# Go with the Flow! *Does the slope or substrate have a greater impact on the speed of water flow?*

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**Field tested with:** 9th grade Integrated Science students, Watsonville High School, Watsonville, CA (Winter, 2014)

**Module Type:** Lecture, lab activity, and discussion

**Duration:** One 2-h class session

**Key materials:**

* Stream tables and Substrates: gravel, sand, sod, clay
* Water and Watering can, bucket, or cup for pouring
* Stopwatches, Calculators, Rulers and Protractors

**Concepts:** continuous vs. discrete data, dependent variables, independent variables, constant variables

**Skills:** Data collection, developing and testing hypotheses, calculating speed, calculating averages, constructing data tables, plotting line and bar graphs, conducting an experiment, analyzing results

**NGSS DCI:** ESS2.C: The Roles of Water in Earth’s Surface Processes

**NGSS Practices:**

1. Asking questions (for science) and defining problems (for engineering), 2. Developing and using models, 3. Planning and carrying out investigations, 4. Analyzing and interpreting data

5. Using mathematics and computational thinking, 6. Constructing explanations (for science) and designing solutions (for engineering), 7. Engaging in argument from evidence

**NGSS CCC:**

2. Cause and effect: Mechanism and explanation, 4. Systems and system models

# Overview:

This project is an opportunity for students to learn:

* How slope and substrate affect the speed of water flow
* How to ask questions, carry out an experiment and develop graphical hypotheses
* How to calculate speed and mathematical averages
* How to plot line and bar graphs, and use data to explain results

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# Background for Teachers

**Why this matters:** Water has a big effect on shaping the earth and is constantly cycling through the landscape. Water moves through diverse natural and human landscapes, including steep and shallow slopes, soils composed of different materials, and paved surfaces. In this lab activity, students will investigate how the speed of water flow changes with different slopes and different substrates.

**Assumed background:** This activity assumes that students:

* Know the difference between control, dependent, and independent variables
* Can use a protractor to measure angles
* Know how to calculate mathematical averages

**Special context:** Water constantly cycles through the earth and the atmosphere, shaping natural landscapes through erosion, deposition, flooding, and landslides, and flowing through human landscapes, many of which involve **impervious surfaces** such as pipes and storm drains. The study of water flow in streams and rivers and on impervious surfaces involves many **variables**. These include the **slope** or **gradient** of a stream, surface, or pipe and the type of **substrate** that water is flowing through. In this lab activity, students will investigate how the speed of water flow changes with different **slopes** and different **substrates**. This is very important to civil engineers, who must understand water flow characteristics on different slopes and substrates with different **permeabilities** when they construct water resource structures and when they predict and mitigate the impacts of natural disasters.

Many factors influence the speed of water flow on the landscape:

* Slope or gradient: Water flows faster on steeper surfaces
* Substrate: Finer grained materials are less permeable to water

In this lab, students will investigate variables that affect water flow speed in a two-part activity: Part 1 will test the effect of slope on the speed of water flow and Part 2 will test the effect of substrate on the speed of water flow.

In Part 1, students will practice collecting continuous data by examining the relationship between slope and water flow rate. Using a protractor and a timer, they will measure the speed of water flow at five different slopes.

Part 2 will focus on collecting discrete data by testing the effects of substrate on water flow rate. Students will measure the speed of water flow over/through four different substrates (gravel, sand, sod, and clay) as well as no substrate. They will conduct three trials for each substrate.

Upon completion of this activity, students will be able to:

* Calculate the speed of water flow
* Explain the relationship between slope and the speed of water flow
* Evaluate the effects of substrates on the speed of water flow
* Understand the difference between continuous data and discrete data

**Scaffolding supplements:** “Go\_with\_the\_Flow\_Presentation.pptx” – PowerPoint introductory lecture; “Go\_with\_the\_Flow\_Worksheet.docx” – A student worksheet to go along with the lecture and lab activity

# Module Description

## Materials:

* Stream tables (1 per group; e.g., from Flinn Scientific: <http://www.flinnsci.com/store/Scripts/prodView.asp?idproduct=22628>)
* Water
* Watering can, bucket, or cup for pouring water (1 per group)
* Stopwatches (1 per group)
* Calculators (1 per student)
* Rulers (1 per group)
* Protractors (1 per group)
* Substrates: gravel, sand, sod, clay

## Preparation:

* The teacher will need to prepare copies of the worksheets (1 per student) in advance as well as gather the necessary lab materials

## Timeline:

1. PowerPoint Introduction – 10 min.
2. Demonstration of continuous vs. discrete data – 10 min.
3. Students break into groups – 5 min.
4. Students test different slopes – 30 min.
5. Students test different substrates – 45 min.
6. Clean-up, finish worksheets, and review – 20 min.

## Starting Point For Inquiry:

Begin by asking students, “When it rains, where does the water go?” Explain that water is constantly moving through the water cycle—some runs along the surface into rivers and lakes, some soaks into the soil and is absorbed by plant roots, some evaporates into the atmosphere, and some goes underground. Ask students what factors they think might influence how fast water travels across the landscape. Tell students to imagine pouring water onto a mountain of sand they built on the beach. Where would the water go? Some would go down the sides, and some would soak into the sand. Ask them to consider how water flow might be different when traveling through a farm field or through a parking lot. Explain that water tries to fill the spaces between soil (substrate) particles and that not all substrates are the same—permeability is a measure of how easily the substrate particles will allow water to fill in the spaces between them.

Civil engineers must understand water flow characteristics when they construct bridges, dams, channels, canals, and levees. Water flow analysis and permeability analysis are very important factors in these construction projects. For example, the concepts of water flow and permeability are used to estimate the amount of water expected to overflow in a certain period of time for flood warnings. Understanding water flow at different slopes and through different substrates allows civil engineers to design safe water resource structures as well as reduce risk of damage from natural disasters such as floods.

## Detailed Procedure:

Distribute the student worksheet and present the PowerPoint presentation that introduces the lab concepts to the students. Have the students complete portions of the worksheet along with the introduction as they learn new vocabulary and concepts. After the PowerPoint presentation, teach students about differences between continuous (e.g., testing the slopes) vs. discrete (e.g., testing the substrates) data collection and explain that they will show continuous data in a line graph and discrete data in a bar graph. Refer to the “Optional” section below for further details.

Introduce the lab protocol

Explain the lab activities to the students. You may wish to review the process of formulating a hypothesis and identifying independent, dependent, and constant variables.

Students break into groups and formulate hypotheses

Divide the students into groups and have them develop their hypotheses and complete the tables in their worksheets about hypotheses and variables before they set up their stream tables.

Students conduct Experiment 1 (testing slopes)

The students will test the effect of five different slopes on the speed of water flow and record their data in the data tables provided on their worksheet.

Students conduct Experiment 2 (testing substrates)

The students will test the effect of four different substrates on the speed of water flow and record their data in the data tables provided on their worksheet.

Clean-up and finish worksheets

Have students clean up their lab areas and return to their seats once they have completed their data collection. Provide time for them to complete their line and bar graphs since they were most likely unable to complete those during data collection.

Review

Have a discussion with the class about what they learned during the activity, as well as challenges they faced through the process. Pool the results from each group and develop conclusions about the effects on slope and substrate on the speed of water flow as a class.

## Assessment Methods:

Students who have mastered the content and process skills intended through this module will be able to complete their worksheets, explain what they found, and support their conclusions based on evidence from their data collection.

## Possible pitfalls:

Students may be tempted to change more than one variable at a time. Emphasize the importance of changing only one variable in a good scientific experiment.

## Glossary:

**Data** – Information observed and collected about something that is used for analysis

**Data table** – Organizational tool for recording data

**Average/mean** – The typical or central value in a set of data, calculated by dividing the sum of all the values by the number of values

**Trials** – Number of times an experiment is repeated

**Accuracy** – How close a measurement is to the true value

**Variable** – Any factor that can be controlled, changed, or measured in an experiment

**Independent variable** – The variable that is changed by the scientist in an experiment

**Dependent variable** – The variable that might change because of what the scientist changes

**Control variable** – Things that the scientist makes sure stay the same in an experiment

**Permeability** – A measure of the ability of water to flow through a soil’s pore spaces

**Impervious surface** – Mainly artificial structures, such as pavements covered by impenetrable materials such as asphalt, concrete, brick, and stone, that do not allow water to soak through them

**Slope** – Steepness

**Substrate** – The material that underlies something

## Optional:

This module provides an opportunity to teach students about collecting different kinds of data. The slope is a continuous variable, while the substrate is a discrete variable. Continuous variables can take on any value in an interval, for example, numbers, years, or, in this particular case, degrees. Discrete variables have a distinct or separate value and are also sometimes called categorical variables. In this particular case, the different substrates (gravel, sand, sod, and clay) are discrete variables.

There is an important difference in collecting continuous vs. discrete data. When collecting continuous data, it is best to sample as many points along the interval as possible. In this activity, this means students should test as many slopes as possible (rather than focus on replicates of each slope) and the data should be shown as points on a line graph. When collecting discrete data, students should test as many replicates as possible for each category and display the data in a bar graph.

# NGSS Standards Addressed

**Disciplinary Core Ideas**

ESS2.C: The Roles of Water in Earth’s Surface Processes

**Science & Engineering Practices**

1. Asking questions (for science) and defining problems (for engineering), 2. Developing and using models, 3. Planning and carrying out investigations, 4. Analyzing and interpreting data

5. Using mathematics and computational thinking, 6. Constructing explanations (for science) and designing solutions (for engineering), and 7. Engaging in argument from evidence

**Cross Cutting Concepts**

2. Cause and effect: Mechanism and explanation

4. Systems and system models

# Guide to supplemental materials

**Lectures**

**“Go\_with\_the\_Flow\_Presentation.pptx”** – an introductory lecture to introduce concepts in the lab and the activity

**Worksheets**

**“Go\_with\_the\_Flow\_Worksheet.docx”** – A student worksheet to go along with the lecture and lab activity