Stormwater and Green Infrastructure Curriculum for Boston Public Schools

Grade 7 | Rain in Our Schoolyard and Water Quality in the Charles River: What's the Connection?

A 4-6 week science unit on stormwater and Green Infrastructure in which students investigate whether their schoolyard contributes to phosphorus pollution in the Charles River. If so, they explore what could be changed. If not, they investigate why not. For schools with or without Green Infrastructure on-site.

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Prepared for: Boston Water & Sewer Commission

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Preface

These two units were developed as part of a partnership between the Boston Water & Sewer Commission and the Boston Public Schools in which Green Infrastructure (GI) was installed at five (5) Boston Public School (BPS) sites. The partnership creates new opportunities for students to explore science, technology, and engineering—and issues of critical importance to the City of Boston today—in an authentic context that is immediately relevant to their lives. Both units align science and engineering concepts related to stormwater and Green Infrastructure with the MA Science, Technology/Engineering (STE) Standards and Science and Engineering Practices. The lessons draw on the ideas, materials, and suggestions of engineers and scientists working on installing GI at the BPS sites, as well as from BPS administrators and teachers.

This is a living document. It is intended to engage teachers as partners in thinking about how these concepts can be taught in ways that will be most meaningful for their students. These lessons provide a framework and a set of activities for you to test in your classrooms and modify in the context of your science curriculum.

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A 4-6 week science unit on stormwater and Green Infrastructure in which students investigate whether their schoolyard contributes to phosphorus pollution in the Charles River. If they conclude that it does, they explore what could be changed. If they conclude that it doesn't, they investigate why it doesn't. Designed for schools with or without Green Infrastructure on-site.

Before You Begin—A Note to Teachers

Rain in Our Schoolyard and Water Quality in the Charles River: What's the Connection?

This unit invites students to explore the connection between rainwater on their schoolyard and water pollution in the Charles River. After learning that excess phosphorus in the Charles River is causing severe damage to the river's ecosystems, students ask: Is our schoolyard contributing phosphorus pollution to the Charles River? What evidence do we have? If so (the case at most schools), what design solutions could we recommend to mitigate the schoolyard's contribution to phosphorus pollution in the river? If not (the case at schools with Green Infrastructure (GI)), how is that being achieved?

They examine GI, a new nature-based technology, as one way that Boston and other cities are working to reduce water pollution in their rivers, lakes, and wetlands resulting from rapid growth of urban areas. Each student develops expertise on one of four types of GI. For the final performance assessment, they use the data they've collected, their GI expertise, and a collaborative analysis of site conditions to recommend a design solution for a specific GI practice on their own schoolyard (or a given school parking lot).

WHAT IF GREEN INFRASTRUCTURE HASN'T BEEN INSTALLED AT OUR SCHOOL?

At all schools, students can analyze what happens to stormwater on their schoolyard, decide whether it is contributing to phosphorus pollution in the Charles River, and make recommendations for how GI could help get more stormwater into the geosphere and atmosphere at their site and/or remove phosphorus from stormwater runoff before it gets to the river.

At GI Pilot Schools with GI features on-site students will likely conclude that their site is contributing less phosphorus to the river. They can investigate the GI features at their school, debate which features and/or site designs are most effective, monitor the volume and quality of stormwater entering and leaving the feature, and recommend modifications accordingly.

Before You Begin

1. Read *Background on Stormwater and GI in Appendix A* and click through the slides in *Appendix D* for an overview of the science and engineering content of the unit.
2. Look over the *GI Fact Sheets* in *Appendix C* to learn about specific GI practices.
3. Print a map of your schoolyard and make copies for students to use. See *Directions for Printing a Map of Your Schoolyard* in *Appendix A*. If you are at a GI Pilot school you will find a map of your schoolyard, and information on the GI features installed on your site, in *Appendix B.*
4. Decide whether for the final performance assessment you want to have students use a) their own schoolyard, or b) the provided *Irving School Parking Lot Case Study*.
   a) If you elect to use your own schoolyard, students will be able to use data they collected throughout the unit, and will have direct knowledge of the schoolyard conditions and how different areas are used when they are constructing an argument for where specific GI features should be located. You can use the entire schoolyard, one area of it; or involve students in choosing the area later in the unit.
   b) If you use the Irving School Parking Lot Case Study for the final assessment the data students need is included in this packet. Their task is to redesign the parking lot using different design criteria and constraints than were used by the design team.
5. Assemble tools students might want to use to investigate schoolyard topography, including:
   - Old tennis, or other balls (to determine the direction water flows)
   - String, twine or rope (30-50 feet)
   - Long tape measure or Smart phone app such as EasyMeasure
   - 1 and 2-liter bottles for carrying water outside
   - Small containers for collecting water samples
   - Sidewalk chalk
6. Consider how you want to adapt lessons using Universal Design for Learning principles and strategies used in classrooms for English Language Learners. Engaging students in middle school is important and place-based learning projects can appeal to students who don't always feel successful in a book-paper-pencil classroom. The investigations in this unit offer an opportunity to help all students develop a science and engineering identify.

Curriculum Connections

Literacy

The problems associated with stormwater runoff and the solutions offered by Green Infrastructure are new and unfamiliar to most people. Education is much needed at the school and community level, creating an authentic need for student presentations—informative or persuasive—in speech, print or digital media.

Math

MA Standards

Ratios and Proportional Relationships 7.RP
A. Analyze proportional relationships and use them to solve real-world and mathematical problems.
3. Use proportional relationships to solve multi-step ratio, rate, and percent problems.

Geometry 7.G
A. Draw, construct, and describe geometrical figures and describe the relationships between them. Solve problems involving scale drawings of geometric figures, such as computing actual lengths and areas from a scale drawing and reproducing a scale drawing at a different scale.
6. Solve real-world and mathematical problems involving area, volume, and surface area of two- and three-dimensional objects composed of triangles, quadrilaterals, polygons, cubes, and right prisms.

Analyzing Data over Time

Online real-time measurements from the OptiRTC Dashboard System at the Irving School and the Charles River Buoy offer many additional opportunities for data analysis. (e.g., How many storm events occurred in the past month or year? What volume of water did each generate? What was the volume of stormwater entering and leaving the grey and green infrastructure systems during each of three storm events).

Social Studies

Students create and use watershed maps. More sophisticated mapping technologies (using topographic features, soil mapping, etc.) are provided in Directions for Printing a Map of Your Schoolyard.
On physical maps use cardinal directions, map scales, key/legend, and title.
Use topographic maps to locate important physical features of a region.

Making a Difference in the Community

These activities invite students to make a direct contribution to their communities, in addition to investigating stormwater runoff and Green Infrastructure (GI). Freshwater is a precious and limited resource. Stormwater at present is treated as a potentially destructive byproduct of rain to be quickly and efficiently disposed of. Students have a chance to help turn that around and help find ways to get rainwater, a valuable part of the natural water cycle, back into the geosphere and the atmosphere.

> The most powerful phenomena from an educational perspective are culturally or personally relevant or consequential to students. [Such phenomena] highlight how science ideas help us explain aspects of real world contexts or design solutions to science-related problems that matter to students, their communities, and society.
>
> —Using Phenomena in NGSS-Designed Lessons and Units Creative commons Attribution 3.0 Unported License at http://creativecommons.org/licenses/by/3.0/

- Students learn that their school is helping to address a serious water quality issue in Boston and that they have a role to play.
- Students learn that tracking the movement of water on sidewalks and streets is critically important—and fun—and something real scientists and engineers do every day as part of their jobs.
- Students learn that people can help mitigate problems like water pollution and climate change using new ideas, technologies, and community practices.

Tackling these challenges requires many different types of people doing many different jobs and working together. You might be one of them!

Environmental Clubs

<u>At schools with GI:</u>

Students could develop a plan to continue to monitor the effectiveness of the GI features at their site with faculty support.

Their "citizen science" data and analysis could inform the future adoption of new GI and maintenance of existing GI.

Students could present their data to the school community, which could mean students working on similar projects at other GI schools, City officials and professionals, or designers/engineers involved in the installation of their school's GI.

<u>At schools without GI:</u>

Interested students could continue to monitor runoff from their school's site with faculty support.

Analysis of their "citizen science" data could lead them to advocate for GI at their school.

Students could present their data to their school community, students working on similar projects at other schools, City officials and professionals, and/or interested designers/engineers.

Summary of Lessons and Related Standards

LESSON	LESSON SUMMARY	STE STANDARDS
1	1. Students learn that excess phosphorus in the Charles is causing severe damage to the river's ecosystem. Earlier river cleanup efforts were a huge success but students are recruited to help solve a new challenge—algal blooms—a result of nutrient pollution in stormwater runoff. 2. Students analyze a map, diagram and table showing how the growth of cities has changed the surface of the land so much that it has altered the natural water cycle. The increase in impervious surfaces has reduced infiltration and evapotranspiration, while increasing stormwater runoff. 3. Stormwater runoff carries large amounts of phosphorus pollution into rivers and streams, harming aquatic life, reducing biodiversity and impacting the entire ecosystem—including humans.	7.MS-LS2-4. Analyze data to provide evidence that disruptions (natural or human-made) to any physical or biological component of an ecosystem can lead to shifts in all its populations. 7.MS-LS2-6 (MA). Explain how changes to the biodiversity of an ecosystem—the variety of species found in the ecosystem—may limit the availability of resources humans use.
2	1. Students model the water cycle in 4 watersheds (forest, agricultural, suburban and urban). They use their models to explain how the Sun and gravity drive the water cycle; how land cover impacts stormwater runoff; and to predict the level of phosphorus pollution downstream. 2. Students plan and conduct an investigation of stormwater runoff in their schoolyard—a model watershed—calculating the level of phosphorus and runoff. 3. Students brainstorm strategies to change the flow of stormwater runoff and are introduced to Green Infrastructure (GI), a new nature-based technology, for treating stormwater runoff.	7.MS-ESS2-4. Develop a model to explain how the energy of the Sun and Earth's gravity drive the cycling of water, including changes of state, as it moves through multiple pathways in Earth's hydrosphere. 7.MS-LS2-5. Evaluate competing design solutions for protecting an ecosystem.
3	1. Students combine information from diagrams, photos and text, to develop models to share their expertise on one of 4 GI practices. 2. Students analyze online real-time data from the Irving School parking lot to compare the impact of (traditional) grey and green infrastructure systems on water quality. 3. Students construct an argument about how their GI practice helps reduce the impact of humans on the natural environment.	7.MS-ESS3-4 Construct an argument supported by evidence that human activities and technologies can mitigate the impact of increases in human population and per capita consumption of natural resources on the environment.
4	1. Students are introduced to a Decision Matrix—a tool engineers use to help them evaluate competing GI options. 2. Students use a Decision Matrix to evaluate GI options for their own schoolyard or for the provided case study.	7.MS-ETS1-2. Evaluate competing solutions to a given design problem using a Decision Matrix to determine how well each meets the criteria and constraints of the problem.
5	Students prepare and present arguments to their colleagues in an engineering design firm, recommending the best location for a GI practice on a given site. Their goal is to reduce phosphorus pollution in the river and improve site conditions on the schoolyard.	

Opportunities for Authentic Argumentation

This chart identifies opportunities for students to collect and use evidence to engage in authentic argumentation on questions for which there is no single answer. Students will need to construct a compelling case with sufficient evidence to convince their peers to arrive at a conclusion.

Lesson	Questions Posed	Students Investigate	Students May Disagree About
1	Is the land cover in our schoolyard closer to pre-development (natural) or post development (urban) conditions?	How can we find out? Students design and conduct an investigation to determine which ground surfaces are porous/ permeable and/or impervious.	Which surfaces are porous/ permeable: Grass? Soil? (may depend on compaction) Rubberized surfaces? Artificial turf? Pavement? (Where GI is installed these "paved" surfaces may be permeable).
2	Where does stormwater runoff in our schoolyard go? Does most stormwater runoff leave the site or remain on-site?	How can we figure out where stormwater goes? Students design and conduct an investigation to determine the flow of water on their schoolyard.	What procedure to use: Look for low spots, drains, sediment deposits; slopes; pour water; use contour maps; observe during a rain. Where stormwater runoff goes: (e.g. to the street, a grassy field, or to existing GI features.)
3	How do green and grey infrastructure affect stormwater runoff differently? *Does* GI reduce stormwater runoff and phosphorus pollution? Can GI help reduce the impact of human population growth on the natural environment?	Students analyze and interpret online real-time data from the Irving School Case Study parking lot. Does this data provide evidence that GI reduces and/or cleans stormwater runoff?	What this data tells us: What doesn't it tell us? Is this data sufficient and compelling?
4	How do engineers choose which GI features to use at a particular site?	Students determine which GI *co-benefits* are most important at their location (i.e. habitat creation, improved air quality). Students determine which GI features best meet the given criteria and constraints.	Which co-benefits of GI should be prioritized at this location. Which GI features best meet the criteria and constraints.
5	Where on our schoolyard (or the case study site) should a given GI feature be installed in order to reduce phosphorus pollution in the river?	Students recommend and provide compelling evidence for where different GI practices should be located on their schoolyard (or case study site).	What is the best design solution? Where on the site should this GI feature be located? Why is this the best GI to use here?

Grade 7 | LESSON 1 | How Does Water Quality in Our Rivers Affect Us?

Anticipated time: (4) 45-minute sessions

Students are introduced to a brief history of water quality in the Charles River, resulting from human activities, both negative and positive. Despite highly successful cleanup efforts aimed at point sources of pollution—sewage, dumping, factory pipes—nonpoint source pollution is causing new problems. Excess phosphorus is resulting in algal blooms—a sign that the river needs our help. Students learn that land cover changes associated with human population growth and the unprecedented expansion of cities has changed the natural water cycle. Increased stormwater runoff carries higher levels of phosphorus into our rivers and streams with cascading effects throughout the ecosystem. Students are invited to help solve the problem by asking and investigating the question: Is our schoolyard contributing to excess phosphorus in the river?

Session 1 | Algal Blooms

Students learn that excess phosphorus in the Charles is causing severe damage to the river's ecosystem. Earlier cleanup efforts of the river were a huge success but students are recruited to help solve a new challenge—algal blooms—a result of nutrient pollution in stormwater runoff.

Session 2 | Stormwater Runoff (2 sessions)

Students analyze a map, diagram, and table showing how the growth of cities has changed the surface of the land so much that it has altered the natural water cycle. The increase in impervious land cover and reduction in vegetative cover have reduced infiltration and evapotranspiration leading to increased stormwater runoff and more phosphorus downstream.

Session 3 | Impact on Biodiversity

Higher volumes of stormwater runoff carry large loads of sediment and nutrients like phosphorus into rivers and streams, harming aquatic life, reducing biodiversity and impacting the entire ecosystem—including humans.

Science & Engineering Standards

7.MS-LS2-4. Analyze data to provide evidence that disruptions (natural or human-made) to any physical or biological component of an ecosystem can lead to shifts in all its populations.

7.MS-LS2-6 (MA). Explain how changes to the biodiversity of an ecosystem—the variety of species found in the ecosystem—may limit the availability of resources humans use. Resources can include food, energy, medicine, and clean water.

LESSON ONE | Session 1 | Algal Blooms

Cleanup efforts to remove trash and point source pollution (factory emissions and wastewater) from the Charles River were hugely successful. Now students are recruited to help solve a new challenge—algal blooms, a result of nutrient pollution in stormwater runoff.

Teacher Preparation

Laminate and post Charles River photos for a gallery walk.

Alert students that the class will be going outside next session so they can bring appropriate clothes to class.

Optional: Play "Dirty Water" by the Standells
https://www.youtube.com/watch?v=KyBJQoCKNaU

Materials Needed

For the class

- Charles River laminated photos
- *What Makes Algal Blooms Dangerous? Speaking of Chemistry* video
- Nutrient Pollution video, EPA

For each student group

- Cards or worksheet of key events in the production of algal blooms

For each student

- Stickie notes to post on photos in gallery walk
- Clipboards or notebook and writing utensils

Student Activity

Setting Up the Question

1. INVITE STUDENT REFLECTIONS ON CHARLES RIVER PHOTOS OVER TIME.

Announce the start of a new unit and invite students to look at the photos without any introduction. "Our topic is connected to the pictures posted on the wall. So, take some time to walk around and look at them. Take a packet of stickie notes and write your reactions to the pictures (talk to a partner if you like). Post your notes near the photos.

Science & Engineering Practices

Asking questions and defining problems.

Analyzing and interpreting data.

How does the water quality of our rivers affect *us*?

What do you notice in the picture? How does the picture make you feel?

What do you think is going on?

When everyone's had a chance to look at all the pictures we're going to talk about what's happening.

Student pairs can each begin at a different photo, all students don't need to progress through the photos in the same sequence.

2. DISCUSS THE HISTORY OF WATER QUALITY IN THE CHARLES.

Explain that this is the story of the Charles River. Orient them to the river. Have they been to it? What do they do there? Or ask about another river closer to them.

Discuss their reactions to the photos. What do you think happened? Can anyone figure out the story that we're looking at here?

- How would the conditions you see affect the plants, animals, and people who use the river?
- What might have caused the river to get so polluted? (People not caring, dumping, letting pollutants go into the river, factory pollution, not understanding that some substances were dangerous).
- What do you think changed? (federal regulations, rules of what you could dump, technology in factories).
- Why do you think it changed? (people started to care, they saw animals dying, they wanted to fish, they didn't like the smell and the pollution).

The Charles River used to be one of the dirtiest rivers in the country and it became one of the cleanest because people started working to clean it up. Boston Harbor is another example.

People wanted to fish and swim and boat in the river again. They wanted a healthy river. Many people worked to change this. Scientists conducted studies to understand how plants and animals were affected, engineers designed new technologies, artists and writers helped educate people by writing stories, and making films, advocates lobbied politicians to pass laws to ensure water quality was monitored, and factories were prevented from discharging pollutants into the river. And many people changed their behavior. They stopped throwing trash, discarded cars and furniture into the rivers and stopped pouring waste oil and grease into storm drains.

----------------------------POTENTIAL BREAK POINT----------------------------

Let's stop a minute to celebrate these achievements in our own city: from one of the dirtiest to one of the cleanest urban rivers in the country! From a filthy harbor to a harbor we can swim in!

Human-created problems can *be mitigated by developing science understanding and engineering solutions.*

In this unit you are going be part of that process. You will be using your science understanding and thinking as engineers to make a real difference in our community.

Setting Up the Question

1. INTRODUCE ALGAL BLOOMS.

As you saw in the gallery walk, despite the earlier successes, today we have a new challenge—algal blooms. We are going to be learning more about the problem in order to help us design solutions.

- Have you seen water that looks like this?
- How might algal blooms impact people or animals and plants in the river?
- Does anyone have ideas of what causes this green scum?

(Students may remember from the Ecosystems in 5th grade that excess nutrients from fertilizer can over stimulate plant growth, causing some to grow too fast, disrupting the balance and harming other organisms).

2. INTRODUCE PHOSPHORUS AS THE CAUSE OF ALGAL BLOOMS.

Show this or a similar video:

- *What Makes Algal Blooms Dangerous? Speaking of Chemistry* (play up to 1:30, or beyond for more chemistry) https://www.youtube.com/watch?v=kNL99XVJjQo

Use a graphic organizer or draw a quick sequence on the board as you go through the sequence of events.

- Phosphorus (from fertilizer, pet and yard waste and fossil fuel particulates) runs into rivers and streams.
- Waterways become overloaded with nutrients, like phosphorus.
- The extra nutrients cause runaway algal and cyanobacteria growth.
- Dense green mats of algae block sunlight and kill plants.
- The algae/cyanobacteria die causing explosive decomposition.
- The decomposing plants consume oxygen, which fish and other organisms need to survive.
- Fish and other aquatic animals suffocate and die.

Student Investigation

1. STUDENT GROUPS CREATE STORYBOARDS EXPLAINING HOW ALGAL BLOOMS FORM.

- Have cards with photos or illustrations to sequence and labels to match. Or record it in notebooks.
- Have students arrange "phosphorus" cards in a sequence to explain how excess phosphorus leads to algal blooms and how algal blooms affect the aquatic ecosystem.

Background Notes:

Phosphorus is naturally occurring and necessary for all living things. But because it is mined and used as a fertilizer for agriculture and lawns much larger amounts of it are in circulation than would be without human intervention.

Excess nutrients in aquatic ecosystems cause patches of algae to expand profusely. This green blanketing of the water is called "eutrophication": it suffocates the life under the slime—killing fish, diminishing biodiversity, and emitting noxious odors. It reduces the value of the water for most human uses—drinking, fishing, swimming or even boating. (Bennett, 25)

When thick blooms of algal growth block sunlight from reaching the plants below, the decay of dead algae uses up the available oxygen in the water, suffocating fish and sometimes causing whole populations of species to be lost. (28)

Options: give students cards naming each step and ask them to arrange them in the proper sequence, or a sheet with graphic images to arrange in sequence and label.

2. STUDENTS READ ABOUT NUTRIENT POLLUTION ACROSS THE COUNTRY.

Engage students in a closed reading as a class or assign as homework.

See readings on Nutrient Pollution in *Appendix C*. The text of "Nutrient Pollution" @ epa.gov is reprinted below.

You may also want to have students read the news articles reporting on the EPA survey of the nation's rivers and streams. Or follow links from the EPA site to information on sources of nutrients.

Careers in Water Management

There is increasing attention on improving and maintaining water resources worldwide. If you find you are interested in what we are doing in this unit there are many related careers that might interest you; aquatic scientists, soil scientists, mechanical engineers, civil engineers, technicians, architects, landscape architects, watershed planners and many more.

Can the class add to this list or research what these people do?

Nutrient Pollution

This text can be found at https://www.epa.gov/nutrientpollution/problem

Nutrient pollution is one of America's most widespread, costly and challenging environmental problems, and is caused by excess nitrogen and phosphorus in the air and water.

Nitrogen and phosphorus are nutrients that are natural parts of aquatic ecosystems. Nitrogen and phosphorus support the growth of algae and aquatic plants, which provide food and habitat for fish, shellfish and smaller organisms that live in water.

But when too much nitrogen and phosphorus enter the environment— usually from a wide range of human activities—the air and water can become polluted. Nutrient pollution has impacted many streams, rivers, lakes, bays and coastal waters for the past several decades, resulting in serious environmental and human health issues, and impacting the economy.

Too much nitrogen and phosphorus in the water causes algae to grow faster than ecosystems can handle. Significant increases in algae harm water quality, food resources and habitats, and decrease the oxygen that fish and other aquatic life need to survive. Large growths of algae are called algal blooms and they can severely reduce or eliminate oxygen in the water, leading to illnesses in fish and the death of large numbers of fish.

Drawing Conclusions

Background Notes:

1. OUR CHALLENGE IS TO DESIGN SOLUTIONS!

To protect aquatic life, we must find a way to reduce the amount of phosphorus getting into our rivers. But how?
We're going to be acting as scientists and engineers for the rest of this unit to research the problem and see if we can find solutions.
We'll investigate how we can, in our own schoolyard, help reduce pollution in the river.

2. INTRODUCE THE EVIDENCE BINDER.

To help us investigate we're going to be doing research and collecting data. We'll need to keep track of our data in a class Evidence Binder (a shared folder in which to put the research and data we collect). What should we add from today? Consider:

- Video on algal blooms
- Storyboards/card sequence on phosphorus and algal blooms
- Student reflections (see homework below)

HOMEWORK OPTIONS:

Write a short reflection about how the disruption of increased phosphorus shifts populations and how this shift impacts the availability of resources for human use.

Write a short reflection on one of the photographs of the Charles River that illustrates how human interactions with waterways impact biodiversity in an ecosystem.

LESSON ONE | Session 2 | Stormwater Runoff

Human population growth and urban sprawl have changed the surface of the land so much that is has altered the natural water cycle, decreasing infiltration and increasing stormwater runoff. Students analyze graphics depicting changes in land cover over time. They connect the drastic increase in impervious land cover to increased stormwater runoff, which in turn leads to phosphorus overloading in the river. They then investigate the percentage of porous/permeable and impervious land cover in their schoolyard, looking for evidence of whether or not their schoolyard contributes phosphorus to downstream waterways.

Science & Engineering Practices

Analyzing and interpreting data.

Planning and carrying out investigations.

How have changes in land cover changed the natural water cycle?

Teacher Preparation

Print site maps of your schoolyard (see *Appendix A for* instructions)
Print and laminate Charles River Photos (*Appendix C*)

Materials Needed

For the class

- Charles River Photos laminated (*Appendix C*)
- Land Cover in Boston 1630 and Today (*Appendix C*)
- Water Cycle Diagram Pre- and Post-Development (*Appendix C*)
- Stormwater Runoff Table (*Appendix E*)

For each student group

- Laminated copies of Land Cover in Boston 1630 and Today
- Laminated copies of the Water Cycle Diagram: Pre- and Post-Development
- Copies of your schoolyard site map

For each student

- Clipboards or notebooks and writing utensils

Student Activity

Setting Up the Question

Our task is to reduce phosphorus pollution in the river. To do this we need to understand more about the history of Boston.

To do that we'll be analyzing some maps and diagrams that show how the growth of cities (or urban sprawl) has dramatically changed our landscape.

1. PROJECT “LAND COVER IN BOSTON 1630 AND TODAY” AND PASS OUT COPIES.

Orient students to this view of Boston. Can they locate where their neighborhood is? Identify any landmarks? Find their school? (Some neighborhoods aren’t on the map because the city hadn’t yet been built out into the water).

Ask them to turn and talk to discuss what differences they notice between the two images. Note: the land area is less in the earlier image because the City had not yet used landfill to expand into the harbor; but our focus today is on the changes in the surface of the land. How has the land surface changed? (From primarily vegetative cover, to a surface largely covered by buildings, pavement, etc.).

2. STUDENTS REVIEW THE GRAPHIC OF A WATERSHED PRE- AND POST-DEVELOPMENT.

Pass out copies of the graphic. Acknowledge that this is a complex diagram and explain that we’re going to look at it closely together to see what we can learn from it.

Give students time to try to make sense of it on their own. Ask them to mark it up, making notes about what is confusing or what they think different aspects mean. Ask questions to guide them to look more closely at the components: arrows, numbers, text, and diagram.

Introduce the vocabulary in context. Wait until students say, “water can’t soak in…to pavement or buildings,” to introduce them to the word for that (“impervious”).

Ask groups to study the graphic and report back three things they notice and one thing that’s different between the two images. Be sure that at least one group notices that the total percentages do not change, but the way they are distributed changes. Be sure they notice that there is no change to precipitation and why that is significant.

Encourage students to use the vocabulary of the graphic ("We noticed in the pre-development graphic that infiltration was 50% and had a thick arrow pointing into the ground compared to the post-development graphic that showed infiltration was 15% and had a skinnier arrow").

During this round, students are just making observations and perhaps comparisons. Some students will begin to offer analysis, but don't insist on it until every group has had a chance to share observations.

Background Notes:

“The creation of impervious surfaces that accompanies urbanization profoundly affects how water moves both above and below ground during and following storm events…[it] affects the quality of that stormwater, and/ the ultimate condition of nearby rivers, lakes, and estuaries.”

National Academies Press, Urban Stormwater in the United States https://www.nap.edu/catalog/12465/urban-stormwater-management-in-the-united-states

3. MOVE FROM OBSERVATIONS TO ANALYSIS OF THE GRAPHIC.

Working in pairs or groups ask students to answer some of the following questions.

- What story is being told here? What differences do you see between the two pictures? Invite them to use their own experience to read the graphic (What happens when rain hits dirt, roofs, grass, streets, trees?).
- Why is there so much more runoff in the post-development image? (Because the water can't get into the ground, most of the ground is impervious).
- What surfaces is water running off in the pre-development image? (rock, compacted ground), in the post-development graphic? (roads, parking lots, sidewalks, buildings/rooftops as well as rock [puddingstone] and compacted ground).
- Which image do you think has more plants? Why do you think that? What ideas does this give you about the role plants play?

4. GENERATE DEFINITIONS.

Ask students to generate definitions for infiltration, evapotranspiration and stormwater runoff based on interpreting the diagram. Quickly go over student ideas and correct if necessary.

5. REPRESENT THE SAME DATA USING NUMBERS ONLY.

The map images and the graphic are two ways of presenting the same information. Both show changes over time from primarily vegetative to primarily impervious land cover. The same information could also be represented as a table.

Create a table with the information from the Water Cycle Diagram: Pre- and Post-Development with students supplying the numbers for each column.

	Natural watershed	Urban watershed
Infiltration	50%	15%
Evapotranspiration	40%	30%
Runoff	10%	55%
Precipitation	100%	100%

Ask what is happening in each column and row. Which numbers are largest? Why? Which change the most? Why is the number for infiltration smaller in the second column ("Urban watershed") than in the first? (Water can't get through the impervious surface). Why is the number for evapotranspiration smaller in the second column ("Urban

Background Notes:

Animation illustrating the process of evapotranspiration.

https://svs.gsfc.nasa.gov/10926

Definitions:

infiltration: The process through which water enters soils below the ground's surface.

evaporation: The process through which a liquid becomes a vapor.

evapotranspiration: The combination of evaporation and transpiration.

transpiration: The process of water being carried from the roots of a plant toward small pores on the underside of its leaves and released to the atmosphere as water vapor.

watershed")? (There aren't as many plants). Why do both columns add up to 100%?

(One possible conclusion is that all precipitation entering a watershed, leaves by one of three routes: infiltration, evapotranspiration, or stormwater runoff).

We've just looked at three ways of representing the same information: map, diagram, and table. Some people get information more easily from pictures, some from numbers. Which of these three did you like best? Invite a couple of responses.

Throughout this unit we will be working with different ways of representing information and at the end you will be presenting information to the whole group to convince them to go along with your recommendation. Notice as we go, which ways of representing information seem clearest to you.

Student Investigation

1. STUDENTS PREDICT LAND COVER TYPES IN THEIR SCHOOLYARD.

Review pre- and post-development graphics.
These diagrams aren't just showing the differences between long ago and the present day, but differences between natural and urban areas today. Ask students to predict whether they think their schoolyard is closer to pre- or post-development percentages of stormwater runoff?

Mark land cover types on the schoolyard site map.
Project your schoolyard site map and give students copies to mark up. Orient students to the map (Try a quick game in which one student names a location—the swing, the lunch door—and others have to find it on the map).

As a class, identify the main areas of the schoolyard, outline and label them on the projected map while students do the same on their maps (parking lot; playground; little kids play area). Decide on a upon color or symbol for marking porous ("permeable") and impervious areas.

Student groups discuss and label each area "permeable" or "impervious."

2. GROUPS REPORT OUT.

Ask students to state their claim for whether the surface of each area is permeable or impervious. Do groups agree about all areas? Which areas are there disagreement on? Can students persuade each other to change their minds?

Notes:

Is the land cover in our schoolyard impervious or porous/permeable?

How can we find out?

For GI Schools:
Students may disagree about what to label some surfaces (artificial turf, porous asphalt). Let their uncertainty remain. They can continue to explore it.

----------------------------------DAY TWO--

Setting Up the Question

1. ASK HOW CAN WE FIND OUT WHETHER OUR PREDICTIONS ARE CORRECT?

Brainstorm ideas: Elicit student ideas for testing whether a surface is impervious. (Pour water on it and see how long it takes to soak in, poke a stick into the ground, other).

Agree on a method all groups will use to test whether or not a surface is impervious. (*use a timer, pour one cup of water on it etc.)*

Agree on a way to record the data. How will the results be recorded?

Student Investigation

1. STUDENTS TEST DIFFERENT AREAS OF THEIR SCHOOLYARD AND RECORD RESULTS ON SCHOOLYARD SITE MAPS.

2. STUDENTS EVALUATE THEIR RESULTS.

As groups report on their findings, discuss their new claims and create a map that the class agrees on. Students will need to back up their claims about whether a surface is impervious or permeable using evidence to convince their peers to change the surface label on the class map.

Consider giving students an opportunity to experiment with different materials to explore which they think are impervious (e.g. a cup of gravel, a cup of grass growing, a cup of plaster of paris.)

LESSON ONE | Session 3 | Impact on Biodiversity

Stormwater runoff carries large amounts of phosphorus pollution into rivers and streams, harming aquatic life, reducing biodiversity and impacting the entire ecosystem—including humans.

Students develop food webs to explain how a change in one population impacts the entire ecosystem, and how stormwater runoff from new construction would affect the organisms in their food web.

Teacher Preparation

Print and laminate 4 watershed photos (*Appendix C*)

Materials Needed

For the class

- Scene or list of organisms typically found in or near a New England river
- Impervious cover and biodiversity graphic (*Appendix C*)

For each student group

- Materials for representing food webs
- Laminated cards of four different types of landscapes with different amounts of impervious cover—forest, farmland, suburban, urban. (You could also choose to include commercial sites, or sites where construction is taking place).

Student Activity

Setting Up the Question

1. REVIEW THE IMPACT OF ALGAL BLOOMS ON MULTIPLE ORGANISMS.

Let's look back at what we know about phosphorus and algal blooms from the first lesson. Ask volunteers to review main points for the class using the storyboards they created in Lesson 1.1.

2. INTRODUCE THE QUESTION OF HOW CHANGES IN ONE POPULATION CAN IMPACT OTHERS.

Post a picture of a typical New England scene or, as a class, create a list of the biotic and abiotic elements they might expect to see along a river

Science & Engineering Practices

Analyzing and interpreting data.

Students analyze and interpret data on the relationship between the percentage of impervious cover and biodiversity in a watershed.

Developing and using models.

Students develop and use models to explain how changes in land cover in an ecosystem can lead to changes in one population—cyanobacteria--that can in turn impact all populations in the ecosystem.

How does impervious land cover affect biodiversity in rivers and streams?

or stream (willow tree, heron, micro invertebrates, macro invertebrates, crayfish, turtles, people).

Student Investigation

1. STUDENTS CREATE FOOD WEBS FOR A TYPICAL NEW ENGLAND RIVER.

Ask students to present their food web (poster, online). What happens if you take one level out? What if no macro invertebrates are left (who eats them?)? If there's nothing for baby fish to eat, nothing for adult fish, then there will be no fish, nothing for heron to eat…etc. Are humans affected?

Make sure students have key elements: consumers, producers, macro invertebrates, and that they are explaining how the dying off of one type of organisms affects the entire food chain.

OPTIONAL: Take pictures, for the Evidence Binder, of the food webs. (Take a second picture after students have modified their posters in the following step).

2. STUDENTS PREDICT WHAT WOULD HAPPEN TO THEIR FOOD WEB IF A LARGE MALL OR ROAD WERE CONSTRUCTED NEAR IT.

Discuss your predictions in your groups and modify your food webs to show what would change. (Students can just indicate the changes by blocking out components with their hands, or crossing off species that would be harmed, or writing a paragraph explaining the changes).

Their food web/ model should make a prediction and students should be able to explain their reasoning.

---------------------------POTENTIAL BREAK POINT---------------------------

Student Investigation continued

3. STUDENTS PREDICT THE IMPACT IMPERVIOUS SURFACES MIGHT HAVE ON BIODIVERSITY.

Scientists have found that there is a direct correlation between the percentage of impervious cover and the biodiversity in a watershed.

For example, rivers in watersheds with lots of impervious surface have fewer types of aquatic organisms in them.

Why do you think that would be? What might be different about the water?

Background Notes:

Biodiversity is the variety of all forms of life and it is essential to the existence and proper functioning of all ecosystems. Habitat loss is a challenge for virtually all species, as humans convert natural habitats to other land uses.

All forms of pollution, from chemicals to nutrient loading, can also pose serious threats to aquatic and terrestrial species.

https://www.epa.gov/enviroatlas/enviroatlas-benefit-category-biodiversity

Turn and talk (or in groups): How do you think the smaller amount of runoff coming from a natural landscape into a river (from water that has infiltrated into the ground— now groundwater moving horizontally and into a river ("base flow")) might be different from water running off a parking lot or road?

Notes:

Possible answers are below. Students may or may not come up with these at this point. You don't need to mention them if they don't. The point is just to get them thinking about what difference the amount of runoff might make to organisms in or near the river.

Water from natural landscape	Water from parking lot and roads
Trickles through the soil, smaller volume, moving slower, enters streams slowly maybe as groundwater/base flow, doesn't erode habitat	Runs faster, a lot at one time, erodes/washes away downstream habitat; flashy and less base flow so water levels fluctuate a great deal
Cooler	Warmer
Doesn't carry as many pollutants	Carries pollutants sitting on the ground (impervious surfaces) into the water: debris, litter, salt and other pollutants (i.e. oil)
Contains small amounts of phosphorus	Picks up lots of phosphorus (causing algal blooms)
Relatively clear	Cloudy water if it has a lot of sediment and other pollutants

Project the Impervious Cover and Biodiversity in Streams graphic relating impervious surface to biodiversity in a stream and handout copies to students.

The point is that they describe the amount of impervious cover in a landscape.

Give students a few minutes in their groups to analyze the graphic on their own and share their thoughts with others at their table. Then ask students to talk about what they see. Why do they think biodiversity would be reduced in watersheds with more impervious cover?

In our next class, we'll be building models of watersheds with different amounts of impervious cover like the ones represented here.

Distribute laminated photos of four different watersheds and assign or ask groups to choose which one they want to model.

Which picture/section in the "Biodiversity and Impervious Cover" graphic do they think is most likely to be found in their Watershed Photo? What percentage of impervious land cover is likely to be in their watershed? What does that mean about the corresponding biodiversity?

Drawing Conclusions

Give students a few minutes to talk in their groups about what they should include in the model of their watershed.

HOMEWORK:

Ask students to submit two pictures (or headlines) or other evidence of a healthy or impaired ecosystem in the Charles (Neponset or Mystic) Rivers. Or, ask them to find evidence of plants, animals, or humans benefiting from clean water in the river. They can do this anytime over the next week, or whenever they find something they want to contribute.

Plan to show this montage at the end of the unit.

Notes:

Grade 7 | LESSON 2 | What Drives the Flow of Water through A Watershed?

Anticipated time: (3) 45-minute sessions

Students develop watershed models that explain how the Sun and gravity drive the water cycle and how impervious cover impacts stormwater runoff and phosphorus levels in local rivers and streams. They map the flow of stormwater on their schoolyard and brainstorm strategies that could help reduce and/or filter stormwater runoff at their school.

Session 1 | Modeling the Flow of Water Through a Watershed

Students model the water cycle in 4 watersheds (forest, agricultural, suburban and urban). They use their models to explain how the Sun and gravity drive the water cycle; how land cover impacts stormwater runoff; and to predict the level of phosphorus pollution downstream.

Session 2 | Drainage Detectives: Tracking Stormwater Runoff in the Schoolyard Watershed

Over two days, students plan and conduct an investigation to track stormwater runoff in their schoolyard. They calculate the level of phosphorus and the volume of stormwater runoff generated in one or more areas of the schoolyard.

Session 3 | Looking for Solutions

Students brainstorm strategies to change the flow of stormwater runoff and are introduced to Green Infrastructure (GI), a new nature-based technology, for treating stormwater runoff.

Teacher Preparation

Alert students ahead of time that they will be going outside for Lesson 2.2 so they can bring appropriate clothing.

Science & Engineering Standards

7.MS-ESS2-4. Develop a model to explain how the energy of the Sun and Earth's gravity drive the cycling of water, including changes of state, as it moves through multiple pathways in Earth's hydrosphere. Clarification Statement: Examples of models can be conceptual or physical.

7.MS-LS2-5. Evaluate competing design solutions for protecting an ecosystem. Discuss benefits and limitations of each design. Solutions could include water, land, and species protection, and the prevention of soil erosion. Design solution constraints could include scientific, economic, and social considerations.

LESSON 7.2.1 | The Water Cycle

Students model the water cycle in 4 watersheds (forest, agricultural, suburban and urban). They use their models to explain how the Sun and gravity drive the water cycle; how land cover impacts stormwater runoff; and to predict the level of phosphorus pollution downstream.

Teacher Preparation

Laminate the photos of 4 landscape types (Watershed Photos for Lesson 2.1 in Supporting Documents). If you feel the class would benefit from a prepared model, pick one of the options to model.

Materials Needed

For the class

- A prepared model if the teacher opts to share one
- https://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=10501
- USGS interactive water cycle diagram choose beginning/ intermediate/or advanced USGS water cycle diagram https://water.usgs.gov/edu/watercycle.html
- https://www.youtube.com/watch?v=iohKd5FWZOE NASA animation showing water cycle in continuous motion day and night
- The Water Cycle—NSF (or similar video)
- Stormwater Runoff Table (*Appendix E*)

For student groups

- Photos on laminated cardstock depicting a forest/ farmland/ suburban town/city
- 9x9 tin foil trays (you may want to put a layer of plastic wrap in each tray before distribution.)
- Plastic wrap
- Sponges cut into small, thin cubes (approx. 2x2x2 cm)
- Colored sugar sprinkles
- Clay
- Aluminum foil
- Cotton balls
- Spray bottles
- Water
- Newspaper for substrate if desired
- Key with picture support showing what each material represents and/or materials station with label and "real world" picture (concrete to representational)
- Homework handout

Science & Engineering Practices

Student teams work together to decide how to represent the flow of water in a watershed through models (physical or conceptual) that explain the water cycle. They include what causes phase changes and revise their models after hearing from other teams.

How does water move through a watershed?

Student Activity

Setting Up the Question

Today's big idea is a focus on the Sun and gravity in the water cycle. Understanding this is going to help us manage our challenge of reducing phosphorus in our community. We can make models of different kinds of watershed to help us think like scientists and engineers. So, what is a watershed?

1. INTRODUCE OR REVIEW THE DEFINITION OF A WATERSHED.

Elicit student ideas about the definition of a watershed.
Which watershed is our school in? Project Charles River Watershed Map with GI Schools and/or watershed map for Neponset or Mystic Rivers and ask if students can locate their school on the map. Encourage them to use the vocabulary in the water cycle diagram and videos to discuss he definition of a watershed.

Tell students the outline of the watershed on the map is the "rim of a bowl" the highest points of land from which all water drains to the low point.

2. HOW DOES THE WATER CYCLE DRIVE THE FLOW OF WATER THROUGH A WATERSHED?

Review or introduce students to the role of the Sun and gravity in moving water through Earth's hydrosphere. We've been looking at parts of the water cycle (precipitation, infiltration, surface runoff, and groundwater) to explore how water moves once it is on the ground. But how does it get into the air?

Use the interactive USGS diagram and/or animations below to frame the discussion.

- NASA: The Water Cycle
  https://www.youtube.com/watch?v=0_c0ZzZfC8c
- NASA animation showing water cycle in continuous motion day and night with text labels for water phases
  https://www.youtube.com/watch?v=iohKd5FWZOE

Ask student groups to analyze the interactive graphic The Water Cycle for Schools USGS. (This graphic can be set for beginning, intermediate or advanced levels). Have each student group research one phase of the water cycle and report on what causes water molecules to move into or out of that phase. Discuss which phases are driven by the Sun and which by gravity.

Show one or both animations.

How can we model the impact of these changes in land cover on the watershed?

Ask students to walk the class through the life of a drop of water based on the video they saw.

3. REVIST THE IMPACT OF LAND COVER ON THE FLOW OF WATER THROUGH A WATERSHED?

Elicit student ideas, referring back to the diagram of the Pre- and Post-Development Water Cycle and the effect of land cover on the path water takes through a watershed.

Student Investigation

1. GROUPS CREATE A MODEL OF A WATERSHED.

Each group creates a model of one of the four (forest, rural, suburban, and urban) landscapes depicted in the laminated photos.

Your model should explain what happens to precipitation that falls in this watershed, including:

- How the water cycle drives the flow of water through the watershed, and
- How the land cover in your watershed affects that flow
- Is your watershed closer to pre- or post-development conditions?

Note: Give students about 15 minutes to construct models.

- Sponges represent wetlands and cotton balls represent trees
- Tinfoil and clay can be used for buildings and pavement.
- A layer of plastic wrap at the bottom represents the groundwater
- Create an area for the stream/pond/ocean
- (Hold off on using the colored sprinkles for the next step)

2. GROUPS PRESENT THEIR MODELS.

Students present their models and explain how water moves through their watershed and how land cover in their model affects the flow of water.

How do infiltration and runoff compare in the Pre- and Post-Development Water Cycle?

3. GROUPS PREDICT AND MODEL PHOSPHORUS LOADING IN THEIR WATERSHED.

Students add the colored sugar sprinkles to represent the amount of phosphorus they think is likely to be found in their watershed. Discuss sources of phosphorus in their watershed (Decide how much you would expect to find in agricultural areas, suburbs, and cities).

Notes:

Phosphorus naturally occurs in small amounts in a forest. Additionally, fertilizer, animal waste, and exhaust emissions are the chief sources of phosphorus pollution. Decide how much you would expect to find in agricultural areas, suburbs, and cities.

Can you use your model to predict how much phosphorus will reach the organisms living in rivers and streams in your watershed? How do plants in your environment affect the flow of water? (increase evapotranspiration and infiltration)

Notes:

How do plants affect the amount of phosphorus that will make it to the rivers and streams? (plants need phosphorus and take it up through their roots)

Have groups spray water on their models. Were their predictions correct?

4. USING MATHEMATICAL MODELS TO CALCULATE PHOSPHORUS LEVELS DOWNSTREAM.

Stormwater engineers use a mathematical model to calculate how much phosphorus and runoff are generated at a site. They can do this because scientists have measured phosphorus levels in many different studies over many years and learned that the levels of phosphorus correspond to land cover types.

We're going to be using a tool that engineers use to calculate the amount of phosphorus a site generates for our schoolyard in a few lessons. Project the Stormwater Runoff Table. Invite students to look at the table and identify the components that they can make sense of and those that are confusing.

Stormwater Runoff Table

Land Cover	Catchment Area (sq ft)	Runoff Volume from 1-inch Storm (gallons)	Phosphorus (lb/acre/yr)
Roofs	-	-	-
Pavement	-	-	-
Trees/landscaping/gardens	-	-	-
Lawn/grass field*	-	-	-
Total	-	-	0.000

Ask groups to predict how levels of phosphorus (the numbers in the last column) might change (would they be larger or smaller?) depending on whether an area was covered with plants and trees, lawns and fields, pavement or buildings.

Have students pull up the table online and insert the same number in each column (30,000 square feet is the area of the Case Study parking lot). Which land cover types generate more phosphorus? Why do you think that is? (Phosphorus is going into the ground, being taken up by plants, filtered by the soil or is washed off from impervious surfaces).

Why do you think lawns and SPORTS fields generate more phosphorus than woods/landscaping/gardens? *(they are more compacted)*

Notes:

Drawing Conclusions

Notebook Reflections

Remind students that they created models to help people understand how something happens in the real world. Ask them to reflect and think about which models worked best to explain how water moves through a watershed. Which worked best at explaining how impervious land cover changes the water cycle?

HOMEWORK:

Draw a diagram of the water cycle in a watershed. Label how both energy from the Sun and gravity drive the cycle. Explain:

- How pollutants are carried into waterways
- How groundwater is recharged
- How the amount of impervious surface affects ecosystems

LESSON 7.2.2 | Drainage Detectives: Mapping Stormwater Runoff in the Schoolyard

What happens to precipitation that falls on our schoolyard?

Students plan and conduct an investigation of stormwater runoff in their schoolyard to determine what happens to rain that falls on the schoolyard. Does it evaporate or infiltrate, or does it leave the site as stormwater runoff? They create a schoolyard watershed map, measure the area draining to one outlet in their sub-watershed, and calculate the volume of stormwater runoff it generates.

Science & Engineering Practices

Developing and using models.

Planning and carrying out investigations.

Using mathematical and computational thinking.

Teacher Preparation

- Select the area of the schoolyard students will map
- Review Drainage Detective Tips (*Appendix C*)

Materials Needed

For the class

- Copies of your schoolyard site map
- Copies of the Irving School Parking Lot Case Study Schoolyard Watershed Map (*Appendix C*)
- Stormwater Runoff Worksheet (*Appendix E*)

For each student group

- A schoolyard site map to record group consensus
- Materials for the investigation: balls, string, tape measure, level, etc.

For each student

- Clipboard or notebook, and pen or pencil
- Copies of schoolyard site map to mark up

Student Activity

----------------------THIS ACTIVITY TAKES TWO DAYS---------------------

Setting Up the Question

Elicit student ideas about where rain or snow ends up on their schoolyard.

1. LINK WATERSHED MODELS TO SCHOOLYARD WATERSHED.

We started this unit looking at the big picture; of how the growth of cities has increased impervious cover so much that it has changed the natural water cycle, dramatically reducing infiltration, and increasing the volume of stormwater runoff.

As your models showed, in any watershed, the type of land cover (soil, plants, rock, pavement) affects how much stormwater gets into the ground or is taken up by plants, and how much runs off. In cities, the high percentage of paved surfaces means a higher percentage of rain becomes stormwater runoff that picks up and carries phosphorus, sediment, and other pollutants into rivers and streams.

Why is this problematic?

Which watershed model do you think our schoolyard is most like?

Which watershed model do you think is our goal?

2. PREDICT WHERE STORMWATER RUNOFF IN OUR SCHOOLYARD GOES.

What happens to precipitation on our schoolyard?

Is our schoolyard generating stormwater runoff?

Notebooks: Ask student groups to discuss and make a prediction in writing about whether their schoolyard is contributing stormwater runoff (and phosphorus) to the Charles River or not.

What is their evidence (the percentage of permeable surface or impervious cover, the number of drain inlets)? How can we tell how much phosphorus is likely being carried by the stormwater (by the type of land cover: forest, grass, buildings, sidewalks, etc.).

Record the claims and evidence each group offers on chart paper. Do all groups agree? If not, can students convince each other to change their minds?

----------------------------POTENTIAL BREAK POINT--------------------

How can we find out where stormwater runoff on our schoolyard goes?

3. INTRODUCE WATERSHED DRAINAGE MAPS.

Introduce the Irving Schoolyard Watershed map as a tool that watershed planners use to map the flow of water.

Project the Irving School Parking Lot Case Study ground photo and aerial shot of the parking lot. Take a few minutes to orient students to the aerial view.

Project the Irving Parking Lot Watershed Map and give students copies. Explain that the arrows describe the direction that stormwater on the surface is flowing.

Ask students to discuss why the arrows are pointing in different directions. Why would stormwater flow in different directions in the same parking lot? (The land slopes in different directions).

Can you find the watershed boundaries? High points can be found where arrows diverge and move in opposite directions. You can draw a line between diverging arrows to show the "rim of the bowl'. (An opportunity to discuss contour lines on a map). Can you find the drain inlets on the map?

Explain the idea that stormwater in the parking lot (or any section of your schoolyard) acts just as stormwater does in a watershed; the path water takes depends on the slope of the land and the land cover.

Student Investigation

How can we determine the path stormwater takes in our schoolyard and create our own schoolyard watershed map?

1. BRAINSTORM IDEAS.

Student ideas might include:

- Looking at our map of impervious and porous/permeable surfaces
- Looking at where there are hills or slopes (high points)
- Looking for catch basins or storm drains or openings in curbs (low points)
- Pouring water on the ground
- Placing balls on the ground and letting them go to find what direction the land slopes
- Looking for evidence of stormwater flow—e.g., sediment deposits, stains and streaks on the pavement
- Using contour maps

What happens to stormwater runoff in our schoolyard watersheds?

Be the rain. If you were the rain where would you go?

Other evidence of water could include: pollen lines from puddles in the spring.

2. DECIDE ON A PROCEDURE.

Agree as a class on one or two methods to use. Or groups could each select their own method; comparing results to see if they arrived at the same conclusion.

Decide how to symbolize low points, flow paths, and watershed boundaries on our map. Use the symbols used in the Case Study watershed map or agree as a class on others.

Allow time for groups to develop a procedure for how they will determine the path precipitation takes and for recording it on their site maps. Groups present their plans to the class and elicit feedback from colleagues.

3. COLLECT SCHOOLYARD WATERSHED DATA.

Once outdoors, remind students of any boundaries they should stay within. Ask one or more groups to briefly review their task.

Allow time for students to use their selected method to track the path water takes in the designated area, using arrows to show the direction of flow on their maps.

After a few minutes reconvene as a group to discuss initial findings. Encourage students to ask questions of each other and debate their results. Where there is disagreement they may need to run more tests.

Having heard from other groups, students return to creating their maps. Ideally students will identify one to three low points to which all stormwater in the schoolyard drains. Once they have found these points choose *one* on which to focus—likely the one where stormwater is flowing over the greatest amount of impervious surface.

The task now is to move back out from the chosen low point/ drain to determine how large the watershed is that drains to that point. Look for the high points that form the "rim of the watershed bowl."

4. CREATE A SCHOOLYARD WATERSHED MAP SHOWING THE CLASS CONCENSUS ON WHERE STORMWATER FLOWS.

Combine results to create a map of the schoolyard watershed(s).

Is our schoolyard generating stormwater runoff? Or is all precipitation going to lawns or landscaped areas? (Some may be GI features they have not yet learned about. At this point, what's important is simply that they've identified where the stormwater flows).

---------------------------POTENTIAL BREAK POINT---------------------------

Background Notes:

Watershed: An area of land that drains to a specific point, such as a river, lake, ocean, storm drain inlet or outfall. Catchments, subwatersheds, and basins all refer to watershed of different scales.

Relative size (big to small) is: basin, watershed, subwatershed, catchment.

Catchment: small watershed area, usually at the individual site level.

Drawing Conclusions

What does this tell us about whether our site is generating stormwater runoff? What evidence did we find? Is precipitation getting into the ground? how? Is it being returned to the atmosphere? how?

Revisit the claims that students made before creating their schoolyard watershed maps, about where stormwater runoff on their site goes and how much of it leaves the site. Do any groups want to change their claim based on what they learned from their investigation?

5. CALCULATE STORMWATER RUNOFF VOLUME AND PHOSPHORUS LOAD FOR ONE LOW-POINT/DRAIN.

Choose one area to focus on for the rest of the unit—most likely the one with the greatest amount of impervious cover.

Calculate the actual or approximate dimensions of the selected catchment area. Estimate, pace off the rough dimensions, measure or use GIS to get the dimensions of your area.

Open the Stormwater Runoff Worksheet again and enter the area (in square feet) for each land cover type found in your catchment area:

Stormwater Runoff Table

Land Cover	Catchment Area (sq ft)	Runoff Volume from 1-inch Storm (gallons)	Phosphorus (lb/acre/yr)
Roofs	-	-	-
Pavement	-	-	-
Trees/landscaping/gardens	-	-	-
Lawn/grass field*	-	-	-
Total	-	-	0.000

OPTIONAL MATH ACTIVITY: Calculating Stormwater Runoff Volume

Engage students in working out the formula embedded in the Table for determining runoff volume (gallons) from the total area (square feet).

Picture the parking lot with one inch of water over the whole parking lot. How can we figure out how much stormwater that is? Elicit student ideas as you walk through the calculation:

- Multiply width x length to find the total area (square feet)
- Multiply area x height (1 inch of rain or 1/12 foot) for the volume (cubic feet)
- Multiply cubic feet by 7.48 to convert to gallons

HOMEWORK: Challenge students to come up with a way to help people understand what that many gallons looks like. How much water is this?

Notes:

LESSON 2.3 | Looking for Solutions

Students brainstorm strategies to change the flow of stormwater runoff in their schoolyard and are introduced to Green Infrastructure (GI), a new nature-based technology being used by Boston and other cities to reduce and clean/filter stormwater runoff.

Teacher Preparation

Review *GI slides* and choose the ones you want to give students the option of analyzing (*Appendix D*)

Review GI Fact Sheets *(Appendix C)*

Materials Needed

For the class

- *W*atershed map for your schoolyard created in previous class
- Don't Runoff video (http://eie.org/engineering-everywhere/curriculum-units/don't-runoff or on YouTube @ https://www.youtube.com/watch?v=3zmp4UXomaU)
- Printed copies of selected slides (*Appendix D*)

Student Activity

Setting up the Question

1. REVISIT SCHOOLYARD WATERSHED MAP: IS OUR SCHOOLYARD GENERATING STORMWATER RUNOFF?

Students at most schools will have found that their schoolyard *is* generating stormwater runoff. Is this a problem?

It means that rainwater and snowmelt that could be infiltrating into the ground (recharging groundwater) or being taken up by plants in the schoolyard are being piped somewhere else through storm drains.

Additionally, as stormwater flows across the asphalt, rooftops, and sidewalks it is picking up phosphorus, along with other pollutants and debris, and carrying them into downstream waterways (harming aquatic ecosystems and limiting people's access to clean water). Consider a hands-on activity showing how water flowing over pavement picks up debris and pollutants.

2. HOW COULD WE REDUCE STORMWATER RUNOFF?

Use the slides in *Appendix D* to review the historical changes that have led to stormwater runoff and to introduce the questions engineers are asking today: How can we reduce stormwater runoff? How can we help "repair" the natural water cycle in cities?

Science & Engineering Practices

Developing and using models.

Obtaining, evaluating and communicating information.

How could the flow of stormwater runoff be changed to reduce the amount of phosphorus getting into our rivers?

If students found that stormwater was *not* running off the site, use this activity to ask why not? What is preventing it from running off?

Review images of:

- Boston land cover maps: 1630 and Today
- Human population growth
- The Natural and Urban Water Cycle Diagram
- Can we Make the Landscape on the Right Work More Like the One on the Left?

Look back again at the Natural and Urban Water Cycle Diagram. To reduce runoff, what do we have to do? Elicit student responses that the way to reduce stormwater runoff is to increase infiltration and/or evapotranspiration. How could we do that?

Student Investigation

1. STUDENTS BRAINSTORM IDEAS FOR REDUCING STORMWATER RUNOFF.

The job of engineers is to reduce the amount of stormwater runoff and phosphorus leaving this site. As an engineer, what would *you* recommend?

Give groups time to generate ideas for reducing runoff and create a list of their ideas. Encourage students to suggest ideas they are tentative about. They don't need to know how they would accomplish it, just to begin to think about what might be worth exploring. Ideas may include:

- Make holes in the ground
- Hold the water back in containers
- Make the ground out of a material that water can go through
- Put in something that absorbs water like a sponge
- Put in plants that could intercept or absorb rain
- Dig a trench to make the water go to a planted area

Does anyone have ideas about how we might be able to remove phosphorus (and other pollutants) from stormwater? How could we keep phosphorus (and other pollutants) from getting into stormwater runoff? (Students may not have ideas at this point. Ideas could include: don't use/outlaw fertilizer; pick up litter and dog waste; plant more plants; keep rainwater off pavement).

2. STUDENTS ANALYZE TWO MODELS FOR MANAGING RAIN IN THE CITY: (GREY AND GREEN INFRASTRUCTURE).

Engineers, scientists and city planners have started working to design alternate ways of managing stormwater in the city. We're going to look at models of both a traditional (grey) infrastructure system and at a new nature-based technology called Green Infrastructure.

Notes:

Let each student group pick one of the models in slides #7-#11 to analyze and interpret for the class using their skills as 'diagram detectives.'

- Stormwater Infrastructure: Managing Rain in the City
- Could We Use Plants instead of Pipes?
- Two Models: Grey & Green Infrastructure
- "How Can we transform the wall? the roof? the ground?
- Comparing Grey & Green Infrastructure: Two Cars diagram
- Comparing Hard v. Soft Engineering

As you look at your diagrams (models of Grey and Green Infrastructure):

- What are the key components of the infrastructure you are looking at?
- What are the advantages and disadvantages?
- Do you see any of the ideas you suggested for reducing stormwater in either diagram?

3. STUDENTS LEARN ABOUT GI PRACTICES BEING USED IN BOSTON.

Tell students they are going to be learning more about how GI works, and they will each become experts in one type of GI.

As we watch this video, *Don't Runoff*, about GI in Boston, let's listen for whether GI engineers are using some of the same ideas you had for how it might be possible to reduce stormwater.

http://eie.org/engineering-everywhere/curriculum-units/dont-runoff

Make a list of the four features to talk about as a group

1. Permeable pavers (infiltration)
2. Tree trenches (evapotranspiration, filtering, infiltration)
3. Bioretention feature, a.k.a., vegetated swale (filtering, evapotranspiration, infiltration)
4. Catch basin (grey infrastructure) and stormwater planter (filtering, evapotranspiration)

Stop the video when new GI features are introduced to label them and give students a chance to identify any connections to their own ideas about how stormwater could be reduced.

Create a class list of the GI features mentioned and identify the stages of the water cycle with which they interact.

Notes:

Permeable pavers. Students might have suggested changing the surface from concrete to something that allows water to pass through, or creating holes for the water to pass through, or some specific material that allows infiltration. Connect the permeable pavers to infiltration and groundwater recharge in the water cycle.

Tree trenches. Students may have suggested diverting the water away from hard surfaces, using plants to soak up the water, or allowing soil to filter the stormwater. (Note that adding plants to bare areas also reduces soil erosion—an idea used in bioretention areas). Tree trenches relate to evapotranspiration and infiltration.

Bioretention feature. Students may have suggested using slopes to convey stormwater, digging holes for the water to sit in while it soaks into the soil, using plants to absorb water, using soil (or the soil's native creatures) to filter out the pollutants. Bioretention features employ evapotranspiration, filtration, and infiltration.

Catch basin and stormwater planter. Ideas may have included diverting the water to a container, using plants, or collecting pollutants on site.

HOMEWORK:

Take pictures of any GI features you can find from your neighborhood, around town, or online and add them to our Evidence Binder.

Notes:

Grade 7 | LESSON 3 | Green Infrastructure: A New Solution

Anticipated time: (2) 45-minute sessions

Students begin to develop expertise in one GI feature. They develop materials to share their knowledge with the class about how their feature works, some of its key benefits, and limitations. Students then compare data from the digital sensors at the side-by-side grey vs. green infrastructure installation in the Irving School parking lot. The students explain how the project achieves one or more of the following goals of Green Infrastructure: removing pollutants, increasing infiltration, or increasing biodiversity.

Session 1 | What's Green Infrastructure?

Students combine information from diagrams, photos and text, and develop models to teach the class about one of four (4) GI features.

Session 2 | What's the Evidence?

Students analyze online real-time data from the Irving School parking lot to compare the impact of (traditional) grey and green infrastructure systems on water quality.

Session 3 | What's the Impact?

Students construct an argument about how their GI feature helps reduce the impact of humans on the natural environment including whether and how it removes pollutants, increases infiltration, and/ or increases biodiversity.

Science & Engineering Standards

7.MS-ESS3-4 Construct an argument supported by evidence that human activities and technologies can mitigate the impact of increases in human population and per capita consumption of natural resources on the environment. Arguments should be based on examining historical data such as population graphs, natural resource distribution maps, and water quality studies over time. Examples of negative impacts can include changes to the amount and quality of natural resources such as water, mineral, and energy supplies.

Lesson 3.1 | What's Green Infrastructure?

Students start to become experts on one GI feature combining information from diagrams, photos and text. They then share their knowledge with the class on how their feature works and some of its most important benefits and limitations.

Teacher Preparation

Review *GI Fact Sheets* (*Appendix C*)

Decide how to assign students to GI Expert Groups. You may want to have two groups working on bioretention systems.

Materials Needed

For the class

- Class list of GI features seen in Don't Runoff video
- Students' brainstorm of ways to change the flow of stormwater

For each student group

- Materials to make posters and/or other models
- Grey Infrastructure Fact Sheet (*Appendix C*)

For each student

A Fact sheet on *one* GI feature:

- Infiltration Practices
- Bioretention Practices
- Permeable Surfaces
- Rainwater Harvesting

At GI pilot schools, and others if you choose, also give students diagrams of the GI features installed at BPS schools (*Appendix B)*

Student Activity

Setting Up the Question

1. INTRODUCE STUDENTS TO THE GI FEATURES THEY WILL BECOME THE CLASS EXPERTS ON.

Students select (or are assigned) one GI feature to learn about in detail. They will become the class experts on this feature.

- Bioretention features: rain gardens, tree pits and bioswales
- Permeable surfaces: porous pavement, permeable pavers, artificial turf, porous playground surfaces

Science & Engineering Practices

Developing and using models.

Obtaining, evaluating and communicating information.

What does Green Infrastructure look like and how does it work?

- Infiltration systems: underground infiltration chambers and drywells
- Rain harvesting systems: cisterns and rain barrels.

2. ORIENT STUDENTS TO GI FACT SHEETS.

Look over the Fact Sheets as a class. Each fact sheet illustrates a set of GI features that share common attributes and use the same general principles to intercept stormwater runoff.

Discuss the types of information on the fact sheets: photos, diagrams, and text. What kinds of information does each provide that the others do not? Which are easiest to understand? Which are confusing? Can you help each other make sense of the parts you don't understand?

3. INTRODUCE EXPERT ROLES.

Each group will become an expert in one type of GI. It will be your job to teach the class how this type of GI works and to tell us what you think its strengths and limitations are in helping to reduce stormwater runoff.

Student Investigation

1. STUDENTS ANALYZE FACT SHEETS FOR ONE GI FEATURE.

Students study the GI features on their fact sheets. What do the features on your fact sheet have in common? What are their key components? (A clue can be found in the title of the page: bioretention features; infiltration practices—but let students come to this for themselves if they can).

Does your GI feature use any of the processes that were on our brainstorming list for reducing stormwater or removing pollutants? (*collecting water—like in a bucket; poking holes in the ground; digging a trench to make the water go someplace else)*? Are they like any of the GI features we saw in the video?

Student pairs might want to focus on one particular feature in their group's GI practice to learn about in depth: rain gardens, bioswales, tree trenches, porous pavers, artificial turf, etc.

2. STUDENTS PLAN MODELS OF THEIR GI FEATURES.

Decide what you want your model to show. Before groups begin working, ask the class what they want to know from each other about their GI feature.

Possibilities could include the following:

Background Notes:

- What materials is it made of?
- What are the main components?
- How do the parts work together?
- How does stormwater enter the feature?
- How does it leave?
- What are the strengths and limitations of this feature?
- What is most surprising about this feature?

Make Initial Sketches. Partners should discuss how they think their feature works and make some initial sketches that answers one or more of the questions above. Bring students together to share the ideas they're working with, and/or ask for help from the group. Students might find ideas from other groups that can improve their own models.

3. VISIT REAL-WORLD EXAMPLES.

Can you find examples of your GI feature on your schoolyard or nearby?

If you don't have GI on-site visit GI installations in the neighborhood (maybe at a GI Pilot School).

Can you identify the components you identified in the diagrams and photos?

If you are at a GI Pilot School go out to the schoolyard to look for these features. If time allows, students could design ways to investigate and test their feature. See Grade 5, Student Investigations and Activities by GI Feature for ideas.

4. STUDENTS DEVELOP MODELS.

Students use the materials provided to develop models that explain to the class how their GI feature works and how it reduces or cleans/filters stormwater runoff.

Drawing Conclusions

In a quick go-round, ask groups to explain one aspect of their feature and how it works.

If you have time, do a gallery walk of students' models.

OR: Project GI Streetscape (*Appendix* D), so students can find their feature or discuss where they would place it in that streetscape.

HOMEWORK:
Ask students to bring in photos or diagrams of objects from everyday life that illustrate or use the processes their GI feature relies on: objects that absorb water, let water pass through it, that catch and hold water, or that slows water down (e.g. a coffee filter, colander, sponge, bucket).

Notes:

LESSON 3.2 | What's the Evidence? Comparing Grey and Green Infrastructure

Students compare water quality from stormwater runoff leaving "grey" and "green" infrastructure systems by analyzing real-time online data from a concrete swale and a bioswale in the Irving School parking lot, comparing flow rates, temperature and volume of runoff treated.

THIS LESSON MAY NEED TO BE ADJUSTED ONCE DIGITAL SENSORS ARE OPERATIONAL!

Teacher Preparation

Review OptiRTC Dashboard for the Irving School parking lot. Use Science Department Login.

If students don't have online access, take a screenshot of the OptiRTC Dashboard for them to use.

Materials Needed

For the class

- Irving School Parking Lot Case Study (*Appendix C*)
    - ground and aerial photos of parking lot
    - photos side-by-side concrete swale and bioswale
    - site map with GI features
- Irving Stormwater Runoff Table (*Appendix E*)
- Link to OptiRTC Dashboard for Irving School parking lot

For each student group

- Models or other materials developed by student GI Experts to teach the class about their GI feature.

Student Activity

Setting up the question

1. ORIENT STUDENTS TO THE PARKING LOT.

Show photos—this is the same school parking lot that we calculated stormwater runoff for earlier using the Stormwater Runoff Table. Look at the previously completed stormwater runoff calculations.

Project the ground level photo and the aerial "before" photo of the Irving School parking lot.

Science & Engineering Practices

Analyzing and interpreting data.

Using mathematical and computational thinking.

What does this data tell us about how GI impacts water quality?

Review the Irving Stormwater Runoff Table. What do we already know about stormwater runoff in this parking lot?

The drainage area (mini watershed) for this parking lot is 30,000 square feet.

Locate numbers for the land cover type (parking lot); the volume of stormwater runoff; and the phosphorus load.

Stormwater Runoff Table

Land Cover	Catchment Area (sq ft)	Runoff Volume from 1-inch Storm (gallons)	Phosphorus (lb/acre/yr)
Roofs	-	-	-
Pavement	-	-	-
Trees/landscaping/gardens	-	-	-
Lawn/grass field*	-	-	-
Total	-	-	0.000

GI has been installed at this site. Show "after" GI installation aerial photo.

Explain that the parking lot was divided exactly in half, with half of the stormwater draining into traditional grey infrastructure/catch basin and storm drain (called a "concrete swale" on the map) and the other half draining to GI (called a "bioswale" on the map).

Show "after" photos of the side-by-side concrete swale and bioswale.

- Ask students what GI feature was used here? (bioswale-bioretention feature)
- Ask the student Bioretention Feature Experts (or experts in bioretention features) to explain to the class how their feature works.

Because they are side-by-side in the same parking lot, with the same volume of stormwater draining into each feature (and because digital sensors were installed in the overflow structures where the water leaves each feature), we have a chance to compare "grey" and "green" infrastructure using real-time measurements.

Use the table to calculate the amount of runoff going through both systems.

Project (and have students access) the Stormwater Runoff Table again and enter new numbers for half the parking lot (15,000 square feet) to calculate the volume of runoff going into each swale.

Teacher Note:

If students don't have online access, take a screenshot of the OptiRTC Dashboard for them to use.

Analyze the data.

Students analyze the data and use it to answer the question: Does GI make a difference? Options could include:

- <u>Option A</u>: Give students data tables from both features without identifying which swale it represents. Ask them to work in groups to predict which data is from the concrete swale and which from the bioswale—and explain their thinking.
- <u>Option B</u>: Prior to looking at the data, ask students to predict whether the speed, temperature, quality, or volume of the water leaving each swale will be higher, lower, or the same—and explain their thinking.

Students then analyze and graph the online data and compare it to their predictions. Online measurements will show:

	Concrete Swale	Bioswale
Rate of flow	Water will be coming out fast.	Water leaves as a slow drip.
Volume of runoff	High volume, unchanged from the volume going in.	Low volume compared to what was going in. Much of the water is retained in the bioretention feature.
Temperature	Warmer (warmed by pavement)	Cooler (cooled as it flows through soil, vegetation)

Discuss the implications of this data. What does this tell us about these two systems?

Drawing Conclusions

After students have compared the two systems, each treating half of the parking lot, let them know that in fact, the water in the concrete swale is not untreated but drains to an underground infiltration chambers. (This information leads into the focus in Lesson 4 on juggling different, sometimes competing, design criteria).

The side-by-side swales were installed to meet a top priority of the client (BWSC)—helping people learn about GI. However, since reducing stormwater runoff and phosphorus loading was an even higher priority, the concrete swale was connected to infiltration chambers installed underground, to ensure that the stormwater entering the concrete swale was also being treated.

Have student Infiltration Experts teach the class about their feature at this point, or at the start of the next class.

Notes:

LESSON 3.3 | What's the Impact?

Students construct an argument about whether the GI feature they have been learning about can mitigate the impact of humans on the natural environment.

Teacher Preparation

Prepare a rubric.

Materials Needed

For the class

- Any support you want to provide for constructing a written argument
- Rubric
- Claims, evidence and reasoning template (sample, *Appendix C*)

For each student

- Student notebooks
- Copy of Rubric
- Copy of CER template

Student Activity

Setting Up the Question

If any groups have not had time to explain their GI feature to the class, do so here.

Student Investigation

Ask students to construct oral or written arguments using evidence to back up their argument that GI does or does not mitigate the impact of human population growth on natural resources and the environment.

They could focus their argument on the GI feature in which they have become an expert.

In their arguments they might want to include:

- the online measurement data from the previous lesson
- how their GI feature reduces stormwater runoff
- how their GI feature reduces phosphorus pollution in the river
- any impact their GI feature has on biodiversity on land and/or in aquatic ecosystems downstream
- how water quality in the river impacts humans

Science & Engineering Practices

Engaging in argument from evidence.

Does GI mitigate the impact of humans on the natural environment?

Drawing Conclusions

Share students' written reflections.

Optional:

Ask students to look at one of two readings to answer the question: What are Sponge Cities? or What are Blue Cities? and report back.

Sponge Cities in China

The Chinese Government has launched the 'Sponge City' initiative to improve water availability in urban settlements. City authorities will use a combination of nature-based solutions (NBS) and grey infrastructure to reduce urban water-logging, improve local ecosystems, and retain urban runoff for eventual reuse.

By 2020, the 16 pilot cities will implement a range of measures, such as green roofs and walls, permeable pavements, and bioswales (constructed filtration channels) to capture water and divert it back into revitalized natural storage for irrigation and cleaning purposes during periods of drought.

The project's objective is for 70% of rainwater to be absorbed and reused through improved water permeation, retention and storage, purification and drainage, as well as water saving and reuse. This goal should be met by 20% of urban areas by the year 2020 and by 80% of urban areas by the year 2030. http://worldwaterday.org/app/uploads/2018/02/fact_sheet_WWD2017_EN_2.pdf

More *on Sponge Cities*

https://www.theguardian.com/world/2017/dec/28/chinas-sponge-cities-are-turning-streets-green-to-combat-flooding

On Blue Cities

https://www.crwa.org/blue-cities

Grade 7 | LESSON 4 | Choosing Among Competing Options

Anticipated time: (2-4) 45-minute sessions

This lesson introduces students to a Decision Matrix, one tool engineers use to help them evaluate competing design solutions. Students examine a completed Decision Matrix for the Irving School parking lot, use it to compare two different GI options, and then create their own Decision Matrix for their own schoolyard (or an alternate one for the same parking lot).

Students explore the concept that the best GI option for a particular site will depend on which criteria and constraints are prioritized. A design team may choose different GI features depending on what's most important to their client: e.g. removing the most phosphorus possible, or keeping the cost below a certain amount.

In *addition,* GI offers 'co-benefits' (increasing neighborhood biodiversity, improving air quality, and more). Some co-benefits will be more important than others at a given site. At one site, keeping or enhancing parking may be a top priority and at another, enhancing the biodiversity of the neighborhood may be more important. The choice of which GI feature to use at a given location will depend on which criteria are prioritized—by you/the design team, or 'the client'.

To choose the best GI feature for a particular location an engineer has to evaluate how well each GI feature can help achieve the prioritized co-benefits (e.g. bioretention features will provide cooling co-benefits that rainwater-harvesting systems will not). Expert groups will score their own GI features to evaluate how well they achieve the desired outcome.

Students can debate which co-benefits are most important and how much each GI feature helps to achieve those co-benefits.

Session 1 | Using a Decision Matrix

Students are introduced to one tool—a Decision Matrix—that stormwater engineers use to evaluate competing GI options for a particular location, in this case the Irving School parking lot.

Session 2 | Developing a Decision Matrix

Students create a Decision Matrix for their own schoolyard, or modify the Decision Matrix for the Irving School parking lot, to see how changing the criteria and constraints of a design challenge may affect the design solution.

Science & Engineering Standards

7.MS-ETS1-2. Evaluate competing solutions to a given design problem using a decision matrix to determine how well each meets the criteria and constraints of the problem.

Note:

The **Schoolyard Data Spreadsheet** contains an information tab with background notes explaining the basis for the automatically generated numbers in the accompanying Tables, but it is not necessary to read it to use the Tables.

Teacher Preparation

The materials used in this lesson are complex. Review them ahead of time, and decide the level at which you want students to engage with them.

Review Scenario A and Scenario B for the Irving School parking lot (*Appendix C*) including the:

- Decision Matrix
- Priority Co-benefits
- Co-benefits Score

Review Your Schoolyard Data (*Appendix E*), you will want to practice using this tool before introducing it to students.

Decide whether students will work with hard copies of these Tables or work directly with the Excel files (or give them the option to choose).

Notes:

LESSON 4.1 | Using a Decision Matrix

Students evaluate competing solutions for the Irving School parking lot, exploring the idea that there is no right answer, and that the choice depends on which criteria and constraints are given priority.

Teacher Preparation

Review Scenario A and B for the Irving School parking lot. Decide the level at which you want students to engage with the Tables presented here. At the most basic level you could just let students know engineers use tools like this to help them make decisions. You could examine the Decision Matrix without getting into how the scores in the last column were arrived at. Or you could engage students in every step of the process.

Decide what to discuss as a group, and what discussion or analysis you want student groups to engage in.

Materials Needed

For the class

- Irving Case Study Scenario A and B (to project) (*Appendix C*)

For each student

- Irving Case Study Scenario A
- Irving Case Study Scenario B

Student Activity

All of the GI features you've become experts on help remove phosphorus by filtering or reducing stormwater runoff. So how do engineers decide which ones to install where?

One way is to use a tool, called a Decision Matrix, that lays out the range of choices for a particular site. The Decision Matrix that we're going to look at is one that engineers at Boston Water & Sewer Commission actually use (somewhat modified).

First, we will look at two different scenarios for the Irving School parking lot to see how a Decision Matrix helped engineers decide which GI features would be best for this location. Then we will create a Decision Matrix for our own schoolyard (or, change the criteria for the Irving School and come up with our own design solutions for the parking lot).

Science & Engineering Practices

Asking questions and defining problems.

Using mathematical and computational thinking.

How do engineers and planners decide which GI practices to use and where?

Setting Up the Activity

1. INTRODUCE THE DECISION MATRIX IN SCENARIO A.

Start by familiarizing yourselves with the Table. Ask students to be detectives again and figure out what information they can find in this Table. What's familiar and what's not?

Identify parts of the Table that are familiar

Students have worked with the Stormwater Runoff Table for the Irving School parking lot in several lessons so the numbers in the Catchment Area, Runoff Volume, and Phosphorus columns should be familiar.

Stormwater Runoff Table

Land Cover	Catchment Area (sq ft)	Runoff Volume from 1-inch Storm (gallons)	Phosphorus (lb/acre/yr)
Roofs	-	-	-
Pavement	27,000	16,830	0.806
Trees/landscaping/gardens	-	-	-
Lawn/grass field*	3,000	224	0.014
Total	30,000	17,054	0.820

Identify parts of the Table that are unfamiliar and/or confusing.

The first column is new—but students can probably decipher that it refers to the different GI options they have been learning about.

Can they infer what the phosphorus "remaining after GI" means? (Don't discuss the numbers yet—just the column heading). And what "construction costs" means? They can likely agree that they have no idea what the last column means (Co-benefits Score). Good to know. Ignore it for now.

2. WHAT DOES THIS MATRIX TELL US?

As a class or in groups analyze the information contained in the matrix.

- What do the two "Phosphorus" columns tell us? (How much phosphorus is generated in the parking lot 'Before GI' and how much will still be generated after installing GI).
- Why is the number in the top row under Phosphorus (0.82) the same in both columns? (if no GI is installed nothing will change).
- Which type of GI removes the most phosphorus? Which removes the least phosphorus?
- Which type of GI costs the most to install? Which is cheapest?

Overview:

Two scenarios—A and B— are provided for the Irving School parking lot showing how different priorities (design criteria) lead to different GI choices.

In both scenarios, the school prioritized 'stormwater education' (about GI).

Getting more precipitation to infiltrate directly into the ground was the 2nd priority in Scenario A. Reducing impervious cover was the 2nd priority for Scenario B.

In Scenario A, the 3rd priority was not losing any parking. In B, the 3rd priority was improving air quality to counter the impact of idling buses and cars in the parking lot.

Scenario B represents the design solutions that were used at the Irving School. Because improving air quality was more important in this scenario than retaining parking spaces, the engineers took out parking spaces to make room for a bioretention feature ("bioswale") between the bus lane and parked cars. The Design Team selected tree species with waxy leaf surfaces or leaf hairs because they help remove particulate matter from the surrounding air.

3. USE THE DECISION MATRIX TO CHOOSE THE BEST GI OPTION.

Engineers, like you, whose job it is to design a solution for a particular site (e.g. the Irving School parking lot), have to meet certain criteria and deal with constraints that limit which GI features make sense. Phosphorus removal and cost are two criteria/constraints that might determine what GI you would recommend. In groups, decide which GI option you would recommend:

- if your client had only $50,000 to spend?
- if your client wanted the most expensive option?
- if the goal was removing the most phosphorus possible?

Do you think the only consideration for installing GI should be cost?

4. INTRODUCE CO-BENEFITS OF GI.

Engineers often have to consider multiple factors when they're selecting the best GI feature to install. The decision might be determined by how much money is available or by the need to remove as much phosphorus as possible. Another criterion may be 'GI co-benefits.'

We've talked about some co-benefits before. Invite *GI Expert Groups* to share co-benefits of their GI features.

Co-benefits include benefits to the ecosystem: GI can increase the biodiversity of a neighborhood by creating wildlife habitat, it can improve air quality or reduce air temperatures, or make it possible to reduce the impact of impervious land cover associated with parking lots.

GI can help solve other problems like parking (by adding parking or moving it to another location), or turning what was formerly all asphalt into green spaces for recreation or play (by increasing shade, or replacing asphalt with artificial turf). GI projects can also be designed to teach people about GI—as we saw earlier with the Irving School parking lot—or to create outdoor classrooms at schools.

However, co-benefits often compete with each other. You might have to take away parking to improve the play space. Or reduce the amount of play space to put in more plants. Which option should you choose?

To select the best GI solution the Design Team has to know which co-benefits are most important to their client.

Together these three things: removing phosphorus, cost and the priority co-benefits comprise the **design criteria and constraints;** the conditions the Design Team has to meet.

Background Notes:

Co-benefits of GI
(or Things GI Can Help Us Do, Besides Removing Phosphorus)

1. **Enhance parking**
(creating space for parking that doesn't require impervious surfaces)

2. **Remove impervious cover**
(increasing the amount of permeable land cover so precipitation can infiltrate into the ground)

3. **Create better spaces for play and recreation**
(nicer looking, cooler, more inviting spaces with less hardscape)

4. **Increase groundwater**
(increasing the amount of precipitation that is infiltrating into the ground)

5. **Increase biodiversity**
(by creating wildlife habitat)

6. **Increase tree canopy**
(providing shade, reducing air temperatures, increasing evapotranspiration)

7. **Improve air quality**
(by removing pollutants from the air)

8. **Educate people about GI**
(designing GI features that help people learn about stormwater runoff and how GI works)

As a class, look back at the Scenario A Decision Matrix.
At the top (just under "Location: Parking Lot" is a box labeled "Priority Co-benefits"—in this case: education, groundwater and parking.

The school's top priorities were: education (teaching people about GI), recharging groundwater, and preserving all existing parking spaces.

If we look at "Priority Co-benefits" we can see why these were their top priorities and what they decided not to prioritize.

Optional: Allow time for students to make sense of how this ranking was done or simply explain that the school used a process to decide which co-benefits were most important and these three things were selected.

5. USE THE DECISION MATRIX TO RECONSIDER THE BEST GI OPTION, THIS TIME INCLUDNG THE CO-BENEFITS SCORE.

Earlier you decided which GI you would choose if your only design criteria were removing phosphorus or cost. But what if you add in your client's top choice for some of the other benefits GI can offer? Does this new factor change anything?

If you take into account the last column ("Co-benefits Score") does it change which GI practice seems best for this site?

Which options got the highest score? (infiltration practices and permeable pavements both scored 70; bioretention features scored ten). If you wanted the GI practice that had the highest score for co-benefits, which would you choose (Infiltration practices or permeable pavements)?

Ask, the Infiltration and Permeable Pavement Expert Groups to weigh in: why do they think infiltration practices and permeable pavements got a high score for the co-benefits that were most important to this client (education, recharging groundwater, and parking)?

Infiltration practices and permeable pavements can both be installed without taking away any parking spaces. Both help rainwater infiltrate into the ground. Can you use them to help teach people about GI? (Ask students to defend their position). With permeable pavements, it is very likely they can teach people about GI; with infiltration practices, maybe not as easily because they are underground and not visible.

Ask groups to reconsider the best GI feature for this site, using the Co-benefits score in addition to phosphorus removal and cost.

Teaching Note:

To see how these scores were arrived at look at the GI Scoring Table on page 3. This Table uses a weighted scoring process to determine how well each GI practice would do to meet the Co-Benefits the school prioritized. You can go through this process with students step-by-step.

If you choose not to go through the process in detail just explain that the scores represent the Design Team's assessment of how much each GI option would help the school achieve the co-benefits listed as their top priorities.

The point of scoring each GI option is to underscore what students already know: that each GI feature has pros and cons. Some will help achieve a particular co-benefit and others will not.

Students could argue that infiltration practices are best for this site because:

- they are second best at removing phosphorus
- cost is in the middle, and
- they get a high score for getting the client the co-benefits that matter most to them.

Or they could argue that the high Co-benefits score for permeable pavements means that is the best choice despite the higher cost.

6. COMPARE COMPETING CO-BENEFITS: PARKING OR AIR QUALITY?

For another example of how the client's priorities can affect the choice of GI, look at the Scenario B Decision Matrix.

Note that the numbers in all the columns are the same except for the last column—the "GI Co-benefits Score." This Matrix is for the same size parking lot. Nothing has changed except that this school prioritized different co-benefits.

In Scenario B, the Co-benefits that the client cared most about were: *education* (also a priority in Scenario A), *reducing impervious cover* (to get more precipitation into the ground), and *air quality.*

How do these compare to Scenario A? (GI education is a priority in both; getting more water to infiltrate into the ground is also a priority—in this case they specifically want to remove impervious cover; but this client didn't need to keep their parking spaces as much as they wanted to improve air quality due to buses and cars idling.

Does any Expert Group think their GI feature can improve air quality? Allow them to make their case.

Which GI feature scored the highest in this scenario? (Bioretention features, at 100). Why is that? (Note: high score for Education, and improving air quality).

Now look at the GI that was installed at the Irving School. Discuss why the Design Team might have chosen the GI options they did. One answer is that they chose to put in a bioswale, with trees, to help remove particulates from vehicle exhaust in the air—a top priority of their client. This meant they had to take out parking spaces to make room for the bioswale, but that was OK because parking wasn't one of their client's top priorities. They used the side-by-side bioswale and concrete swale to help teach people about GI. Underground infiltration chambers were used to infiltrate runoff going to the concrete swale.

Notes:

7. USE THE DECISION MATRIX TO MAKE YOUR OWN RECOMMENDATION.

Optional: Ask groups to choose the scenario (A or B) for which their GI feature represents the best solution.

Construct an argument providing evidence.

Drawing Conclusions

Do groups agree?
Note that there is no one solution.

Notes:

LESSON 4.2 | Developing a Decision Matrix

Students use a Decision Matrix to evaluate competing design solutions. They learn that no single solution (or GI feature) is the correct one, but that design decisions depend on the client's priorities—or design criteria and constraints.

Teacher Preparation

Decide whether students will create a Decision Matrix for their own schoolyard or for the Case Study parking lot. If using the parking lot, use the provided catchment size but create your own co-benefit priorities.

Review the worksheets in the Schoolyard Data Spreadsheet *(Appendix E).*

Decide which steps you want students to go through and which tables in the spreadsheet you want students to complete. To increase the challenge on the Priority Co-benefits tab, students could rank all eight co-benefits. To simplify, limit them to the two to three they consider *most* important.

Materials Needed

All four worksheets used in this lesson are in the Schoolyard Data Spreadsheet (*Appendix E*).

For the class

- "Priority Co-benefits" Worksheet
- Decision Matrix

For each student group

- "Priority Co-benefits" Worksheet
- "Co-benefits Score" Worksheet for each *Expert Group:* Infiltration, Bioretention, Permeable Pavement or Rainwater Harvesting (printed hard copies or Excel worksheet)

For each student

- Access to Schoolyard Data Excel worksheets if needed

Science & Engineering Practices

Asking questions and defining problems.

Using mathematical and computational thinking.

What should the design criteria be for our schoolyard?

Student Activity

Setting up the Activity

Explain that the class is going to create a Decision Matrix for our own schoolyard (or for a school parking lot like the Irving School) to help us evaluate which GI options would be best for this location.

1. EXPLAIN THE STEPS YOU WILL FOLLOW TO CREATE A DECISION MATRIX FOR YOUR SCHOOLYARD.

1. First, we will fill in the Decision Matrix with the data we already know—the size of the catchment area we measured when we mapped our schoolyard watershed (or use data for the Irving School parking lot). (Note: entering this number into the Decision Matrix automatically tells us how much stormwater runoff and phosphorus are generated at the site).

2. Then we'll decide together which GI co-benefits are most important at our site.

3. Each GI Expert Group will score their GI feature based on how well you think it would help achieve the co-benefits we selected as top priorities (scores will automatically transfer from the GI Scoring worksheet to the Decision Matrix).

4. We'll use the Decision Matrix we just created to evaluate which GI options would be best for our location, just as the Design Team did for the Irving School parking lot.

2. ENTER YOUR SCHOOLYARD DATA IN THE STORMWATER RUNOFF TABLE.

Open the Schoolyard Data Spreadsheet and go to the Stormwater Runoff Table. Enter the size of the catchment area you identified when you mapped your schoolyard watershed (in Lesson 7.2.2).

The volume of stormwater runoff and the amount of phosphorus this area generates will be automatically calculated in the columns to the right, *and* in the Decision Matrix.

Open the Decision Matrix and locate these numbers in the Matrix.

Background Notes:

Co-benefits of GI
(or Things GI Can Help Us Do Besides Removing Phosphorus)

1. **Enhance parking**
(creating space for parking that doesn't require impervious surfaces)

2. **Remove impervious cover**
(increasing the amount of permeable land cover so precipitation can infiltrate into the ground)

3. **Create better spaces for play and recreation**
(nicer looking, cooler, more inviting spaces with less hardscape)

4. **Increase groundwater**
(increasing the amount of precipitation that is infiltrating into the ground)

5. **Increase biodiversity**
(by creating wildlife habitat)

6. **Increase the tree canopy**
(providing shade, reducing air temperatures, increasing evapotranspiration)

7. **Improve air quality**
(by removing pollutants from the air)

8. **Educate people about GI**
(designing GI features that help people learn about stormwater runoff and how GI works)

Student Investigation

1. SELECT THE CO-BENEFITS YOU WANT TO PRIORITIZE.

Open the Priority Co-benefits tab and review the co-benefits listed in the left-hand column. In groups, ask students to decide which co-benefits are *most* important for this location.

1. Identify the 2-4 co-benefits that you think should be prioritized.
2. Explain your reasoning in the space provided.
3. Assign a number (from 10-100) for the relative importance of each of the co-benefits you selected.

Have groups report back on the co-benefits they selected and why. Allow time for debate and for students to convince their peers in order to come to a class consensus on the top priorities.

Enter the agreed upon Priority Benefits in the yellow box at the top left of the Decision Matrix.

2. SCORE YOUR GI PRACTICE.

Now that we have decided which co-benefits are most important at our site, we need to understand which GI features could best help us achieve these co-benefits.

GI Expert Groups give their GI features a score by deciding whether their feature helps, hinders, or has no impact on the desired co-benefit (see instructions in Co-benefits worksheet).

If there is more than one expert group for a particular GI feature, did their co-benefit scores agree?

3. USE THE DECISION MATRIX TO COMPARE GI OPTIONS.

Open the Decision Matrix. Discuss and locate the numbers that have been automatically generated from the Stormwater Runoff Table, Priority Co-benefits and the Co-benefits Score from each group's worksheet.

Assign a different set of criteria and constraints to each group and ask them to use the Decision Matrix to come up with a recommendation for the best GI option(s), e.g.:

- You can spend no more than $___.
- All phosphorus above a certain amount must be removed.
- You must achieve one or more of the priority co-benefits.

Alternatively, give all groups the same criteria, allowing them to solve a single design challenge with different solutions.

Teacher Notes:

Students may want to revisit their schoolyard to help them rank GI co-benefits.

Consider going outside before or after groups make their recommendations for the top ranked co-benefits. Being outdoors may help the class discuss their differences, and arrive at a consensus.

Notes:

Drawing Conclusions

Groups report out their recommendations and the reasoning behind their choice. Help students observe how their recommendations vary depending on the criteria and constraints they are required to meet.

There is no one answer. Even working with the same criteria, students might come up with different solutions.

Grade 7 | LESSON 5 | Students Construct GI Recommendations for a Given Schoolyard Site

Anticipated time: (3) 45-minute sessions

PERFORMANCE ASSESSMENT

As experts in one GI feature, students prepare and present arguments to their colleagues at an engineering design firm. They are making a claim for the best place to locate this practice on a given site. Their goal is to reduce phosphorus pollution in the river and improve site conditions.

Session 1 | Developing a Claim

Student teams decide if and where they feel a specific GI feature should be located on their schoolyard and assemble the evidence they will to use to support their claim.

Session 2 | Preparing Models to Support Their Claim

Student teams prepare models that explain why the location they are recommending is the best place for their GI feature at this site and how it will impact stormwater runoff and phosphorus loading in the Charles River.

Session 3 | Making the Case

Teams present their claims to the class along with the evidence and reasoning to support their choice. The class then discusses the merits of each claim, and comes to a conclusion about which were most compelling.

Teacher Preparation

If you want to have students present their arguments to a larger "public" after presenting to the class, reach out to possible audiences ahead of time: e.g., the School Site Council, Principal and/or other members of the school community, community group or City agency.

Science & Engineering Standards

7.MS-ESS3-4 Construct an argument supported by evidence that human activities and technologies can mitigate the impact of increases in human population and per capita consumption of natural resources on the environment. ... based on examining historical data such as population graphs, natural resource distribution maps, and water quality studies over time. Examples of negative impacts can include changes to the amount and quality of natural resources such as water, mineral, and energy supplies.

Science & Engineering Practices

Constructing an argument supported by evidence and reasoning.

LESSON FIVE | Session 1 | Developing a Claim

Students develop a claim for the best place to install a particular GI feature on a given schoolyard site— their own schoolyard or the Irving School Case Study parking lot.

Where should our GI feature be installed on this schoolyard and why?

Teacher Preparation

Prepare a rubric ahead of time. See rubric on argumentative writing at: http://bpsscienceweebly.com/uploads/2/2/1/3/22/3712/argumentative_writingassessment_3_12.pdf

Student arguments should include:

- A compelling claim supported by sufficient evidence and reasoning of the best location on the schoolyard site for their GI feature.
- An explanation of if and how their feature: a) removes phosphorus from stormwater, and/or b) reduces stormwater runoff (by increasing infiltration and/or evapotranspiration).
- If and how their GI features impact biodiversity.
- Why this location represents the best design solution given the site criteria and constraints identified in Lesson 4.
- How using this feature at this location helps mitigate the impact of the increased human population on the environment and is the best means of protecting downstream ecosystems in the Charles and other waterways.
- Explain why clean water is important to people in cities.

Materials Needed

For the class

- Online Evidence Binder

For each student group

- Performance Rubric [to be developed]
- Online Evidence Binder
- Materials for developing posters, models, etc.

Notes:

Student Activity

1. INTRODUCE THE PERFORMANCE ASSESSMENT.

Scenario: The engineering firm you work for is relying on you because of your expertise in one particular GI feature.

You are meeting with other engineers to decide which GI features they are going to install at a given location (your schoolyard or the Irving School Case Study parking lot). Your team will present to the group your recommendation for where your GI feature should be installed and why. It is your team's job to convince your colleagues with compelling evidence and reasoning that your recommendation is the one the company should go with. You are making a claim, supported with evidence and reasoning, for the best location on this site for your GI feature based on a combination of:

- The benefits and limitations of the feature;
- What you know about what the site needs (criteria)—where it could be used to solve problems (e.g. flooding, erosion, lack of shade) and where it would add new value to the site (e.g. recreation, parking, habitat creation); and
- What you know about the site conditions (constraints).

2. REVIEW RUBRIC.

3. STUDENT TEAMS SELECT THE BEST LOCATION ON THE SCHOOLYARD FOR THEIR GI FEATURE.

They should base this selection on the strengths and limitations of the feature in conjunction with the site criteria and constraints provided in the Decision Matrix developed in the Lesson 4. Teams construct an evidence-based argument to support their choice.

4. ENCOURAGE STUDENTS TO USE THE RESEARCH AND DATA IN THE EVIDENCE BINDER TO SUPPORT THEIR CLAIM.

- Site maps of impervious and porous/permeable surfaces (lesson 1.3)
- Watershed models (lesson 2.1)
- Stormwater pathways/drainage area maps (lesson 2.2)
- Volume of stormwater runoff and phosphorus generated at this site (lesson 3.1)
- How much phosphorus the GI feature can remove (lesson 3.1)
- Decision Matrix (lesson 4.2)

5. CONVENE AS A WHOLE CLASS TO DISCUSS/FLAG QUESTIONS, ETC.

LESSON FIVE | Session 2 | Preparing Evidence

Notes:

Student teams prepare models and evidence to support their choice of location for their GI feature.

Teacher Preparation

None. Continuation.

Materials Needed

For the class

- Performance Rubric
- Online Evidence Binder

For each student group

- Materials for making posters and models

Student Activity

1. CHECK IN.

Check in with students before they begin work to ask if they have questions for other groups. Remind them to include the components they need in their models (see rubric). Arguments should include an explanation of how installing this feature at this location will improve water quality in the Charles River (or other local rivers).

2. TEAMS CONTINUE WORKING.

Students groups continue working on their models and the evidence to support their claims of the best location for their GI feature on this site. Encourage students to use the research and data that they have been collecting on this site throughout the unit to support their claim.

3. CONVENE AS A CLASS TO DISCUSS/ FLAG QUESTIONS.

LESSON FIVE | Session 3 | Making the Case

Notes:

Teams present their claims to the class, with the evidence and reasoning to support their choice.

Materials Needed

For the class

- Performance Rubric
- Online Evidence Binder

For each student group

- Materials they have prepared for their presentation

Student Activity

1. TEAMS PRESENT THEIR CLAIMS WITH SUPPORTING EVIDENCE.

Their goal is to convince their peers of the best place for their GI feature.

2. CONSIDER CHANGES TO YOUR MODELS.

After all teams have presented ask students: based on what you heard from other groups are there any changes you would want to make to your presentation?

Are there concepts or evidence you might use next time?

- Which claims were most persuasive and why?
- On the basis of these presentations, which recommendations should be adopted?

3. CELEBRATE YOUR CONTRIBUTION TO THE COMMUNITY.

Acknowledge the contribution of students to improving the water quality in the Charles River (and other Boston area waterbodies) through their recommendations and advocacy for Green Infrastructure.

OPTIONAL: End with the montage of photos students submitted during the unit showing components of healthy river ecosystems (i.e., plants, animals and humans benefiting from clean water in the river).

OPTIONAL: Prepare and conduct pre-arranged presentations to the "public." Options include the School Site council; Principal; other classes; or City agencies, such as Boston Water and Sewer Commission.