# Watershed Modeling STEM Mini-Unit

# Teacher Guide

## Table of Contents

**Unit:** Watersheds

**Subject:** Environmental Science and Earth Science

**Grade Level:** MS/HS

# Mini-Unit Abstract

Teaching Environmental Sustainability - **Model My Watershed**® (TES-MMW) is a collaborative project funded by the National Science Foundation that designs engaging guided inquiry-based curriculum that includes scientific literacy, modeling, data analysis, place-based schoolyard investigations, and extension activities. The lessons in this Watershed Modeling STEM Mini-unit were adapted and updated from the [TES-MMW project curriculum](#) housed on the Innovative Technology in Science Inquiry ([ITSI](#)) portal developed by the Concord Consortium, and highlighted in NSTA's Science Teacher (Marcum-Dietrich, Kerlin, Staudt, Daniels, 2018). TES-MMW incorporates two innovative technologies to help students understand the impacts of human actions on the dynamics of watersheds, and empowers students to make authentic decisions to protect and conserve watersheds. The online [Runoff Simulation](#) is a model of a parcel of land that allows users to change land cover, soil types, and rainfall amounts to determine hypothetical changes in evapotranspiration, infiltration, and runoff rates. The [Model My Watershed® Application](#) is a watershed-modeling GIS web app that uses scientific data from national databases to enable citizens, conservation practitioners, municipal decision-makers, educators, and students to analyze land use and soil data, model stormwater runoff, and compare different conservation or development scenarios that could modify runoff and water quality.

This Watershed Modeling STEM Mini-Unit was designed for middle school students to learn systems thinking and geospatial analysis skills in the context of place-based problem-solving for watershed science. This mini-unit consists of two interactive lessons where students use online GIS based modeling tools to develop an understanding of stormwater dynamics within a watershed. Students will discover how humans impact the water quality of their local watershed by altering the characteristics of the land and changing how water moves through the environment. This place-based mini-unit is an excellent addition to any watershed curricula as it provides real world context to water quality issues and experience with land use planning and design practices. Lesson two includes an optional out of classroom activity where students walk around the school property to discover and map the current conditions at their school, which enhances their understanding of the concepts and empowers their voice in developing actionable plans for improving their school grounds. Each lesson includes suggestions for extension activities that teachers can employ to further the educational experiences for their students. Teachers may find it appropriate to include discussions or activities before beginning the mini-unit that introduces their students to foundational understandings of watershed concepts. Unit vocabulary can be found near the end of this teacher's guide.

Marcum-Dietrich, Nanette, et al. "Our Watershed." *Our Watershed*, Feb. 2018, pp. 39–46.

## Model Overviews:

## Runoff Simulation

The Model My Watershed® - Runoff Simulation is an interactive model used to investigate how changing the type of land cover, amount of rainfall, and soil texture affects where water goes when it rains. The Runoff Simulation animates results from applying the **TR-55** runoff model developed by the U.S. Department of Agriculture and the Small Storm Hydrology Model for Urban Areas developed by Robert Pitt for a single 24-hour rain storm over a hypothetical small unit of land with a single land cover class and a single hydrologic soil group. The Runoff Simulation (https://runoff.modelmywatershed.org/) will work in any web browser.



The Runoff Simulation includes a main graphic showing a parcel of land with **Evapotranspiration**, **Infiltration**, and **Runoff** results indicated, and a control panel on the right side for the variables in the model that can be manipulated. Users can change the amount of precipitation for a 24-hour storm event by adjusting the slider at the top of the variable control panel (blue oval) on the right side of the Runoff Simulation. The results are immediately calculated and shown in the simulation. Land Cover (green oval) options are found below the precipitation slider. Descriptions can be seen by hovering the cursor over one of the 12 Land Cover types, and the user can click any Land Cover to change this variable in the simulation. Hydrologic Soil Group (red oval on the bottom of the variable control panel) works the same way as descriptions can be seen and Soil Groups can be selected with the cursor, which results in a recalculation and change in the model.

# Model My Watershed® Site Storm Model

The online GIS-based Model My Watershed® (MMW) Site Storm Model (https://modelmywatershed.org/) is a component of the WikiWatershed® Toolkit (https://wikiwatershed.org/), a suite of web browser based tools designed to help citizens, conservation practitioners, municipal decision-makers, researchers, educators, and students advance their knowledge and stewardship of fresh water. The Site Storm Model simulates storm runoff and water quality by applying the TR-55 & STEP-L water quality models for a single 24-hour rain storm over a selected land area within the continental United States. The results are calculated based on actual land cover data (from the USGS National Land Cover Database 2011, NLCD2011) and actual soil data (from the USDA Gridded Soil Survey Geographic Database, gSSURGO) for the selected land area of interest.

The Site Storm Model can be accessed online from any web browser at modelmywatershed.org and works best on desktop and laptop computers. It is also optimized for the Firefox browser. MMW works on touch-screen devices such as iPads, other tablets, and laptops with dual keyboard and touch-screen functionality but users may experience some issues with overlapped formatting of tools due to screen size and touch-screen sensitivity.

When you first navigate to the Model My Watershed® application you may be asked to share your location data with the application. Sharing your location will automatically start the application at approximately your current location, but is not necessary for the application to work. You may also see a "login" pop-up window to be given a chance to sign in to the application. You do not need to "Login" to use the MMW application, although creating a login allows you to save your work to return to later, and to share your work with other users. Logging in as a guest gives you access to the full modeling and scenario capabilities of the application, but will you not be able to save and share any data.
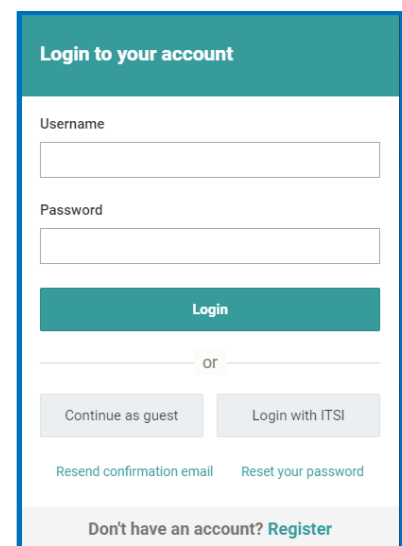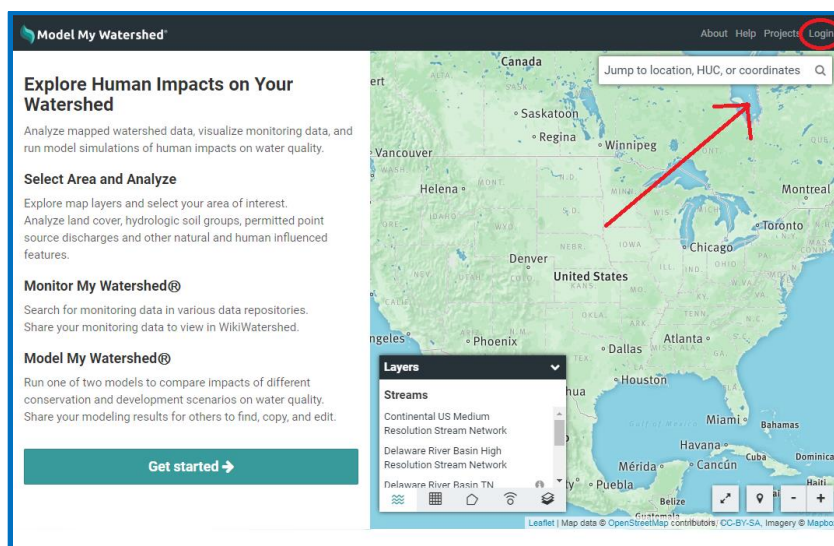


If you do not want to login, click on "Get started" to use the MMW app as a guest. If you have an account already, simply type in your username and password and click "Login." New users can create an account by clicking "Register" at the bottom of the Login pop-up window. Fill in all of the required

fields and submit the form, then check your inbox for an activation email. You must click a link in the activation email to finish the registration process. Check your spam/trash folders if you do not see the account activation email in your inbox. These emails are sometimes blocked by institutional (e.g. business, agency, or school) spam filters, so you may need to contact your systems administrator. For students and teachers who are using the Innovative Technology in Science Inquiry (ITSI) portal, click the "ITSI" button. The ITSI portal option will allow users to login with their ITSI credentials, or through a Schoology account, which prevents users from needing to set up a new account for the application.

Once you have logged into the application, you will see a map looking much like Google maps. If you shared your location, the application may zoom directly to your location; otherwise it will begin by showing a map of the entire lower 48 states of the U.S. As with most online map tools, you can navigate the map by clicking and dragging and zoom by pinching, using a scroll wheel, or using the zoom buttons on the lower right. You can also search for a location by name or address using the "Search" box on the upper right. To go or return to your current location, hit the "My Location" button with a picture of a pin next to the zoom buttons on the lower left.
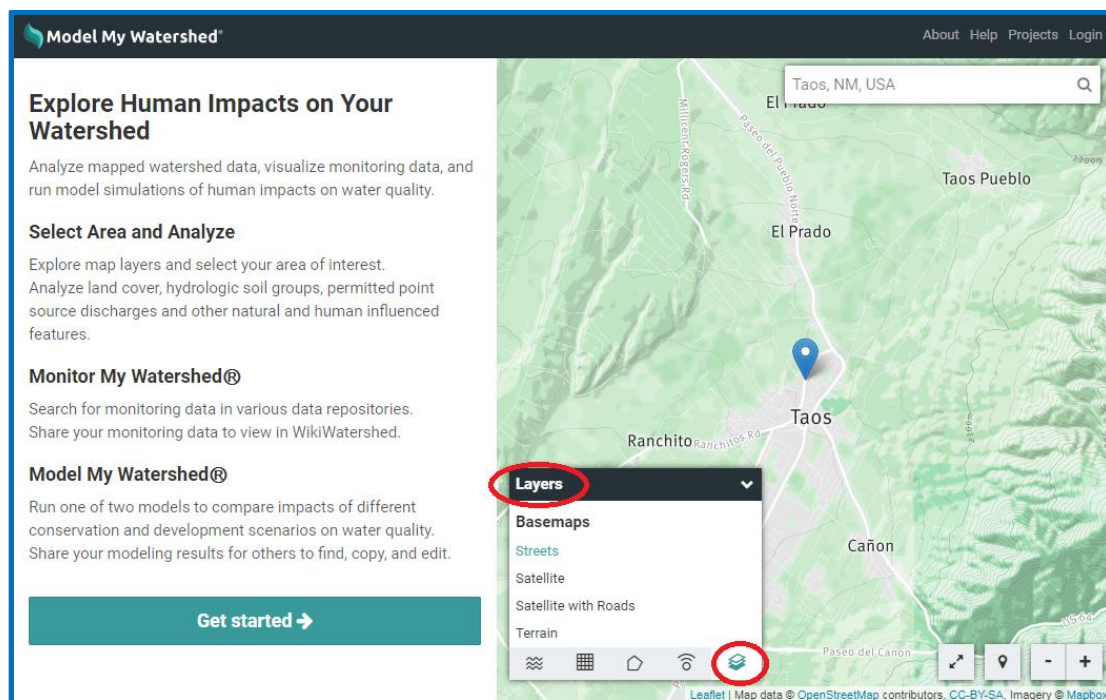


Just as Google maps allows you to switch between road and satellite maps, there are several options for both the base map and data overlays on top of the map. Use the "**Basemaps**" ( ) tab of the "**Layers**" control box to access these. You can select a basemap image and several different types of overlays. The base maps themselves come directly from ESRI or Google Maps and are not built into the application. If you have a very slow Internet connection, the base maps may be slow to load. The overlays include boundary lines (like school districts and USGS hydrologic units) and color shading for land uses and soil types.
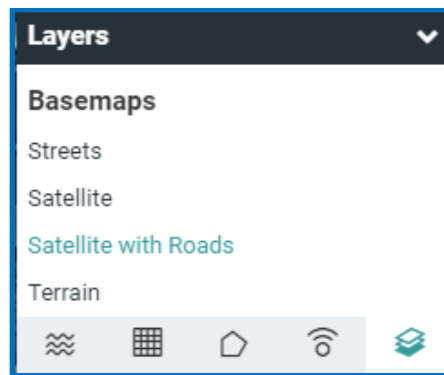
Other tabs in the "Layers" control box are for displaying **streams** ( ≈ ), **coverage grid** ( ▦ ), **boundary** ( ⬠ ), and **observations** ( 📶 ) overlays. Continental US medium resolution stream network, Delaware River Basin high resolution stream network along with other stream overlays are enabled via the "Streams" tab ( ≈ ). The Continental US and Delaware River Basin stream network overlays are zoom dependent. Smaller streams are shown as you zoom in. In the "Coverage Grid" tab ( ▦ ) of the "Layers" control box you can enable color shading of the USGS National Land Cover Database, the USDA Hydrologic Soils Groups, and other data. A slider tool allows you to adjust the transparency of the color shading.
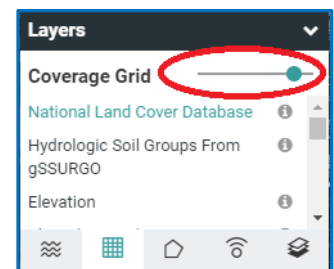


Boundary lines can be added in the "Boundary" tab ( ⬠ ) of the "Layers" control box. You can add boundaries (lines show up in pink) for USGS Subbasin units (HUC-8, HUC-10, HUC-12), county lines, congressional districts, school districts, and municipalities (PA only). Additional watershed data is available in the "Observations" tab ( 📶 ) of the "Layers" control box. These data include USGS and other national river and weather monitoring stations. Please note that observation data is not available in all locations!

Click on "**Get Started**" to begin modeling and viewing additional data. Next select the type of area you would like to study and model. The first option is to "**Select a boundary**" area, with the same boundary options as you saw in the "Layers" control. Additionally in this "Select a boundary" tool, once you select a boundary you can then see the name of the defined areas when you hover over the map. Be aware of your zoom level when selecting by boundaries. If you are at too high of a zoom level, you may not be able to see the boundaries on your map. Your second choice is to "**Draw area**" with the options of free drawing a polygon of any size and shape you choose or drawing a 1 square Km area to model. Your third option is to "**Delineate watershed**". To use this option you must choose your stream resolution (Continental US Medium Resolution or Delaware River Basin High Resolution) then place a blue balloon anywhere on the map to define a point (purple circle). The delineate watershed function finds the most direct point (blue circle) down slope where water would runoff into a body of water. From the blue circle the app then finds the watershed boundary of all land surfaces that would drain to that point. The last option is to "**Upload file**" in which you can upload a shapefile from another GIS program.

As soon as you have selected an area, or closed the box of your custom area, the application will change into geospatial analysis mode. The right side of the screen will now show the area you selected in bright colors with the rest of the map greyed out. The left side of the screen will show the "**Analyze**" pane. The "Analyze" pane contains a wealth of data including; stream network statistics, land cover distribution, hydrologic soil group distribution, county-based estimated number of farm animals, permitted point source discharges, as well as climate, terrain, and water quality data. These calculations and analyses are done on the fly for each area based on nationally available data. You will not get some pre-computed estimate or "canned" number. These are real values based on the most recently available national land cover, soil type, and other datasets. Because of this, the analysis may take a few seconds to complete and you may see a loading wheel as this happens (It is generally very fast with a good Internet connection).



In the analyze pane, you can view the land use, soil type, stream, climate, and other data (some in both tabular and graphical form). Use the tabs at the top of the pane to switch between data types. You can sort the tabular data by type, area, coverage percent, and other units. The bar graph coloring in the land cover distribution matches the colors assigned by the National Land Cover Database and the bar graphs can be used as legends for the land cover and soil group overlays.

The title at the top of the analyze pane will list the name of the area (if selected by boundary) and the total size of the area. You can still change the map zoom and overlays in the map pane. Try turning on the NLCD overlay to compare the layout of land covers on the map to the percent of each land cover in the area. To see a larger area of the map and minimize the analyze pane you can click on the expand/contract map arrows button near the zoom button in the bottom right of the map.

If you realize you made a mistake in selecting your area, hit the "Change area" button at the bottom left of the analyze pane. You will be taken back to the "Select Area" screen. To clear the map and start over completely at any time, click the "Model My Watershed®" title at the top left of the screen. If you are happy with the area you selected, you can move on to modeling and modifying the area by clicking the "Model" tab (green circle in picture below) in the analyze pane on the left side, then selecting from the options. The "Site Storm Model" choice models changes for a single storm event. Users of the NSF-TES MMW curriculum should select "Site Storm Model" for their activities. The other choice, "Watershed Multi-Year Model" shows users additional modeling results over longer spans of time.
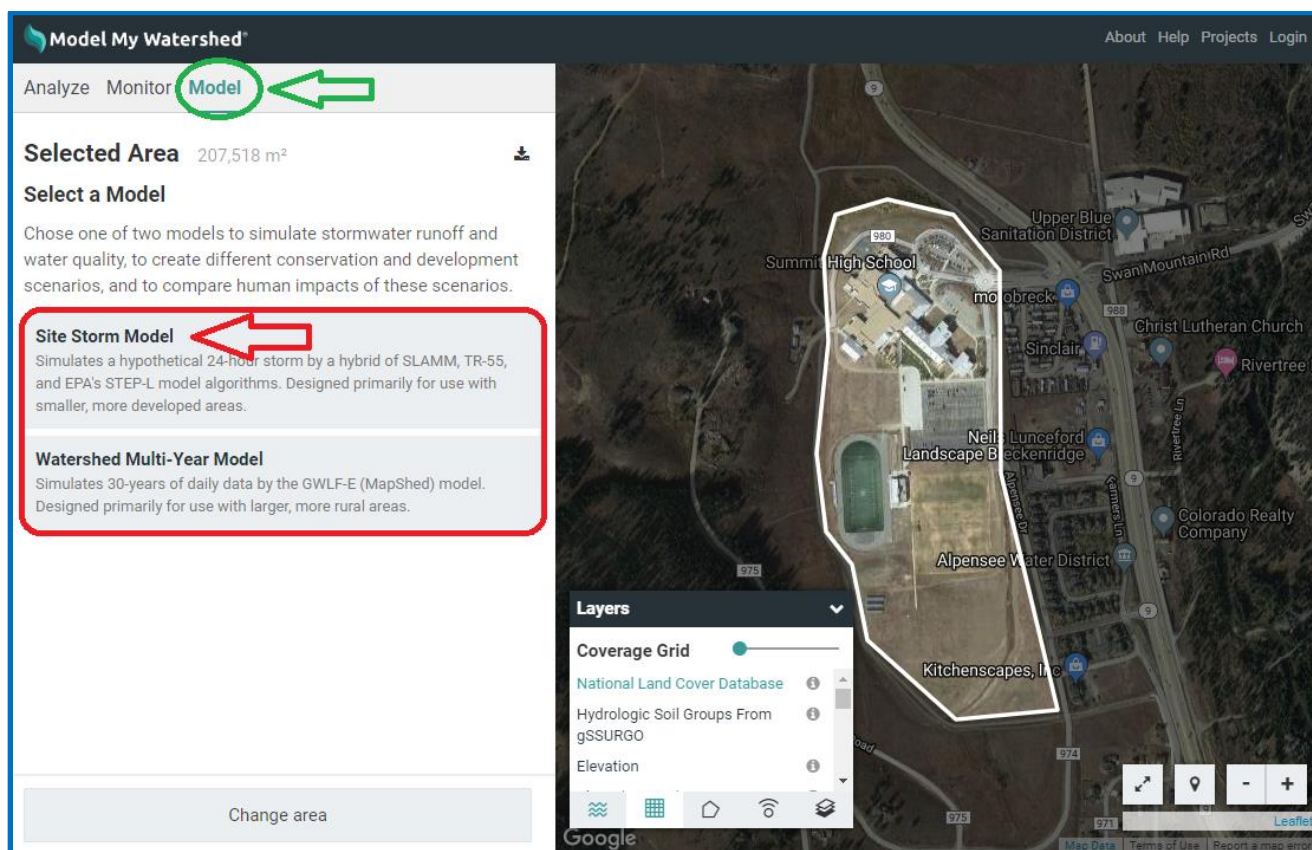


Once you have entered the modeling mode, the application will show runoff and water quality data for the current conditions. The runoff quantities are calculated using a combination of the TR-55 runoff model developed by the US Department of Agriculture and the Small Storm Hydrology Model for Urban Areas developed by Robert Pitt for a single 24-hour rain storm. The water quality parameters are calculated using the EPA's STEP-L water quality model. For more information on the specifics of these calculations, see other documentation at WikiWatershed.org. The runoff tab shows the partitioning of the rainwater into runoff, infiltration, and evapotranspiration as a stacked bar graph. In the water quality tab, you will see both tabular and graphical data showing predicted water quality for any streams in the selected area. Because the model is running with real data on your custom area, it may take some time for the model to run and you may see a loading icon. The 24-hour rain event model is set for 2.50 cm by default but can be changed using the slider near the top right of the map (circled in blue below).

New scenarios, in which you can modify the landscape by changing the land cover type or applying conservation practices can be modeled by first selecting "Add changes to this area" button in the top right corner (circled in red above). At first, this "New Scenario" map and data look exactly like the current conditions map but with two new tool boxes above the map, one for "Land Cover" and another for "Conservation Practices". Each of these is a free-hand drawing tool to modify the current land use. The model output pane also changes to show the original results from the "current conditions" tab and the modified results as you change the landscape. Select a land use or conservation practice from the toolboxes at the top of the screen and then click points on the map to draw an area over which to apply it. As soon as you add a new land use or conservation practice, the model will re-run in the background to calculate what has changed and all of the plots will be updated. You will see loading icons again in the model pane as this happens. Remember that you can expand/contract the map pane to give more screen space to work on landscape modifications. See other documentation for an explanation of how the runoff and water quality contributions of conservation practices are calculated.

As you add land cover changes or conservation practices, you can see the amount of area changed by clicking on any polygon you added. You can also see a list of all of the modifications you made in the scenario by clicking on the space in the upper right of the map pane where it says "x modifications." This gives a "shopping cart" of modifications grouped by the type of modification. You can delete any modification by clicking the trashcan next to it. If it helps to decide where to make changes, you can still use the "Layers" control box to select which overlays to display on the map.
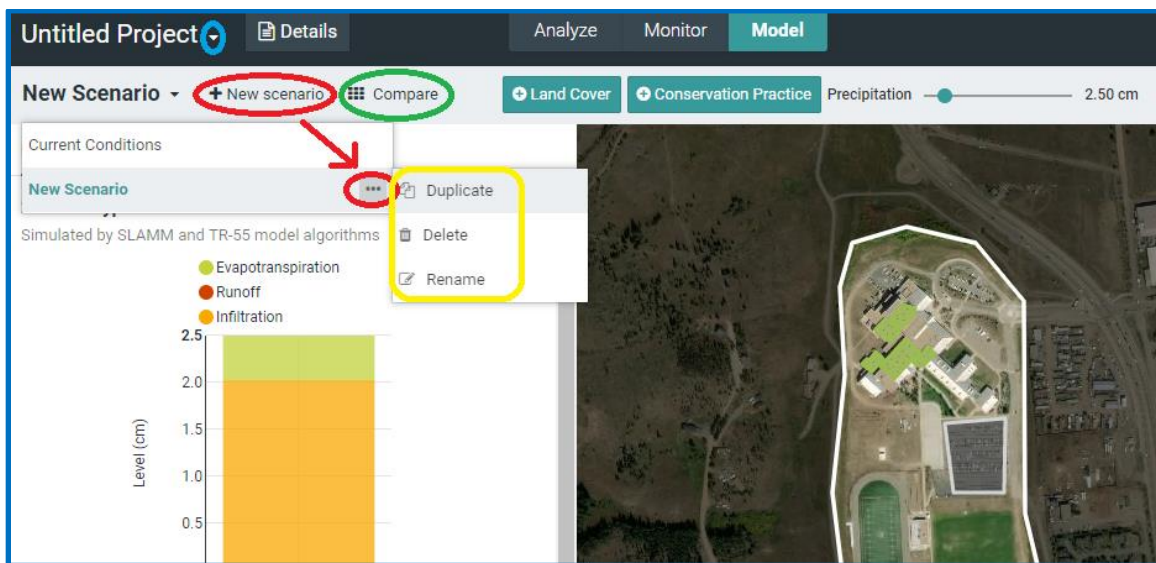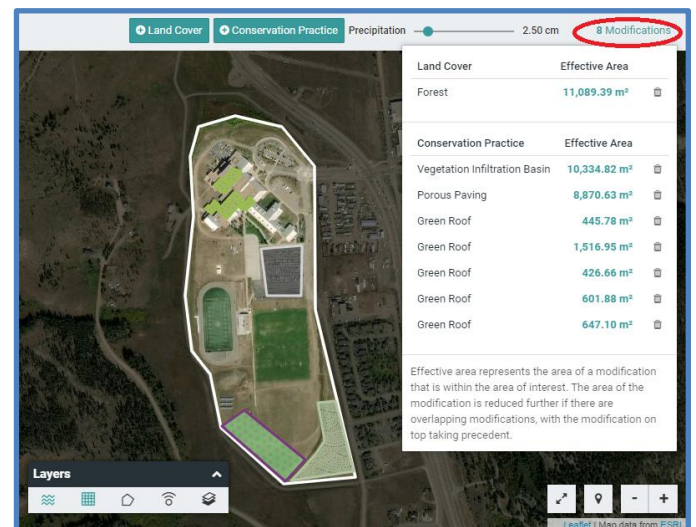




You can create many possible scenarios of landscape modification by clicking on the "+ New Scenario" next to the drop down list of current conditions and scenarios. This opens up a new scenario with no modifications on it (a copy of "Current Conditions"). Scenarios can be renamed by clicking the three dots "…" next to the scenarios in the scenarios drop down list. Select the "Duplicate" option to create a copy of the scenario that you are working on to add or delete more changes while saving your "New Scenario." You can also rename your entire project by clicking the small down arrow (circled in blue above) next to the "Untitled Project" text in the top left corner and, if you are logged in, share your project through the same menu. If you have made your project publicly accessible and given someone the link, they will be able to view all of your scenarios and results. They will not, however, be able to modify it. Any public project can be made private again from the same menu.

Once you have created several scenarios, you can compare all of them by clicking "Compare" (circled in green above) in the upper tool bar. This gives a side-by side comparison of all of the scenarios along with the original conditions before any modifications. It also shows what the partitioning would be if the landscape were 100% forested. This 100% forested condition will give the maximum amount of infiltration for the landscape, given its soils. In the tool bar at the top of the Compare view you can

select the type of output you would like to compare (runoff or water quality), change the amount of precipitation in the 24-hour storm event, and toggle between viewing the data as a graph (📊) or a data table (⊞). At the top of each scenario is a map showing the original area and modifications. When you hover the cursor over a scenario map, you will see a list of the modifications. To scroll through many scenarios, use the "Navigate Scenarios" arrows on the right side of the Scenario maps. Click the ✖ in the upper right hand corner to close the Compare window and return to the scenarios.
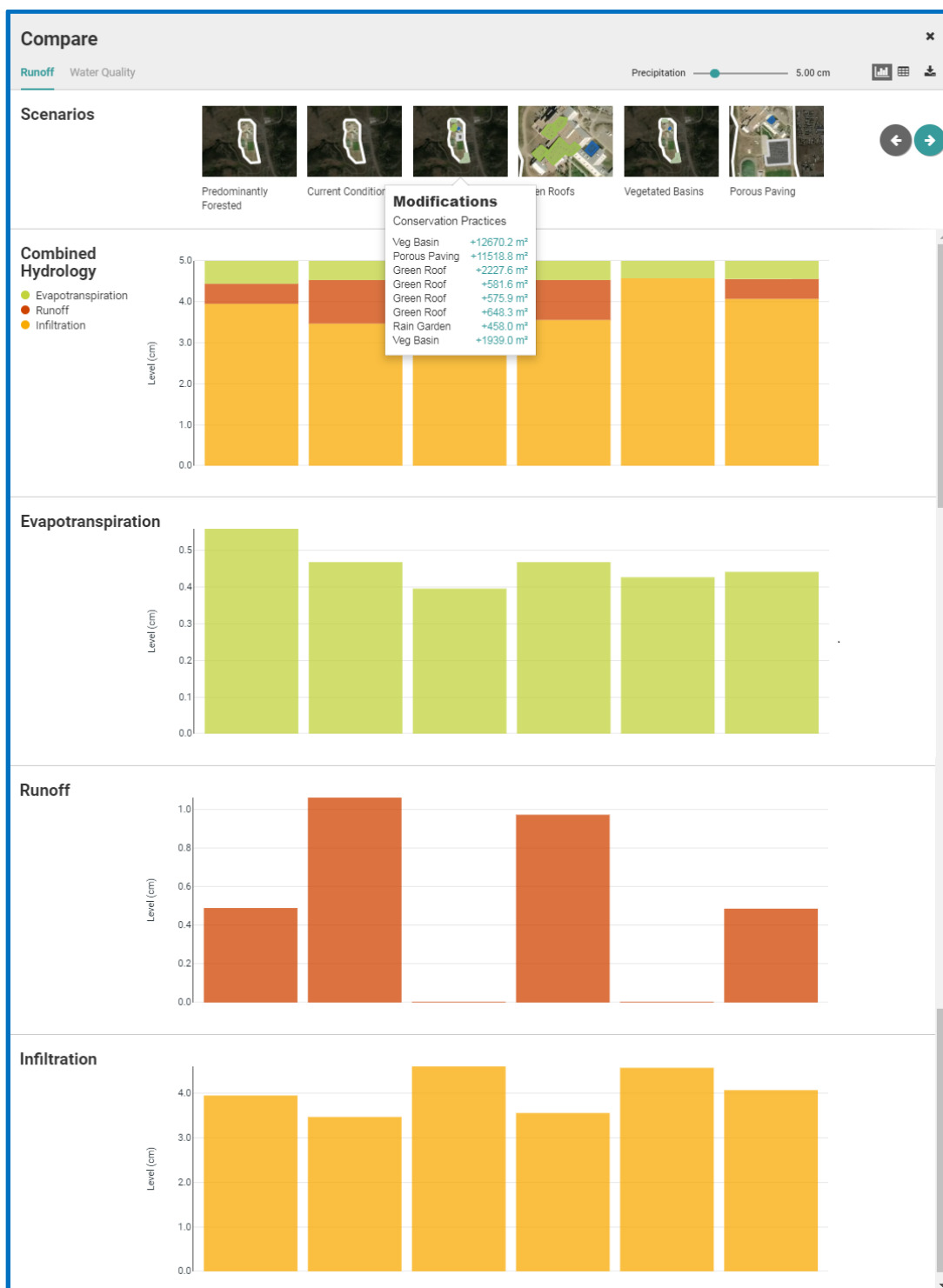
# Mini-Unit Overview and Teacher Preparation

- ☐ **Materials and Equipment (Student Worksheets & Computers)**
- ☐ **Mini-unit Timeline**
- ☐ **Optional Pre-lesson Review**
- ☐ **Map of School Property** (one per student or team) for Lesson Two

## Materials and Equipment

Teachers should have copies of the student worksheets sets for the two lessons that follow made up ahead of time (Lesson One, Lesson Two). Students should work in pairs to ensure an interactive experience and each pair will need a computer with internet browsing access. Students will need colored pencils (red, brown, & green) as well as a blue pen for Lesson Two part I.

## Mini-Unit Timeline

**Lesson One – Effects of Land Cover & Soils in Watersheds: one class period**

**Lesson Two – Modeling Improvements to My Schoolyard: one or two class periods.**
One class option: Part I - Identifying Current Conditions of My Schoolyard is completed in class as a warm-up to the rest of the lab.

Two classes option: Class 1 (Lesson two Part I) – students go outside to walk the school property, map current conditions, and witness how pervious and impervious surfaces affect the movement of water. Class 2 – Students complete the remainder of lesson two in the classroom.

## Background

It may be helpful for your students to review the terms associated with a watershed as preparation for these lessons. In Lesson One, students will revisit the terminology associated with the water cycle, watersheds, and land use. Students should have some background knowledge of point source and non-point source pollution, and a basic understanding of a watershed. A watershed is a system defined by the area of land over which all water drains downhill through a series of streams and rivers to a common outlet (river, lake, bay or ocean). All land is comprised of watersheds. Smaller watersheds are nested within larger ones. The largest watershed in the US is the Mississippi River watershed. It is comprised of other large watersheds, such as the Ohio River and the Missouri River watersheds. Each of the smaller watersheds is also comprised of smaller ones, until you get down to "first order" watersheds, where the water drains off of nearby slopes into the stream channel. There are many more miles of first-order watersheds than there are of larger (higher order) watersheds.
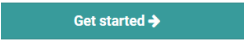


In part I of lesson two, Modeling Improvements to My Schoolyard, students identify land areas on their school's property that are **pervious** and **impervious**. The teacher will need to follow the instructions below to create a map of the school's property to print, copy, and hand out to each team at the beginning of lesson two. Alternately, part I of lesson two could be a "pre-lesson" activity
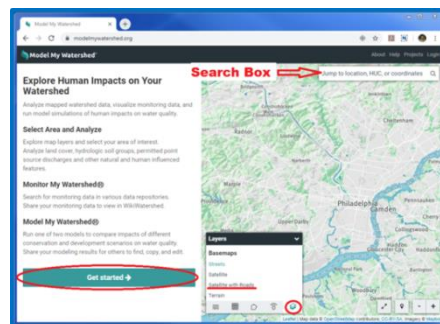
completed in the class period before lesson two begins.  Taking students outside to explore the different land covers on your school's property and pouring water on the surfaces to discover if they are **pervious** or **impervious** would be an impactful learning experience.

## Creating the Map of the School Property & Answer Keys

The teacher should follow these instructions to make a map of the school's property and the Answer Keys before beginning lesson two. Every school will have different answers when analyzing the school property. Answers will vary due to inconsistencies in delineating the property boundaries, although the answers should be similar.
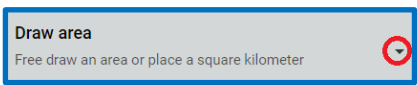
1. Launch the Model My Watershed® application (https://modelmywatershed.org/).
2. Login to Model My Watershed® (see the login instructions in the model overview for help).
3. In the left panel, click on Get Started.  **Get started →**
4. In the "search" box at the top right hand corner of the map enter the name and address for your school.
5. In the "Layers" control box (bottom left corner of map view), click the icon furthest to the right ( ≋   ▦   ⌂   ⌄   ◉ ) to change the "Basemap" to the map that works best for outlining your school's property (Streets, Satellite, or Satellite with roads). *Often the "Streets" view will indicate the boundaries of the property most clearly.*
6. Zoom in or out, and drag the map to see the entire property in the map view screen.
7. In the left panel, click on the black down area in the "Draw Area" box and select "Free draw" to create a polygon of the property for your school.

**Draw area**
Free draw an area or place a square kilometer ⊙

8. Begin by placing the cursor on one corner of your school's property and clicking once. Move the cursor clockwise around the map and click once at each of the corners around the edge of your school's property until you click on the first mark to close the polygon.
9. Your school's property will be delineated and the model will automatically analyze the area and give you base information on the area you selected. If you make a mistake, click on "Change area" at the bottom of the left panel and try again.



10. Toggle between the basemap options and take a screenshot of the map in the basemap that best shows the features of the property which can be colored with a colored pencil or highlighter (*the "satellite" basemap generally works well*). Use photo editing software or the copier tools to maximize the property map to fill a page of paper. Print one map for each student or team of students.
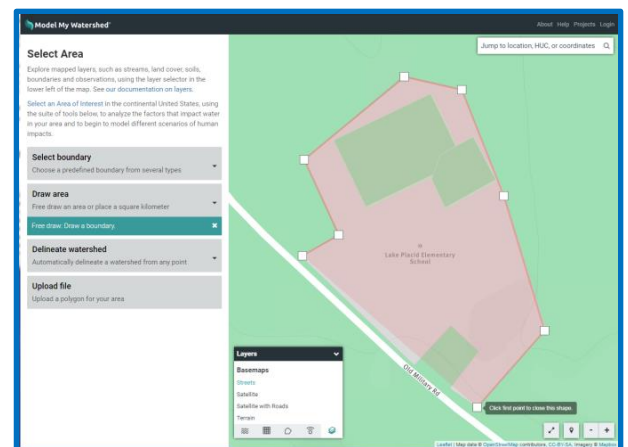
| Satellite with Roads | Satellite | Streets |

11. **Create the answer key for lesson two part II – GIS Mapping and Analysis of My Schoolyard:** In the "Analyze" panel on left of the map, click on the "land" tab and screenshot (snip) the Land Cover data for your answer key. Then click on the "soil" tab and screenshot the Soil data for the other answer key. Save these for Lesson Two.
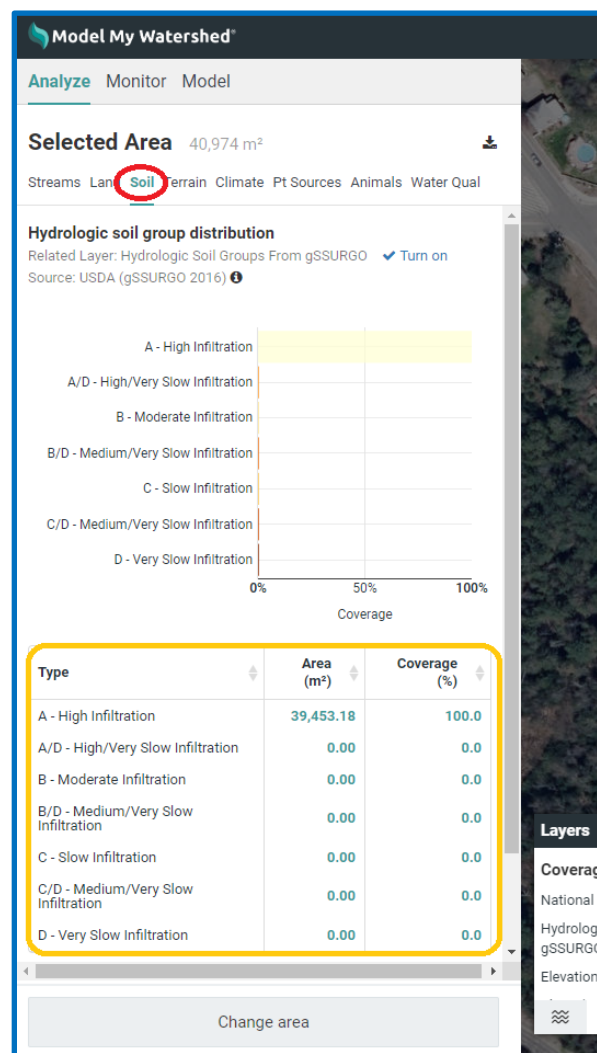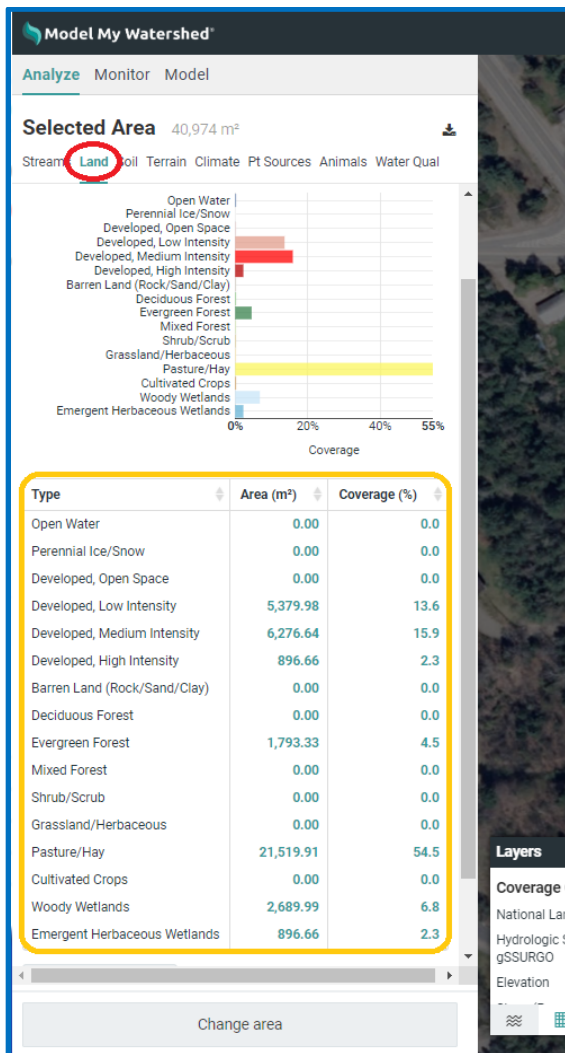
12. **Create the answer key for your school for lesson two Part III – Land Cover Model Comparison:**

- In the left panel "Analyze" pane select the "Model" tab and choose "Site Storm Model" to run a simulation of a 24 hour storm event on your school's property.

- Click on the down arrow next to "Untitled Project" in the upper right hand corner to rename and save the Schoolyard Map Project.
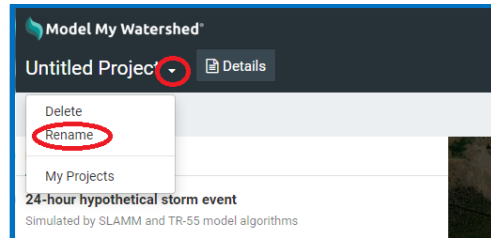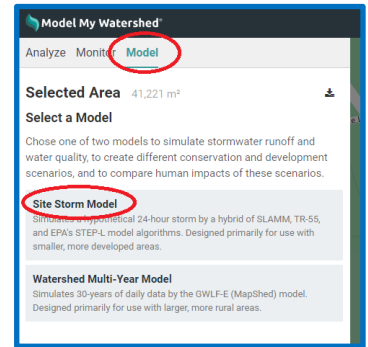
- Move the precipitation slider above the map to **8.0 cm** (circled in blue).
- Click on "Add changes to this area" near the top right of the map (circled in red).
- Click on "Compare" in the top of the panel on the left.
- Click on the data table icon in the top menu to the right of the precipitation slider to view an easy to read table of the data.
- **Screenshot (or snip) a copy of the data in the table comparing your school's current conditions to the "Predominantly Forested" scenario for use in Lesson two Part II.**
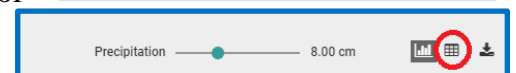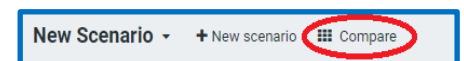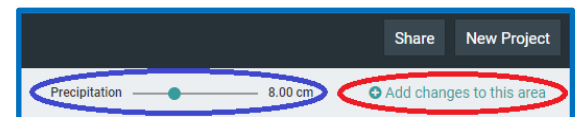
Example:



| Scenarios | Predominantly Forested | Current Conditions | New Scenario |
|---|---|---|---|
| Runoff | 0 cm | 1.012 cm | 1.012 cm |
| Evapotranspiration | 0.537 cm | 0.405 cm | 0.405 cm |
| Infiltration | 7.463 cm | 6.583 cm | 6.583 cm |

# Lesson One

# Effects of Land Cover & Soils in Watersheds

## Background

Lesson one leads students on an exploration of the dynamics of watersheds and the impacts of human activity on local watersheds. Water moves through a watershed via the components of the water cycle. Runoff, water that moves over the surface of an area, combines with pollutants on the ground and can cause erosion. Many human activities intensify the impact of runoff by altering the properties of the land cover, and by contributing to pollutants on the ground. The installation of impervious surfaces decreases infiltration, increases stormwater runoff, and allows for more pollutants to be washed into the waterways. Our understanding of the dynamics of watersheds has led to significant improvements in the ways that humans affect the health of our watersheds by integrating Conservation Practices (also known as Best Management Practices or BMPs) into our land planning policies and management procedures. BMP is a way to describe acceptable practices that could be implemented to protect water quality and promote soil conservation. A BMP can be a structural "thing" that you actually install "on-the-ground." Examples may include runoff diversions, stormwater retention basins, rain gardens, silt fences, stream buffers, green roofs, installing porous (pervious) parking and sidewalk surfaces, and adding groundcover vegetation over bare soil areas. A BMP could also be a land or facilities management decision to reduce pollutants or conserve water. These include composting, xeriscaping, elimination or reduction in hazardous chemicals (pesticides, fertilizers), no-idling policies, installing energy efficient equipment and lighting, and installing water bottle refilling stations.

Students will work in pairs to review the hydro-dynamics of a watershed and then use the online Model My Watershed® - Runoff Simulation to discover how land cover and soil type (Hydrologic Soil Group) affect the movement of water during a 24-hour storm event. Students will assess their own schoolyard to determine how the current conditions on their school's property are impacting the water quality in their local watershed.

**Duration:**   This lesson is designed to be completed in one 50 minute class period

## Materials:

- Lesson one student worksheets
- Computers with internet browsing access

# Standards

**Performance Expectations:**

    MS-ESS3-2: Analyze and interpret data on natural hazards to forecast catastrophic events and inform the development of technologies to mitigate their effects

    MS-ETS1-4: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved

    HS-ESS2-2 Analyze geoscience data to make a claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems

    HS-ESS3-6 Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity

| Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts |
|---|---|---|
| Developing and Using Models Analyzing and Interpreting Data Engaging in Argument from Evidence Constructing Explanations | ESS2.A Earth's materials and systems ESS2.C The roles of water in Earth's surface processes ESS3.B Natural hazards ESS3.C Human impacts on Earth's systems. | Cause and effect Patterns System and models. |

# Introduction

**Essential Question: What can you do to improve water quality in your watershed?**

Do you know of water in your area where fishing or swimming is not allowed or where the water is not safe to drink? Water is a vital natural resource and protecting our water is a national priority. In 1972, the United States Congress passed the Clean Water Act to protect the nation's water. The goal of this important law is to make sure that our lakes, rivers, and streams are "fishable, swimmable, and drinkable." The United States Environmental Protection Agency or EPA is the federal agency responsible for enforcing this law.

However, many waterways in our country are still polluted. Almost fifty years after the Clean Water Act was passed, there are still many places that we cannot safely use for fishing, swimming, and drinking. But thanks to help from everyone, our water is improving due to improvements in land and water **conservation practices**. A **watershed** is a system defined by the area of land over which all water drains downhill through a series of streams and rivers to a common outlet (river, lake, bay or ocean). Take a moment to review the parts of a watershed in the diagram on the next page to begin this activity.



Attributed to Dr. James Almendinger
St. Croix Watershed Research Station
2016
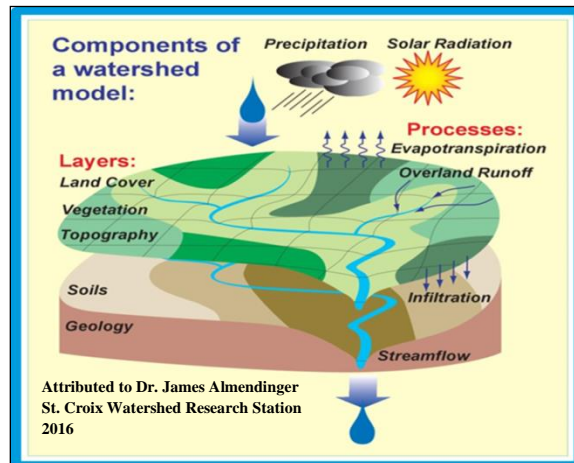
All conservation starts with the land. Gravity, topography, **soil type**, and **land cover** play important roles in **watersheds**. Gravity causes water to travel from the highest to the lowest elevation in a land area. Topography refers to the elevation changes (slopes) and physical features (hills and valleys) of an area that affect the direction and speed of water flow. Soil type impacts **runoff** and **infiltration**. Different types of land cover in a watershed determines to what degree water infiltrates, accumulates (remains as puddles), or flows over the land (runoff).

- **Precipitation** (rain, sleet, snow or hail) that falls on land can either **evaporate** directly from the surface back into the air, soak into the ground (**infiltration**), or **runoff**.
- Water that infiltrates into soil with vegetation can be absorbed by the roots of plants and be released through leaves (called **transpiration**).
- **Evapotranspiration** is the term used to describe all of the water that returns to the atmosphere directly by evaporation, or by transpiration.
- Precipitation that does not return to the atmosphere via evapotranspiration may infiltrate downward through soil and rock layers as **groundwater**. Groundwater is used to supply water to many houses and cities, and it keeps streams and rivers flowing (called recharge) during long time periods without any precipitation (**droughts**).
- Precipitation that moves downhill over the surface is called **runoff**. Runoff can cause **erosion** when moving over land without significant vegetation and carry **sediment** and **pollution** into waterways.



Modified from original
M. W. Toews Oct. 2007
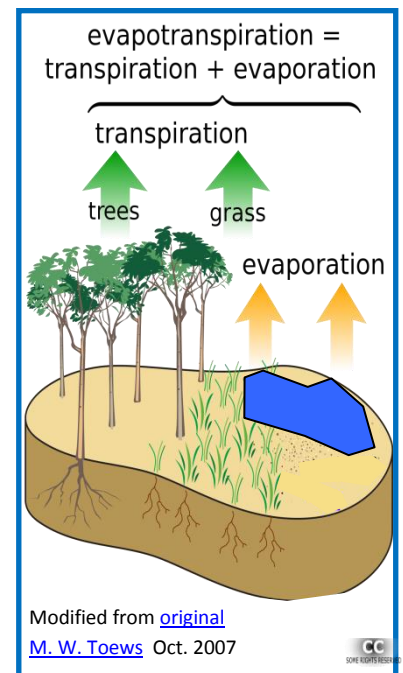
# Learning Objectives

- Students will identify how land cover, rainfall totals, and soil texture affect evapotranspiration, runoff, and infiltration using an interactive computational model.
- Students will interpret the impact of land cover and soil texture on the movement of water through a watershed system.

# Introducing the Simulation Model

The **Model My Watershed® - Runoff Simulation** is an interactive model used to investigate how changing the type of **land cover**, amount of rainfall, and **soil type** (Hydrologic Soil Group) affects where water goes after it rains. On a computer, navigate to runoff.modelmywatershed.org (or click on the link below) to open the Runoff Simulation and discover some of the important features.



### Click here to start the Runoff Simulation.

In the **Runoff Simulation**, the column in the middle has the labels ET (green in the bar graph), R (red in the bar graph), and I (yellow in the bar graph). What do these labels stand for?

R = _____**Runoff**_____          I = _____**Infiltration**_____

ET = _____**Evapotranspiration**_____
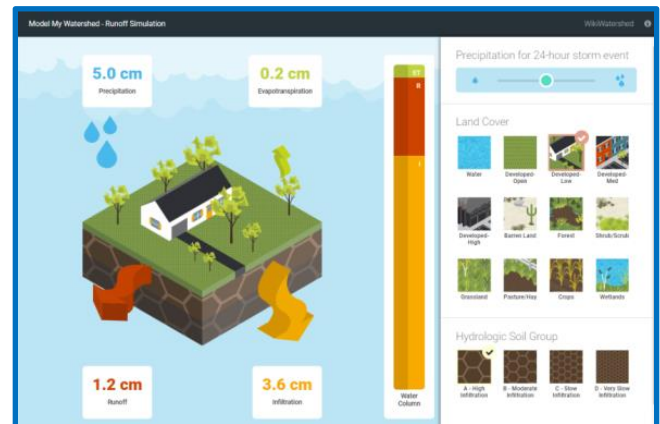
# Part I

## Investigating Land Cover

The term "**land cover**" is used to explain what is happening on a particular piece of land. Land cover describes the physical features (types of vegetation, buildings, etc.) as well as how the land is being used (farming, residential, commercial, and undeveloped). Each land use type affects the movement of water in a **watershed** differently. In areas where there is a lot of pavement, for example, most rainwater runs off into storm drains that take the water directly to storm sewers and then to streams or rivers.



Land cover surfaces that prevent **infiltration** are called **impervious.** Land cover types that allow water to infiltrate into the ground are called **pervious**. If the land has lots of trees or unmown grass, the water can soak into the ground. Lawns are not good at soaking up water because the roots of grass are very dense and mowing makes the ground too hard to allow much water through. The same is true of row crop fields. Plowing the field into rows does the same thing that the mower does – making the soil hard.

Use the **Runoff Simulation** to investigate how each land cover type affects where water goes when it rains.

- Notice that the model displays three sections along the right-hand side, representing three different variables (**precipitation** at the top, **land cover** type in the middle, and **soil group** at the bottom). Set the "Precipitation for a 24-hour storm event" to **8.0 cm** of rain and set the "Hydrologic Soil Group" to **B-Moderate Infiltration** (silt loam or loam).
- Hover the cursor over each of the land cover choices to read the brief descriptions and answer the following questions.

    1. Which land cover type has the most impervious surfaces?  **Developed, High Intensity**

    2. Which land cover type has the most vegetation (and give the amount in %)?

        **Grassland**                                           **> 80** %

    3. Which land cover type has the least vegetation (and give the amount in %)?

        **Barren land**                                          **< 15** %

- Click on the "Developed – High Intensity" icon to change the land cover and see what happens to the amount of **evapotranspiration**, **runoff**, and **infiltration**. Record this data in the table below.
- Continue clicking on each of the other land cover types and watch how the type of land cover affects evapotranspiration, runoff, and infiltration.
- Select two other land cover types around your school and record the evapotranspiration, runoff, and infiltration results for each in the data table below (**8.0 cm of precipitation / Soil Group B**).

| Land Cover | Evapotranspiration (cm) | Runoff (cm) | Infiltration (cm) |
|---|---|---|---|
| Developed - High Intensity | **0.0 cm** | **6.4 cm** | **1.6 cm** |
| | **Answers will vary** | | |
| | | | |

Which type(s) of land cover produces the most amount of runoff? Why?

**Water Land Cover produces the most amount of runoff as the ground under the body of water is already saturated (pores are filled with water) so the ground cannot absorb any more water which prevents infiltration. There is also limited vegetation for transpiration. Developed land (including High & Medium Intensity) and Barren Land also create a lot of runoff.**

What type(s) of land cover would increase the amount of water infiltration from a storm event?

**Answers may vary.  Wetlands, Forests, Shrub/Scrub, and Grasslands allow for the most infiltration due to the porous nature of the soils, which are enhanced by the roots of the vegetation in these Land Cover types.  All of the Land Cover Types (except for Open Water) would increase infiltration when compared to Developed – High Intensity.**

# Part II

## Investigating Hydrologic Soil Groups

The "dirt" in your yard is what scientists call soil. Soil is made up of broken down rocks, decomposed roots, leaves, and other organic material. Soil also contains water, air, and living things like bacteria, fungi, and protozoans. Soils have pores too, spaces between the pieces of rock and organic material that are filled with air, which allows water to soak in (**infiltrate)** and move downwards. When scientists and engineers look at different soils, they consider the size of the particles in the soil and its effect on pore size and their ability to allow water to infiltrate the soil. Smaller soil particles create smaller pores that make it harder for the water to pass through. The **Runoff Simulation** has four types of **hydrologic soils**: A-High Infiltration, B-Moderate Infiltration, C-Slow Infiltration, and D-Very Slow Infiltration.

- Set the Runoff Simulation to a **land cover** that best describes your schoolyard and record the land cover you selected at the top of the Data Table. Check to make sure the precipitation bar is set to a 24-hour storm event of 8 cm. of precipitation and the soil group is set to A-High Infiltration (sand). Record the amount of **evapotranspiration**, **runoff**, and **infiltration** that occurs.
- Select each of the other soil group types and record the evapotranspiration, runoff, and infiltration results for each in the data table below (**8.0 cm of precipitation**).

Land Cover at Your School:___<span style="color:red">**Answers depend on the conditions at your school**</span>___

| Hydrologic Soil Group | Evapotranspiration (cm) | Runoff (cm) | Infiltration (cm) |
|---|---|---|---|
| A-High Infiltration | <span style="color:red">**Answers vary due to Land Cover Type selected**</span> | | |
| B-Moderate Infiltration | | | |
| C-Slow Infiltration | | | |
| D-Very Slow Infiltration | | | |

**Progress Checkpoint:**  Compare the data in the table. Which **soil group** produces the least amount of **runoff**? Why do you think this happens?

<span style="color:red">**The A – High Infiltration Soil Group produces the least amount of runoff.  This happens because the soil is made of larger particles with larger pores to allow water to pass through more easily.**</span>

## Analysis & Conclusion

Set the Runoff Simulation for the current conditions at your school by selecting the best match for Land Cover and Soil Group and record your choices at the top of the data table. Run the simulation with an 8.0 cm 24-hour storm event and record the results for e**vapotranspiration**, r**unoff**, and i**nfiltration.**

Land Cover:___<span style="color:red">**Answers will vary**</span>___     Soil Group:___<span style="color:red">**Answers will vary**</span>___

| Evapotranspiration (cm) | Runoff (cm) | Infiltration (cm) |
|---|---|---|
| <span style="color:red">**Answers will vary due to selected Land Cover and Soil Group**</span> | | |

Given the current conditions of your school's land cover and soil type, how would you assess the impact from your school's property on the local watershed from runoff?

**Students should use their understanding of the factors that influence runoff and infiltration to "grade" their school's property during precipitation events. Students may include first hand experiences with conditions during large storms in developing their assessment.**

*The Land Cover for most schools will fall into the "Developed" categories (Low, Medium, or High Intensity). If more than half of the precipitation that falls on the property becomes runoff, then these properties would have a negative impact on the local watershed. A possible "grading" scheme could look like this:*

| Land Cover Type | Assessment |
|---|---|
| *Developed – High Intensity* | *Significant Water Quality Impact* |
| *Developed – Medium Intensity* | *Moderate Water Quality Impact* |
| *Developed – Low Intensity* | *Low Water Quality Impact* |

*Likewise, the selected Soil Group will also have a large impact on infiltration and runoff as soils with slow and very slow infiltration rates will increase runoff and exacerbate the impact on local watersheds. More runoff will likely result in more pollutants and sediments being carried into the local water ways and storm management systems, which will negatively affect the local watershed. Students may also consider the impact of local point source and non-point source pollution in their assessment. For example, parking lots typically have impervious surfaces and often cars that are not properly maintained will drip fluids.*

Which condition (land cover or soil group) would be easiest to change at your school to protect the local watershed, and why?

**Students should identify Land Cover as the easiest condition to change on their school grounds as changing the Soil Group would require excavating the area (including under buildings) and replacing the soils and substrate. Many Land Cover changes are relatively simple and include conservation and best management practices (BMPs).**

## Application

Think about everything that you learned about **runoff, infiltration, evapotranspiration, land cover, soil type,** and **land use**. What could your school do to reduce its impact on the local **watershed**? Explain how and why your suggestions will work.

**Students should recognize that implementing land cover changes on their school property would be the best way for the school to reduce its impact on the local watershed. Any BMPs can be included in their plan such as; changing mown grass areas to Pasture/Hay, Grasslands, or Forests, installing rain gardens, green roofs,**

**or porous paving/sidewalks, installing vegetation infiltration basins, or even retrofitting existing stormwater drainage basins with vegetation. Ideally all suggestions would work to reduce runoff (that can carry pollutants and overwhelm local streams) and increase infiltration to protect the local watershed.**

## STEM Career Extension

What is a Fluvial Geomorphologist? Click on this **LINK** (or navigate to https://youtu.be/0teypmM5yeY) to watch a video about how STEM education and skills led into an exciting career at Stroud Water Research Center.

**Teachers can play this video for the class by visiting https://youtu.be/0teypmM5yeY**



What parts of the **watershed** does a fluvial geomorphologist study? How does Dr. Daniel's research relate to the topic of **runoff** that you've been studying in this unit?

**Fluvial Geomorphologists study the land in a watershed and how it changes due to the flow of water and the interactions with the living and non-living things in the watershed. Generally Fluvial Geomorphologists study the abiotic (non-living) factors in a watershed, although the example that Dr. Daniel gives in the video is about the effect of caddisfly webs in stabilizing rocks in the bottom of the streams. Dr. Daniel's research can help explain the changes or damage that can happen in a watershed if there is too much runoff, as well as how to stabilize the structure of rivers.**

# Lesson Two

# Modeling Improvements to My Schoolyard

## Background

Lesson two allows students to discover how changes in Conservation Practices and Land Cover on their school grounds will impact the local watershed. Students are introduced to six common conservation practices, also known as best management practices (BMPs), which reduce runoff, promote infiltration, and minimize pollution in streams. They will learn to use the [Model My Watershed® (MMW) Site Storm Model](#), to create a variety of scenarios with Conservation Practices (and/or Land Cover changes) added to their school grounds to minimize the impact on the water quality in their local watershed.  The Site Storm Model is a powerful online GIS tool that includes real data from national data bases for land cover, soil type, stream maps and data, water quality, and more.  The Site Storm Model is a professional grade application that can be used by teachers, students, land use planners, conservation planners, scientists, citizen science groups, and the public to understand how human activities and the installation of BMPs can protect and conserve the quality of water in their watersheds. In this culminating activity students will create scenarios to reduce runoff and improve infiltration by modifying the actual conditions at their location and developing a best land management proposal to protect the water quality in their local watershed. Students should refer to the maps of the school property that they create in **Part I – Identifying Current Conditions of My Schoolyard** to decide which conservation practices could be applied and where they could be located. Students should be encouraged to choose conservation practices and land cover changes that are plausible and make sense for their school grounds. They should consider all of the current activities that take place on and around their schoolyard and think about how conservation practices could be applied while still using the land for the same activities.

**Conservation practices** (also known as best management practices or BMPs) are actions and decisions made during the design, preservation, construction, and management of built areas to reduce negative impacts on the environment. As people develop the land by building houses or other structures they cause an impact on the watershed.  Certain construction choices (green building design) and land management practices can preserve the health of a watershed by intercepting **precipitation** to minimize runoff and the transportation of pollutants into streams and rivers. Conservation practices that can be built into green buildings and grounds might include: rainwater capture for use in irrigation or flushing toilets, waterless toilets, low flow faucets and showers, composting of leftover food scraps, green (vegetated) roofs, rain gardens, rainwater retention basins or bio-swales, **porous** sidewalks or parking lots (materials with connected pores that are **pervious** and allow water to **infiltrate** into the ground), constructed wastewater wetlands, planting of trees along streams, restrictions on use of fertilizers or harmful cleaning chemicals, no-till agriculture, cluster housing, etc.

### Rain Gardens

A rain garden is s conservation practice that reduces runoff where a shallow depression in the landscape collects rain water from a roof, driveway, or street and allows the water to slowly infiltrate into the ground. Rain gardens are often planted with native grasses and flowering perennials to enhance infiltration and evapotranspiration, help filter out pollutants, and provide food and shelter for butterflies, song birds and other wildlife. More complex rain gardens with drainage systems and amended soils are often referred to as bioretention basins.





### Vegetation Infiltration Basins

Vegetation infiltration basins are large landscaped depressions designed to impound stormwater runoff to prevent flooding and allow waters to infiltrate slowly into the ground. The vegetation in these basins promotes infiltration and evapotranspiration, prevent erosion, and protect the quality of water in a watershed by mitigating stormwater runoff.

### Porous Paving

Porous paving is a conservation practice where the surface of parking areas and walkways are constructed with materials that have connected pores or spaces between the surface blocks that allow water to infiltrate into the ground. A layer of gravel is often installed below the surface to hold the water as it slowly infiltrates into the ground underneath.





### Green Roofs

Green roofs are flat or gradually sloped roofs that are covered in layers of materials that include a waterproof liner, a variety of drainage materials, growing media, and topped with a layer of plants that are adapted to surviving in high temperatures and drought conditions. Green roofs can be designed to retain stormwater, slow down runoff, and can improve the quality of the water as certain plant species absorb pollutants.

**No-Till Agriculture**

No-till agriculture is a best management practice whereby farmers plant crops without disturbing the soil or removing the plants that are already there. No-till agriculture improves the infiltration rate of the soil, reduces erosion, and builds the organic matter and nutrient cycling in the soil.

**Cluster Housing**

Cluster housing is a method of residential development where homes are built in groups close together which allow for larger open spaces between the buildings. The larger open spaces are often planted with trees and vegetation that enhances infiltration, reduces runoff and erosion, and provides recreational space for the inhabitants.

For more information on conservation practices (BMPs) at Stroud Water Research Center, visit our website: https://stroudcenter.org/about/facilities/mec/. Stormwater PA also publishes the PA BMP Manual online (http://www.stormwaterpa.org/from-the-foreword.html).

## Duration

This lesson is designed to be completed in one 50 minute class period (if **Part I – Identifying Current Conditions of My Schoolyard** is completed in the classroom), or over two 50 minute class periods if teachers are able to complete part I of lesson two by taking students outside to explore the different land covers on your school's property. Teachers can make this field trip of the school property an impactful learning experience by pouring water on the different areas around the schoolyard to help students discover the difference between **pervious** and **impervious surfaces** while students add these to their school property maps.

## Materials

- The School Property Map (created by the teacher in the lesson preparations)
- Colored pencils (red, brown, and green) and a blue pen
- Lesson Two Student Worksheets
- Computers with internet browsing access

# Standards

**Performance Expectations:**

- MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- MS-ESS3-2 Analyze and interpret data on natural hazards to forecast catastrophic events and inform the development of technologies to mitigate their effects.
- MS-ESS3-4 Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.
- HS-ESS2-2 Analyze geoscience data to make a claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.
- HS-ESS3-6 Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.

| Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts |
|---|---|---|
| Developing and Using Models<br>Analyzing and Interpreting Data<br>Engaging in Argument from Evidence<br>Constructing Explanations and Designing Solutions | ETS1.B: Developing Possible Solutions<br>ETS1.C: Optimizing the Design Solution<br>ESS2.A Earth's Materials & Systems<br>ESS2.C The Roles of Water in Earth's Surface Processes<br>ESS3.B Natural hazards<br>ESS3.C Human impacts on Earth's Systems<br>ESS3.A: Natural Resources. | Cause and Effect<br>Patterns<br>Stability and Change<br>System and System Models<br>Interdependence of Science, Engineering, & Technology<br>Influence of Science, Engineering, & Technology on Society and the Natural World |

# Introduction

**Essential Question: How can I improve my watershed… starting with my schoolyard?**

In this activity you will analyze your school's property using online modeling software and develop plans to reduce the amount of **runoff** from your school's property. Runoff can be detrimental to the health of a **watershed** as it can wash pollutants off the surface of the ground and carry them into local waterways. Runoff can also create **erosion** and increase the amount of sediment suspended in the waterways which makes the water "murky" and can clog the gills of organisms that breathe dissolved oxygen from the water. **Conservation practices** (also known as best management practices or BMPs) are actions and decisions made during the design, preservation, construction, and management of built areas to reduce negative impacts on the environment. As people develop the land by building houses or other structures they cause an impact on the watershed. Certain construction choices (green building design) and land management practices can preserve the health of a watershed by intercepting **precipitation** to minimize runoff and the transportation of pollutants into streams and rivers.

---

Conservation practices that can be built into green buildings and grounds might include: rainwater capture for use in irrigation or flushing toilets, waterless toilets, low flow faucets and showers, composting of leftover food scraps, green (vegetated) roofs, rain gardens, rainwater retention basins or bio-swales, **porous** sidewalks or parking lots (that are **pervious** and allow water to **infiltrate** into the ground), constructed wastewater wetlands, planting of trees along streams, restrictions on use of fertilizers or harmful cleaning chemicals, no-till agriculture, cluster housing, etc. For more information on conservation practices (BMPs) at Stroud Water Research Center, visit our website: https://stroudcenter.org/about/facilities/mec/.

## Learning Objectives

- Students will identify buildings and land areas as **pervious** and **impervious**, and discover various green building and **conservation practices** that improve **watersheds** by increasing **infiltration** and decreasing **runoff**.
- Students will model possible changes in conservation practices and **land cover** on their school's property and describe the impact of these changes on their local watershed.
- Students will design a watershed plan for their schoolyard that maximizes the health of the watershed by implementing conservation practices and land cover changes.
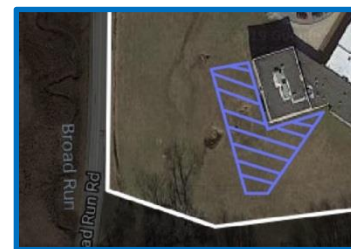
## Part I

### Identifying Current Conditions of My Schoolyard

Your first job will be to assess the impact of your school's property on the local watershed and then create proposals for how to reduce this impact. First we need to consider the state of your school's property as it is today. Using the map that your teacher provides, work in pairs to identify the boundary of your school's property and then map the pervious and impervious areas at your school.

- Use a red pencil to shade in the areas on your map of the School's property that are **impervious** (water cannot infiltrate) such as pavement, sidewalks, roofs, etc.
- Use a brown pencil to shade in areas that are **pervious** to water and covered in vegetation.
- Use a green pencil to shade in areas where conservation practices (BMPs) have already been incorporated onto your school's property (examples: green roofs, rain gardens, rain barrels, etc.).
- Create a key on your map to define the various shaded areas on your map (***Show students the examples from*** Appendix 1.1 & 1.2)

#### Prediction

Use a blue pen to indicate the places on your map of the school's property where you **predict** you may be able to implement conservation practices (BMPs) to reduce runoff and increase infiltration.



## Part II

### GIS Mapping of My Schoolyard

*Students will recreate the Schoolyard map that they used in Part I in the online Site Storm Model. Teachers should demonstrate this process on a display while the students follow along on their computers. Students should use the Schoolyard map from part I to help them define the school property by knowing where to click on the "corners." If students have individual accounts they will be able to save their project, share their work with a teacher (or others) and develop their plans further for extension activities.*

The Model My Watershed® (MMW) Site Storm Model is an interactive watershed-modeling app that allows users to delineate an area of land, identify and analyze specific characteristics (land cover, soil group, climate, terrain, etc.) from professional data bases, model stormwater runoff and water quality impacts, and compare the effects of various conservation or development scenarios. On a computer go to ModelMyWatershed.org to open the Model My Watershed® App and investigate your school grounds.
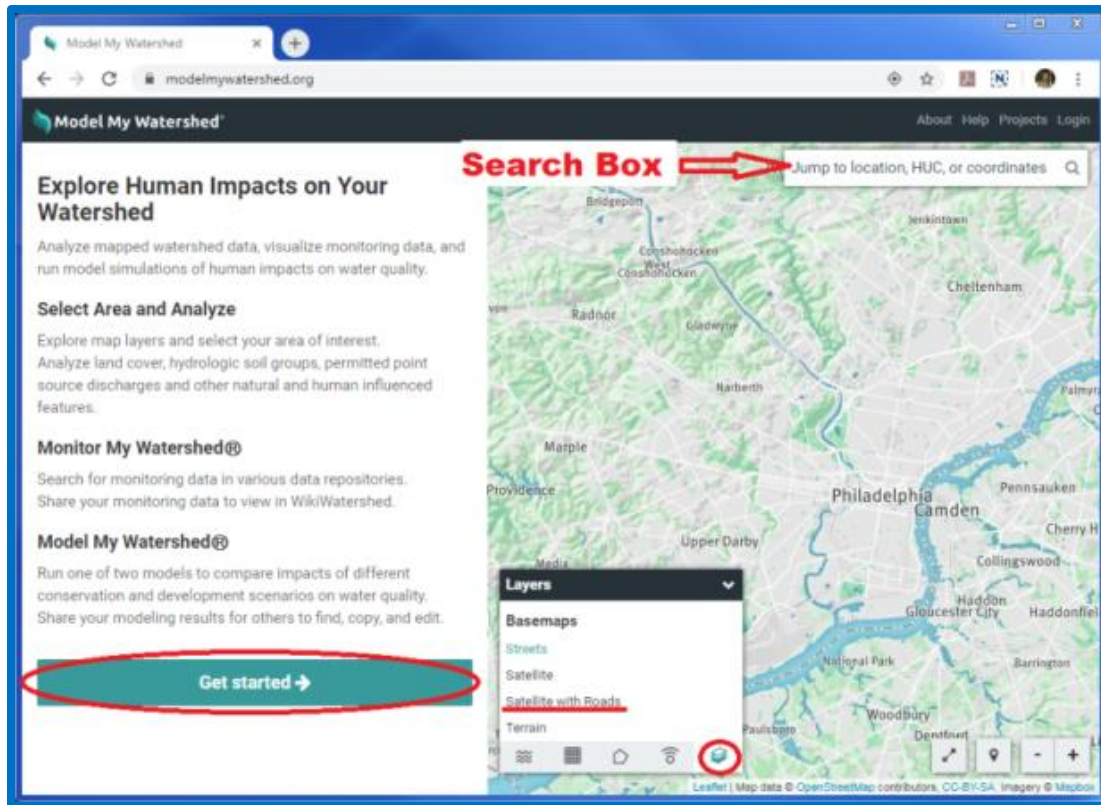


**Click here to start the Model my Watershed® App**

- In the left panel, click on Get Started.
- Type in the address for your school in the search bar in the top right corner of your map.
- In the bottom left corner of the map you will see a "Layers" control box. Click on the furthest icon to the right in the bottom of this dialogue box to select the "Basemaps" tab and select "Satellite with Roads."
- Zoom in or out and drag the map to show all of your school's property in the map viewing area.
- In the left panel, click on the black down arrow in "Draw area" and select "Free draw" to re-create the polygon of the property for your school that matches the map your teacher gave you in Part I. Begin by clicking on one corner of your school's property. Moving clockwise click at each of the corners around the edge of your school's property until you click on the first mark to close the polygon. Your school's property will be delineated and the model will automatically analyze the area and give you base information on the area you selected. If you make a mistake, click on "Change area" at the bottom of the left panel and try again.
- Click the tabs in the analyze box to learn about your school's property, and record the information below.
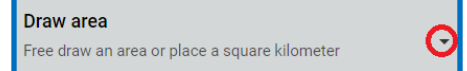
## Recording Data from the Analyze Box

1. What is the total "Selected Area" for your school's property? _____ m$^2$

2. Select the land tab and record the Land Cover types and percentages of coverage your your school:

_____ _____ %     _____ _____ %

_____ %     _____ _____ %

_____ %     _____ _____ %

_____ _____ %     _____ _____ %

_____ _____ %     _____ _____ %

3. Select the "Soil" tab and record the predominant Soil Group: _____

# Part III

## Land Cover Model Comparison

Now we will use the Site Storm Model to investigate how changing the current land cover conditions at your school to a forest would affect stormwater runoff and water quality in the local watershed.



- In the left panel "Analyze" pane select the "Model" tab, and then choose "Site Storm Model" to run a simulation of a 24 hour storm event on your school's property.

- Move the precipitation slider in the bar above the map to **8.0 cm.**
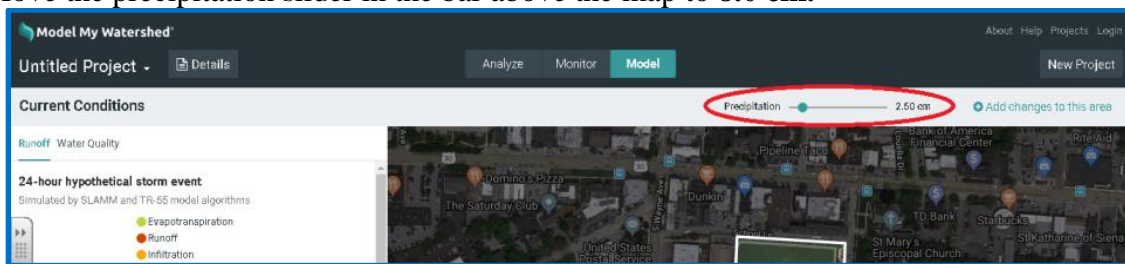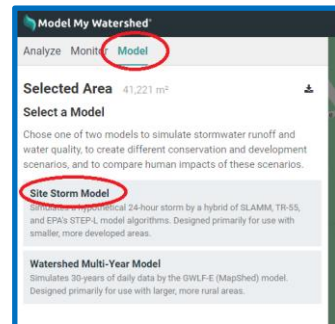


- Click on "Add changes to this area" in the bar above the map right of the precipitation slider.



- Then click on "Compare" in the top of the panel on the left of the map.



- Click on the data table icon in the top menu to the right of the precipitation slider to toggle to an easy to read table of the data.



---
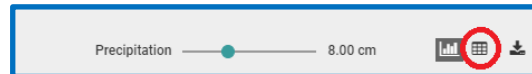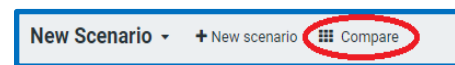
4. Record the Water Depth results for the first two land cover scenarios, "**Predominantly Forested**" and "**Current Conditions**" in the data table below.

| Land Cover | Evapotranspiration (cm) | Runoff (cm) | Infiltration (cm) |
|---|---|---|---|
| Predominantly Forested | Answers for Water Depths should be "close" to the Teacher's Answer Keys created when creating the School Property Map for part 1. | | |
| Current Conditions | | | |

- Toggle back to the Combined Hydrology graphs by clicking on the "graph" icon to the right of the precipitation slider.

Precipitation ———●——— 8.00 cm

5. Look at the results for evapotranspiration, runoff, and infiltration in the data table, as well as the Combined Hydrology graphs, and compare the "Current Conditions" at your school with the "Predominantly Forested" scenario. Make some observations about the two scenarios and include data on how evapotranspiration, runoff, and infiltration changed as a result of the land cover change.

**Students should recognize a substantial decrease in the amount of runoff and an increase in infiltration and evapotranspiration in the "Predominantly Forested" land cover scenario. Students may quantify the results by comparing the amounts involved, or by describing the change in relative terms.** *Examples: The predominantly forested scenario had much less runoff than the Current Conditions. The predominantly forested scenario reduced runoff by 60%! The predominantly forested scenario reduced runoff to 2.03 cm from 5.02cm at our current condition during a 24 hour storm event of 8.0*

# Part IV

## Modeling Conservation Practices at My School

Now you will use the site storm model to explore and model some Conservation Practices that could be added to your school's property to reduce runoff and improve infiltration.

- Close the "Compare" window by clicking on the ✖ in the top right hand corner.
- Click on the teal colored ⊕ Conservation Practice button to view the practices that you could add to the scenario. Hover the cursor over each Conservation Practice to learn more about them.
- Start by adding a **Green Roof** to the tops of some of the buildings (flat or low slopes only) at your school by selecting "Green Roof" and then click on one corner of your school's roof in the map (zoom in to make it easier to see the features of the roof). Moving clockwise, click along the edges of the roof at each of the corners until you click on the first mark to close the polygon and define where the Green Roof would be installed. The simulation will install the Green Roof and the data in the model will update. Repeat this process until you have changed all of the flat roofs at your school to Green Roofs.

- When you are finished adding Green Roofs, click on the down arrow next to the "New Scenario" Title in the top left, move the cursor to the three dots to the right of "New Scenario" in the drop down menu and click on the three dots to "Rename" your project "Green Roofs."



- Then click on ![+ New scenario] again to add a different plausible Conservation Practice to your school's property. Each time you select ![+ New scenario] the model will return to the original "Current Conditions" scenario.

- To "Add" multiple Conservation Practices while saving each scenario separately, return to the "Scenario" dropdown menu and select "Duplicate." This will create a duplicate scenario upon which you can add more Conservation Practices. Likewise, if you want to remove some practices, you can make a copy of a scenario, duplicate and rename the copy, then click on a Conservation Practice to see the area involved and to "Remove" the modification.



- Create up to three scenarios for various plausible combinations of proposed Conservation Practices at your school. Develop a "best plan" for integrating Conservation Practices onto your school's property to protect your watershed by minimizing runoff and maximizing infiltration and evapotranspiration. Be sure to consider the current activities at your school and propose installations of Conservation Practices only in areas where they will not interrupt normal activities. **Students should be coached to avoid interrupting normal activities to create "plausible" conservation plans. Changing the entire schoolyard and buildings to a forest is not typically feasible.**

- When you are finished, click on the ![Compare] button in the top left panel to analyze the results of your proposed scenarios. You can delete excess scenarios by clicking on the three dots next to the scenario you want to remove, and choosing "Delete."

- Toggle to the data table by clicking on the data table icon to the right of the precipitation slider to fill in the data below.
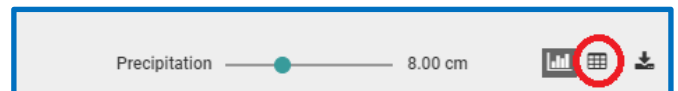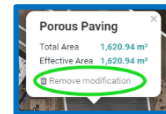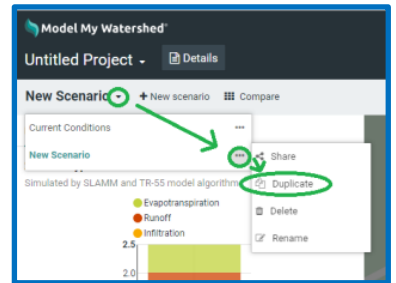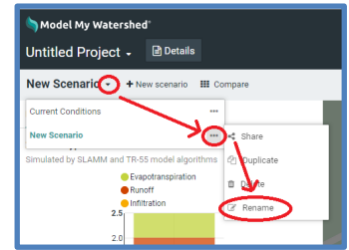


## Compare

**Runoff**  Water Quality

| Scenarios | Predominantly Forested | Current Conditions | Green Roofs | Porous Paving and Rain Garden |
|---|---|---|---|---|
| **Runoff** | 0.009 cm | 0.917 cm | 0.795 cm | 0.696 cm |
| **Evapotranspiration** | 0.526 cm | 0.23 cm | 0.23 cm | 0.218 cm |
| **Infiltration** | 1.965 cm | 1.353 cm | 1.475 cm | 1.587 cm |

**If students are able to login to the Model my Watershed® platform, they should be directed to save a copy of their project. The projects can be shared with the teacher to be used for grading purposes as well as possible extension activities (ex. School Ground BMP Plan Competition). Students could also be directed to capture screen shots of the results (Ctrl and PrtSc then paste into a document (Word or Google) to be printed or shared with the teacher.**

| Conservation Plans | Predominantly Forested | Current Conditions | Green Roofs | | | |
|---|---|---|---|---|---|---|
| **Runoff (cm)** | | | | | | |
| **Evapotranspiration (cm)** | | **Answers will vary based on the scenarios** | | | | |
| **Infiltration (cm)** | | | | | | |

## Analysis

6. Which scenario that you developed created the best outcome for protecting your watershed with the least runoff and the most infiltration?

    **Answers will vary based on the scenarios developed by the students.**

7. Are there any compromises or additional features you might need to include to assure that important activities (e.g., parking, access to areas, sports fields, etc.) could still happen at your school?

    **Answers will vary based on the scenarios developed by the students. Students should consider the changes to land cover and land use in their proposed scenario. Some land normally used for outdoor activities (sports, fire drills, recess) may be converted and would require those activities to be moved. New land activities or learning stations may be created in these spaces as a result of their proposed changes.**

## Conclusion

Q: Describe the land conservation practices (BMPs) that you included in your "best plan" and explain why you chose these features. Which conservation practices are appropriate for areas on your school site? Explain how and why your design will improve your watershed. (Hint: Consider the size of the areas, types of conservation practices, costs to implement the practices, and impact on usage of the areas).

*Students should describe their proposed changes and defend their plans with plausible reasoning. Green roofs, porous paving, rain gardens, and vegetated infiltration basins are appropriate for many school sites. These four conservation practices can be applied to smaller areas and can be used for education purposes. All of these, plus no-till agriculture and cluster housing are appropriate for communities. No-till agriculture and cluster housing are used in larger areas and will have larger effects on runoff and infiltration amounts.*

_____

_____

_____

_____

## STEM Career Extension

What is an Environmental Data Manager & GIS Specialist?  Navigate to https://youtu.be/f8nhf8q2yJA) and watch a video about how STEM education and skills led into an exciting career at Stroud Water Research Center.

**Teachers can play this video for the class by visiting https://youtu.be/f8nhf8q2yJA**
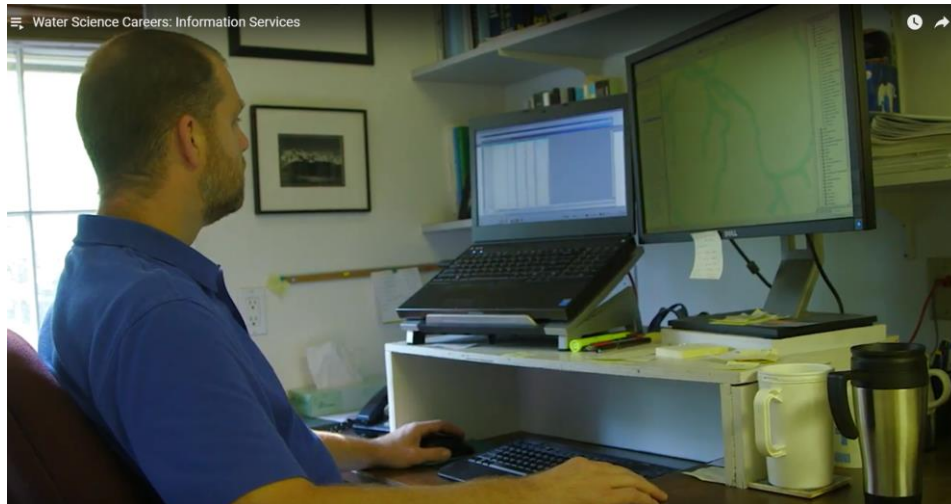


What does an Environmental Data Manager & GIS Specialist do to help further the research of watershed scientists and educators?  What background knowledge and experiences were critical in helping Dr. Dow complete his work? How is Dr. Dow's work connected to developing plans to install Conservation Practices?

*Dr. Dow is responsible for managing and storing all of the data gathered by the scientists, and developing layers to showcase the data in GIS platforms.  He completes statistical analysis of the information that is collected and helps scientists understand their findings. Dr. Dow's childhood provided him with many opportunities to play and explore creeks and streams that inspired him to want to help conserve and protect these resources. His love of math and computers also helped him to develop the skills he needed to be an Environmental Data Manager. Installing conservation practices requires extensive planning and analysis to create effective plans, so his understanding and use of GIS systems is instrumental in his work.*

# Extension Activities

## Lesson One Extensions

**Exploring Land Cover and Soil Groups:**

- o Create a Campus Land Cover Report by taking pictures of impervious and pervious surfaces around your school. Classify the examples as natural or man-made, and describe the impact of each surface on the health of the watershed.
- o Collect soil samples from various locations around your school and determine what Hydrologic Soil Group you think best describes the soil at your school.
- o Create a graph from the data you collected with the Runoff Simulation to compare the effects of Land Cover or Soil Type on the movement of water.
- o Using the Runoff Simulation, run the scenario again with current conditions for your house and compare the results for your house with the results for your school. Create a graph of this data to demonstrate the differences.

## Lesson Two Extensions

**BMP Watershed Conservation & Stewardship Plan for Your Community**

Have the students identify an area of land in their community that they think is having a negative impact on the health of their local watershed. Students should use Model My Watershed® to analyze the location of their choice and experiment with different scenarios to develop watershed & stewardship plans for the property they chose that maximizes the health of the watershed by implementing conservation practices and land cover changes. Students should seek to create plans that lead to the lowest amounts of runoff and greatest amounts of infiltration while keeping in mind all of the current activities and uses of the land and/or improving public access and resources. Have the students present their plans to the class, administrators, school board members, or the community.

**School Grounds BMP Watershed Conservation & Stewardship Competition**

Create a competition between the students in your class/school whereby students use Model My Watershed® to design the best Watershed Conservation & Stewardship plans for your school by creating scenarios with **plausible land cover and conservation practices** that maximizes the health of the watershed. Students should experiment with different scenarios until they develop a schoolyard plan that leads to the lowest amounts of runoff and greatest amounts of infiltration while keeping in mind all of the current activities and uses of the land. Have students present their plans to their classmates and defend their ideas and designs. Add a panel of judges to enhance the presentation challenge, provide feedback on their plans, and vote on the best plans (consider inviting school administrators, facilities managers, other teachers, and members from the community like planning commissioners, parks and recreation managers, and school board members).

**School Expansion Project**

Introduce a scenario where your school is planning to build a new building (or expand a current building) on campus. Have students work in teams to develop plans for where the new construction would happen and include Conservation Practices to offset the impact from additional runoff into their local watershed.

**One Kilometer Land Use Comparison**

Starting at modelmywatershed.org, have students click on "Draw area" and use the "Square Km" function to draw a square kilometer in different areas (urban, suburban, rural) to collect data and compare how different land cover areas affect local watersheds. Students could chose a few different sites, or each student could get assigned an "area" to investigate and then all students could share and compare their findings.

# Vocabulary

**Cluster housing** – When developers build a community, they can build the houses closer together and leave other areas open and undeveloped where they plant trees and other plants that will soak up the rain. This reduces flooding and allows water to soak back into the ground.

**Conservation practice** - Control measures consisting of managerial, vegetative, and structural practices that reduce the loss or degradation of soil and water. Also known as best management practices (BMPs).

**Developed land** - Land areas where humans have altered the landscape and installed constructed materials (asphalt, concrete, buildings, etc) over 30 percent or more of the area.

**Elevation** – The distance above sea level.

**Erosion** - The wearing away of land surfaces by wind or water, intensified by land-clearing practices related to farming, residential or industrial development, road building, or logging.

**Evaporation** – The process of changing water from a liquid (water) to a gas (water vapor) by adding energy (heat). Water vapor is water molecules that are suspended in the air. Warm air has more energy and can contain more water molecules, which is why it often feels more humid in warm weather.

**Evapotranspiration** - The combined processes by which water moves from the land to the atmosphere by transpiration from plants, and by evaporation from surface waters, soils, and other moist surfaces.

**Flood** - Any relatively high streamflow that overflows the natural or artificial banks of a stream. Floods may be caused by long-lasting rainfall over a broad area, locally intense thunderstorms, rapid melting of snowpack, or obstructions to normal stream flows.

**Green roofs** - A conservation practice where the roof of a building is partially or completely covered with vegetation and a growing medium, planted over a waterproofing membrane. It may also include additional layers such as a root barrier and drainage and irrigation systems.

**Groundwater** - Water found underground in the cracks and spaces (pores) in soil, sand and rock. Groundwater is stored in and moves slowly through geologic formations of soil, sand and rocks called aquifers.

**Hydrologic Soil Group** - A classification system used to describe the ability of a soil to allow infiltration and movement of water through the soil. The soils are rated from High Infiltration (A) to Very Slow Infiltration (D).

**Impervious** – A land surface area that does not have connected pores and cannot allow liquids and gases (including water) to infiltrate the ground which results in more runoff.

**Infiltration** – The process of water soaking into the ground.

**Infrastructure** - The physical and organizational structures and facilities (e.g., buildings, roads, and power supplies) built by humans that are needed for the operation of a society or organization.

**Irrigation** – Application of water or wastewater to land areas to supply the water and nutrient needs of plants.

**Nonpoint source pollution** - Pollution from different sources that occur over a wide area and are not easily identified from a single source. Nonpoint source pollution often results from runoff that picks up and carries natural and human-made pollutants into lakes, rivers, wetlands, coastal waters, and groundwater.

**No-till agriculture** - An agricultural best management practice whereby farmers plant crops without disturbing the soil or removing the plants that are already there. No-till agriculture improves the infiltration rate of the soil, reduces erosion, and builds the organic matter and nutrient cycling in the soil.

**Pervious** - A land surface area that has connected pores which allows liquids and gases (including water) to pass through the material and infiltrate into the ground.

**Photosynthesis** – The process by which plants and some other organisms use sunlight to make foods from carbon dioxide and water. Photosynthesis in plants generally involves the green pigment chlorophyll and generates oxygen as a byproduct.

**Point source pollution** - Any single identifiable source of pollution from which pollutants are discharged, such as a pipe, ditch, ship or factory smokestack. Factories and sewage treatment plants are two common types of point sources.

**Pollution** – Chemicals, pathogens and other harmful things that could have a negative effect on people and other living things in an environment.

**Porous** - A material, rock, or soil that has connected pores that allows liquids or gases (including water) to pass through. Porous land surfaces allow water to infiltrate into the ground.

**Porous paving** - A conservation practice where the surface of parking areas and walkways are constructed with materials that have connected pores or spaces between the surface blocks that allow water to infiltrate into the ground. A layer of gravel is often installed below the surface to hold the water as it slowly infiltrates into the ground underneath.

**Rain garden** - A conservation practice that reduces runoff as a shallow depression in the landscape collects rain water from a roof, driveway, or street and allows the water to slowly infiltrate into the ground. Rain gardens are often planted with native grasses and flowering perennials to enhance infiltration and evapotranspiration, help filter out pollutants, and provide food and shelter for butterflies, song birds and other wildlife. More complex rain gardens with drainage systems and amended soils are often referred to as bioretention basins.

**Rain water capture** – Catching rain water in a barrel or cistern in order to reuse it for another purpose.

**Rainwater retention basin (or bioswale)** - A long, channeled depression or trench that receives rainwater runoff (as from a parking lot) and has vegetation (such as grasses, flowering herbs, and shrubs) and organic matter (such as mulch) to slow water infiltration and filter out pollutants.

**Runoff** – Water that does not infiltrate into the ground and runs across the surface of the land, which can cause erosion and carry pollutants and sediment into streams, rivers, lakes, storm-water basins, or sewers.

**Sediment** - Particles from rocks or biological materials that have been transported by, suspended in, or deposited by air, water, or ice or that are accumulated by other natural processes. Some typical sediments are pebbles, sand, clay, silt, salts, and diatomaceous earth.

**Slope** – The angle of the land compared to the horizontal, which affects the movement of water. Water flows from higher to lower elevations, down the slopes of the land. Water will flow faster down a steep slope, and slower on a gentle slope.

**Soil moisture** - The quantity of water contained in the soil.

**Sustainability** – An approach for human interactions that respects the value of the environment and employs methods of using resources wisely so they are not depleted or permanently damaged. Sustainably designed buildings conserve the use of resources such as water and energy.

**Temperature** - Measure of the amount of heat (kinetic energy) in a given area.

**Topography** - The physical features or shape of the land (mountains, hills, valleys, etc.), which affects where water flows.

**Transpiration** - The process whereby plants release water back into the atmosphere through pores (stomata) on the surface of leaves, stems, and flowers.

**Tributary** – A stream or river that flows into a larger stream, river, or lake.

**Vegetated infiltration basin** – A landscaped depression with permeable soils, and covered with plants, that catch stormwater runoff to prevent flooding, enhance infiltration and evapotranspiration, and protect the quality of water in a watershed.

**Wastewater wetland** – A constructed marsh or swamp area designed to treat sewage or stormwater with wetland vegetation and natural biological processes that break down wastes and permeable soils that filter and clean the water.

**Water quality criteria** - Levels of water quality expected to make a body of water suitable for its designated use. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.

**Watershed** - A system defined by the area of land over which all water drains downhill through a series of streams and rivers to a common outlet (river, lake, bay or ocean).

**Wetlands** – Land areas where the soil is almost always wet throughout most or all of the year. There may or may not be water visible at the surface.

# Appendix

## Best Management Practices Resources

Best Management Practices and Low Impact Development Explained: https://youtu.be/coFbdMB-q0U

Stormwater Pollution & Green Infrastructure Solutions: https://youtu.be/ATNy-vaIPXI

Innovative Stormwater Management at a Neighborhood Scale: https://youtu.be/emQ8p6LGByU

NYC Green Infrastructure: https://youtu.be/zrhw2cMTpJs

Intro to Easy Design of LID/BMP/GI Stormwater Controls: https://www.youtube.com/watch?v=2Wyl1WemcKs

Stormwater PA BMP Manual: http://www.stormwaterpa.org/bmp-manual-introduction.html

## Lesson Two Part 1 – Identifying Current Conditions Sample Schoolyard Map

## Figure 1.1

## Figure 1.2