AP® Environmental Science

WATER QUALITY ASSESSMENT CURRICULUM

This is a condensed version of the Teacher Guide for the Water Quality Assessment Curriculum (Code 5845-PKG). Content for all sections is not included but section titles are listed to show the organization of the product.

TEACHER GUIDE

Water Quality Assessment Package – Product Description

The AP® Environmental Science WATER QUALITY ASSESSMENT PACKAGE is an extensive curriculum that uses the exploration of the Water Quality Index to teach students STEM-based skills that they will apply to five classroom and field activities.

The WATER QUALITY ASSESSMENT PACKAGE (5845-PKG) includes a Water Quality Educator Outfit and a Water Quality Index Module. (Each available separately)

Water Quality Educator (Code 5870-01) contains:

Thermometer, Armored (Code 1066)
Dissolved Oxygen Kit (Code 5860-01)
pH Kit (Code 5858-01)
Nitrate-Nitrogen Kit (Code 3354-01)
Phosphate Kit (Code 3121-02)
Turbidity Kit (Code 7519-01)
Alkalinity Kit (Code 4491- DR -01)

Water Quality Index Module (Code 5845) contains:

Nutrient – TTC/MacConkey BioPaddles (Code 5553) for coliform testing
Salt/TDS/Temp Tracer (Code 1749) for TDS determination
Water Quality Index CD

The Water Quality Assessment CD contains the Student Guide and Teacher Guide which include background materials and instructions for each of the five activities. The Teacher Guide also includes recommended topics for student review, completed spreadsheets, and answers to student questions. Resources for the activities — including data spreadsheets, additional activities, and PowerPoint presentations on related topics — are provided on the CD. Digital files can be viewed directly by the students or files can be printed and distributed.

TEACHER GUIDE CONTENTS

ORGANIZATION OF THE WATER QUALITY ASSESSMENT CURRICULUM PACKAGE

The AP® Environmental Science WATER QUALITY ASSESSMENT PACKAGE is an extensive curriculum that uses the exploration of the Water Quality Index to teach students STEM-based skills that they will apply to five classroom and field activities.

The Student Guide and Teacher Guide include background materials and instructions for each of the five activities. The Teacher Guide also includes recommended topics for student review, completed spreadsheets, and answers to student questions. Resources for the activities — including data spreadsheets, additional activities, and PowerPoint presentations on related topics — are provided on the Water Quality Assessment CD. Digital files can be viewed directly by the students or files can be printed and distributed.

TEACHER NOTES and answers to student questions are printed in GREEN.

Active links to external web sites and files on the CD are printed in BLUE.

The Water Quality Assessment CD contains:

Study Guides (PDF)

- Teacher Guide
  - Standards, Objectives, And Requirements
    - AP® Environmental Science Topics Outline
    - Critical Elements of Lab and Field Activities
    - STEM Education Standards Overview
    - STEM Extension Objectives
    - Water Quality Assessment Curriculum Package Objectives
    - Data Analysis
    - Time Requirements
    - Safety
  - Activity Answer Key
  - Water Quality Assessment
    - Water Quality Assessment Overview
      - Watersheds
      - Pollution
      - Wastewater Treatment
      - Water Quality Index
      - Calculating the Water Quality Index
      - Water Quality Index Rating
    - Activities
      - Activity 1 Determine the Water Quality Index for the Kansas River Watershed
      - Activity 2 Do Water Quality Values Change over a 24 Hour Period?
      - Activity 3 Do Water Quality Values Change Within a Watercourse Cross-Section?
      - Activity 4 Environmental Impacts on Mill Creek Tributary
      - Activity 5 Field Activity: Determine the Water Quality Index of a Local Watercourse
  - References
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- Student Guide
  - Water Quality Assessment
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References
Resources

Graphics Files (PDF)

- Kansas River Basin Watershed Map
- Watershed Topo Map Examples

Field Test Procedures (PDF)

Dissolved Oxygen
Fecal Coliform
Biological Oxygen Demand
pH
Temperature Change
Nitrate
Phosphate
Turbidity
Total Dissolved Solids
Total Alkalinity
Chemical Reactions
Field Data Form
Water Quality Index Worksheet

STEM-Based Activities

- Measure Water Flow – Field Activity
- Design a Streamflow Gage – Field Activity
- Gather Streamflow Data – Online Activity
- Construct a Stage Rating Curve – Math Activity
- Build A Watershed – Classroom Activity

Presentations (PowerPoint, iPad, iPod, PC, or Mac movies)

- Coliform Testing PowerPoint
- Water Pollution PowerPoint
- Statistical Analysis PowerPoint
- Statistical Analysis (Extended) PowerPoint
- Water Quality Index PowerPoint
- Watershed Ecology PowerPoint

Data Spreadsheets (EXCEL) (Activities 1-5)

Glossary (PDF)

Resources

- Chemical Reactions
- Test Kit Instruction Links
- MSDS Link

STANDARDS, OBJECTIVES, AND REQUIREMENTS

AP® Environmental Science Topics Outline

Meets Section VI (Water Pollution) content requirement:

Types, sources, causes and effects, cultural eutrophication
Groundwater pollution
Water treatment
Maintaining water quality
Clean Water Act and other relevant laws

Critical Elements of Lab and Field Activities:

Concepts

Watersheds
- Watershed structure
- Flowing (lotic) systems
- Still (lentic) systems
- Watershed functions

Water Quality Index
- Role and parameters (Q factor & weighting)
- Interpretation

Physical Water Quality Parameters
- Temperature, Turbidity

Chemical Water Quality Parameters
- pH, Alkalinity, Dissolved Oxygen

Biological Water Quality Parameters
- Coliform

Nutrients
- Nitrogen & phosphorous

Hydrological Variables
- Discharge (flow)

Pollution (point/non-point discharge)

Trophic State
- oligo, meso, eutrophic, hypereutrophic

Field Experience

Critically observe environmental systems
Utilize appropriate techniques and instrumentation

Collection And Data Analysis

Analyze and interpret data, including appropriate statistical and graphical presentations

Communication

Think analytically

Communicate accurately and meaningfully about observations

STEM EDUCATION STANDARDS OVERVIEW

Experimental/ Engineering Design Investigating Scientific Method Measurement Data Analysis Communication Technology	A.1.2 Design and conduct scientific investigations. A.1.3 Use technology and mathematics to improve investigations and communications. A2.1 Conceptual principles and knowledge guide scientific inquiries. A.2.3 Scientists rely on technology to enhance the gathering and manipulation of data. New techniques and tools provide new evidence to guide inquiry and new methods to gather data, thereby contributing to the advance of science. The accuracy and precision of the data, and therefore the quality of the exploration, depends on the technology used. E.1.1 Identify a problem or design an opportunity. E.1.2 Propose designs – choose alternative solutions. E.1.3 Implement a proposed solution. E.1.4 Evaluate a proposed solution. E.1.5 Communicate!	2. AA Identification of the criteria and constraints of a product or system. 8.H Begin the design process … 9.K Create a prototype to test a design concept 11.O Refine the design. 11. P Evaluate the design solution. 11.R Communicate observations. 12.O Operate the system to validate the design.	ET 1 (Designed World) Study of designed systems, processes, materials, and products. ET1.A (Products, Processes, Systems) ET1.B (Nature of Technology) ET1.C Using Tools and materials) ET 2 (Engineering Design) Creative and iterative process for identifying and solving problems under constraints. ET2.A (Defining and Researching Technical Problems) ET2.B (Generating and Evaluating Solutions) ET2.C Optimizing and making Tradeoffs) ET3 (Technological Systems) Effectively using technology systems. ET3.A Identifying and Modeling Technological systems) ET3.C (Control and Feedback) ET4 (Interactions of technology & Society) Decisions are affected by technology. ET4.A (Interactions of technology & society) ET4.B (Interactions of Technology and Environment) ET4.C (Analyzing issues involving technology & Society)	1.0 Understand numbers, ways of representing numbers, relationships among numbers, and number systems. 2.0 Algebra: Understand numbers, ways of representing numbers, relationships among numbers, and number systems. 3.0 Geometry: Analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships. 4.0 Measurement: Understand measurable attributes of objects and the units, systems, and processes of measurement. 5.0 Data analysis & Probability: Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them. 6.0 Problem Solving: Build new mathematical knowledge through problem solving. 7.0 Recognize reasoning and proof as fundamental aspects of mathematics. 8.0 Organize and consolidate their mathematical thinking through communication. 9.0 Connections; Understand how mathematical ideas interconnect and build on one another to produce a coherent whole. 10.0 Create and use representations to organize, record, and communicate mathematical ideas.
Concept Principles & Knowledge	Watersheds Water Quality Index Physical water quality parameters Chemical water quality parameters Biological water quality parameters Pollution (point/non-point discharge) Trophic State Constructing graphs and hydrographs Data and statistical analysis			

Consolidated STEM Standards	
	S = National Science Education Standards (NSES) - K-4, 5-8, 9-12
	T = International Technology & Engineering Educators Association (ITEA) - K-2, 3-5, 6-8, 9-12
	A framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (NRC; 2011) - Draft
	E = Accreditation Board for Engineering and Technology (ABET) - 11-12
	A framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (NRC; 2011) - Draft
	M = National Council of Teachers of Mathematics (NCTM) - PreK-2, 3-5, 6-8, 9-12 Consolidated STEM Standards

STEM EXTENSION ACTIVITY OBJECTIVES

Measure Water Flow

Students will:

- Follow instructions to construct transect lines
- Calculate stream velocity
- Use the float method to estimate the flow of a local stream
- Examine the relationship between stream cross-sectional area, stream length, and water velocity

Design a Streamflow Gage

Students will:

- Design a streamgage that will function continuously and meet USGS criteria
- Determine gage on a daily basis
- Create a stage rating curve with the data

Gather Streamflow Data

Students will:

- Identify a local stream
- Access local real-time streamflow data from the USGS website
- Construct a hydrograph
- Interpret the data

Construct a Stage Rating Curve

Students will:

- Use streamflow data to construct a rating curve
- Interpret the data

Build a Watershed

Students will:

- Demonstrate watershed connections and boundaries
- Determine how the placement of manmade structures and surfaces impact runoff
- Determine how water flows from higher elevations to lower elevations
- Determine how activities upstream can impact downstream ecosystems

WATER QUALITY ASSESSMENT PACKAGE OBJECTIVES

Students will:

- Set up a spreadsheet to calculate and graph water quality index values for selected sampling station locations in the Kansas River basin and its associated tributary inlets
- Generate summary statistical data for a selected sampling station location in the Kansas River basin over a 3-month period including:
    - » Sample size (n)
    - » Mean ($\bar{x}$)
    - » Standard deviation (SD)
    - » Standard error of the mean (SEM)
    - » Data range (max/min)
- Generate a WQI line graph ("Chart" in Excel) for Kansas River basin sampling station locations
- Assess significant variations in sampling regarding:
    - » Transverse and vertical sampling points in a watercourse
    - » 24-hour sampling period
- Quantify the environmental impacts on Mill Creek tributary
- Determine a local watershed boundary (Field Activity)
- Design a sampling strategy to assess overall water quality within a watershed (Field Activity)
- Perform up to nine tests to determine a Water Quality Index for a local body of water (Field Activity)

DATA ANALYSIS

In all activities students will determine Water Quality Index values using water quality parameter data that is provided or collected by the students in the field. In each activity, students will interpret the data, conduct statistical analyses, and write a summary report.

ACTIVITY 1 Determine the Water Quality Index for the Kansas River Watershed – 10 locations/90 data points

ACTIVITY 2 Do Water Quality Values Change over a 24 Hour Period? – 12 hour measurements/108 data points

ACTIVITY 3 Do Water Quality Values Change Within a Watercourse Cross-Section? Smoky Hill River – 6 locations/54 data points

ACTIVITY 4 Environmental Impacts on Mill Creek Tributary – 10 locations/90 data points

ACTIVITY 5 Field Activity: Determine the Water Quality Index of a Local Watercourse – 2 locations/20 data points

- The data spreadsheets for each activity are formatted in Microsoft® Excel® and Apple® Numbers™.
- Students are instructed to present data in the form of a spreadsheet as part of the activities. They may present the data in the form of a table if they do not have the ability to create a spreadsheet.

NOTE: Due to rounding preferences in calculations, student answers may not exactly match the answers provided in the Teacher Guide.

Statistical Analysis

Students will:

Collect, examine, summarize and interpret quantitative data to understand causes, patterns, relationships, and trends. The following topics should be reviewed with students.

- Spreadsheet functions
- Graphing
- Sample size (n)
- Mean ($\bar{x}$)
- Standard deviation (SD)
- Standard error of the mean (SEM)
- Data range (max/min)

A PowerPoint presentation about statistics is included, called “Statistical Analysis”. It reviews measures of center; introduces the Water Quality Index as a weighted mean; and discusses data analysis. A second PowerPoint presentation, named “Statistical Analysis (Extended)”, expands on the first with nine extra slides reviewing variance, standard deviation, and standard error of the mean (SEM).

TIME REQUIREMENTS

Activities 1-5A – Classroom Activities

- Allow at least one hour per activity. You may choose to split certain test parameter data among student groups who can later pool results.

Activity 5B - Field Activity

- Allow at least 2 hours for sample collection at each sampling location. Alternately, you may wish to collect a composite class sample.
- Sample analyses should be performed within three hours of collection. If transporting samples over long distances (e.g. 10 miles or 30 minutes transit time) ice and place collected samples in coolers. Samples may be refrigerated overnight (no longer than 12 hours) at 4°C. Samples should be allowed to warm up to 25°C, and mixed by inversion prior to analyses.
- Obtain parental permission forms if students are to collect field samples.
- Time estimates for analysis activities performed in the field and/or laboratory. Test parameters labeled as "Field" have procedures or portions of procedures that must be performed in the field. Parameters labeled "Lab" may also be performed in the field except when incubation is required.

Dissolved Oxygen (DO)	5 minutes – Field
Fecal Coliform Density	10 minutes – Lab 18-24 hours – Lab (Incubator at 35°C required)
Biochemical Oxygen Demand (BOD)	Part 1 (DO) 5 minutes – Field 10 minutes – Lab Part 2 (BOD) 5 days
pH	5 minutes – Lab
Temperature Change	30 minutes – Field
Nitrate (Nitrate-nitrogen)	10 minutes – Lab
Phosphate	10 minutes – Lab
Turbidity (Total Suspended Solids – TSS)	10 minutes – Lab (turbidimetric) 10 minutes – Field (Secchi disk)
Total Dissolved Solids (TDS)	10 minutes – Lab
Total Alkalinity	10 minutes – Lab

SAFETY

Safety in Sampling

- All skin that could potentially be in contact with water should be covered. Wear rubber gloves and boots, if necessary. The use of an extension device for sampling will minimize exposure to the water.
- When monitoring close to a wastewater treatments plant or heavy industrial area, surgical masks should be worn to protect against aerosols. Aerosols are windborne contaminants that can be breathed deeply into the lungs.
- Consult your nearest Health Department, Department of Natural Resources, or the U.S. Environmental Protection Agency (EPA) for specific warnings about local rivers. Some stretches of rivers and land bordering rivers may contain dangerous levels of toxic contaminants in the sediment. If in doubt, consult local authoroities.
- Avoid sampling from heavily used bridges, and only do so after consulting the local public works department. Sampling sites with steep banks should be avoided, if possible.

Safety in Running Tests

- Read the safety information on the label of each reagent. These labels provide very specific first aid and chemical information.
- Ensure that students and others understand the dangers of treating reagents casually or endangering others through “horseplay”.
- Wear safety goggles particularly when performing water quality tests that require shaking a chemical mixture.
- Wash hands after performing water quality tests. Avoid placing hands in contact with eyes or mouth during monitoring.
- Follow the general safety guidelines for your particular school or organization.
- Ensure a safe monitoring experience by using the following:
    - » Safety goggles for each student
    - » Clean pail or bucket for washing hands
    - » Jug of clean water for washing hands
    - » Soap (biodegradeable if possible)
    - » Towels
    - » Waste container for chemical waste
    - » Plastic gloves
    - » Eye wash bottle
    - » First aid kit

Permission forms should be completed and signed for students involved in field activities.

All reacted test samples, except coliform bacteria, can be disposed of by flushing down the drain with excess water. While in the field, reacted samples can be poured together into a waste container for later disposal. See the coliform bacteria procedure in the Resource folder for coliform test disposal.

Students should also:

- **WEAR** appropriate personal protective equipment when handling chemicals, biological, and physical hazards.
- **WEAR** appropriate clothing — no sandals or open-toed shoes, no cut-offs, or baggy clothes, and no dangling jewelry. In the field, it is best to wear long pants and shirts with sleeves, especially if sensitive to poison ivy or insect bites. Certain sampling activities may require waders and/or a boat. Make sure proper flotation devices are worn.
- **KNOW** where the emergency equipment is and how it works.
- **UNDERSTAND** hazards and risks regarding working with chemicals, instruments, and in the field.
- **WASH HANDS** after performing an experiment or collecting field samples.
- **WEAR** a life jacket when working around or on water.

WATER QUALITY ASSESSMENT OVERVIEW

Topics covered…

- Watersheds
- Pollution
- Water Quality Index
- Calculating the Water Quality Index
- Water Quality Index Rating

Activity 5B – Determine the Water Quality Index of a Local Watercourse (Field Activity)

1. Review Safety Information
2. Sample Collection
3. Data Collection

   Assign each student or group of students a test parameter.

WATER QUALITY PARAMETERS		
Monitored Water Quality Parameter	Estimated Time	Notes
Dissolved Oxygen (DO)	5 minutes – Field 10 minutes - Lab	Titrimetric 60 mL sample Method: Modified Winkler Titration Range: Range: 0-10 ppm O_2 Resolution: 0.2 ppm O_2 Reported As: ppm DO, and % saturation IMPORTANT: When collecting a water sample, fill the collecting bottle to the top. Allow the water fill the bottle slowly so to not add any additional oxygen.
Fecal Coliform Density	18 – 24 hours Lab	Bacteriological 40 mL sample Method: Nutrient-TTC/MacConkey Agars Range: 0 – 109 CFUs/100mL Reported As: Total viable count (TVC) and total coliform CFUs/100mL Incubator at 35 ±2°C is required.

Biochemical Oxygen Demand (5-day)	Part 1 (DO) 5 minutes – Field 10 minutes – Lab Part 2 5 days	Titrimetric 120 mL sample Method: Modified Winkler Titration Range: Range: 0-10ppm O_2 Resolution: 0.2 ppm O_2 Reported As: ppm DO IMPORTANT: When collecting a water sample, fill the collecting bottle to the top. Allow the water to fill the bottle slowly so to not add any additional oxygen.
pH	5 minutes Lab	Colorimetric 10 mL sample Method: Mixed Indicator, Octa-Slide 2 Comparator Range: 3.0 – 10.5 (0.5 pH unit) Reported As: pH units
Temperature Change	30 minutes Field	Thermometer Method: Standard thermometer Range: -5 – 45 °C Reported As: °C
Nitrate	10 minutes Lab	Colorimetric 5 mL sample Method: Zinc Reduction, Octa-Slide 2 Comparator Range: 0 – 15 ppm NO_3^-N (0 – 66 ppm NO_3) Reported As: ppm Nitrate-Nitrogen (NO_3^-N) To convert to Nitrate, multiply comparator result by 4.4.
Phosphate	10 minutes Lab	Colorimetric 10 mL sample Method: Ascorbic Acid Reduction, Low Range Comparator Range: 0 – 2.0 ppm PO_4 Reported As: ppm Orthophosphate Test sample should be clear; filter if necessary. Best results are obtained when solution temperatures are 23-25°C. Phosphates exist in three forms: orthophosphate, metaphosphate (or polyphosphate) and organically bound phosphate.
Turbidity	10 minutes Lab 10 minutes Field	Turbidimetric 50 mL sample Method: Disappearing dot method Range: 5 – 100 JTU Reported As: Jackson Turbidity Unites (JTU) Or Method: Secchi Disk (for water over 16 feet deep) Range: 16 to 60 feet Reported As: Feet/inches Secchi disk is the easiest way to measure turbidity in the field.
Total Dissolved Solids (TDS)	10 minutes Lab	Electronic 50 mL sample Method: Conductivity Reported As: mg/L

Have students follow the Water Quality Test Procedure to test the water samples for each parameter.

Parameter	Test Procedure	Test Required
These test procedures must be started or completely performed at the sampling location:		
Water Temperature	Temperature Change	Thermometer, Armored (Code 1066)
Dissolved Oxygen	Dissolved Oxygen	Dissolved Oxygen Kit (Code 5860-01)
BOD	Biological Oxygen Demand	Dissolved Oxygen Kit (Code 5860-01)
Water Flow	Measure Flow	Measre Water Flow - STEM-based activity
These tests can be performed in the field or in the lab:		
Fecal Coliform Density	Fecal Coliform	Nutrient –TTC/MacConkey BioPaddles (Code 5553)
pH	pH	pH Kit (Code 5858-01)
Nitrate	Nitrate	Nitrate-Nitrogen Kit (Code 3354-01)
Phosphate	Phosphate	Phosphate Kit (Code 3121-02)
Turbidity	Turbidity	Turbidity Kit (Code 7519-01)
Total Dissolved Solids	Total Dissolved Solids	Salt/TDS/Temp Tracer (Code 1749)

4. Enter Data

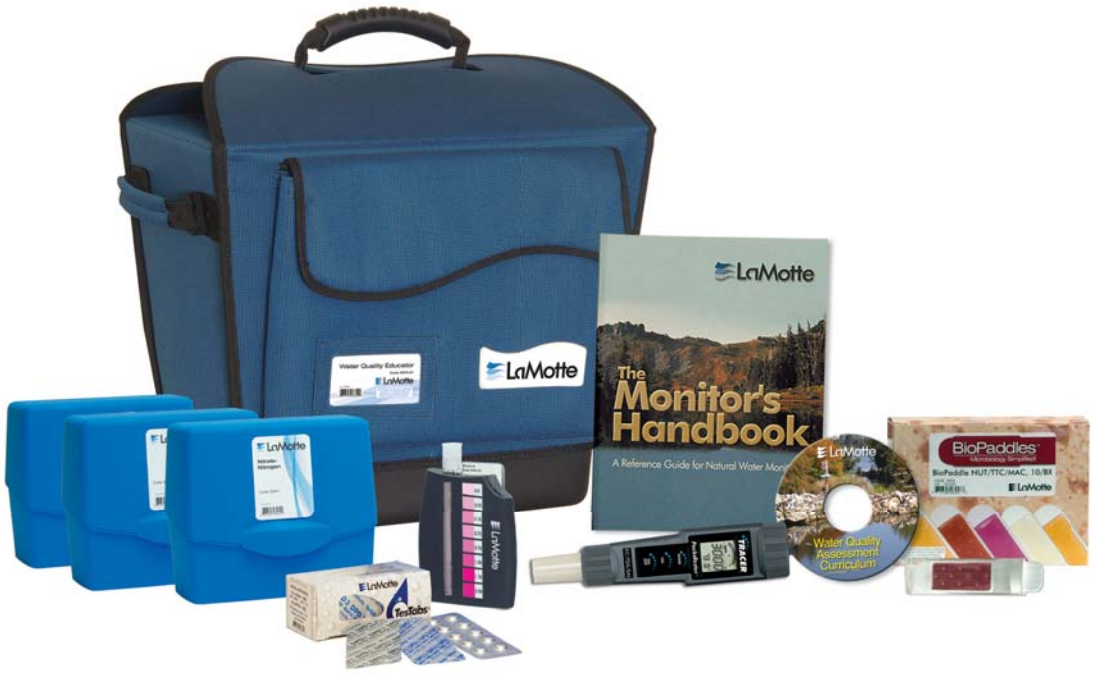
1. Have students enter field data on the Field Data Form and the Water Quality Index Worksheet.
2. Have students set up a spreadsheet that will calculate the WQI for sampling site. The spreadsheet should include the following:
   - Correct measurement units for each test parameter
   - Weather observations
   - Sample collection date and time
   - Flow
   - Q-values
   - Weighting factors
   - Calculated WQI and corresponding WQI score rating

5. Deviations

Have students pool collected data and note deviations for the following parameters:

- DO
- BOD
- pH
- Nitrogen
- Phosphorous

6. Analysis Questions



WATER QUALITY ASSESSMENT CURRICULUM PACKAGE (Code 5845-PKG)

Water Quality Educator (Code 5870-01)

- pH
- Nitrate-Nitrogen
- Phosphate
- Dissolved Oxygen
- Alkalinity
- Turbidity
- Temperature
- Monitors Handbook
- Water Quality Testing CD

Water Quality Assessment Curriculum Module (Code 5845)

- BioPaddles
- Total Dissolved Solids Tester
- Water Quality Assessment CD

Water Quality Index Worksheet

Parameter	Test Result	Units	Q-value	Weighting Factor	Weighted Q-Value
DO	***100***	% Saturation	***99***	0.17	***16.8***
Fecal Coliform	***500,000***	CFU/100 mL	***2***	0.16	***0.3***
BOD	***16.8***	mg/L	***15***	0.11	***1.7***
pH		pH units		0.11	
Temp Change	***0.5***	°C	***90***	0.10	***9.0***
Nitrate		mg/L NO_3	***53***	0.10	
Phosphate		mg/L PO_4	***72***	0.10	
Turbidity		NTU	***57***	0.08	
TDS		mg/L	***71***	0.07	

Water Quality Index = _____

Water Quality Rating = _____

WQI Rating	
WQI	**Rating**
0-25	Poor
26-50	Fair
51-70	Average
71-90	Good
91-100	Excellent