Kai: Environmental Scientist
Career Pathway Lesson

Sampling: When, Where, & How Much

Storm Water Career: Scientist

All Careers Full- Course Lesson Plan #:
7 of 15

Next Lesson Plan Title (Full-Course):
Water: Flow & Quality

Select Career Short-Course Lesson Plan #:
3 of 6

Next Lesson Plan Title (Short-Course):
Water: Flow & Quality

SUMMARY

In this lesson, students will learn about designing a storm water monitoring plan. They will explore the steps necessary to create a robust sampling design, discuss methods to ensure that the data collected is accurate and reliable, and perform sampling data analysis.

FOCUS & GOALS

In learning about sampling, students will:

- Understand the importance of storm water sampling for evaluating and assessing the impacts of runoff
- Explore the main components of designing a storm water sampling study
- Evaluate the accuracy and precision of study methods and results

MATERIALS NEEDED

- Activity Worksheets
- Aim for the Pollutants Target
- Mock Site SWPPP Map (from Lesson 2)
- Mock Site Land Use Map with Channel
- Sampling Result Cards
- Clay, Play-Doh, or other malleable materials
- Colored pens or pencils

LEARNING OBJECTIVES

- Identify the goals of storm water monitoring
- Describe types of water quality parameters
- Analyze the topography and outlets of a site to determine sampling locations
- Identify accuracy and precision within a storm water monitoring plan
- Review and analyze water quality data to determine impairments, trends, and potential treatments for a site

VOCABULARY

Accuracy - How close the acquired results are to the actual value.

Biological Parameters - Biotic characteristics, such as biodiversity and species abundance.

Chemical Parameters - Information about the chemical makeup of the storm water, such as pH, oxygen and nutrient levels.

Physical Parameters - Observable measurements of the storm water, such as temperature and flow rate.

Precision - How close the acquired results are to one another.

Storm Water Monitoring - The process of conducting sampling and collecting quantitative data on parameters within the storm water runoff of a target area.

Background

In previous lessons, students explored how storm water flows through a community, its interaction with local land uses and surface materials, and how local watersheds may be affected. They also designed storm water infrastructure to address a storm water-related flooding problem. In this lesson, they will build upon that knowledge to understand the importance of sampling storm water, in order to evaluate storm water quality and better understand its impact on local waterways and the larger watershed. They will also learn how storm water parameters may change over time, perhaps due to the installation of storm water treatment designs or seasonal variability, and why it is important to create an accurate, precise, and complete monitoring plan to evaluate these trends, changes, and impacts.

Storm water monitoring describes the process of conducting sampling and collecting quantitative data on parameters within the storm water runoff of a target area. Parameters are characteristics, such as pH, turbidity, or the concentrations of certain pollutants. The goals of monitoring are to characterize storm water, determine if certain parameters exceed water quality standards, identify the potential sources of pollution, evaluate the effectiveness of current treatment activities, and study the impact of storm water pollution on local waterways and watersheds. The data collected and analyzed can help to determine whether storm water is polluted, identify the sources of certain pollutants of concern, inform future treatment designs or the targeted implementation of other best management practices, give insights into the health of a watershed and the impacts of polluted storm water discharge, and support a more effective and efficient storm water management strategy. Environmental scientists might assist in the creation of the monitoring study design, conducting research and literature reviews on the health of receiving waters and the watershed, handling sampling site identification and reconnaissance, collecting and analyzing storm water samples, analyzing storm water quality data and sample results, and writing reports detailing the study's sampling efforts, results, and conclusions.

Oftentimes, monitoring is required for sites, such as industrial facilities or entities within a municipal separate storm sewer system, as specified in National Pollutant Discharge Elimination System permits, detailed Storm Water Pollution Prevention Plans, and regulated under the Clean Water Act. Monitoring guidelines have been developed by the Environmental Protection Agency and other state-level and professional organizations to guide monitoring activities and ensure that the data collected is useful and reliable. Additionally, to provide relevant data analysis and study conclusions, the monitoring results must be compared to benchmark or baseline values to determine whether pollutant levels or other parameters exceed normal or safe conditions. These benchmark values may be determined by national or state regulations, scientific studies, or baseline samples collected as part of the monitoring plan prior to sampling activities.

In order to have a reliable set of storm water quality data, you must have a robust sampling protocol, which includes both precise and accurate sampling collection, preparation, and analysis. Precision describes how close the acquired results are to one another. In sampling, this means that duplicate samples, which are samples taken at the same site and time, should have very similar results upon analysis. Accuracy describes how close the acquired results are to the actual value. In storm water sampling, this means that the levels of various pollutants within the collected samples should accurately reflect the associated levels of the storm water in the target drainage area. Such precision and accuracy can be achieved through quality assurance and quality control (QA/QC) measures, which aim to identify, correct, and minimize any error that might occur during the sampling process. For example, one QA/QC measure that can be conducted before sampling activities is consistently calibrating sampling instruments against standard concentrations. Another QA/QC measure commonly used during laboratory testing is the preparation of samples with known pollutant concentrations and/or spike samples which are then tested alongside field samples. Creating a monitoring and sampling plan that is accurate and precise allows for the reliable and effective analysis of the quality of storm water discharge that may be adversely affecting nearby waterways or the larger watershed.

To ensure that monitoring effects and results are both accurate and precise, a sampling study design must be carefully developed, keeping the following questions in mind during the development process:

- **What are the goals of monitoring efforts?**

  Determine the point of the study and define what questions about water quality you want to answer. This provides the foundation for your study and will help determine the "what", "where", "when", and "how much" questions of your monitoring program.

- **What will be monitored?**

  Define your parameters of interest, meaning what you will measure to evaluate storm water quality. These parameters can be physical, chemical, or biological characteristics. Physical parameters describe observable measurements of the storm water, such as temperature and flow rate. Chemical parameters encompass information about the chemical makeup of the storm water, such as pH, oxygen and nutrient levels, metals, and dissolved solids. Biological measurements describe biotic characteristics, typically when evaluating the biodiversity of the receiving water to determine the influence of storm water discharge. The selected parameters should be determined by the monitoring goals and should be consistently measured over time in the target watershed, waterbody, or site, to allow for analysis and comparison. Additionally, the method of lab analysis should be selected, using accepted and standardized techniques along with robust QA/QC measures to ensure that laboratory analysis is accurate.

- **Where will monitoring occur?**

  Identify the locations at which storm water samples will be collected. These sites should be carefully selected based on specific criteria, such as sufficient discharge for collection, safety of personnel, representativeness of pollutant levels, and drainage area. Common storm water sampling sites are the outlet of pipes and culverts, within or at the mouth of channels and storm drains, at the outlet of treatment structures, or in areas where surface runoff might collect, like a driveway. Site access should also be considered, especially when sampling in deep inlets, steep slopes, or far outfalls. Tools such as extension poles or rope could be employed to assist sample collection at certain sites.

- **When will monitoring occur?**

  Determine the magnitude or depth of a storm event necessary to require sample collection. For example, the sampling team might track projected weather conditions and mobilize once the sampling site is predicted to receive 0.05 inches of rainfall in the next hour. In addition, the monitoring goals may require sampling at specific times and frequencies or during certain time periods. For example, the sampling team might collect a sample from one site every five minutes to record how the storm water quality changes over time during a rain event. Lastly, if baseline monitoring is required, the collection period for baseline samples and the amount of time between baseline sampling and the beginning of sample collection must be determined. For example, baseline monitoring might be conducted by collecting daily samples over five days, ten days prior to the start of sample collection.

- **How much monitoring will occur?**

  Quantify the ideal number of samples that should be collected to satisfy your monitoring goals. Samples should be collected over a period of several years and across various seasons, to document seasonal and annual variations in pollutant concentrations. For example, different trends might occur in the wet (November 1-April 30 in Hawai‘i) versus dry seasons (May 1-October 31 in Hawai‘i) which may be important to understand when characterizing a site’s storm water quality.

- **How should monitoring be conducted?**

  Specify monitoring protocols, such as sample collection techniques, data collection requirements, and analytical methods. Your study may want to employ different sample collection techniques, depending on the goal of your study. Automatic sampling, where devices collect samples at precise intervals once storm water flow reaches a sufficient depth, can record the change in storm water quality over the course of a storm or create composite samples, while grab samples, where the sampling team collects a discrete sample at one point in time, can provide measurements of storm water quality parameters for the first flush of storms. Data collection requirements describe the data that the sampling team gathers during a sampling event, in addition to the samples themselves. These data could include site conditions, such as pictures of the site or notes on rain intensity or surface runoff, storm event details, such as total rainfall depth, or sample descriptions, such as any visual observations about the samples. Finally, the analytical methods through which you analyze and draw conclusions from the sampling results is important to document and standardize. This might include mapping or modeling, graphing results, or conducting data calculations, such as the average concentration of certain pollutants.

- **How will the quality of the data be validated?**

  Create QA/QC measures to ensure a high level of confidence in the data and demonstrate the data’s accuracy and precision. Some examples of QA/QC procedures are the proper documentation of sampling events and sample preparation, collection of duplicate and blank samples, the verification of data entries and data manipulation, and proper chain of custody completion. Blank samples are samples of distilled or deionized water that can be used to identify contamination during lab analysis or in sampling equipment. A chain of custody documents the transfer and handling of samples between recipients from collection to analysis.

In this lesson, students will learn more about the differences between accuracy and precision through a hands-on activity. They will gain experience creating a storm water sampling study design by analyzing a mock site and identifying potential sampling sites that may provide important information about the site’s storm water runoff. Finally, they will harness their inner environmental scientist to review storm water sample data, understand the importance of long-term sampling efforts, and draw inferences and conclusions about the site’s storm water quality and impacts on the larger watershed.

I. Bullseye! Activity

1. Introduce the topic of accuracy versus precision to the students. Explain the definition of both accuracy and precision.
2. Have students break out into small groups and distribute the Bullseye! worksheet and Precision and Accuracy Diagram.
3. Provide each group with an Aim for the Pollutants Target and a ball of clay. Direct the students to create smaller balls of clay using the materials provided.
4. Explain that the first part of this activity is to place their target on the floor and drop the clay balls in different ways, aiming for the pollutants at the center of the target. Students should drop the balls from at least shoulder height, but can test dropping the balls from different heights, with different release styles, or even different angles.
5. The students should record the locations of the clay balls on their worksheet and evaluate the precision and accuracy of their method.
6. When all the groups have finished, lead a class-wide discussion about the accuracy and precision of the groups' results.
   ○ What influenced precision?
   ○ What influenced accuracy?
7. Have the students consider how the locations of their clay ball drops relate to the locations of sampling sites within a storm water monitoring plan. Just as the locations of the clay balls demonstrate precision and accuracy, sampling sites must be chosen carefully, as they can impact the accuracy and precision of monitoring efforts and data. Discuss a few of the following questions:
   ○ What factors should be considered when selecting sampling sites?
   ○ Does taking multiple samples at a site improve precision?
   ○ Does sampling at multiple sites improve accuracy?
8. To conclude, have the students work through Part 2 of the Bullseye! worksheet individually, which leads them through evaluating the precision and accuracy within the sampling method scenarios. Upon completing the activity, they should discuss their answers within their small groups.

II. Following Water to the Outfall Activity

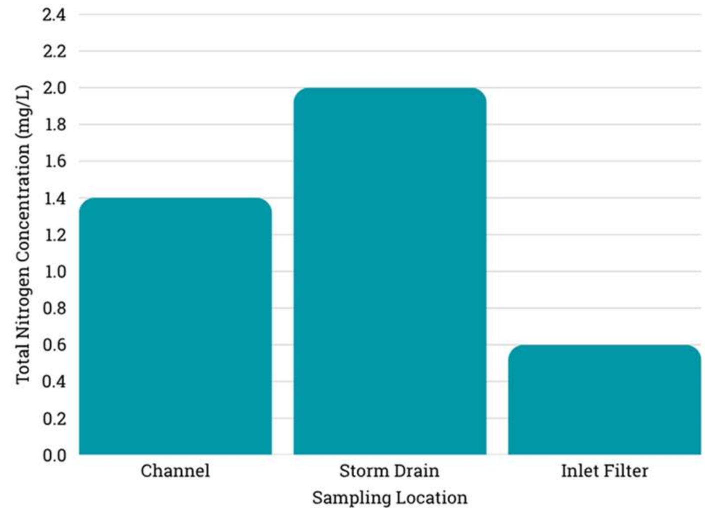
1. Share with students that they will now try their hand at creating a monitoring plan for the Mock Site in the Waikele Watershed from Lesson 2 and Lesson 5.
2. Provide or have the students retrieve their Mock Site SWPP Map, distribute the Following Water to the Outfall worksheet and Mock Site Land Use Map with Channel, and have them work through the Steps 1-3 in the worksheet, either individually or in small groups.
3. Explain to the students that areas where water discharges, or drains, out of the site are optimal locations for storm water sampling. These outfalls convey the surface runoff flowing from the area of study to surrounding areas and therefore, provide important information about the levels of pollutants and contaminants present in the site's storm water discharge. Some examples of sampling locations are the outlet of pipes and culverts, within or at the outlet of channels and storm drains, at the outlet of treatment structures, or in areas where surface runoff might collect, like a driveway.
4. Direct the students to use their knowledge of the site and the provided maps to determine sampling locations to complete Step 4 and 5 of the worksheet. The students will identify four to five potential sampling outfalls and consider the pollutants that may be present at each outfall based on its surrounding environment.
5. Have the students present their sampling locations, describing their reasoning for selecting these particular sites.

III. Storm Sampling T-RAIN-ing Activity

1. Distribute the Sampling Location Map to the students and direct them to look at the Sampling Location Map and the three indicated sampling locations at the culvert, storm drain, and biofilter outlet. Ask them to compare and contrast these sites to the ones they identified in the last activity.
2. Pass out one Sampling Results Card to each student and a copy of the Storm Sampling T-RAIN-ing worksheet. Assist the students as they work through Step 1-2 and explain that the method for writing a

III. Storm Sampling T-RAIN-ing Activity Continued

Sample Identification (Sample ID) may vary between different sampling designs. Prior to beginning sampling, it is important to ensure that all team members are familiar with the sampling locations and ID protocols for the particular study. Correctly labelling samples prevents future errors, such as mixing up the sampling results, or allows the team to identify which sample may have been an anomaly. The students should use their Sample ID to identify the site's results and what they are able to learn about their sampling site.



Sample Graph: Total Nitrogen at three monitoring sites on January 8

3. Have the students form a group with other students that share the same sampling location: channel, storm drain, or inlet filter.
4. Discuss the definitions of Total Nitrogen (TN) and Total Suspended Solids (TSS). TN is the sum total of ammonia, nitrates, and nitrites in water. While it is an essential nutrient, excess nitrogen can have an adverse effect with sources from over-fertilization or decaying vegetation, wastewater treatment plants, or agricultural runoff. TSS is the solid particles which are present in the water and do not dissolve. The particles can be sedimentary in nature (of sand, silt, or clay), organic matter, such as decaying leaf debris or animal waste, or from human sources, such as vehicle tire wear, exhaust emissions, or construction material.

Sample Graph: Total Nitrogen at storm drain monitoring site across five sampling events

5. Direct the groups to discuss their various sampling results, work together to graph the results for TN and TSS, and analyze the graphs to determine trends or differences in the wet weather and dry weather concentrations for their sampling site. Explain to students that the wet weather season for their site is November 1 to April 30 and the dry weather season is May 1 to October 31. Let them know that the baseline, or maximum acceptable, pollutant levels for this site for TN are 0.6 mg/L during the dry season and 0.8 mg/L during the wet season, while the baseline levels for TSS are 55 mg/L during the dry season and 80 mg/L during the wet season.
6. Next, have the students form another group with other students that share the sampling date.
7. Direct the students to discuss their various sampling results, work together to graph the results for Total Nitrogen (TN) and Total Suspended Solids (TSS), and analyze the graphs to determine trends or differences between the pollutant concentrations at the three sampling locations.
8. Lead a class discussion about the conclusions drawn by each group, as well as the overall takeaways about the seasonal and location-based variations in pollutant levels at the Mock Site.

Adaptations and Resources

Storm Patrol Project Based Learning Track

- Students work on the Measure & Monitor section of their workbook, reflecting on the watershed that they identified in Lesson 3 as that in which their site is located, as well as the storm water runoff and pollution that their site might contribute to the watershed. They then compare this information with the watershed's documented impairments and water quality issues to determine the impact and contribution of their site.

- As a team, students use the information they have gathered to create a sampling study design that will help them gain a better understanding of their site's contribution to storm water pollution. They should identify the goals of the study, what will be monitored, where monitoring will occur, when monitoring will occur, how much monitoring will occur, and other important monitoring and sampling procedures to ensure precise and accurate evaluation of their site.

Activity-Centric Learning Track:

Conduct Activities I , II, and III.

Tips to Truncate Lesson:

- Eliminate or assign the Project Based Learning Activity as homework.
- Prepare the storm water sampling data graphs for Activity 3 ahead of time for students to analyze and identify trends or areas of concern.
- Assign the Following Water to the Outfall activity as homework and have the students present about their chosen sampling locations at the beginning of the next class session.

Tips to Extend Lesson:

- In the Bullseye! Activity, discuss with the students what might change about their dropping methods if the conditions were different in the following scenarios:
    - The target is moved outside, where conditions may be sunny, windy, rainy.
    - One team member moves the target slowly from right to left as the clay ball is dropped by another team member.

  Just as their target conditions vary, sampling site conditions can vary between locations and over time. The students should conduct trials with the scenarios.
- Have the students research the pollutants impacting the watershed in which they live and design a monitoring plan to characterize the storm water runoff from within their neighborhood that may contribute to watershed pollution.

Resources:

- State of California Department of Transportation, *Stormwater Monitoring Guidance Manual*, https://dot.ca.gov/-/media/dot-media/programs/environmental-analysis/documents/env/ctws-ot-20-350-04-01-monitoring-guidance-manual-a11y.pdf.
- Environmental and Engineering Services, *Quality Assurance for Municipal Stormwater Programs*, http://stormwaterok.net/addtl/INCOG%20QA%20Guidance%20-%20July-06.pdf.
- Environmental Protection Agency, *Total Nitrogen*, https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P10070OQ.TXT
- Minnesota Pollution Control Agency. *Total Suspended Solids (TSS) in stormwater*, https://stormwater.pca.state.mn.us/total_suspended_solids_tss_in_stormwater