook and its watershed. Indian Brook is on the state 303d list for stormwater impairment. Kara Lenorovitz and Erin Bessey from their respective schools have contacted city officials in Colchester and Essex asking for sampling site recommendations and an update on stormwater improvement projects in both towns. The students are planning to attend a Brook clean-up day for one of their stewardship projects. Another group working with Ms. Lenorovitz is designing a school rain garden.

As stated earlier, all participants in the Stream Monitoring and Stewardship Project are required to complete an outreach and/or stream stewardship project. The WA Outreach & Education Coordinator will gladly act as the initial liaison between community groups, watershed associations, and town and state officials. It is the goal of this program to increase knowledge and awareness about watershed health and water quality issues in the Lake Champlain Basin and surrounding waters. The best way to accomplish this is through students extending their knowledge and understanding into the community to educate lifelong learners so that we can all make positive impacts to the health of our waters

Chapter 9: Water Quality In Vermont

Vermont is divided into 17 major basins through which roughly 7,100 miles of rivers and streams flow. The Vermont Watershed Management Division – Monitoring, Assessment and Planning Program is the governing body responsible for monitoring and assessing these waterways, providing support and guidance to volunteer monitoring groups, providing grants and technical support for nonpoint source pollution management, implementing regulatory programs, preparing watershed plans for the 17 major basins, and developing strategies for bringing waters into compliance with water quality standards.

The Vermont Division of Water Quality classifies Vermont waters as either Class A or Class B. Class A waters comprise only 3% of all waters in the State, and are further subdivided into Class A(1), ecological waters that are managed in their natural state, or Class A(2), Public Water Supplies. Class B waters make up the remaining 97% and are managed depending upon their classification as type B1, B2, or B3. Waters are also given the assessment categories of full support, stressed, altered, impaired or unassessed. Full support waters meet all use support standards for the water's classification type and management type. Stressed waters support the classification type, but the water quality and or aquatic habitat may have been disturbed by human impacts, but not to a degree where designated uses have been altered or impaired. Altered waters include those where aquatic communities are altered from their expected ecological state and where water quality violations have been documented, but the EPA does not consider the problem to be pollutant caused, or where the pollutant was a result of historic stream channel alterations that are no longer occurring. Impaired waters do not meet one or more of the Water Quality Standards due to a pollutant of human origin. Lastly, waters deemed as unassessed do not have adequate monitoring data to categorize them under the former.

Impaired Waters

Every two years, all impaired waters are placed on a 303(d) List under Part A (requires the development of a TMDL or Total Maximum Daily Load to be scheduled), Part B (TMDL is not required), or Part D (TMDL is already completed). This list is named as 303(d) based on the section of the Clean Water Act that mandates their management. A TMDL dictates the amount of a given pollutant that can enter a body of water without negatively impacting water quality standards.

Important links to Vermont Water Quality reports, standards, and fact sheets:
http://www.vtwaterquality.org/

http://www.vtwaterquality.org/mapp/htm/mp_mapp.htm

http://www.vtwaterquality.org/mapp/htm/mp_assessment.htm

Watershed Associations

There are numerous organizations involved in the conservation, management, and advocacy of watersheds in Vermont. The Lake Champlain Basin Program maintains a list of watershed associations categorized by the basin they are located in (http://atlas.lcbp.org/). If you are planning a river study in your area, a local watershed association can provide useful background information on the watershed, and can provide information on what monitoring questions would be useful to ask. They may also be interested in the data that your student group collects. Making local contacts in support of your monitoring program will increase the relevancy of the data you collect, and will result in a stronger program overall. The Watersheds United Vermont (http://www.watershedsunitedvt.org/) is a network of watershed association that should also be referred to as you develop your outreach and stewardship project.

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Appendices

Appendix A. Stream Monitoring & Stewardship Program Application

UVM WATERSHED ALLIANCE — Increasing knowledge, fostering stewardship in Vermont youth

A UVM Extension/Lake Champlain Sea Grant program in partnership with the Rubenstein School of the Environment and Natural Resources.

www.uvm.edu/watershed

Stream Monitoring & Stewardship
PROGRAM APPLICATION

Please type or print legibly.

Part I. Contact Information and Background

Teacher Information:

Name:____Home Phone: ______________________

School Name and Address:

____

Work Phone:____________________Fax:_____________________Email: _______________________

What are the best days/times to contact you by phone and at what number?

____

____

Teaching Assignment:

Please list the course(s) you plan to include in the Stream Monitoring Program.

Science courses *Grade(s)* *# Students*

____

____

Teacher Background:

How many seasons have you participated in a program with UVM WA? _________

If this is your first season, briefly describe your prior experience in watershed monitoring and/or fieldwork:

Watershed Information:

In what major watershed is your school located? (See http://www.uvm.edu/watershed for more information)___________________________

Have you chosen a monitoring site(s)?______Y______N

If yes, please describe the site (average river depth and width, substrate, access) and estimate the travel time and mode of transportation to the site from school.

Is owner permission needed to access the site?______Y______N
If you have not yet chosen a site, would you like assistance in doing so?______Y______N

PART II. Program Details

Program Options:

Please check the elements you would like to include in your Stream Monitoring Program. A short description is given on pages 3– 5. Additional information is available at our website: www.uvm.edu/watershed. Note the Study Design/Equipment Demonstration and the Community Outreach project components are mandatory. Watershed Educators from UVM are trained to help in the classroom, lab and/or field with each of the program elements. Please contact Ashley Eaton if you have any questions.

PROGRAM ELEMENT	REQUIRED TIME (approximate*)
□ **Watershed Model Demonstration/Discussion**	1 – 1 ½ hours
□ **Study Design and Equipment/Methods Demo (mandatory)**	1+ hour
□ **Introduction to Watersheds and Water Quality Monitoring**	30 minutes – 1 hour
□ **Habitat/Physical Assessment**	1 hour
Chemical Monitoring □ pH □ Dissolved Oxygen □ Phosphorus □ Conductivity	1+ hour (all parameters)
□ **Benthic Macroinvertebrate Sampling – Streamside Survey**	1+ hour
□ **Microbiology** Total Coliform/E.coli Bacteria (Quanti-Tray) – sample processed in the lab	10 minutes (24 – 48 hours processing)
□ **Outreach/Stewardship Project (mandatory)**	varies

*varying travel time to monitoring sites, varying class sizes, and addition/subtraction of parameters may greatly change estimated time

I_____can_____cannot commit an appropriate amount of instruction time for the Stream Monitoring Program elements I have selected.

Our spring stream monitoring program season begins in **April and runs through early June**. The fall monitoring begins in **September and runs until early November**. Please indicate your first and second choices for program dates (or days of the week if you are flexible) and include starting and ending times for each date that allow ample time for all program components selected. We will do our best to accommodate your needs but may not be able to fulfill all your requests depending upon our availability and travel costs.

PART III. Signatures

I understand the benefits and requirements of participation in the UVM Watershed Alliance Stream Monitoring Program and would like to participate with my students.

____ _______________

Teacher's Signature Date

PLEASE EMAIL or MAIL APPLICATION TO:

UVM Watershed Alliance
Rubenstein Ecosystem Science Laboratory
3 College Street
Burlington, VT 05401
Phone: 802.859.3086 x305
www.uvm.edu/watershed

For questions or additional information, contact Ashley Eaton, Interim Outreach and Education Coordinator, by phone at 802.859.3086 x305, or email at ashley.eaton@uvm.edu

Appendix B. Stream Monitoring & Stewardship Program Description

Additional information is available in the Stream Monitoring and Stewardship Program Handbook available online at http://www.uvm.edu/watershed/programs/stream-monitoring-stewardship.

Watershed Model Demonstration/Discussion
Grade Level: 5th – 12th
Time Required: 1 – 1 ½ hours
Description: This interactive table-top model by EnviroScape® is designed to introduce key watershed concepts including the definition of watershed, types and sources of pollution, effects of pollution on humans and ecosystems, the differences between non-point and point source pollution, and best management practices.

Study Design and Equipment/Methods Demo (mandatory)
Grade Level: 5th – 12th
Time Required: 1+ hour
Description: It is imperative that students understand the scientific method and identify the monitoring questions driving the field study before collecting data. Introducing the study design and the methods that we'll use in the field will increase the quality of the data collected and help to ensure that the field experience goes smoothly and efficiently. One of several options for covering these topics is self-paced exploration stations (see program handbook for additional information).

Introduction to Watersheds and Water Quality Monitoring
Grade Level: 7th – 12th
Time Required: 30 minutes – 1 hour
Description: This PowerPoint presentation covers the definition of a watershed, effects of impervious surfaces on the water cycle, benefits of healthy watersheds, reasons why we monitor water quality, and an introduction to aquatic ecology and water quality parameters; available for your independent use or can be presented by Watershed Educators.

Habitat/Physical Assessment
Grade Level: 5th – 12th
Time Required: 1 hour
Description: Monitoring physical characteristics of the river can provide a context for evaluating chemical and biological parameters, and can be the simplest and most effective way of evaluating a river's health if time and resources are limited. It can also be useful to compare physical assessments from year to year to understand the dynamics of a river system. Physical parameters include stream depth and width, velocity, substrate, discharge, and transparency.

Chemical Monitoring
Grade Level: 5th – 12th except where noted under equipment/methods
Time Required: 1+ hour (for all parameters)
Description: Chemical monitoring allows us to view water quality parameters as a snapshot in time. Collecting chemical data can be useful for identifying areas for further investigation, and can help students better understand the differences between and interactions of abiotic and biotic components of an aquatic ecosystem.

pH (10 minutes)

Equipment/Methods: Hach pH test strips

Dissolved Oxygen (20 minutes)

Equipment/Methods: Hach Dissolved Oxygen Test Kits (Winkler Method), demonstrate for grades 5th – 8th; YSI 85 Meter

Phosphorus (15 minutes)

Equipment: Hach Pocket Colorimeter II Test Kit, demonstrate for 5th and 6th grades

Conductivity (10 minutes)

Equipment: YSI 85 Meter

Benthic Macroinvertebrate Sampling

Grade Level: 5th – 12th

Time Required: 1+ hour for Streamside Survey; 4 hours for Intensive Laboratory Inventory

Streamside Survey: In this method, all work is done in the field. This involves collecting the sample using a net, sorting and identification of major groups (mostly orders, a few families, some classes) of benthic macroinvertebrates, and assessment of primary habitat characteristics. Approximately 0.28 square meters of the stream bottom are sampled. The relative abundance and richness of the each major group is determined, a field sheet is filled out, and the organisms are returned to the stream.

Microbiology

Grade Level: 5th – 12th

Time Required: 10 minutes (sample collection), 24 – 48 hours (sample processing)

Total Coliform/E.coli: We use the Quanti-Tray method to quantify Total Coliform and *E. coli.* A 100 ml water sample is collected in the field, kept on ice, and processed in the lab no longer than 6 hours after the sample was collected. We use two different nutrient reagents: Colilert, which is EPA certified for testing ambient waters and has an incubation time of 24 – 28 hours; and Colisure, which is not EPA certified for testing ambient waters (it's EPA certified for testing drinking water), but has an incubation time of 24 – 48 hours. We will email you with your results.

Outreach/Stewardship Project (mandatory)

Grade Level: 5th – 12th

Time Required: varies

Description: UVM Watershed Alliance emphasizes action based on unbiased scientific information. The Community Outreach/Stewardship component allows students to utilize their creativity while they apply their findings and become engaged in their local community.

Community Outreach: Program participants have presented their findings to local planning commissions, school boards, watershed groups, and parents. Other *Community Outreach* projects have included the production of a series of public service announcements broadcast on the radio, brochures, websites, and participant led lessons for younger students.

Conservation Service/Stream Stewardship: Opportunities exist to partner with community organizations to implement on-the-ground conservation service or stewardship projects. UVM Watershed Alliance can assist your class in identifying a meaningful project and establishing a partnership with the appropriate community organization. Examples in the past have included riparian tree plantings, invasive species removal and clean-up days.

Appendix C. Additional Resources (Online)

Vermont Water Resources

Lake Champlain Basin:

ECHO at the Leahy Center for Lake Champlain (www.echovermont.org)—*Aquarium and science center on Burlington's waterfront*

Lake Champlain Basin Program (www.lcbp.org)—*Information and outreach about issues facing Lake Champlain's watershed.*

Lake Champlain Initiative (www.lcbp.org/cbei.htm)—*Consortium of environmental education groups throughout the Lake Champlain Basin*

Living in Harmony with Vermont Streams: A Citizen's Guide to How Streams Work
http://winooskiriver.org/images/userfiles/files/Stream%20Guide%201-25-2012%20FINAL.pdf

Vermont Department of Environment and Conservation:

Water Quality Division (www.vtwaterquality.org)

Directory of Watershed and Lake Associations of Vermont
(www.anr.state.vt.us/cleanandclear/orgs/index.cfm)

Vermont Lay Monitoring Program
(www.anr.state.vt.us/DEC/waterq/lakes/htm/lp_lmp.htm)

Project WET/Healthy Water Healthy People Program
(www.anr.state.vt.us/dec/waterq/lakes/htm/lp_monitoringguide.htm)

VT Natural Resources Board Water Resources Panel (http://www.nrb.state.vt.us/wrp/index.htm)

VT Water Quality Standards (www.nrb.state.vt.us/wrp/publications/wqs.pdf)

VT DEC 303(d) list of waters
(http://www.anr.state.vt.us/dec/waterq/planning/docs/pl_2006.partA.pdf)—*Vermont's 2006 list of impaired waterways*

Federal Resources

Environmental Protection Agency:

Office of Wetlands, Oceans and Watersheds (www.epa.gov/owow/)

Volunteer Monitoring (www.epa.gov/owow/monitoring/volunteer/)

Surf Your Watershed (www.epa.gov/surf)—*Locate, use and share information about your watershed*
The Volunteer Monitor (www.epa.gov/owow/monitoring/volunteer/vm_index.html)—*The national newsletter of volunteer water quality monitoring*

What's Up with Our Nation's Waters?
(www.epa.gov/owow/monitoring/nationswaters/waterspdf.html)—*Information about water quality from the EPA's Office of Water*

National Organizations

American Rivers (www.amrivers.org)—A *nonprofit organization dedicated to the protection and restoration of North America's rivers*

http://cwn.org/American Whitewater (www.americanwhitewater.org)—*American Whitewater restores rivers dewatered by hydropower dams, eliminates water degradation, improves public land management and protects public access to rivers for responsible recreational use*

Clean Water Network (www.cleanwaternetwork.org)- *"Working to keep the promise of the Clean Water Act."*

http://cwn.org/River Network (www.rivernetwork.org)—"*Connecting people, saving rivers."*

Benthic Macroinvertebrates

Benthic Macroinvertebrates in our Waters
(www.epa.gov/bioindicators/html/benthosclean.html)—*From the EPA Biological Indicator of Watershed Health site.*

Key to Aquatic Macroinvertebrates (www.dec.ny.gov/animals/7105.html)—*From the NY Department of Environmental Conservation's Stream Biomonitoring Unit. Color Pictures of BMIs*

For Educators

GREEN (www.earthforce.org/section/programs/green)—*Global Rivers Environmental Education Network; provides great resources on helping youth develop long-term watershed stewardship.*

Educating Young People About Water (www.uwex.edu/erc/eypaw/)—*Wisconsin Extension's water education site. Provides links to searchable water curriculum database*

USGS Water Science for Schools (www.ga.water.usgs.gov/edu/index.html)—*Information, pictures, data and maps related to water science*

This information is updated on our website more frequently than within the pages of this handbook. Please visit http://www.uvm.edu/watershed for news and updated resource links.

Appendix D. Frequently Used Benthic Macroinvertebrate Identification Keys (Links)

List of frequently used identification keys. Look for these keys on our website under the Stream Monitoring & Stewardship Program pages and the Additional Resources page. Due to formatting issues we are not able to supply these as digital "hard copies".

1. **ID Guide to Freshwater Macroinvertebrates (Stroud Water Research Center)**
   http://www.stroudcenter.org/education/MacroKey_Complete.pdf

2. **Stream Macroinvertebrates (Maryland Department of Natural Resources) - 4 sensitivity groups**:
   http://www.dnr.state.md.us/streams/pdfs/dnr_bugsheet.pdf

3. **Key to Macroinvertebrate Life in the River (University of Wisconsin)**:
   http://watermonitoring.uwex.edu/pdf/level1/riverkey.pdf

4. **WV Save Our Streams Benthic Macroinvertebrate Field Guide**
   http://www.dep.wv.gov/WWE/getinvolved/sos/Documents/Benthic/WVSOS_MacroIDGuide.pdf

5. **A Simple Picture Key: Major Groups of Benthic Macroinvertebrates Commonly Found in Freshwater New England Streams (River Watch Network)**
   http://cdflyfishers.org/Fly%20Tying/aquatic%20organisms.pdf

Appendix E. Equipment and Materials Suppliers

Below are several companies that supply water quality monitoring equipment. It can be useful to call a few different sources as prices can vary and several different companies have overlapping inventories. Most companies offer technical advice through their customer service line that can be very helpful if you have questions about what type of product to use or how to use a product that you have already purchased.

Item(s)	Company	Phone	Website
Watershed Model	EnviroScape	(703) 631-8810	http://www.enviroscapes.com
General Monitoring Supplies	Ben Meadows	(800) 241-6401	http://www.benmeadows.com
	Carolina Biological Supply	(800) 334-5551	http://www.carolina.com
	Forestry Suppliers	800-647-5368	http://www.forestry-suppliers.com
	Wildlife Supply Company	(800) 799-8301	http://www.wildco.com
Chemical Test Kits	Hach	(800) 227-4224	http://www.hach.com
	La Motte	(800) 344-3100	http://www.lamotte.com
Quanti-Tray Supplies (Coliform Monitoring)	IDEXX	(800) 321-0207	http://www.idexx.com

Appendix F. Supervisory Units, Sub-Basins, and Watershed Associations/Organizations

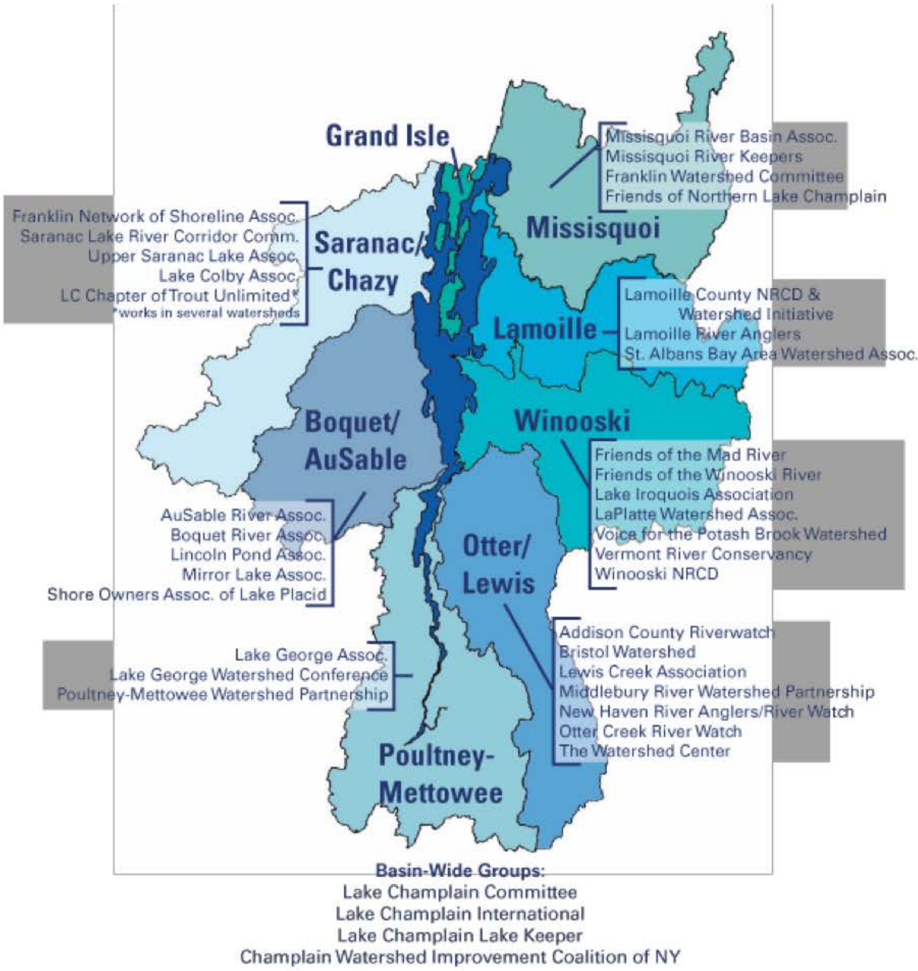
This list is a compilation of organizations/associations involved in watershed stewardship, divided by sub-basins within the Lake Champlain Basin. The purpose of this list is to provide teachers/educators with resources to connect with organizations in their community in order to engage their students in activities for watershed stewardship. Please visit the Watersheds United Vermont website for more information about this state-wide watershed association group helping to educate and focus action in and around our watersheds. http://www.watershedsunitedvt.org/

The Watershed Alliance would be happy to help teachers/educators make these connections by communicating with organizations, researching relevant and current projects in your area or helping you create your own unique project to fulfill the Community Outreach and Stream Stewardship portion of the Stream Monitoring and Stewardship Project. Scheduling/coordination for an outreach or stewardship project should occur directly between organizations and teachers/educators.

Lake Champlain Sub-Basin	Lake Champlain Basin Supervisory Unions	Association/ Organization
Missisquoi River	•Franklin Central SU (23) •Franklin Northeast SU (20) •Franklin Northwest SU (21)	Missisquoi River Basin Association http://www.troutrivernetwork.org/mrba/index.html Missisquoi River Keepers Franklin Watershed Committee Friends of the Northern Lake Champlain
Lamoille River	•Franklin West SU (22) •Lamoille North SU (25) •Lamoille South SU (26) •Milton Town SD (10)	Lamoille County NRCD & Watershed Initiative http://www.lcnrcd.com/ Lamoille River Anglers St. Albans Bay Area Watershed Association http://www.uvm.edu/giee/AV/NF/StAlbans/
Otter/Lewis	•Addison Central SU (03) •Addison Northeast SU (01) •Addison Northwest SU (02) •Rutland Northeast SU (36) •Rutland South SU (33)	Addison County Riverwatch Bristol Watershed Lewis Creek Association http://www.lewiscreek.org/ Middlebury River Watershed Partnership New Haven River Anglers/River Watch http://www.newhavenriveranglers.com/ Otter Creek River Watch The Watershed Center
Grand Isle	Grand Isle SU (24)	Lake Champlain Basin Program http://www.lcbp.org/

Lake Champlain Sub-Basin	Lake Champlain Basin Supervisory Unions	Association/ Organization
Winooski River	•Barre SU (61) •Burlington SD (15) •Chittenden Central SU (13) •Chittenden East SU (12) •Chittenden South SU (14) •Colchester SD (07) •Montpelier SD (45) •South Burlington SD (16) •Washington Central SU (32) •Washington Northeast SU (41) •Washington West SU (42) •Winooski SD (17) •Essex town SD (59)	Friends of the Mad River http://www.friendsofthemadriver.org/ Friends of the Winooski River http://www.winooskiriver.org/ Lake Iroquois Association Voice for the Potash Brook Watershed Vermont River Conservancy http://www.vermontriverconservancy.org/ Winooski Watershed NRCD http://www.vacd.org/winooski/
Poultney/ Mettowee	•Rutland Northeast SU (36) •Addison-Rutland SU (04) •Rutland Southwest SU (38) •Rutland Central SU (37) •Rutland City SU (40)	Lake George Association http://www.lakegeorgeassociation.org/ Lake George Watershed Coalition http://www.lakegeorge2000.org/ Poultney-Mettowee Watershed Partnership http://www.pmnrcd.org/
New York: Saranac/Chazy	n/a	Franklin Network of Shoreline Association Saranac Lake River Corridor Comm. Upper Saranac Lake Association Lake Colby Association http://www.lcbp.org/watersheds/lcolby.htm
New York: Boquet/ AuSable	n/a	AuSable River Association http://www.lcbp.org/watersheds/ara.htm Boquet River Association http://boquetriver.org/ Shore Owners Association of Lake Placid http://www.lcbp.org/watersheds/soa.htm

Below is a Lake Champlain Basin map displaying sub-basins in New York, Vermont, USA and Quebec, Canada, with their regions' watershed associations/organizations.



Additional Resources:

•Refer to *Lake Champlain Basin Supervisory Unions* to find which SU your school belongs to on the following page

•*Watersheds and Lake Associations of Vermont Directory* by the Vermont Dept. of Environmental Conservation

http://www.vtwaterquality.org/planning/docs/305b/pl_305b-apdxh.pdf

•*Lake Champlain Basin Program* website

http://www.lcbp.org/

• *Winooski River Landowner's Assistance Guide* by the Friends of the Winooski River

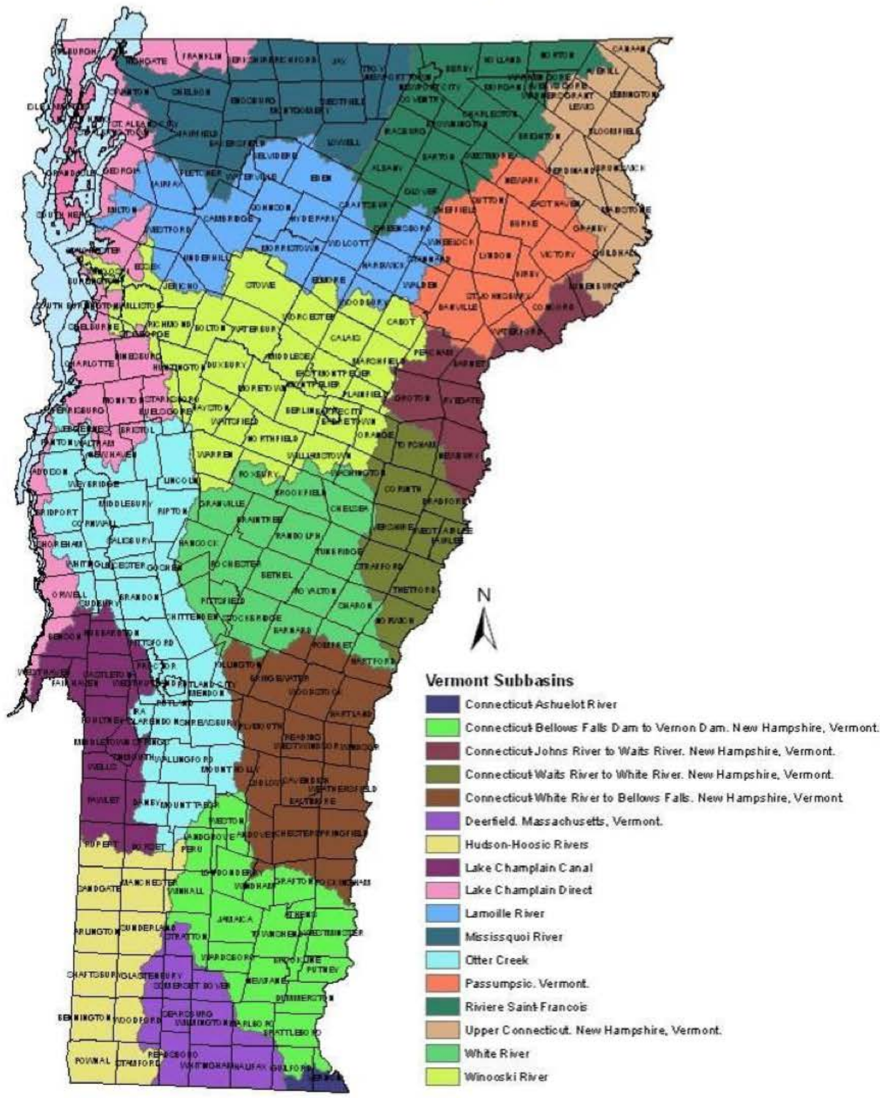
http://www.winooskiriver.org/Land_Owner_Assistance_Guide

http://winooskiriver.org/images/userfiles/files/Stream%20Guide%201-25-2012%20FINAL.pdf

Benthic Macroinvertebrates in our Waters--from the EPA Biological Indicator of Watershed Health site.

Key to Aquatic Macroinvertebrates--from the NY Department of Environmental Conservation's Stream Biomonitoring Unit. Color Pictures of BMIs

Appendix G. Vermont Sub-Basins (Map)



Appendix H. Glossary of Watershed Model Terms

*adapted from the EnviroScape User's Guide Glossary

Acid Rain. Precipitation rendered (made) acidic by airborne pollutants. May contain toxic chemicals, such as mercury, that have escaped into the air from burning fossil fuels

Accuracy. The degree of agreement between the sampling result and the true value of the parameter or condition being measured; most affected by equipment and methods being utilized.

Algae/algae bloom. Green water plants; any of the large group of aquatic organisms that contain chlorophyll but lack special water carrying tissues. Through the process of photosynthesis, algae produce the majority of food and oxygen in water environments

Bacteria. A large group of microscopic organisms of many different shapes, generally without chlorophyll. Some bacteria are helpful (as in a fermentation process), but certain species can cause diseases such as swimmer's itch, pneumonia or typhoid fever, among others.

Best management practices (BMPs). Structural, nonstructural, and managerial techniques recognized to be the most effective and practical means to control nonpoint source pollutants, yet are compatible with the productive use of the resource to which they are applied.

Clean Water Act (1972). The federal Clean Water Act has been public law since 1972. It requires the development of comprehensive programs for preventing, reducing, or eliminating the pollution of navigable waters and groundwaters and improving the sanitary condition of surface and underground waters.

Combined sewer overflow (CSO). When stormwater systems are linked to sewer treatment systems, excessive stormwaters (rain events) added to the wastewater already in the system cause the excessive waters to bypass treatment and flow directly into rivers, streams and lakes.

Comparability. The degree to which data from one stream can be compared to data from another.

Completeness. The amount of valid data obtained versus the amount planned; usually expressed as a percentage.

Erosion. The gradual wearing down of land by water, wind or melting snow. Soil is lost from streambanks, forests, hilly ground, lawns and farm fields.

Eutrophication. The premature aging of a waterbody due to excessive nutrients and low oxygen levels. For example, phosphorus and nitrogen found in fertilizers and manure can cause sudden and excessive growth of algae and aquatic plants. When these plants die, aerobic microbes deplete dissolved oxygen as they decompose this dead organic matter.

Fertilizers. Chemical fertilizers applied by growers contain phosphorus and nitrogen. When excessively or improperly applied, chemical fertilizers enter waterbodies via runoff and contribute to eutrophication.

Habitat. The physical environment or typical place within which a plant or animal naturally or normally lives and grows.

Land use. The type of activities humans carry out on various area of land define land use (ie industrial, residential, agriculture).

Benthic Macroinvertebrates (BMIs). Bottom dwelling animals that lack an internal skeleton and are visible to the unaided eye. BMIs collected from streambeds can be used as indicators of stream health.

Nonpoint source (NPS). Pollution that cannot be traced to a specific origin or starting point, but seems to flow from many different sources. NPS pollutants are generally carried off the land by stormwater (or melting snow) runoff. The commonly used categories for nonpoint sources are agriculture, forestry, urban, mining, construction, dams and channels, land disposal, and saltwater intrusion.

Pesticide. An agent applied to crops, lawns, golf courses, or in household settings in order to manage pests (includes fungicides, herbicides, insecticides, rodenticides)

pH. "Potential of hydrogen." A measure of the degree of the acidity or the alkalinity of a solution as measured on a scale of 0 to 14. Levels outside the normal range (pH 6.5-8.0) adversely affects aquatic life.

Phosphorus. A non-metallic element essential to life and found in fertilizers and animal waste. Excessive amounts introduced by runoff (and other ways) causes eutrophication in waterbodies.

Point source. Pollution discharged into waterbodies from specific, identifiable pipes or points, such as an industrial facility or municipal sewage treatment plant

Precision. Your ability to reproduce the same results for a sample; most affected by human error.

Representativeness. The degree to which collected data represents actual stream condition; most affected by sampling site location.

Riparian Buffers. Vegetation (grasses, shrubs, and/or trees) directly adjacent to rivers, streams and lakes that traps water and associated pollution and prevents it from running off the land (acts as buffer); a BMP that helps prevent nonpoint source pollution.

Riparian zone. The area where bodies of water meet upland areas which exhibits characteristics of both water and land areas.

Runoff. The portion of precipitation that remains on the land until it ultimately reaches streams, rivers, lakes or other waterbodies.

Sediment. Matter that settles to the bottom of a liquid; deposited by water, wind or glaciers

Septic tank. A holding tank for collecting residential wastewaters. Used as an alternative to municipal sewer systems (esp. in rural areas). Wastewater collected in septic tanks must be treated before being released into the watershed.

Temperature. Altering stream temperatures due to industrial processes or removal of streamside vegetation negatively affects aquatic life (for example, raising stream temperatures affects trout, a cold-water species)

Topography. The elevation profile of a land area. In the eastern US, where underground water flow is limited, watersheds can be delineated using topographical features.

Wastewater treatment plant. Sometimes synonymous with sewage treatment plant, but often an industrial treatment facility that processes the water to remove toxic and hazardous substances.

Watershed. A region or land area that may contain several rivers, streams, or lakes that ultimately drain to a particular watercourse or body of water.