Macrosystems EDDIE:

Exploring Tradeoffs in Water Quality Management Using Environmental Data

Instructor's Manual

Module Description

Many water management decisions come with tradeoffs. One important example of such a decision is the use of chlorine in the drinking water treatment process. Chlorination is an important disinfection step in water treatment and is needed to protect water consumers from harmful pathogens (such as bacteria). However, when there are high amounts of organic matter in the raw water, chlorination can result in the formation of potentially cancer-causing disinfection byproducts. Environmental sensor data on water quality conditions, such as organic matter measurements from drinking water reservoirs, can help inform water management decision-making and reduce the risk of unintended consequences due to use of chlorine in water treatment.

In this module, you will explore organic matter data collected from drinking water reservoirs and learn how to interpret these data to inform your decision-making about chlorination during drinking water treatment.

Focal Question: How can we use environmental data to inform our understanding of the tradeoffs involved in water management decision-making?

Pedagogical Connections

Phase	Functions	Examples from this module
Engagement	Introduce topic, gauge students' preconceptions, call up students' schemata	Short introductory lecture introducing high-frequency water quality data and disinfection byproducts (DBPs); explaining how data are collected and can be used to assess potential DBP formation; students answer introduction questions
Exploration	Engage students in inquiry, scientific discourse, evidence-based reasoning	Students explore high-frequency water quality data of fluorescent dissolved organic matter (fDOM) at a focal drinking water reservoir site of their choice and learn how these data relate to potential DBP formation
Explanation	Engage students in scientific discourse, evidence-based reasoning	Students interpret data to identify when DBP formation is most likely by converting fDOM to total

This module was initially developed by: Lofton, M.E., Cooke, R.L., and C.C. Carey. 15 August 2024. Macrosystems EDDIE: Using Using High-Frequency Data to Manage Water Quality. Macrosystems EDDIE Module 9, Version 1. https://serc.carleton.edu/eddie/teaching_materials/modules/module9.html. Module development was supported by NSF grant EF-2318861. This document last modified: 16 August 202420 February 2026 by M.E. Lofton.

		organic carbon (TOC), which is often used by operators to assess DBP formation risk
Expansion	Broaden students' schemata to account for more observations	Students view fDOM data from different times of year in a drinking water reservoir case study, convert these data to TOC concentrations, and decide whether to enact additional treatment measures to mitigate DBP formation risk
Evaluation	Evaluate students' understanding, using formative and summative assessments	Students answer questions and solve problems regarding water treatment regulations and mitigating DBP formation risk; they can check their own answers using a Canvas quiz or submit their answers via a Word document to their instructor

Learning Objectives

By the end of this module, students will be able to:

- Define what disinfection byproducts are (Activity A)
- Describe the environmental and water treatment processes that influence the formation of disinfection byproducts (Activity A, B)
- Understand the trade-offs between disinfection and byproduct formation that can occur when chlorinating water, and treatment techniques that can be used to manage these tradeoffs (e.g., coagulation, activated carbon filters) (Activity A, B)
- Use environmental data visualizations to identify when additional treatment techniques to avoid disinfection byproduct formation should be used to meet water quality objectives (Activity B, C)

How to Use this Module

This module was developed as part of a virtual, asynchronous curriculum for students training to become water treatment plant operators. This entire module can be completed in one 2 to 3-hour lab period, two 75-minute lecture periods, or three 1-hour lecture periods. The module is designed to be fully accessible for both in-person, hybrid, and completely virtual, asynchronous courses. Open-source versions of all module materials are available on this website and module activities can also be imported into Canvas from the Canvas commons. Students complete module activities using an R Shiny web application, and can answer questions either using a Canvas quiz or by typing them into a student handout which can be downloaded from the app.

In-person or virtual synchronous lesson structure, depending on the time available for your class:

- Three classes (50-60 minutes)
    - Class 1 – Introductory lecture (10 min.) and completion of Introduction and Activity A, Objectives 1 and 2 (40 min.)
    - Class 2 – Finish Activity A and take questions as needed; completion of Activity B, Objectives 3 and 4 (40 min.)
    - Class 3 – Finish Activity B and take questions as needed; completion of Activity C (30 min.); wrap-up (10 min.)
- Two classes (75-90 minutes)
    - Class 1 – Introductory lecture and completion of Introduction and Activity A; start Activity B
    - Class 2 – Finish Activities B & C followed by 10-15 minute discussion and wrap-up
- One class (2.5-3 hours)
    - Introductory lecture – 10 mins, Activity A – 40 mins, break – 10mins, Activity B – 40 mins, break – 10 mins, Activity C – 30 mins, wrap-up – 10 mins

Quick overview of the activities in this module:

- **Activity A:** Explore how disinfection byproducts are formed during the drinking water treatment process and examine tradeoffs between disinfection and byproduct formation.
- **Activity B:** View and interpret environmental data that can indicate when naturally-occurring DBP precursors are present.
- **Activity C:** Make water treatment decisions using environmental data that can indicate when DBP precursors may be present.

Module Workflow (for either in-person or virtual instruction)

1. Instructor chooses whether to deliver the module using Canvas or not. If using Canvas, the instructor should import the module to their course from the Canvas commons. If not using Canvas, all module materials can be accessed from this web page.
2. Students view a short (~10 minute) introductory video either in Canvas or in the R Shiny web application. The same video is linked from both locations. Alternatively, instructors may choose to modify the introductory presentation and present it themselves. An editable version of the slides is provided with the teaching materials below.
3. Students navigate to the R Shiny web application and follow the workflow instructions outlined on the Introduction tab:
    1. Watch the introductory presentation provided in Canvas and embedded in the interactive R Shiny web application if you have not already done so.
    2. Watch the “Guide to Module” video embedded in the interactive R Shiny web application to learn about key features of the module that will help you complete module activities and answer questions. Optionally, you can also go through the “Quick-start” guide to the module using the button at the top right corner of the module web page.
    3. Select a focal reservoir.
    4. Open the Canvas quiz questions associated with the reservoir you have chosen OR if you are not using Canvas, download a copy of all the questions as a Word document by clicking the “Download student handout” button.
    5. Work through the module to complete the Introduction questions and Activities A, B, and C in this web app. When you are prompted to answer questions, enter your answers in the Canvas quiz. Be sure to fill in the Canvas quiz that corresponds to the reservoir site you have chosen! If you are not completing the module using Canvas, you may type your answers into the Word document.
    6. If you would like to take a break and come back later, or if you lose internet connection, all you have to do is re-load this web app, re-select your reservoir site in the Introduction, and you will be able to resume your progress. On Canvas, you can

save your quiz responses using the "Save" button. In Word, you can save your answers in the document on your computer.

7. When you have finished the module activities, be sure to submit your Canvas quiz for grading. If you are completing the module by answering the questions in a Word document, be sure to submit the document to your instructor for grading.

4. The instructor can choose how to assess student module question responses. If using the Canvas quiz, all self-grading questions are worth 1 point by default, and short answer questions are worth 0 points. The point values may be adjusted by the instructor. If using the Word document, point values are not assigned to questions; this is left to the discretion of the instructor.

Important Note to Instructors:

The R Shiny app and other instructional materials used in this module are regularly updated, so these module instructions will periodically change to account for changes in the code. If you have any questions or have other feedback about this module, please contact the module developers (see "We'd love your feedback" below).

We highly recommend that instructors familiarize themselves with the Shiny app prior to the lesson. This will enable you to be more prepared to answer student questions.

Guide to Introductory PowerPoint Presentation

Note: the numbers below match the PowerPoint slide numbers. The text for each slide is also in the "Notes" of the PowerPoint, so can be viewed when projecting in Presenter View.

1. Welcome to the Macrosystems EDDIE module: Exploring Tradeoffs in Water Quality Management Using Environmental Data. This module has been developed in collaboration by water treatment instructors at Mountain Empire Community College and freshwater scientists at Virginia Tech. The module is part of the Macrosystems EDDIE program, which stands for Environmental Data-Driven Inquiry and Exploration, and is supported by a grant from the United States National Science Foundation.
2. This module includes three activities, which are all designed to introduce concepts related to assessing water quality and collecting high-frequency water quality data. In Activity A, students will explore how disinfection byproducts are formed during the drinking water treatment process and examine tradeoffs between disinfection and byproduct formation. In Activity B, students will view and interpret environmental data that can indicate when naturally-occurring DBP precursors are present. In Activity C, students will make water treatment decisions using environmental data that can indicate when DBP precursors may be present.
3. All of the activities are designed to address the focal question for this module, which is: How can we use environmental data to inform our understanding of the tradeoffs involved in water management decision-making?

4. Today, we will focus on the tradeoff that can occur between chlorination, an important step in the water treatment process to remove potentially harmful pathogens, and the formation of disinfection byproducts. Disinfection byproducts, or DBPs, are compounds that are unintentionally created during the drinking water treatment process. Many of them are known to be carcinogens, or capable of causing cancer. There are dozens of different DBP compounds. Two common classes of DBPs are trihalomethanes, pictured on the bottom left of the slight, and haloacetic acids, pictured on the bottom right.
5. Disinfection byproducts form when DBP precursors, which can be organic matter or inorganic compounds in drinking water sources, react with chlorine during the disinfection process. Organic matter is derived from living organisms and contains carbon. Inorganic matter may also contain carbon but is not derived from living organisms. When DBP precursors, such as naturally-occurring organic matter, react with chlorine during the treatment process, DBPs may sometimes form.
6. DBPs are monitored by water sampling. Once a quarter, water samples from both treatment plants and distribution systems must be tested for a range of DBPs. In addition, raw and filtered water are tested once a month for total organic carbon, or TOC. High TOC levels can indicate the presence of DBP precursors, which may form DBPs during treatment.
7. Some forms of organic matter can be measured using sensors deployed in a drinking water reservoir. We can develop a relationship between these sensor data and total organic carbon (TOC) to determine when DBP precursors might be present. If precursors are present, we can adjust treatment processes to mitigate DBP formation risk. In this way, environmental data can help us avoid the formation of disinfection byproducts.
8. Today, we are going to explore environmental data from drinking water reservoirs in southwest Virginia, and then use that data to explore tradeoffs in drinking water treatment decisions. For example, some of the data are collected using YSI EXO sensor, which is pictured on the bottom right of the slide. This sensor is deployed at a fixed depth in the reservoir, attached to a catwalk. In this module, you will work with fluorescent dissolved organic matter data collected by this sensor.
9. fDOM stands for fluorescent dissolved organic matter. Characteristics of fDOM are: 1) it is derived from living things (like tree leaves or phytoplankton) and contain carbon; 2) fDOM compounds are not particles, but are dissolved in the water; 3) if light is transmitted through the water, these fDOM compounds will emit their own light in response through the process of fluorescence. One everyday example of dissolved organic matter are the coffee compounds that dissolve from the coffee grounds into the water and turn the coffee brown. fDOM is measured using sensors that transmit light at a particular wavelength through the water and then measure how much light is emitted from the fluorescent organic matter compounds in return. Because it is a form of organic matter, the presence of fDOM can also indicate that DBP precursors are present.

Thus, higher fDOM may mean an increased risk of DBP formation during the treatment process.

10. You will have the option to explore fDOM data from one of two reservoirs located in southwest Virginia: Falling Creek Reservoir or Beaverdam Reservoir. Both reservoirs are located in Vinton, Va, near Roanoke, and are owned and operated by the Western Virginia Water Authority as drinking water supply reservoirs.
11. You will use high-frequency fDOM data from your chosen reservoir to assess the risk of DBP formation and make water treatment plant operation decisions. In Activity B, you will convert fDOM to total organic carbon to assess when DBP formation is most likely in your reservoir. In Activity C, you will complete a drinking water reservoir case study and view fDOM data from different times of year in a reservoir. Then, you will decide whether to enact additional treatment measures to avoid DBP formation during the treatment process.
12. This module has four learning objectives (read objectives).
13. I will now give a brief overview of the module activities. In Activity A, you will complete two objectives. First, you will learn about factors affecting DBP formation and drinking water thresholds for DBPs. Second, you will explore tradeoffs in disinfection vs. DBP formation.
14. In Activity B, you will learn more about the focal drinking water reservoir that you select to work with during the module. Then, you will view and interpret organic matter data from your focal reservoir.
15. In Activity C, students will complete a scenario which asks them to make water treatment decisions using organic matter data.
16. The module can be accessed through your course Canvas site or through the link provided by your instructor. You will complete module activities in an R Shiny app, which is an interactive website. Be sure to complete the ”Quick-start” guide to the module and watch the video that explains the interactive module features. Questions are embedded in the app and you will answer these in a Canvas quiz or word document.
17. Thank you for participating!

Guide to Shiny App

Introduction

This is the landing page of the Shiny app. It gives an overview of the module, outlines the workflow for the module for students, and provides instructions about how to save and resume progress. Students will select the focal reservoir that they would like to work with on this page. If not using Canvas, this is also where students will download the module report into which they should type their answers. **Students should answer questions 1-3 (hereafter, denoted as Q1-3).** We have observed a tendency to forget about these questions as students skip straight to Activity A!

Students must select a focal reservoir on the Introduction page to be able to complete the rest of the module activities!

Activity A: Access and explore high-frequency water quality data

Activity A challenges the students to read and interpret plots of high-frequency water quality data from their focal reservoir.

Tips for Activity A:

- **Important: Tell the students to watch the embedded videos and read the embedded slides and text in each section as this will explain what is happening within each objective and help answer questions.**
- If teaching synchronously, walk around the room/move between breakout rooms and make sure that everyone can follow along with the Shiny app successfully.
- **When you close class, remind students to save their progress by saving their Canvas quiz or Word document. Also remind them that in order to resume their progress, they will have to re-select their reservoir in the Introduction when they re-load the app.**

Activity B: Use high-frequency water quality data to make water treatment plant operation decisions

Students will interpret high-frequency data from different times of year (summer, fall, spring) and use the data to make decisions about the depth from which to extract water for treatment at a drinking water treatment plant.

Tips for Activity B:

- **Important: Tell the students to read through the detailed text within each objective. We have embedded lots of directions, hints, and troubleshooting help within the Shiny app text! We encourage instructors to read and work through the Shiny app before teaching the module so that you are familiar with all of the steps of this activity.**
- If you are continuing from a previous lesson, it is good to show the students how to resume their progress in the app by re-selecting their focal reservoir site in the Introduction.
- In Objective 3, students will be given their first questions that are not multiple choice/multiple response. If using Canvas, be sure they follow the instructions for how to format their answers, or their answers will be automatically graded as incorrect in the Canvas quiz.
- In Objective 4, students will be asked for the first time to create, read, and interpret a plot of high-frequency data from their reservoir. Be sure students understand the plots are interactive and they can zoom in and out. In addition, they can see the actual data values on the plots by hovering over the data with their pointer. These interactive tools will be critical to help them answer module questions.

- Remind students to answer questions in their Canvas quiz or Word documents as they go. Also, if possible, encourage students to compare their decisions with other students working on the same or different reservoirs. One effective way of doing this is to ask students to briefly present one or more figures from Activity B to the class at the end of the lesson, and discuss how they used the figures to make decisions about water extraction depth.
- Walk around the room/move between breakout rooms and make sure that everyone can follow along the Shiny app successfully.
- **When you close class, remind students to save their progress by saving their Canvas quiz or Word document. Also remind them that in order to resume their progress, they will have to re-select their reservoir in the Introduction when they re-load the app.**

Activity C: Make water treatment decisions using water quality forecasts

This is a slightly shorter activity than A or B with one objective. Students use high-frequency data and water quality forecasts to make decisions about whether to enact additional treatment measures around the time of fall turnover to ensure the water treatment plant they are operating meets regulatory standards for turbidity.

Tips for Activity C:

- **Different students may make different decisions, and that is ok!** Emphasize to students that they will not be graded on what decision they make. The point of the exercise is to think about how to use data to make decisions, and then evaluate both their decisions and the usefulness of the data to the decision-making process.

Resources and References

Recent publications about EDDIE modules:

- Carey, C. C., R. D. Gougis, J. L. Klug, C. M. O'Reilly, and D. C. Richardson. 2015. A model for using environmental data-driven inquiry and exploration to teach limnology to undergraduates. Limnology and Oceanography Bulletin 24:32–35.
- Carey, C. C., and R. D. Gougis. 2017. Simulation modeling of lakes in undergraduate and graduate classrooms increases comprehension of climate change concepts and experience with computational tools. Journal of Science Education and Technology 26:1-11.
- Klug, J. L., C. C. Carey, D. C. Richardson, and R. Darner Gougis. 2017. Analysis of high-frequency and long-term data in undergraduate ecology classes improves quantitative literacy. Ecosphere 8:e01733.
- Farrell, K.J., and C.C. Carey. 2018. Power, pitfalls, and potential for integrating computational literacy into undergraduate ecology courses. Ecology and Evolution 8:7744-7751. DOI: 10.1002/ece3.4363

- Carey, C. C., Farrell, K. J., Hounshell, A. G., & O'Connell, K. 2020. Macrosystems EDDIE teaching modules significantly increase ecology students' proficiency and confidence working with ecosystem models and use of systems thinking. Ecology and Evolution. DOI: 10.1002/ece3.6757
- Moore, Tadhg N., R. Quinn Thomas, Whitney M. Woelmer, and Cayelan C. Carey. 2022. Integrating ecological Fforecasting into undergraduate ecology curricula with an R Shiny application-based teaching module. *Forecasting* 4 (3): 604–33. DOI: 10.3390/forecast4030033
- Woelmer WM, Moore TN, Lofton ME, Thomas RQ, Carey CC. 2023. Embedding communication concepts in forecasting training increases students' understanding of ecological uncertainty. Ecosphere 14: e4628.
- Mary E. Lofton, Tadhg N. Moore, Whitney M. Woelmer, et al. A modular curriculum to teach undergraduates ecological forecasting improves student and instructor confidence in their data science skills. *ESS Open Archive* . April 09, 2024.
  DOI: 10.22541/essoar.171269260.08508117/v1

We'd love your feedback!

We frequently update this module to reflect improvements to the code, new teaching materials and relevant readings, and student activities. Your feedback is incredibly valuable to us and will guide future module development within the Macrosystems EDDIE project. Please let us know any suggestions for improvement or other comments about the module by sending an email to MacrosystemsEDDIE@gmail.com or filling out the form at the following link: https://serc.carleton.edu/eddie/macrosystems/faculty_feedback.

Answer Key

On the following pages are two answer keys, one for each focal reservoir that students may choose to work with for the module. These keys are specifically formatted to be able to be converted into a Canvas QTI zipped file and imported into Canvas using the tool provided at https://site.nyit.edu/its/canvas_exam_converter. Because student decision-making and answers related to evaluating their decision-making will vary for each individual student, answers to these questions are not provided. The instructor can choose how to assess student module question responses. If using the Canvas quiz, all self-grading questions are worth 1 point by default. The point values may be adjusted by the instructor. If using the Word document, point values are not assigned to questions; this is left to the discretion of the instructor.

Beaverdam Reservoir

1. Which of the following is a correct definition of disinfection byproducts?

a) substances used to disinfect the water, such as chlorine

b) naturally-occurring substances that can create cancer-causing compounds during water treatment, such as organic matter

*c) substances that are unintentionally created during the disinfection process and can cause cancer, such as trihalomethanes

2. How do disinfection byproducts form?

*a) when chlorine reacts with organic or inorganic compounds during the treatment process

b) when high-nutrient fertilizers are used in a watershed

c) when inorganic material is accidentally introduced into the treatment plant

3. How can environmental data be used to help avoid the formation of disinfection byproducts?

a) environmental sensors can measure how much organic matter is present in a drinking water reservoir

b) environmental sensors can provide data in real-time or near real-time, which is useful for informing management decision-making

*c) both a and b

d) neither a nor b

4. Which of the following correctly describes DBP precursors (compounds in the water that can lead to DBP formation during treatment)?

a) DBP precusors can be naturally-occurring

b) DBP precursors can be organic compounds

c) DBP precursors can come from sources related to human activities (e.g., agriculture)

d) DBP precursors can be inorganic compounds

*e) all of the above

5. Exposure to DBPs has been associated with which of the following health concerns?

a) eczema

b) diabetes

*c) cancer

6. Which of the following is NOT a type of DBP?

a) trihalomethanes

*b) chloramines

c) haloacetic acids

7. Which best describes the "breakpoint" in the chlorination process?

a) the point at which adding more chlorine to the treatment system will lead to an exceedance of the MRDL

*b) the point at which complete disinfection is achieved and free residual begins to build up

c) the point at which formation of DBPs is most likely

d) the point at which chlorine begins to break down organic matter DBP precursors

8. Breakpoint chlorination has been achieved when

*a) the expected residual is less than or equal to the actual residual

b) the actual residual is less than the expected residual

c) neither of the above

9. What chlorine dosage should be applied to raw water with a demand of 0.6 mg/L and an intended residual of 1.2 mg/L? Round your answer to the nearest tenth (e.g., 1.2).

* 1.8

10. What should the chlorine feed rate setting be in lb/day if the plant flow is 1.1 MGD and the required chlorine dose is 1.5 mg/L? Report your answer to the nearest tenth (e.g., 12.4).

* 13.8

11. Use the following information to answer Q11-Q13. A chlorinator setting of 20 lbs chlorine per day results in a chlorine residual of 0.3 mg/L. The chlorinator setting is increased to 23 lb/day. The chlorine residual increases to 0.54 mg/L at this new dosage rate. The average flow being treated is 1.5 MGD. On the basis of these data, what is the expected increase in residual? Round your answer to the nearest hundredth (e.g., 0.12).

* 0.24

12. Using the information provided in Q11, what is the actual increase in residual? Round your answer to the nearest hundredth (e.g., 0.12).

* 0.24

13. Using the information in Q11 and your answers to Q11 and Q12, is breakpoint chlorination being reached?

*a) yes

b) no

c) the answer cannot be determined from the information given

14. Which of the following is NOT a method for removing DBP precursors prior to disinfection?

a) increase coagulation time or add more coagulant

b) use activated carbon filters to remove organic matter

*c) increase the frequency of TOC testing

d) pass water through a membrane that filters out DBP precursors

15. What is the name of your selected reservoir?

* Beaverdam Reservoir

16. What is the four-letter site identifier of your selected reservoir? Use lower case (e.g., ‘fcre’).

* bvre

17. What is the use of your selected reservoir?

a) recreation

b) irrigation

c) hydropower

*d) drinking water supply

18. What is the reservoir area in square feet of your selected reservoir? Provide your answer as a whole number (without decimal points) and with no spaces or commas (e.g., 123456).

* 4240658

19. What is the maximum depth of your reservoir in feet? Round your answer to the nearest whole number.

* 46

20. Which of the following is NOT a characteristic of fDOM?

*a) it is composed of particles

b) it is dissolved in the water

c) it is derived from living things and contains carbon

d) it fluoresces when exposed to light at particular wavelengths

21. fDOM is measured in quinine sulfate units, or QSU. Which of the following is true regarding QSU?

a) QSU is an indirect measure of fDOM

b) calibrating sensors using QSU enables consistent fDOM measurements across sensors and reservoirs

c) QSU compares organic matter fluorescence to the fluorescence of known concentrations of quinine sulfate

*d) all of the above

22. How is fDOM related to DBPs?

a) fDOM molecules are DBPs

b) the presence of fDOM molecules is correlated with other molecules in the raw water that are DBPs

*c) high fDOM levels in raw water may indicate the presence of DBP precursors which will form DBPs during treatment

d) high fDOM levels in raw water may indicate that treated water will exceed the MRDL

23. On what day of the year did the highest observed fDOM occur in your reservoir? Write out the full month name and day (e.g., September 20).

* July 10

24. On what day of the year did the lowest observed fDOM occur in your reservoir? Write out the full month name and day (e.g., September 20).

* November 17

* November 16

25. Based on the data in the figure and your understanding of how fDOM levels relate to DBPs, on what day of the year is the risk of DBP formation during treatment highest in your reservoir according to the fDOM data? Write out the full month name and day (e.g., September 20).

* July 10

26. In your focal reservoir, what is the corresponding TOC in mg/L for the highest observed fDOM in your reservoir? Round your answer to the nearest tenth (e.g., 3.1).

* 4.3

27. The U.S. Environmental Protection Agency (US EPA) has a rule regarding removal of TOC from drinking water during treatment (see table below). The percentage of TOC that must be removed during treatment depends on the amount of TOC in the raw water (see the first column of the table), as well as the raw water alkalinity (second, third, and fourth columns of the table). Use the fDOM-to-TOC converter to determine how much TOC should be removed from a reservoir with an fDOM concentration of 40 QSU and a raw water alkalinity of 50 mg/L. Report your answer in mg/L of TOC to the nearest tenth (e.g., 2.1).

* 2.9

28. For Feb. 20, what is the corresponding TOC in mg/L of the fDOM observation for today? Use the fDOM to TOC converter to help answer the question. Round your answer to the nearest tenth (e.g., 3.1).

* 8.3

29. Which best describes the pattern in fDOM data over the previous month?

a) increasing

*b) decreasing

c) steady (very little change)

d) highly variable, but neither increasing nor decreasing overall

30. Do you decide to increase the coagulation time to reduce the risk of high TOC and potential DBP formation in the filtered water? There is no right or wrong answer to this question. Type ‘yes’ or ‘no’.

* yes

* no

31. For Apr. 15, what is the corresponding TOC in mg/L of the fDOM observation for today? Use the fDOM to TOC converter to help answer the question. Round your answer to the nearest tenth (e.g., 3.1).

* 9.2

32. Which best describes the pattern in fDOM data over the previous month?

a) increasing

b) decreasing

c) steady (very little change)

*d) highly variable, but neither increasing nor decreasing overall

33. Do you decide to increase the coagulation time to reduce the risk of high TOC and potential DBP formation in the filtered water? There is no right or wrong answer to this question. Type ‘yes’ or ‘no’.

* yes

* no

34. For Aug. 20, what is the corresponding TOC in mg/L of the fDOM observation for today? Use the fDOM to TOC converter to help answer the question. Round your answer to the nearest tenth (e.g., 3.1).

* 13.2

35. Which best describes the pattern in fDOM data over the previous month?

*a) increasing

b) decreasing

c) steady (very little change)

d) highly variable, but neither increasing nor decreasing overall

36. Do you decide to increase the coagulation time to reduce the risk of high TOC and potential DBP formation in the filtered water? There is no right or wrong answer to this question. Type ‘yes’ or ‘no’.

* yes

* no

Falling Creek Reservoir

1. Which of the following is a correct definition of disinfection byproducts?

a) substances used to disinfect the water, such as chlorine

b) naturally-occurring substances that can create cancer-causing compounds during water treatment, such as organic matter

*c) substances that are unintentionally created during the disinfection process and can cause cancer, such as trihalomethanes

2. How do disinfection byproducts form?

*a) when chlorine reacts with organic or inorganic compounds during the treatment process

b) when high-nutrient fertilizers are used in a watershed

c) when inorganic material is accidentally introduced into the treatment plant

3. How can environmental data be used to help avoid the formation of disinfection byproducts?

a) environmental sensors can measure how much organic matter is present in a drinking water reservoir

b) environmental sensors can provide data in real-time or near real-time, which is useful for informing management decision-making

*c) both a and b

d) neither a nor b

4. Which of the following correctly describes DBP precursors (compounds in the water that can lead to DBP formation during treatment)?

a) DBP precusors can be naturally-occurring

b) DBP precursors can be organic compounds

c) DBP precursors can come from sources related to human activities (e.g., agriculture)

d) DBP precursors can be inorganic compounds

*e) all of the above

5. Exposure to DBPs has been associated with which of the following health concerns?

a) eczema

b) diabetes

*c) cancer

6. Which of the following is NOT a type of DBP?

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8. Breakpoint chlorination has been achieved when

*a) the expected residual is less than or equal to the actual residual

b) the actual residual is less than the expected residual

c) neither of the above

9. What chlorine dosage should be applied to raw water with a demand of 0.6 mg/L and an intended residual of 1.2 mg/L? Round your answer to the nearest tenth (e.g., 1.2).

* 1.8

10. What should the chlorine feed rate setting be in lb/day if the plant flow is 1.1 MGD and the required chlorine dose is 1.5 mg/L? Report your answer to the nearest tenth (e.g., 12.4).

* 13.8

11. Use the following information to answer Q11-Q13. A chlorinator setting of 20 lbs chlorine per day results in a chlorine residual of 0.3 mg/L. The chlorinator setting is increased to 23 lb/day. The chlorine residual increases to 0.54 mg/L at this new dosage rate. The average flow being treated is 1.5 MGD. On the basis of these data, what is the expected increase in residual? Round your answer to the nearest hundredth (e.g., 0.12).

* 0.24

12. Using the information provided in Q11, what is the actual increase in residual? Round your answer to the nearest hundredth (e.g., 0.12).

* 0.24

13. Using the information in Q11 and your answers to Q11 and Q12, is breakpoint chlorination being reached?

*a) yes

b) no

c) the answer cannot be determined from the information given

14. Which of the following is NOT a method for removing DBP precursors prior to disinfection?

a) increase coagulation time or add more coagulant

b) use activated carbon filters to remove organic matter

*c) increase the frequency of TOC testing

d) pass water through a membrane that filters out DBP precursors

15. What is the name of your selected reservoir?

* Falling Creek Reservoir

16. What is the four-letter site identifier of your selected reservoir? Use lower case (e.g., ‘fcre’).

* fcre

17. What is the use of your selected reservoir?

a) recreation

b) irrigation

c) hydropower

*d) drinking water supply

18. What is the reservoir area in square feet of your selected reservoir? Provide your answer as a whole number (without decimal points) and with no spaces or commas (e.g., 123456).

* 1306427

19. What is the maximum depth of your reservoir in feet? Round your answer to the nearest whole number.

* 31

20. Which of the following is NOT a characteristic of fDOM?

*a) it is composed of particles

b) it is dissolved in the water

c) it is derived from living things and contains carbon

d) it fluoresces when exposed to light at particular wavelengths

21. fDOM is measured in quinine sulfate units, or QSU. Which of the following is true regarding QSU?

a) QSU is an indirect measure of fDOM

b) calibrating sensors using QSU enables consistent fDOM measurements across sensors and reservoirs

c) QSU compares organic matter fluorescence to the fluorescence of known concentrations of quinine sulfate

*d) all of the above

22. How is fDOM related to DBPs?

a) fDOM molecules are DBPs

b) the presence of fDOM molecules is correlated with other molecules in the raw water that are DBPs

*c) high fDOM levels in raw water may indicate the presence of DBP precursors which will form DBPs during treatment

d) high fDOM levels in raw water may indicate that treated water will exceed the MRDL

23. On what day of the year did the highest observed fDOM occur in your reservoir? Write out the full month name and day (e.g., September 20).

* October 4

24. On what day of the year did the lowest observed fDOM occur in your reservoir? Write out the full month name and day (e.g., September 20).

* May 2

25. Based on the data in the figure and your understanding of how fDOM levels relate to DBPs, on what day of the year is the risk of DBP formation during treatment highest in your reservoir according to the fDOM data? Write out the full month name and day (e.g., September 20).

* October 4

26. In your focal reservoir, what is the corresponding TOC in mg/L for the highest observed fDOM in your reservoir? Round your answer to the nearest tenth (e.g., 3.1).

* 4.7

27. The U.S. Environmental Protection Agency (US EPA) has a rule regarding removal of TOC from drinking water during treatment (see table below). The percentage of TOC that must be removed during treatment depends on the amount of TOC in the raw water (see the first column of the table), as well as the raw water alkalinity (second, third, and fourth columns of the table). Use the fDOM-to-TOC converter to determine how much TOC should be removed from a reservoir with an fDOM concentration of 40 QSU and a raw water alkalinity of 50 mg/L. Report your answer in mg/L of TOC to the nearest tenth (e.g., 2.1).

* 2.9

28. For Feb. 20, what is the corresponding TOC in mg/L of the fDOM observation for today? Use the fDOM to TOC converter to help answer the question. Round your answer to the nearest tenth (e.g., 3.1).

* 8.3

29. Which best describes the pattern in fDOM data over the previous month?

a) increasing

*b) decreasing

c) steady (very little change)

d) highly variable, but neither increasing nor decreasing overall

30. Do you decide to increase the coagulation time to reduce the risk of high TOC and potential DBP formation in the filtered water? There is no right or wrong answer to this question. Type ‘yes’ or ‘no’.

* yes

* no

31. For Apr. 15, what is the corresponding TOC in mg/L of the fDOM observation for today? Use the fDOM to TOC converter to help answer the question. Round your answer to the nearest tenth (e.g., 3.1).

* 9.2

32. Which best describes the pattern in fDOM data over the previous month?

a) increasing

b) decreasing

c) steady (very little change)

*d) highly variable, but neither increasing nor decreasing overall

33. Do you decide to increase the coagulation time to reduce the risk of high TOC and potential DBP formation in the filtered water? There is no right or wrong answer to this question. Type ‘yes’ or ‘no’.

* yes

* no

34. For Aug. 20, what is the corresponding TOC in mg/L of the fDOM observation for today? Use the fDOM to TOC converter to help answer the question. Round your answer to the nearest tenth (e.g., 3.1).

* 13.2

35. Which best describes the pattern in fDOM data over the previous month?

*a) increasing

b) decreasing

c) steady (very little change)

d) highly variable, but neither increasing nor decreasing overall

36. Do you decide to increase the coagulation time to reduce the risk of high TOC and potential DBP formation in the filtered water? There is no right or wrong answer to this question. Type 'yes' or 'no'.

* yes

* no

This module was initially developed by: Lofton, M.E., Cooke, R.L., and C.C. Carey. 20 September 2025. Macrosystems EDDIE: Exploring Tradeoffs in Water Quality Management Using Environmental Data. Macrosystems EDDIE Module 10, Version 1. https://serc.carleton.edu/eddie/teaching_materials/modules/module10.html. Module development was supported by NSF grants EF-2318861 and RISE-2438447. This document last modified: 20 February 2026 by M.E. Lofton.

Module authorship contributions: MEL, RLC, and CCC conceptualized the module. MEL drafted and revised all module materials with substantial feedback from RLC and CCC.