PREFACE

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1. Introduction

Water quality has become an increasingly important issue during the past several decades. It is of concern in geographically water rich eastern Massachusetts, with our numerous rivers, streams, ponds, estuaries, and bays. Water quality provides a window on the health and vitality of the hundreds of local ecosystems within the 61 communities served by the MWRA.

Water quality provides a strong basis for educational inquiry. For example, how do the salinity, temperature and chemistry of an estuary change as the tide comes in, peaks and recedes, and what might this information tell us about the flushing action of the tides? Does industrial pollution affect a body of water? Do development and roadways have an impact on local water, and if so, what is that impact?

To help teachers bring these and other concepts related to water quality into their classrooms, the MWRA has developed this water quality testing program. It includes equipment for testing:

- Temperature
- pH
- Dissolved Oxygen (DO)
- Biochemical Oxygen Demand (BOD)
- Nitrates
- Total Dissolved Solids (TDS) and Salinity
- Turbidity
- Total Coliform Bacteria

This manual contains background information, lesson ideas, procedures, data collection and reporting forms, suggestions for interpreting the results, and extension activities.

It is important for teachers to bear in mind that *this is a field testing program*. As such, students will spend time in the field, performing tests on their community's water: oceans, marshes, rivers, bays, lakes, ponds, wetlands and streams. To succeed in the field, students must be assigned specific tasks, and they should practice field techniques in the lab or classroom before going into the field. Sections III and IV of this manual offer suggestions for making the field work successful and ensuring the students' safety.

This program is geared toward a broad student population: grades 6 - 12. We expect that educators will adapt these activities and lessons as necessary to make them suitable and appropriate for their students.

If, at any time, you have suggestions for additional activities, additional tests, or ways to improve this program, please submit your suggestions to the MWRA's School Program. We will make every effort to share them with other participating teachers.

To use the Water Quality Testing Kit, teachers must attend a full-day workshop. If you would like additional information about either the kit or a workshop, please call the MWRA at (617) 242-6000 and ask for the School Program.

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The workshops for this program are free, six-hours long, and carry Continuing Education Units (CEUs). Once teachers have attended, they may sign up to borrow the kit at no charge (although a deposit may be required). Preference will be given to schools within the MWRA service area.

2. Why the MWRA Provides this Program

The MWRA provides safe, reliable drinking water and is up-grading sewage treatment for 2.5 million people and 5,500 industries. We make every effort to protect our region's water and watershed lands, and our efforts require many difficult public policy decisions. Ultimately, our success will be measured by the healthfulness of our water resources, the reliability of our water supply, the rates our customers must pay, and the ability of the entire region to work together to confront and solve difficult problems in the fairest and most technologically appropriate manner.

Our customers are well served by efforts to inform the public, which should begin in the schools. Today's young people will be tomorrow's decision makers and rate payers. They will be burdened with the responsibility of confronting and solving tomorrow's

problems, and we want to provide them with the tools they will need to make the best possible choices.

3. Program Overview

This testing program for fresh water and salt water consists of eight tests. It is designed for use by middle school and high school students. These tests, while simple and safe, require practice, care, and rigorous adherence to laboratory and safety procedures.

- *The kit contains some chemicals which, if mishandled, could be dangerous. Proper protective clothing, including rubber gloves, eye protection and lab aprons, is essential!*

In addition, this is a field testing program, with students performing at least some of the tests in the field. Field testing requires proper preparation. Students should know the test procedures before going into the field; they must also be aware of safe field practices and the potential dangers of working in the field. (Chapter 3 of this manual addresses field testing preparation.)

Students using this kit will be able to see a "snapshot" of the quality of a particular body of water. The most interesting and meaningful water quality data emerges when a particular body of water has been tested over time. Such long-term monitoring reveals changes over days, months and seasons. It could also reveal the presence of currently unknown sources of pollution. Long-term monitoring could result in an entire photo album, so you may want to undertake your own monitoring program over a number of years.

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This manual contains all of the information you need to carry out the tests. It also contains a *Data Recording Form* that you may reproduce for students, as well as ordering information if you choose to purchase your own kit.

4. Program Objectives

A. *To enable students to learn basic water quality tests and techniques.*

B. *To increase student awareness of the importance of water quality.*

C. *To increase student understanding of the factors that contribute to water quality.*

D. *To lead students to an understanding that each of us has responsibility for maintaining the quality of our water.*

A. *To enable students to learn basic water quality tests and techniques.*

These tests will expose students to field testing techniques and lab methods. The results will be valid, even if they are not as accurate as more refined testing methods. In certain cases, we have chosen test equipment based on the technique it can

teach over the accuracy of results. For pH, for example, we could have selected a simple digital meter. While the results from the meter would have been more accurate, its use would convey little about lab methods. Instead, we have included two pH tests: a reagent/colorimeter test for more accurate testing results, and pH paper for spontaneous testing of liquids in the environment. We selected a digital meter for Total Dissolved Solids (TDS) and Salinity because it is the only reasonably simple test for TDS, and analyzing the results requires slightly more effort than simply reading numbers from a digital face. Likewise, the Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) tests use a standard process called the Winkler Method. Easier options exist, but we felt that the lab practice and technique made this a more valuable student exercise.

B. To increase student awareness of the importance of water quality.

Water quality is critical to human survival. Civilizations grew and flourished in areas with ample supplies of high quality water, and where water quality declined, those cultures either ended or faced the horrors of epidemics.

With the industrial revolution came changes in human-made pollution. For almost three centuries now, humans have tested the ability of the earth to adapt. While we have learned that the earth is highly adaptable, we have also learned that there are limits. Increased knowledge of diseases and the environment, and the resulting requirements of strict legislation, such as the Clean Water Act and the Safe Drinking Water Act, have compelled us to pay greater attention to and spend more money on the quality of our waterways. In the waning years of the twentieth century, it has become clear just how much a community depends on the quality of its water.

This program will help students become aware of the condition of the waterways within their own communities.

C. To increase student understanding of the factors that contribute to water quality.

Pure water - H_2O - is a laboratory concept. Because water is a "universal solvent," virtually everything around us affects the quality of our water. Atmospheric gases and contaminants dissolve in rainwater on its trip to earth. Once on the ground, water continues to dissolve a broad range of solids, gases and liquids. In addition, plant life, sunlight, nutrients and other variables affect the levels of oxygen and carbon dioxide in the water, and they in turn affect the plant and bacterial life. The digestive processes of animals introduce bacteria to water, and coliform bacteria serve as an effective indicator for other pathogens that might be dangerous to

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humans. Fertilizers, natural and chemical, are washed into the waterways by rain, raising the level of nutrients, such as nitrogen, in the water, and the nutrients in turn promote the growth of algae and plant life.

High levels of algae and other non-dissolved solids block sunlight, and decreased sunlight leads to decreased photosynthesis, decreased plant life, and increased plant decay. These factors lead to lower oxygen levels, providing an important window on the overall health of our region's water.

D. To lead students to an understanding that each of us has responsibility for maintaining the quality of our water.

Water quality is affected by a wide range of factors, the most significant of which is human activity. Most human activities occur collectively, as part of the operations of society. While the impact of individual actions may seem insignificant, each individual can make an important contribution to water quality by not dumping harmful chemicals down the drain or onto the ground; by understanding the impact of pesticides and fertilizers; or by respecting the importance of wetlands and saltwater marshes. When massed together, these individual contributions can have a large positive effect.

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5. Target Audience

This program is intended for use by middle school and high school students in a wide range of classes, such as chemistry, earth science, physical science, ecology, biology, and non-science disciplines. It could also be used in AP and special needs classes, with environmental clubs, or it could be integrated with other disciplines, such as government, geography, and social studies. In addition to being used at school, it is also appropriate for use by scout troops, clubs and other organizations.

6. The Structure of Each Lesson

In this manual, each test contains enough information to make it a full lesson. Each test unit contains the following sections:

a. The *Brief Summary* section provides a quick glimpse into the test and test procedure.

b. The *Background* section puts the lesson into context. What is the water quality issue under discussion? What factors might cause results to be out of the normal range? What are the implications of this test on humans and human health? Animals? Nature? Agriculture? Recreation? Industry?

II INTRODUCTION TO WATER

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1. Water: A Remarkable – Yet Limited – Substance

All the water that has ever or will ever exist on earth is already here. Ninety-seven percent of that water is in the world's oceans; two percent is frozen; and less than one percent of the world's water is accessible fresh water! It is imperative that we zealously protect the earth's water supply. Once a water source, such as a river or ground water aquifer, is polluted, it could remain contaminated for a very long time. Protecting water is of the utmost importance because life on earth could not exist without water.

Water is one of the few substances on earth that may be observed in three forms simultaneously: solid, liquid and gas. It is not uncommon to look at a pond or stream in winter and see all three forms together: ice along the shore, liquid in the middle, and vapor rising from the surface or floating overhead in the form of clouds.

Water is the only substance that expands when it freezes rather than contracting. A volume of solid steel weighs more than an equal volume of molten steel. Ice, on the other hand, floats. Imagine how the world would differ if ice were heavier than water: as bodies of water froze, the ice would sink, sending warmer water to the surface where it too would freeze. Whole bodies of water would freeze solid, and life on earth as we know it could never have evolved. As it is, fortunately, a floating layer of ice protects underwater life from the severe cold rather than threatening it.

Water has an extremely high heat capacity. It can absorb and retain a great deal of thermal energy without undergoing dramatic temperature changes. As a result, oceans serve as highly effective buffers, protecting the earth's land mass from extreme temperature changes despite extreme fluctuations in the atmospheric climate.

Water has the highest surface tension of any liquid on earth except mercury, so it supports objects that are heavier than itself. Thus insects can "walk on water." This high surface tension also promotes "capillary action," which is why plants and trees can pull water "up" through their roots with no visible effort, seeming to defy gravity.

Water is the "universal solvent." What we generally think of as "water," therefore, is really a solution of many different chemicals. As a solvent, water is inert, so few of the chemicals that dissolve in water actually change its chemistry. As a result, water is a truly "renewable" resource that can almost always be separated from its solutes and salvaged for reuse.

2. The Many Types of Water

"Fresh" and "salt," "pure" and "clean" are all adjectives used to describe water. These distinctions are very important in a study of water quality.

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The major division in the world of water is between "fresh" water and "salt" water. The terms address the total quantity of salts dissolved in the water. Sea water contains 35 parts per thousand (ppt) of dissolved salts. Fresh water contains measurable amounts of salts, but less than would make the water taste salty or destroy the quality of crop land. Many people consider water to be "fresh" if it contains less that one part per thousand of dissolved salts.

"Brackish" water contains more dissolved salts than "fresh" water and less than "sea" water. It has salt concentrations between 1 ppt and 35 ppt and is generally found in areas where fresh water and sea water meet, such as *estuaries*, which are mixing areas where rivers empty into the ocean. This program covers the testing of any type of water found in nature: fresh water, brackish water, and sea water.

"Pure" water is H_2O. Steam and distilled water are virtually "pure." When water evaporates in nature, it is pure for an instant, but contaminants immediately begin to dissolve in it. As a result, pure water may be produced in a laboratory, but it is virtually impossible to find in nature.

"Clean" water is a subjective term, the meaning of which depends on the intended use

of the water and on state and federal regulations. Drinking water may be considered "clean" if it does not contain toxic contamination or harmful bacteria. Lake or sea water may be considered "clean" if it appears clean (that is, it has low turbidity, or it allows a lot of light to pass through it); it may be considered "clean" if the level of toxicants in the water is sufficiently low to allow fish populations to thrive; or it may be considered "clean" if there are no unsightly algae blooms. In other words, "clean" has meaning in terms of a specific use, and it applies equally well to fresh and salt water.

3. Why Is Water Quality Important and What Factors Affect Water Quality?

All life forms on earth depend on water for survival. When the quality of the water is compromised, they may have problems surviving. Maintaining water quality, therefore, is essential to maintaining life on earth.

Almost everything we do affects water quality. Even our use of water at home can have a significant impact.

At home...

- If we use water wastefully, we could deplete the region's water supplies. As the supplies diminish, the available water has less ability to dilute minerals and contaminants. Good water conservation practices are an important accompaniment to a water quality testing program such as this one.
- Lawn and garden chemicals - fertilizers, insecticides and herbicides - can run off into the storm drains and local waterways during storms.
- Household hazardous wastes, such as solvents, paints, waste oils, and other chemicals flushed down the drain or poured into storm drains quickly make their way to local waterways. The sewer system is designed to handle sewage - human and domestic waste products - not hazardous or toxic materials.
- Improperly maintained or overused septic systems or cesspools allow excess nitrogen and bacteria to enter the region's water supplies.

In society...

- Larger scale lawn and garden chemical runoff - from parks, golf courses, and crop lands - enters the region's waterways during each storm, raising the level of nutrients, such as nitrogen or phosphates, altering the pH, or contributing toxic chemicals, such as pesticides, that might harm the environment.

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- Each rain washes road debris, such as oil, bits of tire rubber, and gasoline into the local waterways. This debris adds hydrocarbons and solids to the water, and often raises the turbidity.
- Industrial pollution threatens our waterways, adding a variety of contaminants, often in high concentrations, to our region's water.

4. How Does Water Quality Testing Differ in Fresh Water and Salt Water?

Whether your sample is fresh, sea, or brackish water, all of the tests contained in this kit work the same. The results of the test, however, may vary.

Temperature: Because of the ocean's size and currents, temperature ranges in sea water will generally be less dramatic than in inland water. Thermal pollution (from such sources as industrial cooling) will be apparent in both sea water and fresh water.

Dissolved Oxygen, Biochemical Oxygen Demand, pH, Turbidity: Temperature, water chemistry, sunlight, and plant life affect these factors.

Nitrates: Elevated nitrate levels generally result from chemical fertilizers. While nitrates are present in sea water, particularly in bays, estuaries, and harbors with sewage or agricultural runoff, they will generally be higher in fresh water, particularly around farms, parks, golf courses, and areas with many septic systems.

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Total Coliform Bacteria: Coliform bacteria come from the intestines of warm-blooded animals and are found in both fresh water and sea water. You will probably find coliform bacteria in most samples of untreated water. This kit uses a simple presumptive test that merely indicates the presence of - not the quantity of - total coliform bacteria. Thus, you will not be able to discern whether or not they exist at dangerous levels.

Total Dissolved Solids and Salinity: Both of these tests use the same digital meter, but the procedures and the results differ. In fresh water, the total dissolved solids will be less than 1 ppt (1,000 ppm). Sea water from the open ocean has a salt concentration of about 35 ppt in the open ocean. (In Boston Harbor, the salinity varies from about 20 to 30 ppt because of tidal flows and the emptying of rivers.) Brackish water falls between the sea water and fresh water. The digital tester has a range of only about 950 ppm (or 1900µs), so sea water and brackish water must be diluted prior to testing.

III Field Testing Procedures and Notes

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1. How to Select Sites

Eastern Massachusetts offers many types of sites for collecting water samples: streams and rivers, lakes and ponds, fresh and salt water marshes, as well as bays, estuaries, harbors, and the ocean. Choosing from among these options should be a matter of convenience (what are you near?), safety (where can you collect samples safely?), and significance (what will have the most meaning for your class?).

If you select a site in your own community, you and your students may already know about convenient locations for taking samples, such as a swimming beach, boat launch or fishing dock. If you are interested in a site in another community, the town's municipal offices may be able to help locate a convenient access point.

2. Safety Considerations

Selecting a safe site may limit the places where you can collect samples. Find a site with enough room that all of your students will have easy access to the water. Your students should be able to collect samples without wading into the water. Before selecting a field site, inspect it yourself!

- Avoid places where the banks are slippery or steep, and where vegetation or rocks restrict access.

- Avoid places where the water moves swiftly or where waves are high.
- In estuaries, bays and along the sea shore, take the tides into account. A location that may look safe at low tide may pose dangers at high tide; a place that seems accessible at high tide may not be at low tide.
- Select sites that are removed from roads and highways. You do not want your students wandering into traffic - or traffic wandering into them!
- If you plan to collect samples from bridges, make sure the walkway is separated from the traffic and that there are safety rails on the bridge. (You will need ropes to haul up samples.) Students should not lean over the rails.
- If you use a boat, stress safety.

Before the site visit, give each student a copy of page 69 on *Student Safety*. It stresses the precautions for water safety practices and for doing the tests. If possible, take a chaperone along to help enforce these safety practices.

3. Performing Tests Safely

Performing the water quality tests requires handling both breakable equipment and hazardous chemicals. Students should practice the same safety precautions in the field as they do in the laboratory.

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The kit contains Material Safety Data Sheets (MSDS) for each chemical. These contain all the safety information you will need, including dangers, treatments and disposal.

- Each student should have the proper protective equipment: aprons, gloves and eye protection.
- Be sure to have enough clean water on hand to flush chemicals in case of an accident.
- Dispose of chemicals properly.
- Have your students practice handling the equipment before the field test. (See *Chapter IV*, Pre-Site Visit Preparation, page 21.) They must be particularly cautious not to drop or break the equipment.

4. Choosing Sampling Locations

Test results will vary depending upon your sampling location. For example, the temperature, dissolved oxygen and turbidity level of water from the middle of a lake or harbor may differ from samples taken at the shore, and water from near the surface may differ

from water taken at mid-depths or from the bottom.

Safety and strategic considerations will probably prevent you from collecting samples at all locations. Nevertheless, you can achieve the goals of this program and relay a valuable educational lesson by taking samples at more accessible locations. Students will experience the hands-on science involved in the field tests, and they will become aware of the interconnections between water quality issues and human use. As part of your follow-up discussion, you can hypothesize how the water quality might differ at different locations.

If you have a choice of sampling locations, one may be more "representative" than another. For instance, water taken from a steep bank or a dock would probably be more indicative of the whole pond or bay than water in a shallow, protected cove. Testing samples from both sites might provide valuable comparisons.

5. Work To Be Completed in the Field

To ensure accurate results, only a few tests must be completed in the field. Once these tests are completed, you may bring the remaining sample water to the classroom to complete the tests.

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The following tests are the only ones that must be completed in the field:

- *Temperature:* Record the air temperature and the water temperature at the site.
- *pH:* Measure the pH at the site. Exposure to air will quickly change pH of subsurface samples.
- *DO:* Fix samples for the Dissolved Oxygen Test. Each group of students will need 20 mL of fixed sample, and each sampling bottle contains 60 mL, so you will need one bottle of fixed sample for every three groups. (You should complete the DO titration within eight hours of fixing the sample.)

If the entire class cannot visit the sampling site, either you or a small group of students could complete these procedures in the field, and the class could complete the rest of the testing in the lab later that day.

6. Obtaining Permission from a Landowner

Check to see if your site is on private property. If it is, explain to the property owners what you would like to do and ask for their permission. Stress the educational purpose of the program, and emphasize that the program has nothing to do with regulation or litigation. Some landowners might like to participate with your class.

7. What Students Should Wear

Students should expect to get wet and dirty in the field, and they should not hold back from participating out of concern for their clothing. Be sure they wear clothes that are appropriate for the weather conditions, and emphasize warmth. Even if it seems warm at school, students should bring jackets, and in cooler weather they should have hats and gloves. If possible, at least one member of each group should have rubber boots so he or she can collect samples without getting his or her feet wet. Ideally, everyone should wear waterproof boots or, if the weather is warm, old sneakers.

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