Stormwater and Green Infrastructure Curriculum for Boston Public Schools

Curriculum Appendix A
Resources for Teachers

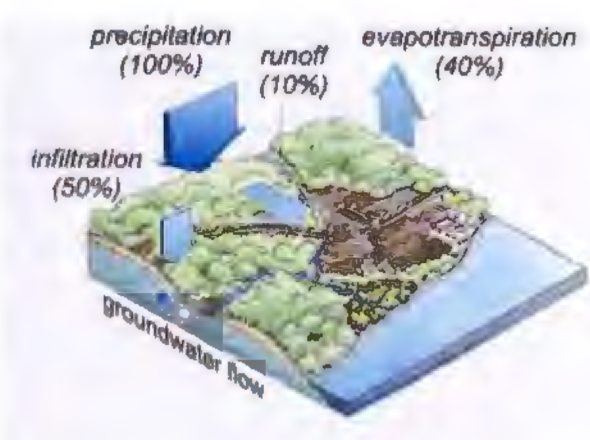
Background on Stormwater and Green Infrastructure

THE FATE OF PRECIPITATION IN THE URBAN LANDSCAPE

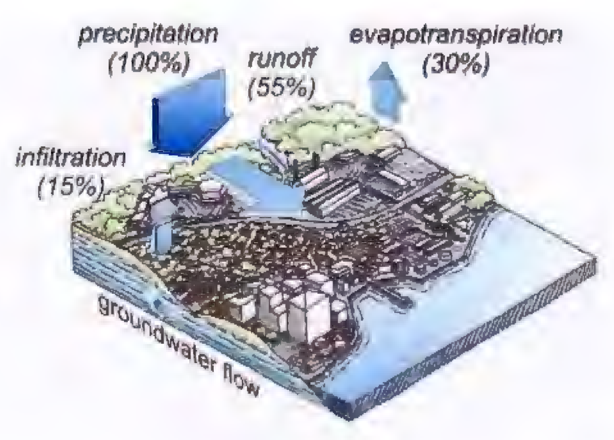
Water exists in the environment as vapor in clouds; as a liquid in precipitation, oceans, rivers and lakes, and groundwater; and as a solid in ice. **Precipitation** is the process by which water is released from clouds to the earth. Much of the rain and snow that falls on a natural, pervious landscape is recycled through infiltration and evapotranspiration. **Infiltration** is the process of rainfall soaking into the ground. Groundwater can feed rivers and lakes through subsurface flows or fill underground aquifers used for drinking water. Plants also take up a significant amount of rainfall, much of which is released back into the atmosphere through **evapotranspiration**. A small portion of precipitation is converted to surface runoff which drains directly to surface waters.

In the altered urban landscape, precipitation falls more frequently impervious surfaces such as pavement, which reduces the amount of infiltration that can occur. Also, there is less vegetation to take up precipitation and promote evapotranspiration. In an urban setting, a larger percentage of the precipitation becomes **stormwater runoff** that flows across the land surface to rivers, lakes, and oceans. Some surface water is recycled back into the atmosphere through evaporation. This alteration to the water cycle in the urban landscape leads to a number of problems, including increased flooding, water pollution, and loss of groundwater reserves.

The Fate of Precipitation in Natural Systems



The Fate of Precipitation in Altered, Urban Systems



Urbanization causes changes to the natural water cycle, specifically increases in the proportion of precipitation becoming surface runoff. Surface runoff leads to flooding, water pollution, and impacts to aquatic ecosystems.

THE PROBLEM WITH STORMWATER RUNOFF

Stormwater runoff is rainwater or snowmelt that flows over the land surface. In cities, most stormwater flows over pavement into a piped storm drain system that carries it into a body of water, such as a lake, river, or ocean. Although rain is basically clean as it falls from the sky, it can pick up anything from our streets, rooftops, and yards. Everything from oil, gasoline, pet waste, soap, fertilizers, pesticides, bacteria, and trash can be carried into storm drains and underground pipes that empty into local waterways like the Charles River. The growth of cities has had a major impact on the pollution of rivers, lakes, and oceans. Conversion of vegetated landscapes into buildings, roads, parking lots and other impervious surfaces has reduced the amount of rainfall that is taken up by plants (evapotranspiration) or absorbed into the ground (infiltration). These changes to the natural hydrologic cycle result a greater proportion of rainfall becoming surface runoff, which can lead to flooding, water quality impacts such as algal blooms, changes in river morphology, impacts to groundwater, as well as harm to aquatic ecosystems and wildlife habitats.

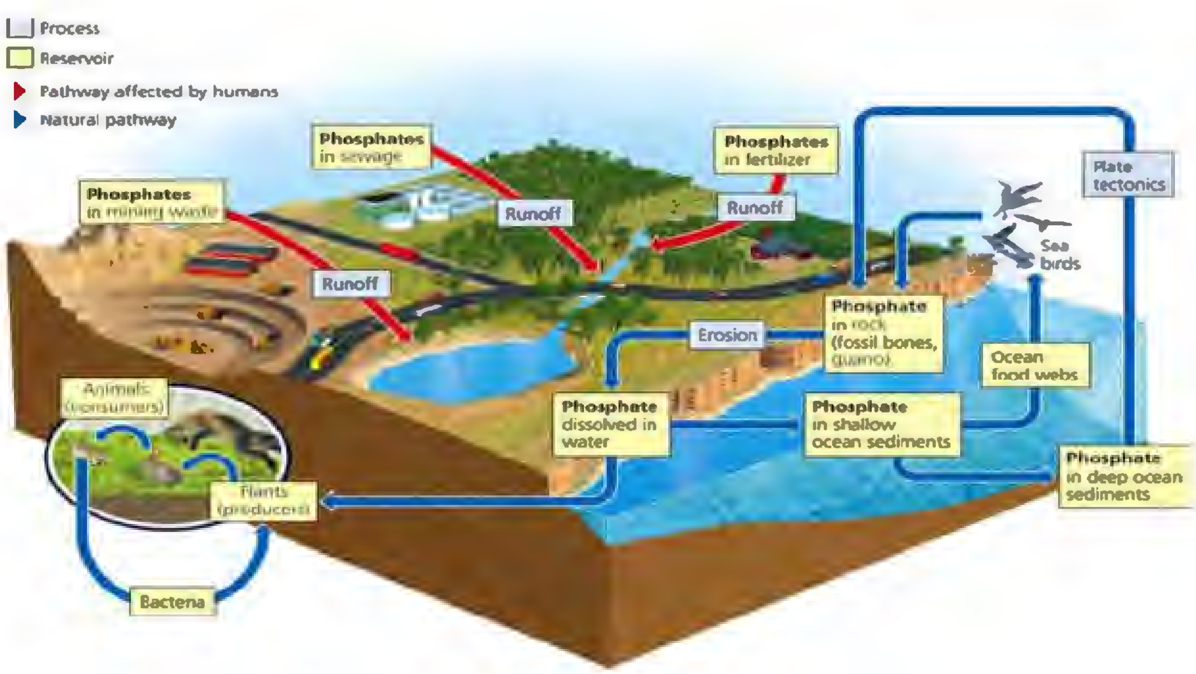
Because stormwater runoff in urban areas can cause flooding, engineers built drainage systems to get water quickly off of roads, sidewalks, and parking lots. The drainage network consists primarily of curbs, drain inlets, and underground pipes that carry flows away from buildings and roads to outfalls that discharge directly into waterways. This system of catch basins and pipes is called traditional or **grey infrastructure**. While grey infrastructure moves water away from roads and buildings quickly, it also takes away water that could be taken up by plants or infiltrated into the ground. Much of the time, pollutants in surface runoff do not get removed before dumping into the nearest waterway.

Traditional drainage management includes pipes and other grey infrastructure to get water away from buildings and roads. This leads to discharges of polluted water directly to oceans, lakes, and streams.

A BIT ABOUT PHOSPOHORUS

Excess phosphorus in a waterbody can lead to algal blooms, oxygen depletion, and fish kills.

One of the problems that stormwater contributes to is phosphorus pollution in major waterways. **Phosphorus** is a naturally-occurring chemical element that is abundant in sedimentary rock and is used by all living things to help them grow. It is normally released into the environment slowly by physical and chemical weathering or erosion. In urban environments, however, phosphorus derived from detergents, sewage, fertilizers, and oil/gas products can overload waterways. For example, when vehicles burn gasoline, they release phosphorus pollution into the air that settles onto impervious surfaces. Phosphorus pollution settling on impervious surfaces is washed off when it rains, and is eventually carried through stormwater runoff into lakes and rivers like the Charles River. An overabundance of phosphorous can trigger cyanobacteria growth, algal blooms, and hypoxia (oxygen depletion), which can be detrimental to the health of humans and animals. Some cyanobacteria can produce toxins that can be harmful to people and animals who touch or drink the water. Stormwater runoff that enters our waterways before it is cleaned can also make its way into drinking water sources, swimming areas, and fishing areas, polluting them with pathogens and other bacteria and making them unsafe for humans and wildlife to use.



Phosphorus cycle (Living in the Environment 17th ed., Miller, 2012)

MORE ON THE CHARLES RIVER

Most of the stormwater in Boston and the towns to the north and west of Boston flows into the Charles River. The Charles River runs for 80 miles from Echo Lake in Hopkinton to Boston Harbor. Historically, the river has been used as a source of power for mills as well as a way to dispose of waste products such as chemical dyes and sewage. Groups such as the Charles River Watershed Association and laws like the Clean Water Act have helped protect the Charles River from these threats. Although the water isn't clean enough to drink, fish, or swim in, it is safe for boating most of the time. Today, there are restrictions on the amount of phosphorus that can be discharged into the river. The Boston Water and Sewer Commission is tasked with reducing phosphorus loads from the wastewater and stormwater drainage system in the City. Some sewage still gets into the river during heavy rains a lot, because there are a few places in Boston that still have a combined sewage and stormwater system that can overflow to the Charles. Most of the drainage system in the City has been separated and the Commission, along with other City agencies, is investing in green infrastructure to better manage stormwater contributions.

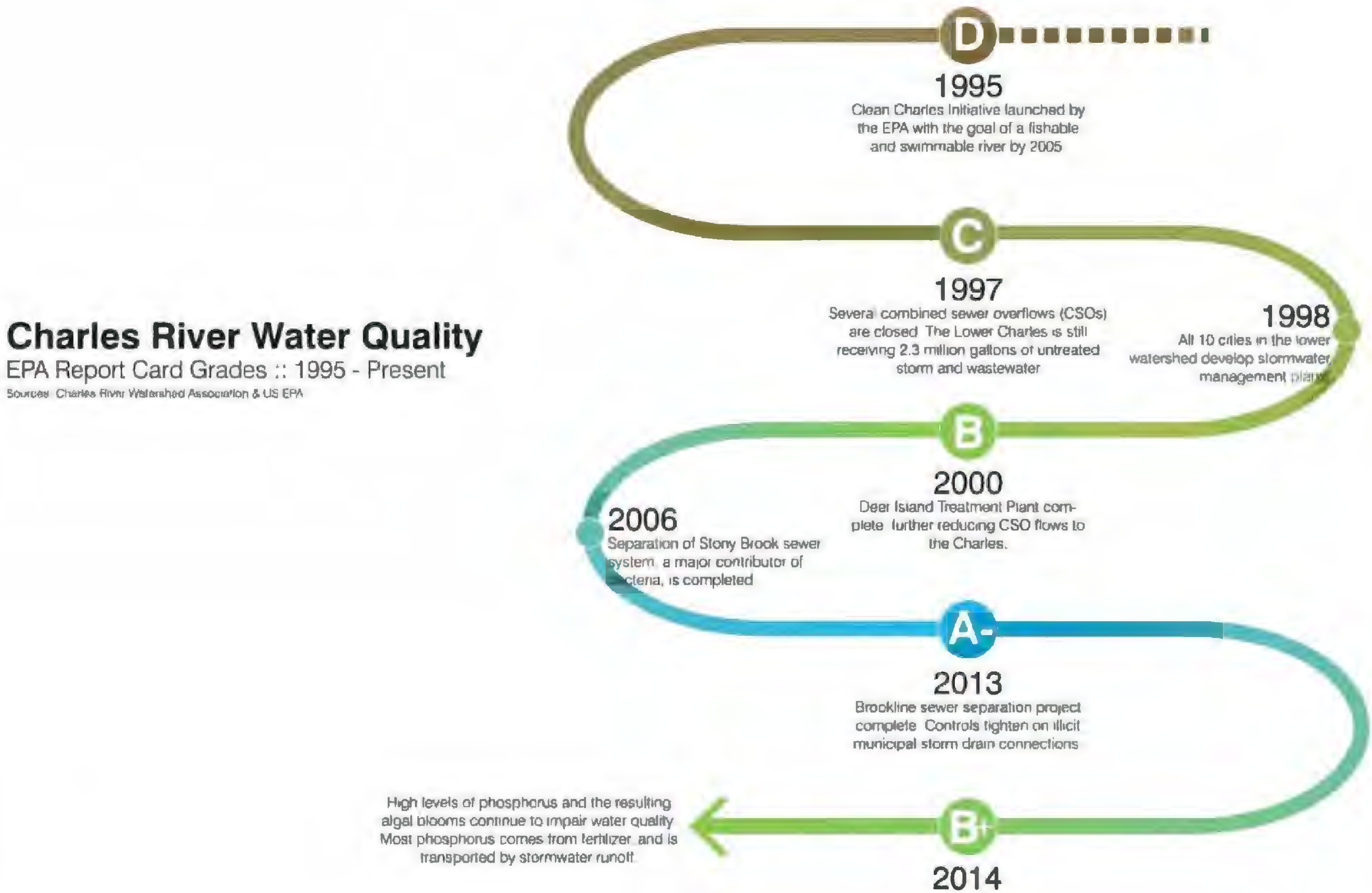
The U.S. Environmental Protection Agency has given the Charles River a water quality report card every year since 1995. The first grade was a D, which meant that the river was not safe for boating most of the time. Recently, the river has been getting B's, B+'s, and even an A- for its low levels of bacteria pollution, making phosphorus pollution from stormwater runoff one of the biggest threats the Charles River faces.

Other things we can do to help the Charles River

- Clean-up and properly dispose of pet waste;
- Disconnect runoff from your home using rain barrels, rain gardens, and other practices;
- Use phosphorus-free detergents;
- Don't wash or repair your car on the street where stormwater runoff can pick up soaps and automotive fluids;
- Use compost instead of fertilizer;
- Plant trees that can intercept rainfall;
- Help keep debris and litter out of storm drains; and
- Educate others about the impact of stormwater on the Charles River.

HOW CAN WE REDUCE STORMWATER POLLUTION?

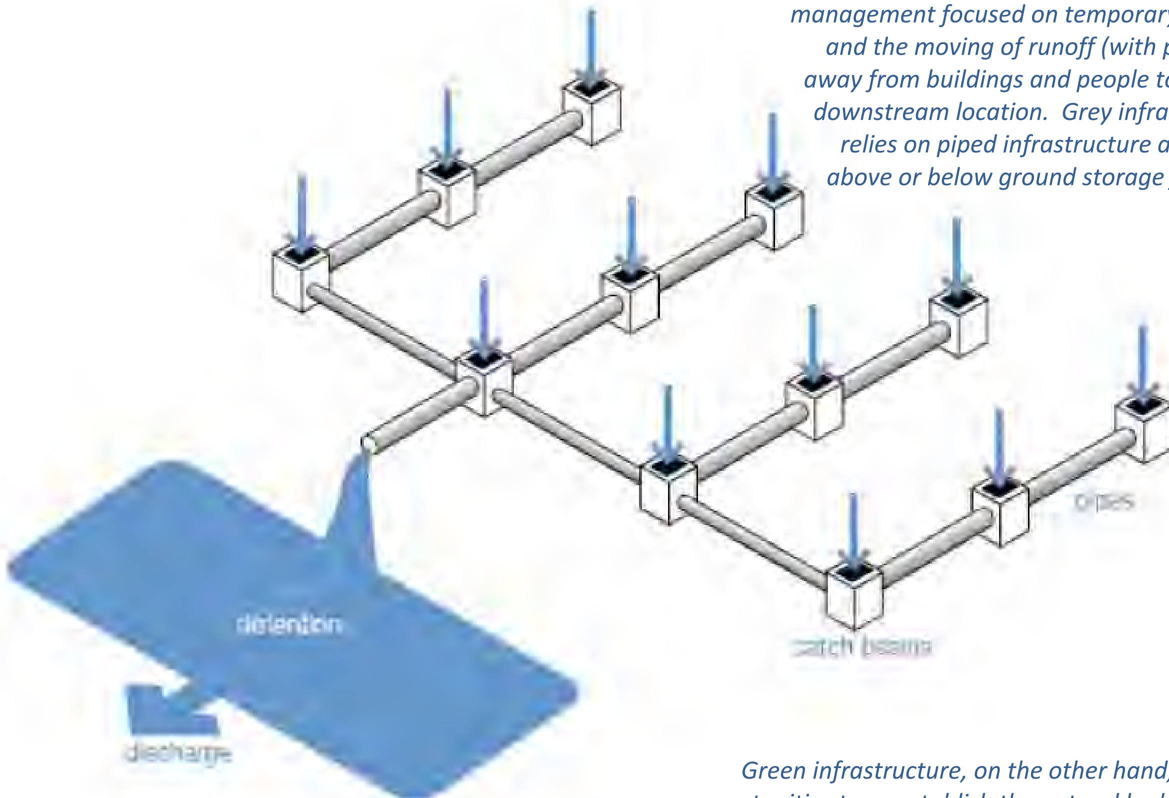
What if urban stormwater was managed in a way that better mimicked the natural cycle of water? What if we could bring vegetation back to our cities to promote more evapotranspiration? Could we create more opportunities to infiltrate stormwater and reduce the amount of polluted surface runoff going to our waterways? We can and we are through the use of Green Infrastructure (GI). Unlike the conventional grey infrastructure approach to stormwater management, GI relies less on pipes and more on plants, soil, and other engineered materials to reduce runoff volumes and filter out pollutants. Bioretention, pervious pavements, infiltration practices, and rainwater reuse/harvesting are different types of GI being used throughout the City to re-establish the balance of the natural water cycle. GI is incorporated into parks and open space, roadways, parking lots, schools, and backyards.



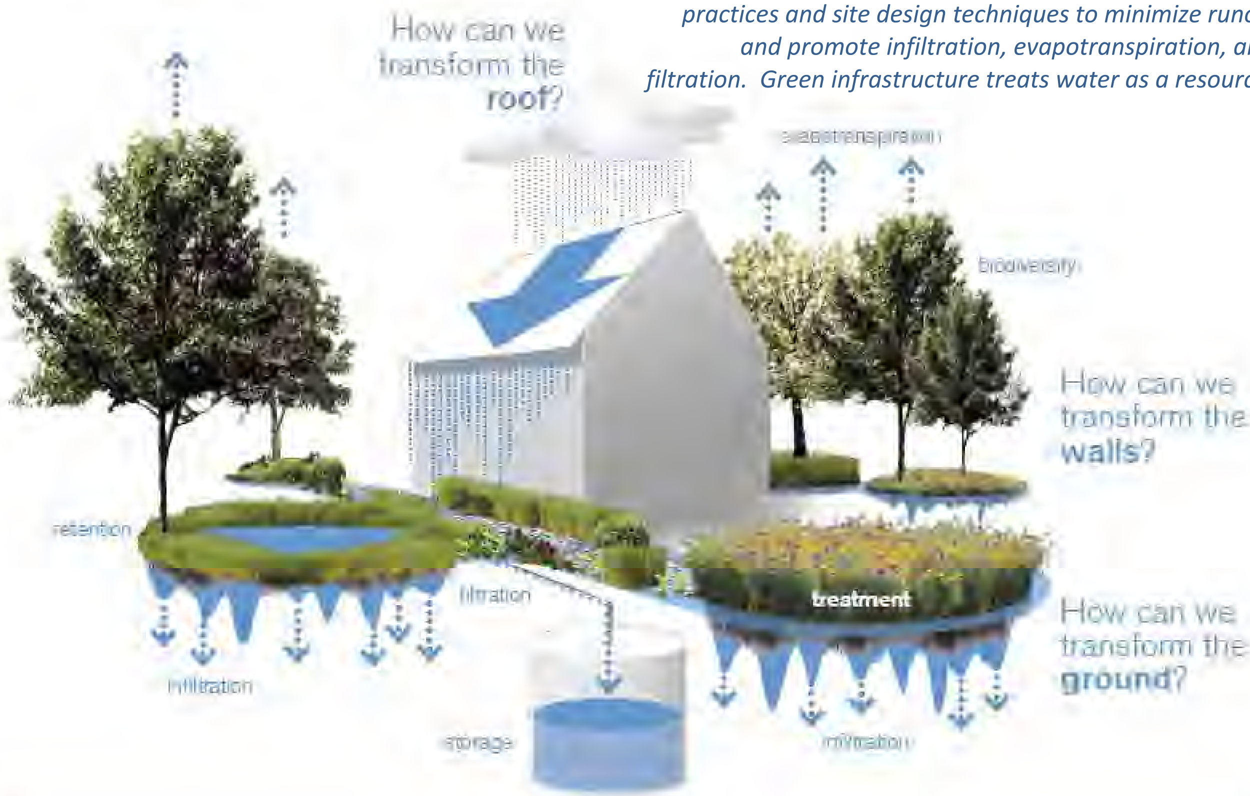
Timeline of water quality scores in the Charles River.

Graphic Credit: Offshoots, Inc.

Conventional "pipe & pond" stormwater management focused on temporary storage and the moving of runoff (with pollution) away from buildings and people to a single downstream location. Grey infrastructure relies on piped infrastructure and large, above or below ground storage facilities.



Green infrastructure, on the other hand, focuses on opportunities to re-establish the natural hydrology of an urban area. It relies on a distributed network of smaller practices and site design techniques to minimize runoff and promote infiltration, evapotranspiration, and filtration. Green infrastructure treats water as a resource.



University of Arkansas CDC, 2010

Glossary

Best Management Practice (BMP): Feature or practice used to prevent or control pollution. May include prohibiting certain activities or following maintenance procedures.

Bioretention: A vegetated depression that allows for infiltration, evapotranspiration, and cleaning of stormwater runoff using plants and an engineered soil media. Generally planted with perennials and grasses that can tolerate both wet and dry conditions. Name commonly used as a category of green infrastructure that filters runoff using plants including rain gardens, bioswales, planters, and tree filters.

Bioswale: A linear bioretention facility that cleans stormwater runoff while conveying flows from one location to another.

Catch Basin: An open or grated storm drain inlet on the ground, pavement, or curb where runoff is directed into the drainage system. Typically designed with grates, sumps, and or hoods to trap trash, debris, sediment, and oils being carried by stormwater. Also referred to as drain inlets.

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

Combined Sewer System: A system in which residential and commercial wastewater (from sinks, bathtubs, toilets, etc.), and stormwater runoff are collected and transported in the same pipe system. During dry weather, wastewater is carried to a wastewater treatment plant. During periods of heavy rain, however, the combined sewer system can reach capacity as stormwater flows into the pipes. When the pipes in a combined sewer system become overloaded, the excess stormwater and wastewater overflows into local rivers and lakes, this is called a combined sewer overflow (CSO). Combined sewer systems were the prevalent municipal sewer system prior to the 20th century and are still operating in older cities like New York, Boston, and Cambridge. These cities have been actively separating their sewer systems or enhancing capacity, in fact much of Boston has been separated.

Cistern: Any type of barrel, tank, or other container that stores rainwater for reuse.

Curb Inlet: An opening in the curb that allows runoff to enter into a stormwater practice.

Downspout: A vertical pipe that carries water from the roof of a building to the ground.

Engineered Soil: A composition of soil that does not naturally occur on site, but rather is mixed and installed for a particular purpose. For example, soils for bioretention facilities are a mostly sand with a specific amount of clay, silt, and organic matter.

Evaporation: the process of liquid water ponded on a surface converting into water vapor. If done through a plant, it is considered evapotranspiration.

Green Infrastructure: The use of soil, vegetation, and other materials to naturally manage stormwater runoff as a means of creating healthier urban and suburban environments. Green infrastructure can be implemented on a large scale, as in a large network of preserved or created natural areas that provide wildlife habitat, protection against floods, and improve air and water quality. On a small scale, the use of green infrastructure techniques like rain gardens, bioswales, rain barrels, permeable pavement mimics nature by capturing water and carrying it slowly through cities.

Grey Infrastructure: Used to characterize conventional stormwater management that relies on pipes, large above ground (ponds), or below ground storage (tunnels and tanks) for getting runoff away from buildings and people and discharging at a single outfall location. Also used in reference to underground structures designed to expanding storage capacity of a combined sewer system to help reduce CSOs.

Impervious Cover: Hard surfaces such as pavement, sidewalks, buildings, or parking lots, where water cannot flow down into the soil below.

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

Infiltration Practices: Group of engineered green infrastructure practices designed to put rainfall into the ground including underground chambers, infiltration trenches, dry wells, etc.

Native Soil: The existing soil in a particular geographic area.

Nutrient Pollution: This occurs when an excess of nutrients, namely nitrogen and phosphorus, are present in the air or flow as runoff from asphalt and other impervious surfaces into rivers and lakes, usually after heavy rains. This excess of nutrients feeds the growth of algae and potentially harmful bacteria. If a large growth of algae (an "algal bloom") occurs, it can negatively impact the habitat by blocking sunlight from reaching plants and performing photosynthesis, thus decreasing the availability of oxygen that aquatic animals need to survive.

Overflow Structure: A vertical pipe or specified outlet that allows excess water from a stormwater practice to discharge back into the drainage network or receiving water.

Observation Well: a small diameter, capped pipe at the surface that when opened, allows for observation of water level in an underground pipe network, such as an underdrain or infiltration practice.

Perforated: Pierced with holes that allow liquids or gases to pass through. Typically used to describe underdrain pipes.

Permeable Pavement/Paver: Surface such as asphalt, concrete, or paver block that is designed to allow water to pass through it.

Pervious: Allowing water to pass through it. Same as permeable and porous.

Phytoremediation: Using plants to remove pollutants from soil or water.

Plant Uptake: The process of plants absorbing water and nutrients in order to grow.

Rain Garden: A landscaped depression designed to collect and filter rainwater running off of driveways, rooftops, or streets. A type of bioretention facility, rain gardens are less engineered Rain gardens can take many shapes and sizes. Plants can be neatly manicured or more "wild" and "natural" looking.

Rainwater Harvesting: Use of cisterns or other storage tank to collect rain water for temporary storage and subsequent reuse for primarily non-potable uses (e.g., irrigation, flushing toilets).

Sanitary Sewer: A series of pipes that collects and transports only wastewater (sewage) and does not include stormwater.

Sedimentation: Suspended sediment particles that have eroded from the surrounding landscape settle out in water as the water sits in place.

Storm Drain System: A pipe system designed to collect and move stormwater only, and direct it into a nearby lake or river. Unlike a combined sewer system, areas with separated storm drain systems have accompanying separated sanitary sewer systems to carry household and industrial wastewater.

Storm Duration: The length of a storm (in hours).

Storm Intensity: The rate of rainfall (in inches per hour).

Storm Sewer: A series of pipes that collects and transports only stormwater.

Stormwater Runoff: Rain and snowmelt flowing over the land surface. Runoff picks up pollution such as excess fertilizers, bacteria and animal waste, road salt, and excess sediment and soil. This mixture often flows into storm drains, where it eventually flows into a nearby lake or river.

Structural Soil: Soil that can be compacted as needed to support a paved surface while also supporting the growth of tree and plant roots.

Surface Water(body): Water that is contained by stormwater ponds, rivers, lakes, estuaries, bays, dams, wetlands, oceans.

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.

Underdrain: a perforated pipe installed at the bottom of a stormwater practice that can drain excess water if infiltration is slow.

Urbanization: land development that results in conversion of natural or rural areas to residential, commercial, and industrial uses, etc. Generally, results in loss of vegetation and increased impervious cover.

Urban Infrastructure: A structure or system that supports the urban environment. Examples: Roads, bridges, buildings, water distribution, sanitary and storm sewers, stormwater pond, electricity transmission lines, cable and internet.

Wastewater: Water that has been used by people for washing, flushing, manufacturing etc. Sewage is a type of wastewater.

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 different watershed scales.

Directions for Printing a Site Map of Your Schoolyard

You have 3 options for printing a site map of your schoolyard. Print your school site maps before beginning the unit, or engage students in printing them as part of the unit. Detailed steps are provided below.

1. Boston Water & Sewer Commission's Education page is the simplest.
2. Google Earth gives you the added ability to take measurements using lines and polygons drawn on your map.
3. MassGIS Online provides aerial imagery, parcel, topography, and soils information. Streams, wetlands, watersheds, and other information may be of interest to students.

1. Boston Water & Sewer Commission

Go to BWSC stormwater website where large PDF maps of the city will be posted for your use. These maps will include aerial images, property boundaries, topography, and soils. You will need to identify the Map Tile your school is located on and then download that tile. From there you can locate/zoom to your school site, take a screen capture and print. More instructions will be available on the BWSC website.

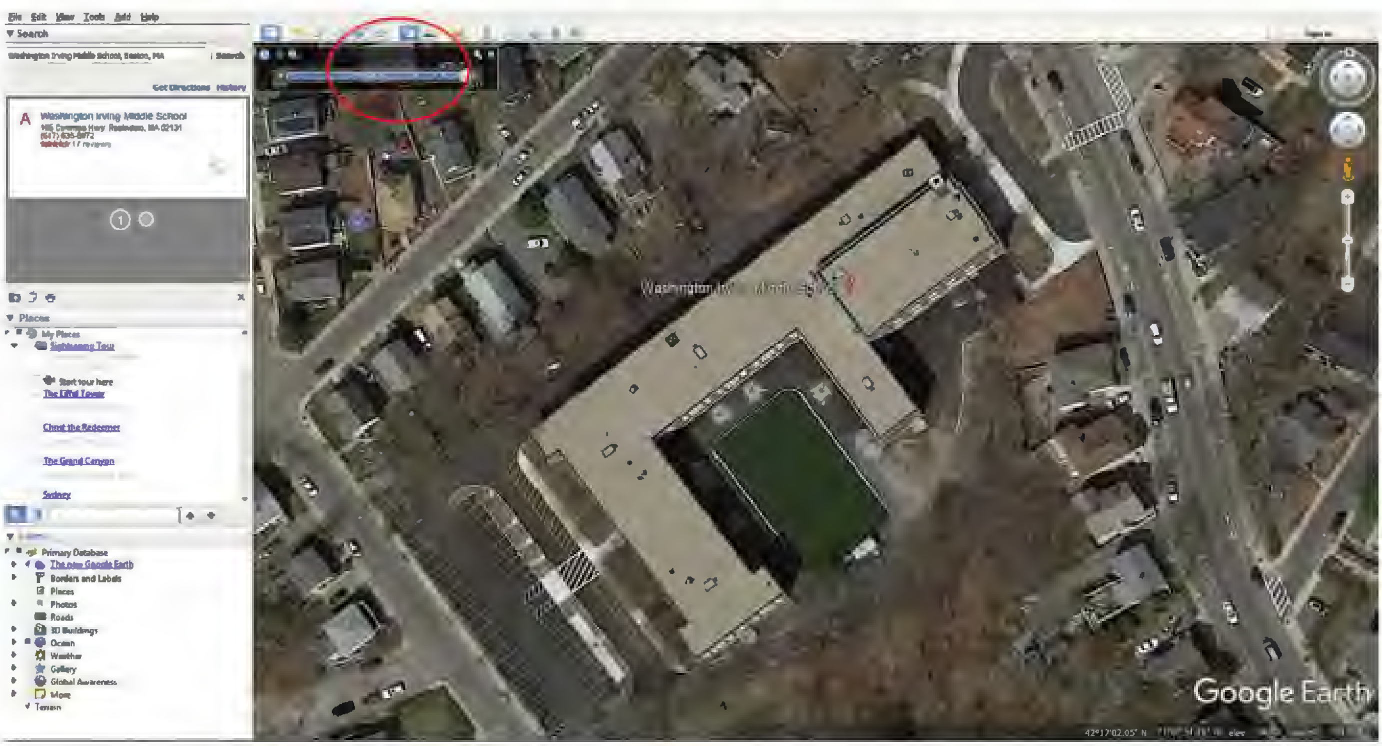
2. Google Earth

Use google maps (or google earth) to find your school. Google Earth pro version offers you the ability to take measurements of lines and polygons drawn on your map, which would be helpful in calculating the size of drainage areas and land cover types. Go to Google Maps: https://www.google.com/maps

Step 1. Type the name or address of your school into the search bar in the upper left-hand corner of the window. Be sure to include the city and zip code.

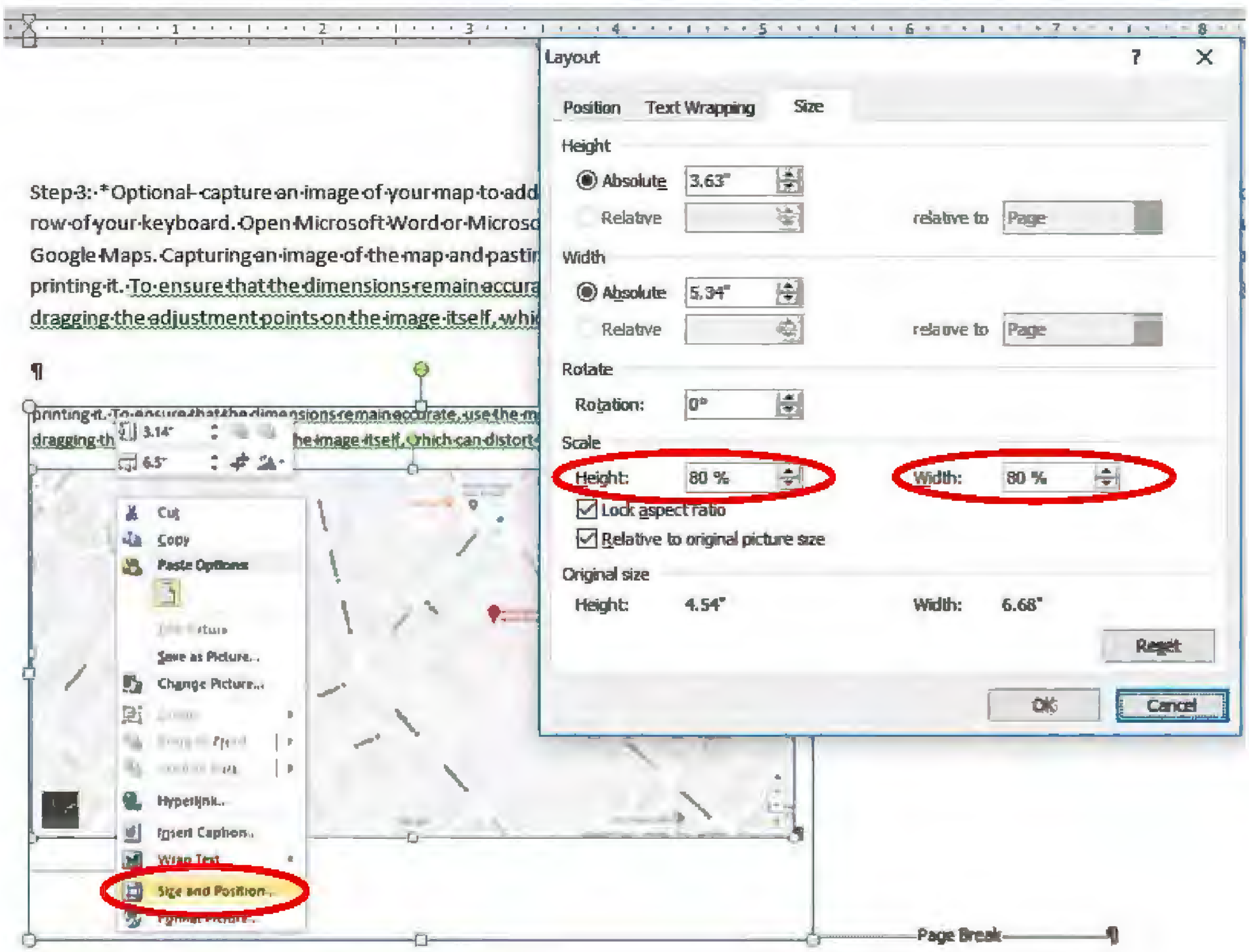
Step 2. Adjust the zoom level to see the entire school property using the scroll button on your mouse or the plus and minus symbols in the lower right-hand corner of the window. If necessary, use the arrow to the right of the address search bar to collapse the search panel so that the entire map is visible. Note that if you use Google Earth, you often have more aerial option years to choose from.

This screen shot from Google maps shows an aerial taken prior to GI construction in 2017.

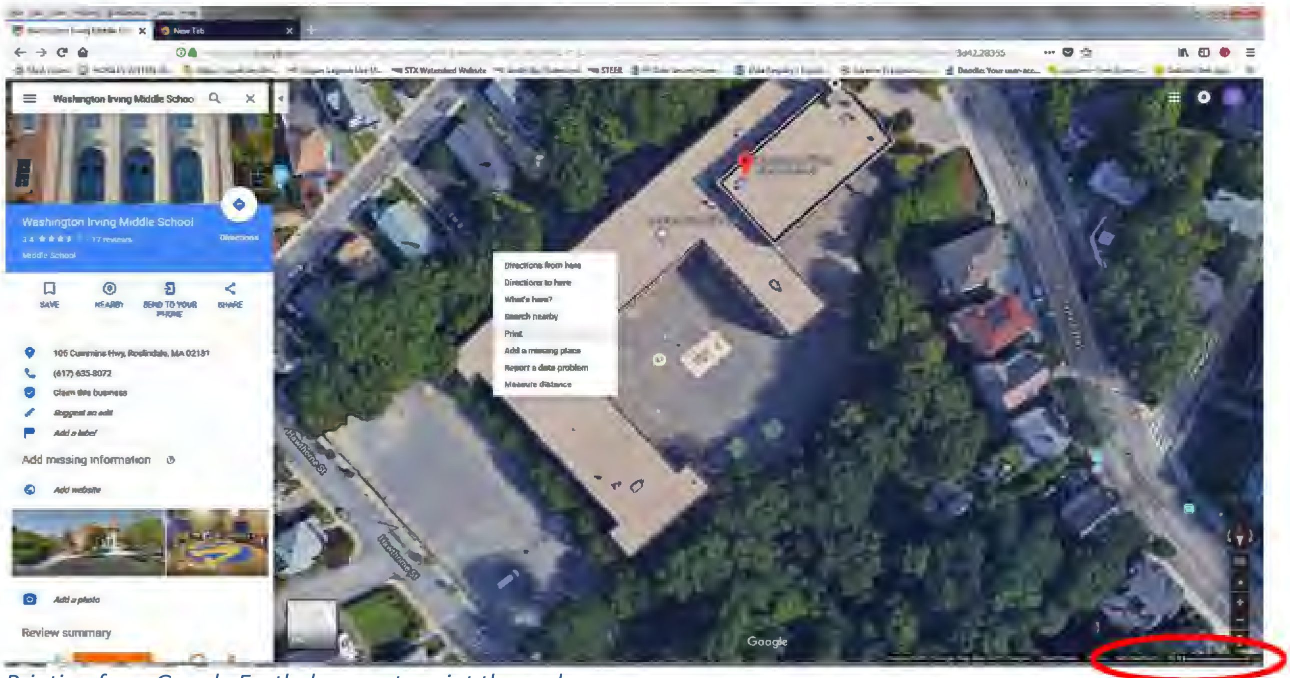


This screen shot from Google Earth shows the most recent aerial imagery that was taken after GI construction in 2017. You can select the "history" button and select past aerials as well (red circle).

Step 3. Optional- capture an image of your map to add to a worksheet or Powerpoint presentation by pressing the Print Screen key on the top row of your keyboard. Open Microsoft Word or Microsoft Powerpoint and use the “Paste” function to insert the screen capture you just made in Google Maps. Be sure to include the scale. Capturing an image of the map and pasting it in a Word document or a PowerPoint slide allows you to crop the image using the “Format” menu in the toolbar before printing it. To ensure that the dimensions remain accurate, use the menu that appears when you right-click on the image to resize it rather than dragging the adjustment points on the image itself, which can distort the dimensions of the features on the map.



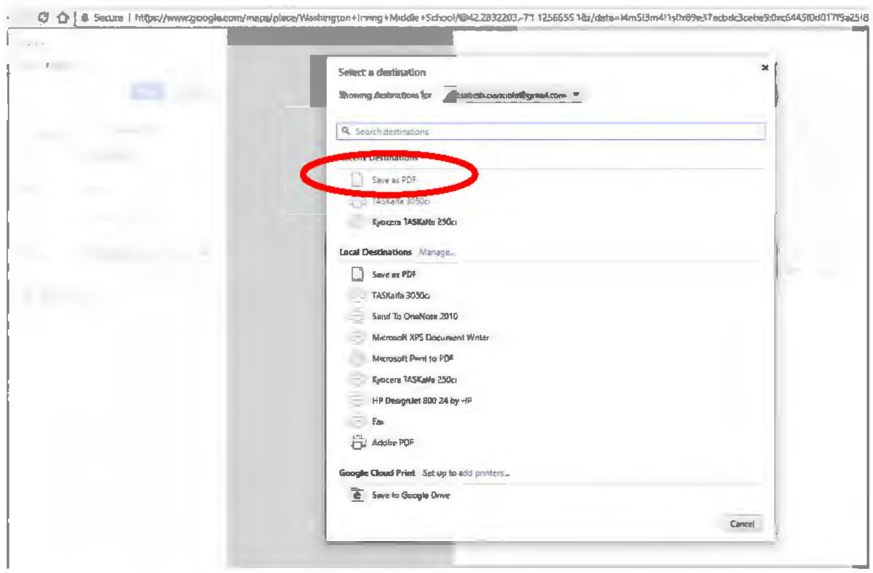
Step 4. Print the map for students to use from Google Maps by selecting, "Print" from the menu that appears when you right-click on the map. Your students will be able to use the scale bar in the bottom right corner of the image to measure lengths and distances on the map.



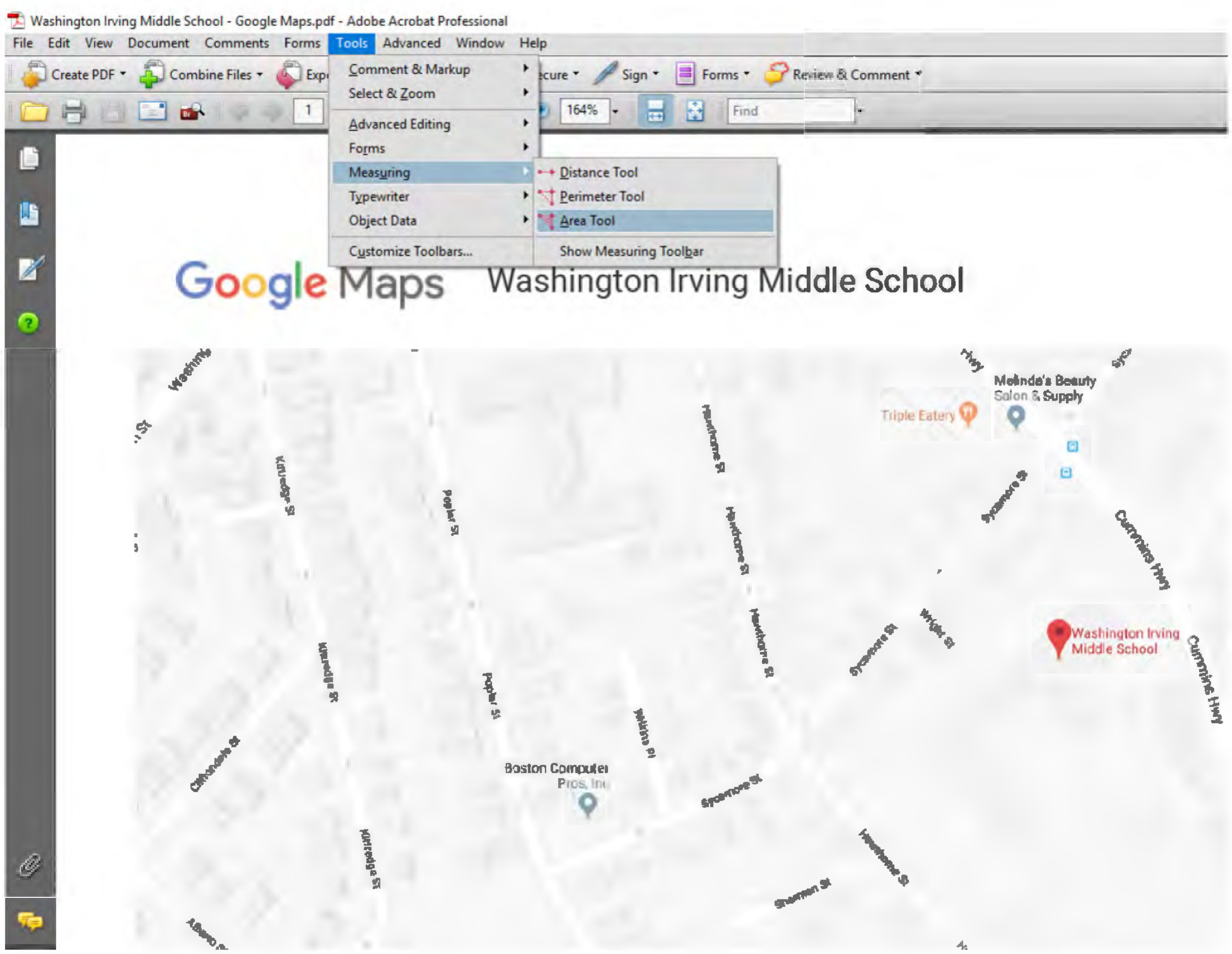
Printing from Google Earth, be sure to print the scale.

Print from Google Earth by clicking on the printer icon in menu bar.

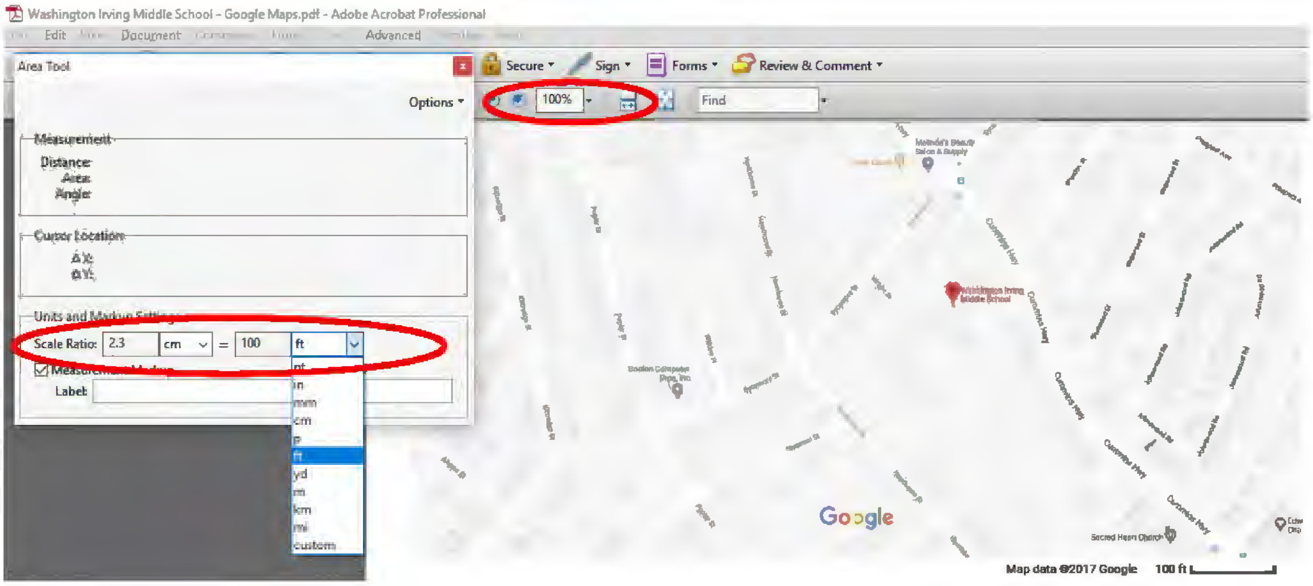
Step 5. Save your map as a PDF file. To do this from Google Maps, right-click on the map and select “Print” from the menu that appears and click the “Print” button in the upper right-hand corner of the window, as you did in Step 4. Instead of using your printer, choose “Save as PDF” in the subsequent menu. You will then be able to choose the location where you would like to save the map and change the map title.



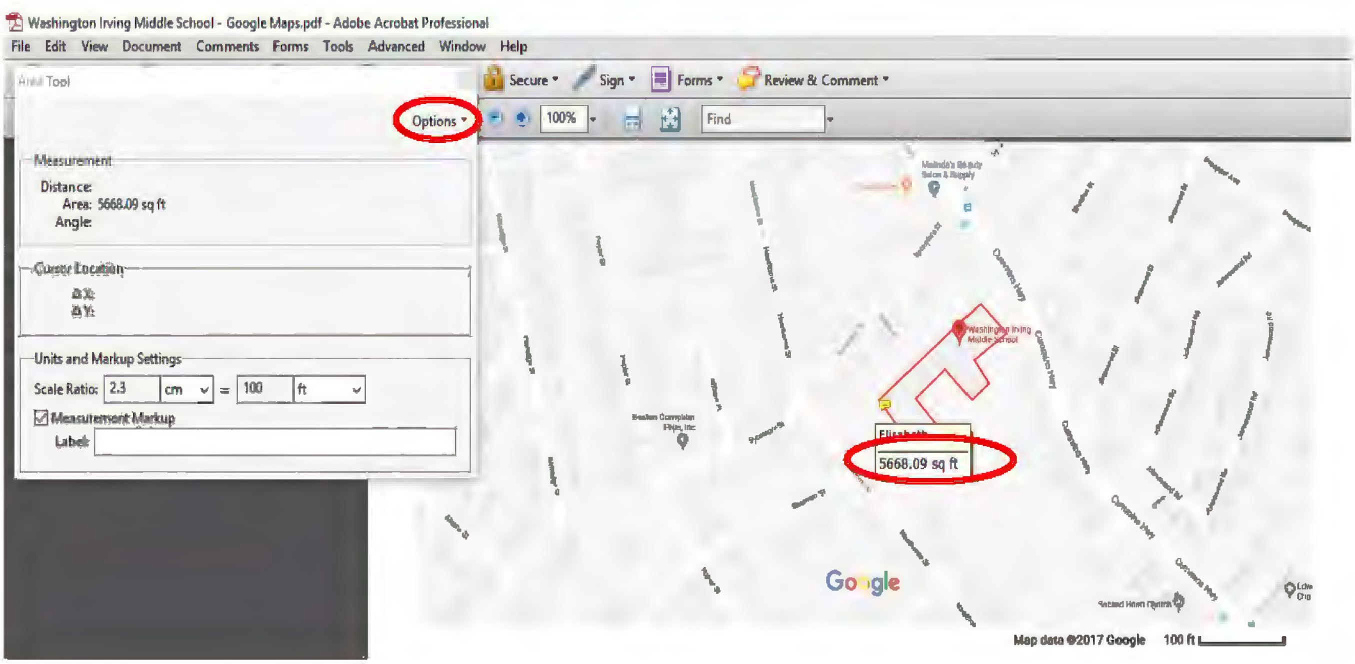
Step 6. To have your students use Adobe software to measure areas, have them navigate to the file location of your map and open it using Adobe Acrobat Professional. In the toolbar, open the “Tools” menu and select “Measuring,” then “Area Tool.”



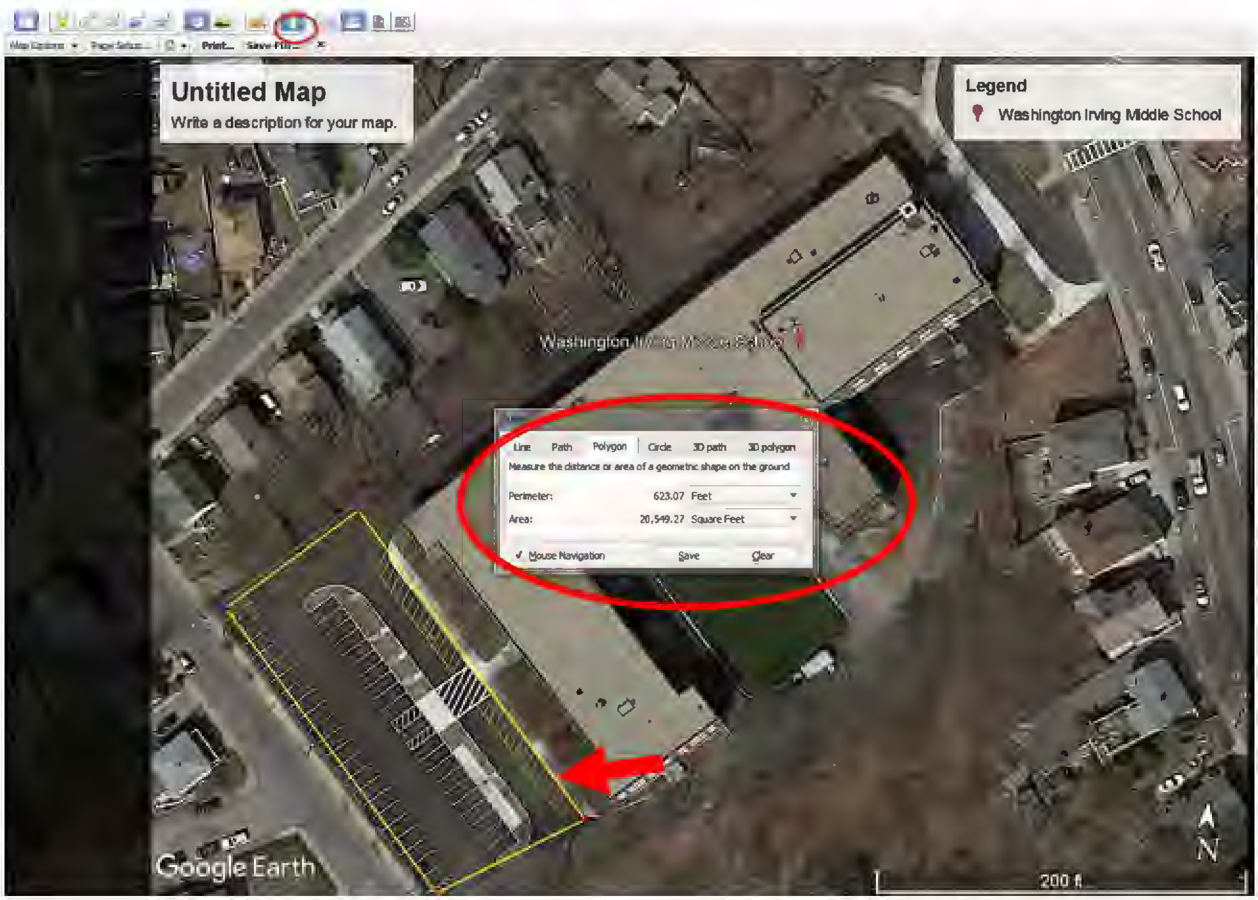
Step 7. When the Area Tool window appears, have students measure the length of the scale bar on the map (at 100% zoom) and enter the measurements in the Scale Ratio.



Step 8. Use the plus sign cursor that appears to trace around a straight-edged feature on the map, such as a school building or parking lot. You will need to click once in order to trace around each corner and click twice in order to close the polygon. Adobe will then create an annotation that calculates the area of the polygon. You can export the annotations to Microsoft Excel using the Options menu in the Area Tool window for ease of summing areas of various shapes.



Note: If you are using Google Earth, you can draw polygons and make measurements without saving as a PDF. Click on the measuring tool in the toolbar, select line or polygon in the ruler menu, and use the cursor to draw your area to be measured. You can change the unit of measurement in the ruler menu.

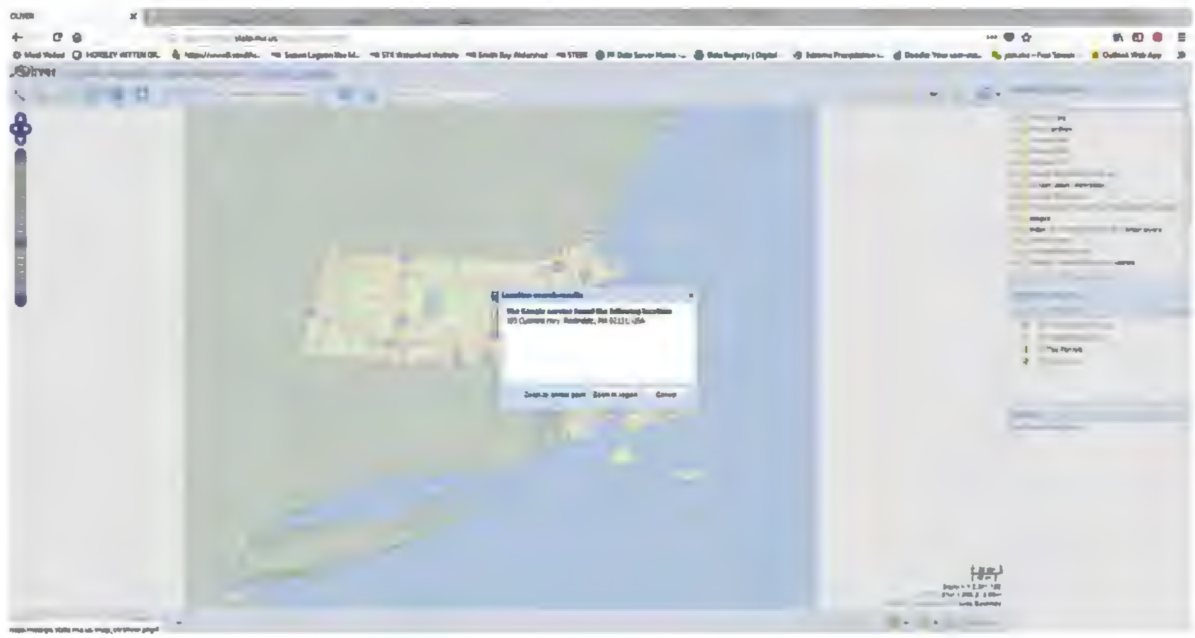


3. MassGIS Online

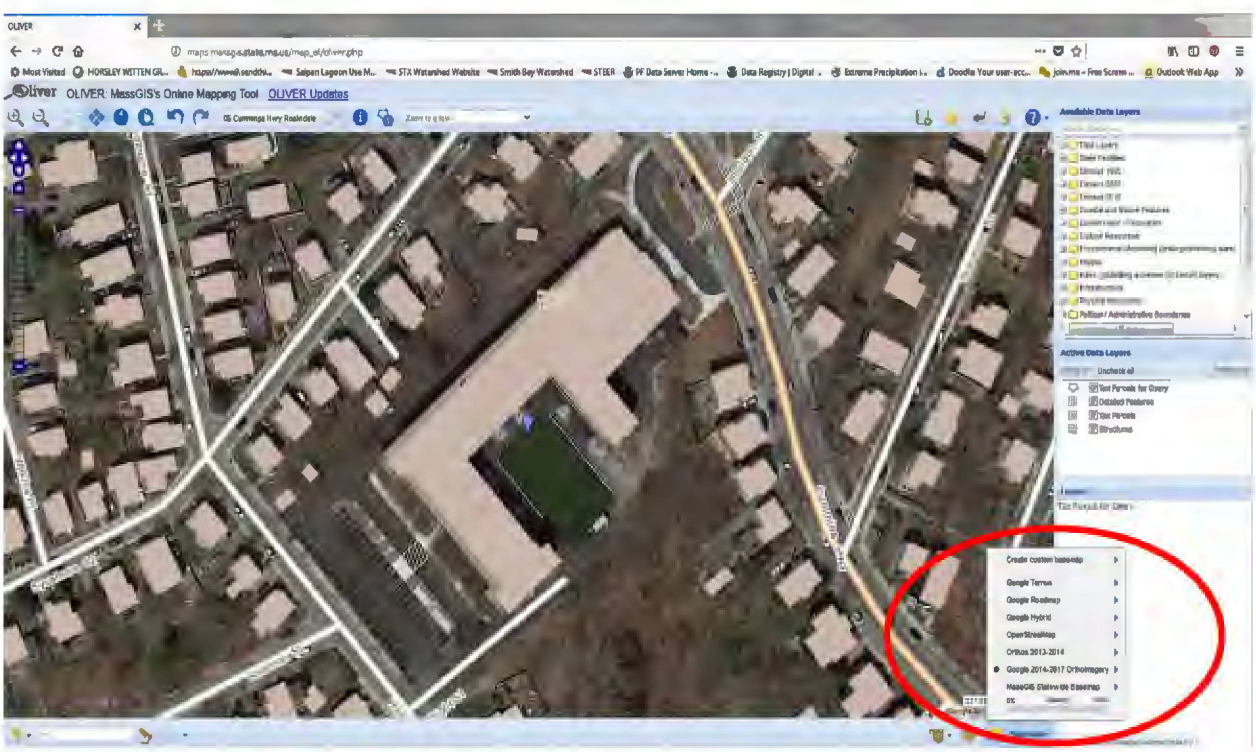
You can go to MassGIS Online, which provides access to many different types of mapping information that can be further explored by students. At a minimum, you will want to use the aerial imagery, parcel, topography, and soils information. Streams, wetlands, watersheds, and other information may be of interest depending on where your school is located.

Step 1. Go to https://www.mass.gov/get-a-map, click on the Open OLIVER interactive tool (or just go to http://maps.massgis.state.ma.us/map_ol/oliver.php).

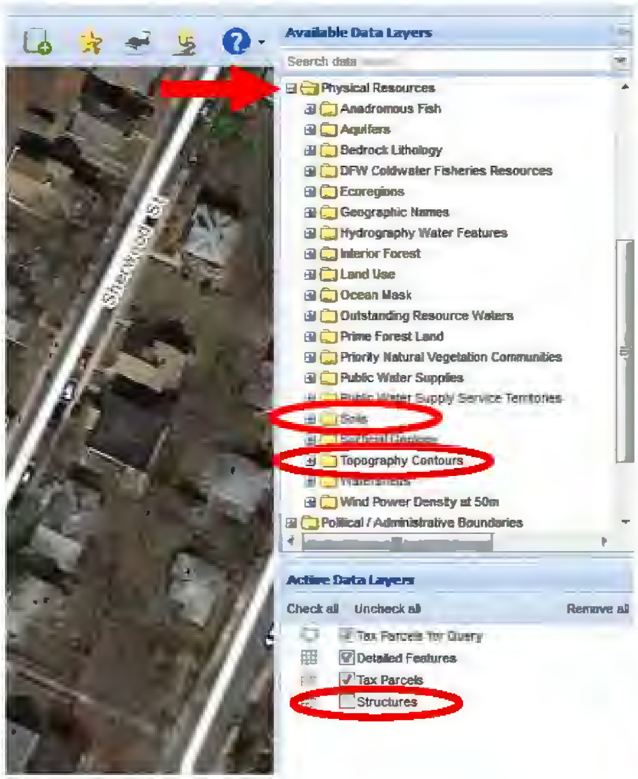
Step 2. Enter the address and town of the school. And zoom to that location

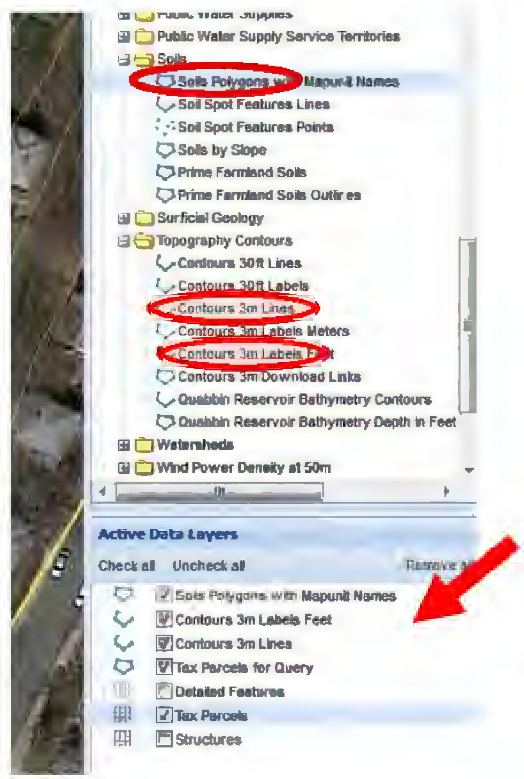


Step 3. Go to bottom right and select basemaps. Choose the image you want, most likely the most recent date.



Step 4. In the column on the right, turn off "structures" layer by unchecking the box in the Active Data Layers menu. Search through the Available Data Layers menu for the Physical Resources folder. Open that folder and find the soils and topography folders. Click on soil polygons and 3m contour lines and labels. These layers will be moved into the Active Data Layers for your map.





Step 5. You can print or save your map your map using the print button or File menu in the top left. Or you can just do a screen capture (make sure to get the scale). You cannot take measurements in the Mass Online map.

Guide to Outdoor Teaching and Learning

Tips for Outdoor Teaching

If you haven't taken your class outdoors before, consider these tips:

1. Choose a special gathering place outside where you begin and end each lesson. Begin by reiterating (or eliciting from students) the instructions you gave indoors, and debrief before going back in.
2. Decide ahead of time what routines you will use for getting in and out of the building. You may want to practice these routines once or twice before beginning these investigations.
3. Consider using a different door than students use at recess.
4. Every student should have a notebook or clipboard and pen or pencil, and/or the supplies they need for the investigation.
5. Carrying supplies may help students take themselves and the task more seriously.
6. Assemble a bucket of tools that you take out each time, which students can elect to use on their own to answer questions that arise (sidewalk chalk, tape measures, string).
7. Consider building in an initial lesson in which students are largely getting oriented to the outdoor environment—perhaps conducting a scavenger hunt or mapping activity—and learning outdoor routines. Their task may be simple, and the time outdoors, brief. In your mind this may be a "practice" lesson, but don't identify it as such.
8. Working as field scientists requires dressing for the weather. Alert them a day ahead of time that you will be going outdoors, and discuss appropriate clothing. Going out in the rain is one of the best ways to learn about stormwater runoff. Rain jackets and boots will be useful of course, but not all students will have them. Some teachers keep a few extra ponchos on hand.
9. Engage students in figuring out how to conduct research in the rain. They are scientists studying rain, what strategies can they come up with? Someone (you or several students with an umbrella and cell phone) could take video of water flow; some things can be observed out the window, some might require getting wet.

See Online Support for Outdoor Teaching at BPS Science Department

Suggested Field Experiences

- Visit the river closest to you (Charles, Neponset or Mystic) to give students firsthand experience of a river ecosystem (to kayak, muck about, or collect data in the field).
- Visit examples of green infrastructure around town.
- Follow water downhill from your school until you reach a body of water. Invite students to determine the water body closest to the school.
- Visit the Waterworks Museum and Chestnut Hill Reservoir
- Visit the Boston Water and Sewer Commission

Drainage Detectives: Tips for Creating a Schoolyard Watershed Map

As Drainage Detectives students create a watershed map of their schoolyard identifying smaller watersheds (aka catchments, or drainage areas) within it.

Use the tips below to help students plan and develop an investigation of the path stormwater runoff takes on their schoolyard. Each school will be different, but these basic tips should help with most sites. Remember it's ideal to observe water flow when it's raining. Engage students in figuring out how that could be done.

Key to their investigation: surface runoff flows downhill. A watershed is the total upland area that drains to a given low point.

1. Orient students to the aerial site map of the schoolyard.

Your map may have topographic contours showing elevations, but that is not necessary. Being outside, you can see how the topography changes.

Identify the boundaries the students are restricted to for this activity (i.e., the property line, parking lot, or back of school). Depending on number of students, size of area to cover, etc., assign groups to different parts of the schoolyard. They will report back on their section to create a schoolyard watershed map.

2. Look only at surface flows.

Just look at surface flows and assume that stormwater going into an inlet structure goes directly to the City's drainage system (unless there is an obvious connection to GI). If you want to take it up a notch, see more sophisticated drainage detectives below.

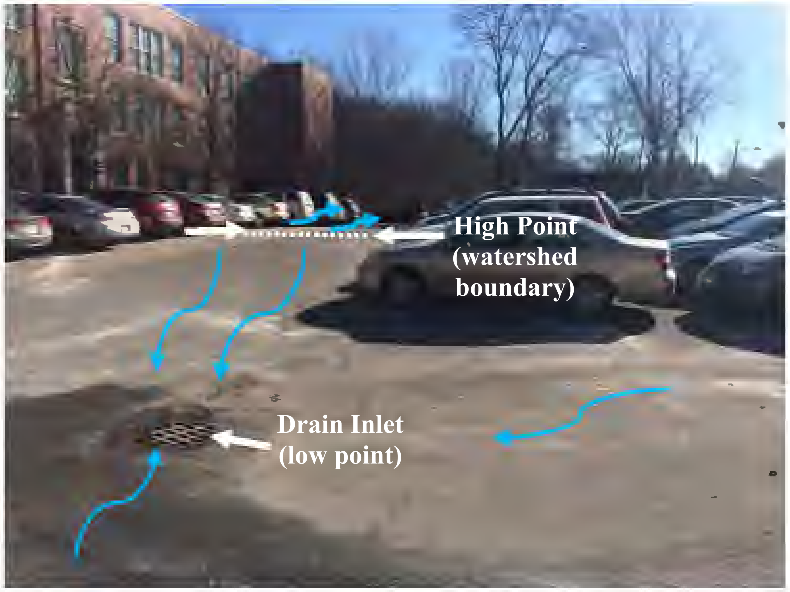
3. Identify the obvious low points.

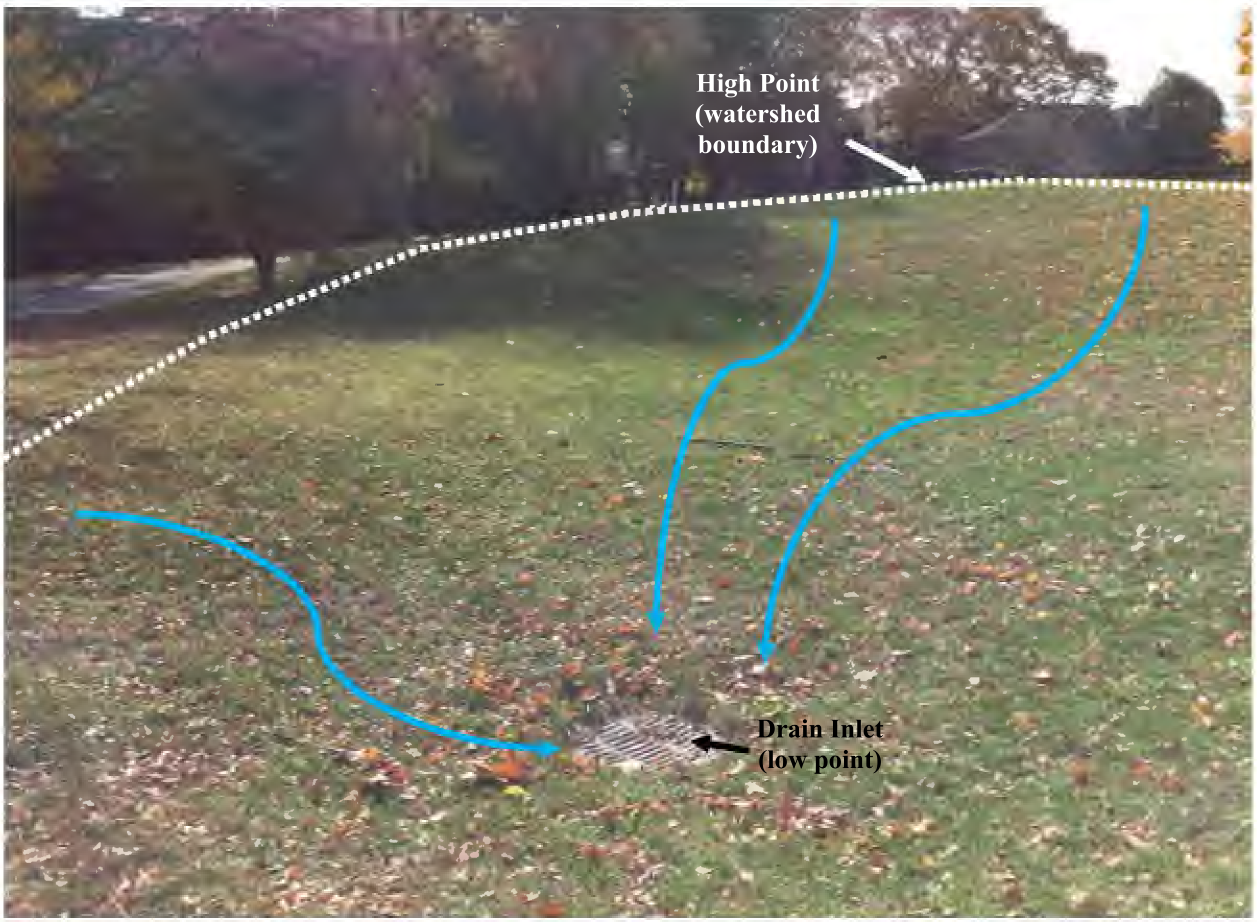
Encourage students to find and map visible drain inlets/catch basins. These could include:

a. flat, open grates in the pavement or in the yard (solid manhole covers are not inlets unless they accept surface runoff);

b. curb inlets that direct where rain goes; or

c. swales, curbing, curb cuts, or other features that direct surface flows to low points such as the street or grassed areas. Not all sites have a formalized drainage infrastructure (i.e., no catch basins).





Being outside is really the best way to identify individual drainage areas/watersheds at your school. Look for low points and high points, starting with drain inlets.

4. Delineate watersheds for each inlet/catchbasin.

a. Stand on top of the inlet and look around. Inlets are located at a lower elevation than their immediate surroundings—at the bottom of the "watershed bowl." Each inlet collects runoff from its individual watershed. Parking lots are good places to see this since most are visibly pitched to improve drainage. This might be hard to see if parking lot is full of cars during the school day, unless the inlets are in the middle of the drive aisle.

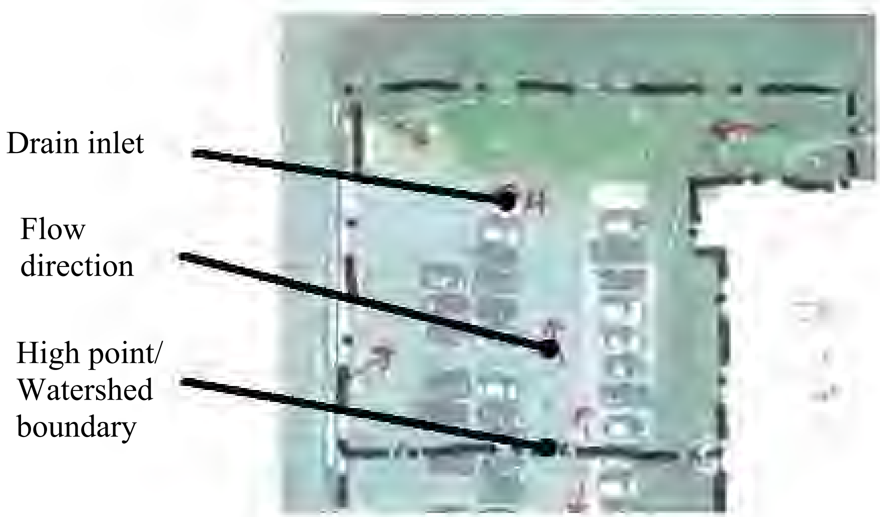
b. Imagine it was raining. What is the furthest distance from the inlet that rain falls and comes your way? Students could find and map the "rim of the bowl" around each inlet by walking outward in all four directions. They should be looking for high points in elevation, or the watershed divide where runoff drains to the inlet on one side of the divide and towards a different direction on the other side.

c. If your site is relatively flat, eyeballing high points and flow paths can be challenging. Students could look for staining that might indicate flow lines. Or use a tennis ball, or level, or hook up a garden hose to help determine which way the ground slopes.

d. Mark the high points around each inlet on the map with a dot. Connect the dots; this is the watershed boundary for each inlet. Draw flow arrows indicating the flow path runoff takes from the top of the watershed to the inlet at the bottom.

e. Look for roof downspouts. If you don't see any, then the roof probably has internal drains and ties into the drainage system underground. If you do see downspouts, be sure to account for their discharge when considering the watershed boundary. Depending on the quality of your aerial map, you may have to make some assumptions about the shape and size of rooftop areas.

f. Repeat for all inlets.



Use aerial maps to mark low points and high points. From here, you can draw flow directions and drainage boundaries.

5. **Identify other low points and their watersheds.**
   a. Not all low points are drain inlets. Some low points are locations where water ponds, vehicle entrances where runoff flows out onto street, or cuts in curbing where runoff goes into landscaping, grass, or an obvious stormwater management practice—i.e. GI.
   b. Look at your map. Where do areas outside of the previously delineated inlet watersheds drain?
   c. If your school is by a surface stream, maybe there is an outfall pipe that discharges directly to the stream.

Sometimes, surface drainage doesn't go to a drain inlet, rather it flows directly to street or off-site through driveways or through curb cuts into landscaping or stormwater practices.

6. **Take it up a notch.**

You may be able to map the underground drain pipe network, which is cool. This will require getting your hands-on school site plans and/or opening up inlet and manhole covers to look for pipe connections. The lowest pipe in a structure is the one that drains out. Some manhole covers indicate junctions between stormwater drainage pipes (connections between drain inlets), but some are sanitary sewer. You can't always trust what is written on the lid, but you can generally tell by the smell and dry weather flow.

In general, pipes are straight (connect directly from one structure to another) with manholes located at junctions and turns. It is fun to open these to show kids the amazingly complex underground piped network. However, only do this with the school's facility managers and test it out in advance. If due for cleaning, inlets and manholes can be full of water/clogged and you won't be able to see anything. You'll need a crowbar or pick axe to open. Be sure traffic won't be a problem.

Popping manholes can be a fun exploration for older kids as it provides insight into runoff volumes and flow directions during or after rain events, and helps students to better understand the engineering of an underground pipe network.

Professional Development Recommendations

Professional development will be important for this unit. Teachers recommended a one-day session prior to the start of school held at one of the 5 BPS GI Pilot schools with green infrastructure on site. Ideally it would include the following.

1. **Review and discuss**
   a. Lesson content
   b. Opportunities for autthentic argumentation
   c. How to maximize community engagement opportunities

2. **Background Knowledge**
   a. The Charles River: its polluted past, landmark clean-up efforts, and current water quality challenge: algal blooms due to excess phosphorus.
   b. Phosphorus; a natural element, essential for plant growth; but the natural phosphorus cycle altered by humans leads to phosphorus overloading severely damaging aquatic ecosystems in urban waterways.
   c. Stormwater runoff: a result of urbanization and changes in land cover leading to stormwater runoff-- the biggest water pollution problem today and the primary cause of phosphorus/nutrient overloading.
   d. Green infrastructure: engineering solutions that replace traditional grey infrastructure (pipes) with features that use the natural hydrological cycle and properties of plants to manage and clean stormwater runoff.

3. **Schoolyard Data Collection**
   Conduct data collection on the PD site replicating the steps students go through to analyze their schoolyard. Identify how these activities will be different at GI and non-GI sites. Map the schoolyard watershed; calculate the area of one catchment area and use it to determine stormwater runoff, and phosphorus load generated by that area. Prioritize site needs; and score the ability of different GI practices to meet these needs.

4. **Outdoor Teaching and Learning**
   Activities should model successful strategies for taking learning outdoors, and give teachers a chance to develop outdoor protocols to use with their students.

5. **Opportunities for authentic argumentation about stormwater and/or GI**
   Teachers should use evidence collected on-site to persuade their colleagues to agree with their position and arrive at a conclusion as a group. (see Argumentation Chart)

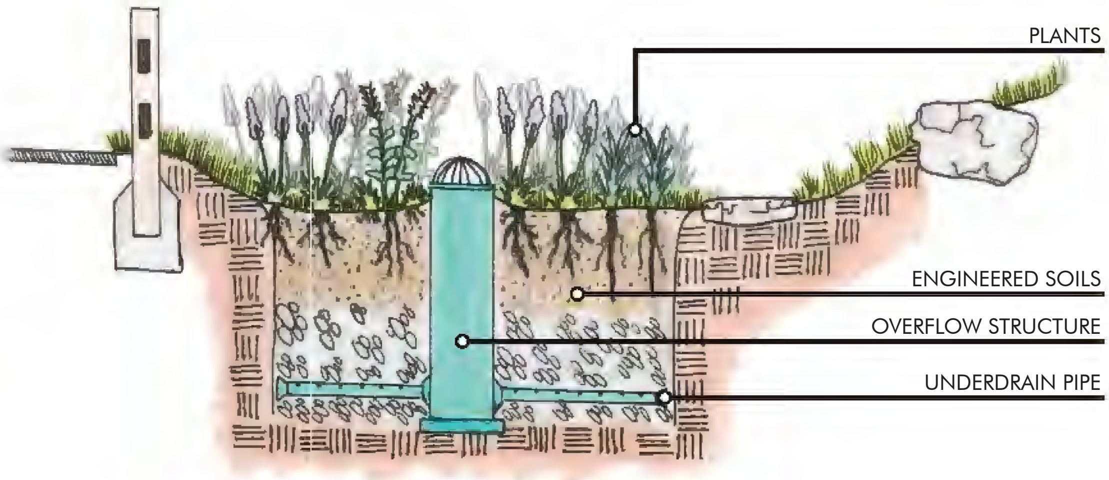
6. **Leave with the following in-hand**
    - ❑ Downloaded aerial photo of your schoolyard and "schoolyard site map"
    - ❑ The area of your schoolyard you will use for student investigations or a plan to involve students in the decision.
    - ❑ Decide whether to use your own schoolyard or the Case Study for the final performace-based assessment.
    - ❑ Locations for: the nearest water body; nearby GI installations; and your school's location in the Charles River (or other) watershed.

Stormwater and Green Infrastructure Curriculum for Boston Public Schools

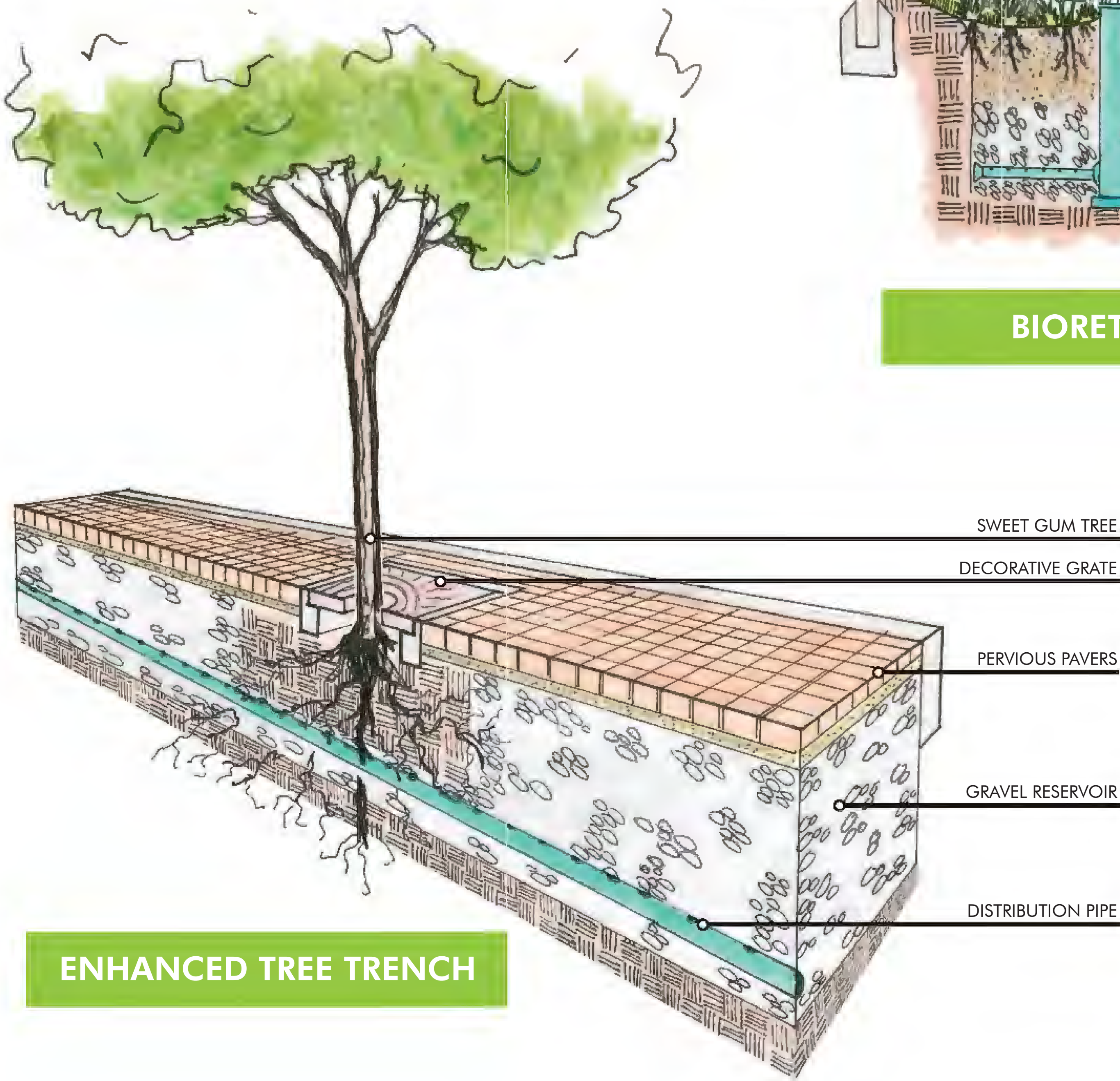
Curriculum Appendix B

GI Pilot School Resources

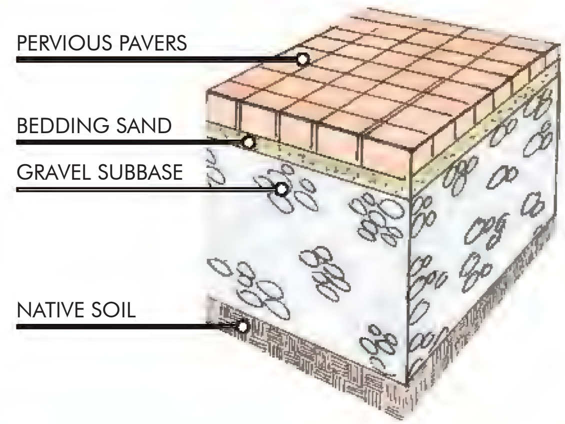
DAVID A. ELLIS ELEMENTARY SCHOOL



BIORETENTION



ENHANCED TREE TRENCH



PERVIOUS PAVERS

List of GI Features at the Ellis

1. Bioretention/rain garden
2. Porous pavers
3. Tree trench

Plantings at Ellis

A unique plant community was created at each of the five (5) Boston Schoolyards to test and compare how various matrixes of plants would perform in green infrastructure at urban schoolyards. Each school's plant palette was designed differently, so the planting strategies can be compared over time. The plantings are designed to be an educational centerpiece for each school and additionally provide wildlife food and habitat in addition to stormwater cleansing benefits. The planting designs are entirely comprised of low-maintenance plants to minimize weeding, irrigation and long-term maintenance inputs over time once the plants established.

The Ellis school bioretention includes plant species that represent a wet native forest floor in New England. Water flows into the bioretention area that is filled with shade-tolerant native woodland plants common to the Boston area including many ferns species: *Polystichum acrostichoides, Osmundastrum cinnamomeum, Onoclea sensibilis, Dryopteris marginalis, Dennstaedtia punctilobula* and *Thelypteris noveboracensis*. White woodland flowering plants, *Anemone canadensis* and *Aster divaricatus* are included within the wet woodland fern planting. Three new native woodland tree species are also added in the schoolyard: *Amelanchier laevis* and *Hamamelis virginiana* provide early spring flowers, and *Liquidambar styraciflua* is planted within the tree trench that cleanses the stormwater.

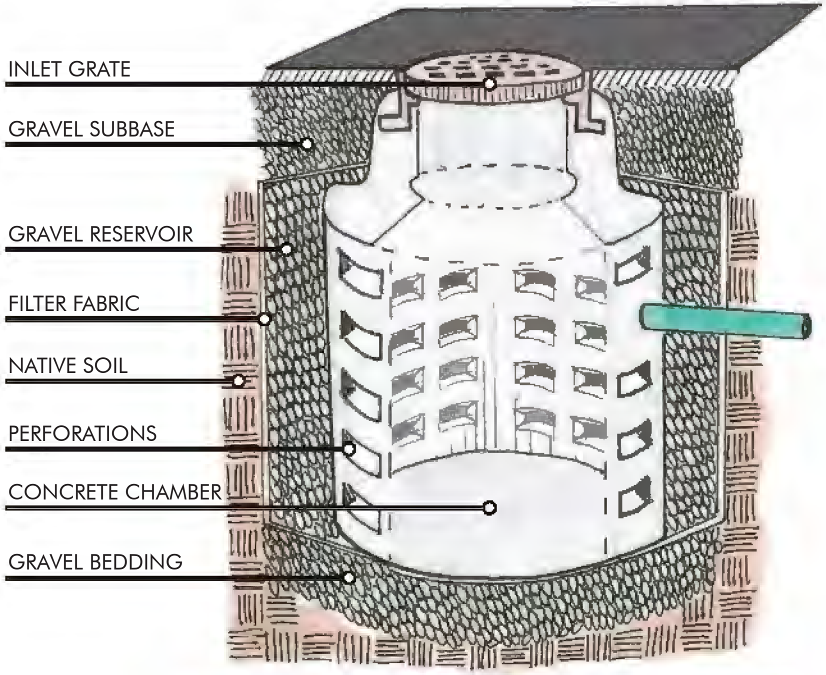
Ideas for how teachers/ students can engage with the plantings at Ellis:

- How many different kinds of ferns can you find in the bioretention planting? Look at the spore structures on the back of some of the leaves. How do fern plants reproduce that is different from other plants?
- What are the differences in the leaf shape in the garden? Use the various leaves in the garden to explain the difference between simple shaped and pinnate shaped leaves.

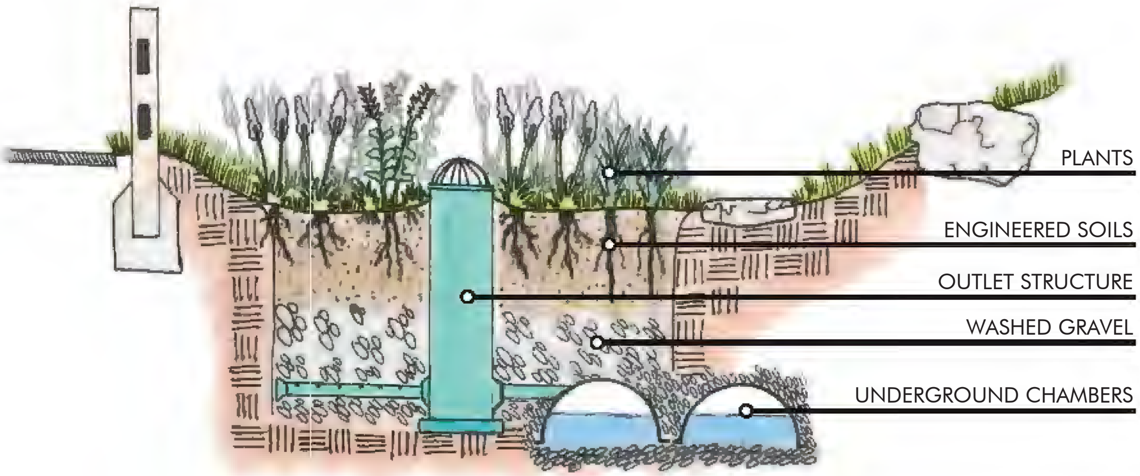
Suggested GI Activities

- ❑ Have general discussions about how different surfaces handle rain. surface runoff vs infiltration vs evapotranspiration
- ❑ Compare drainage on traditional pavement vs. porous pavers vs. landscaped areas. How does slope and tree canopy affect it?
- ❑ See activities by practice type at end of Appendix B.
- ❑ Delineate drainage area to bioretention inlet.
- ❑ Use rain paint in repaved area as an art project only visible when it rains.

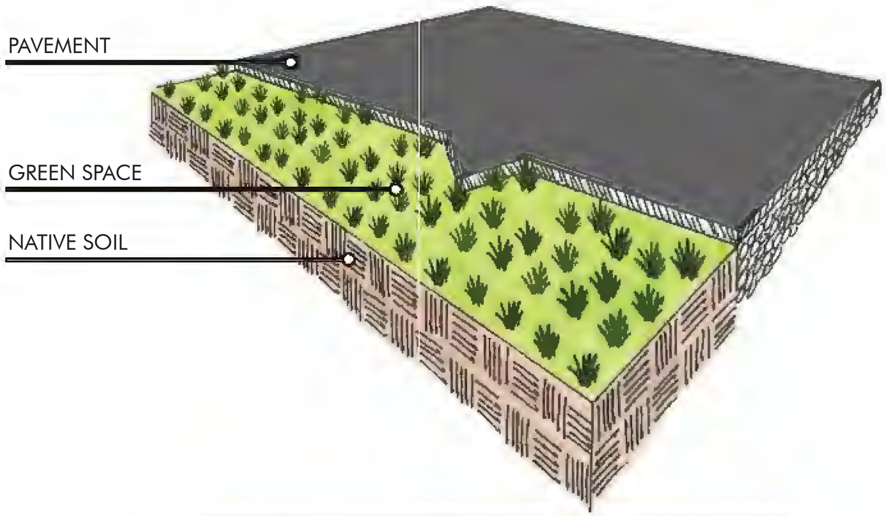
RAFAEL HERNANDEZ SCHOOL



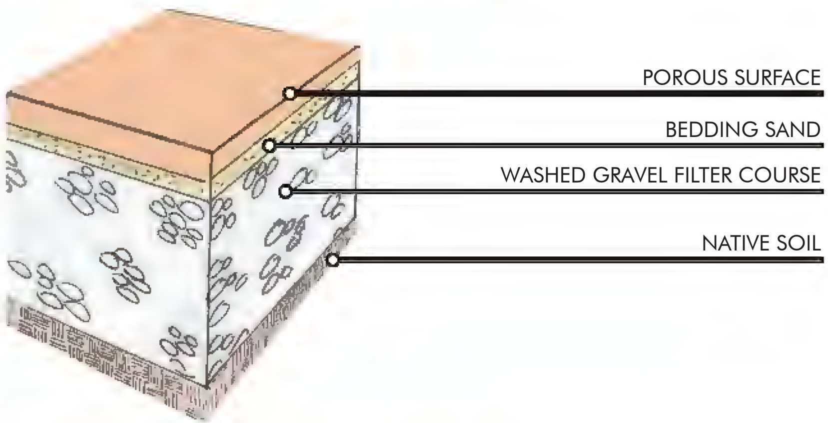
DRY WELL (RECHARGER)



BIORETENTION WITH UNDERGROUND CHAMBERS



PAVEMENT REMOVAL



POROUS PLAYGROUND

List of GI Features at Hernandez:

1. Above ground Cistern/rain tank
2. Below ground Cistern (pump/tank)
3. Bioretention
4. Infiltration chambers (under bioretention)
5. Drywells
6. Porous playground surface

Plantings at the Hernandez School:
A unique plant community was created at each of the five (5) Boston Schoolyards to test and compare how various matrixes of plants would perform in green infrastructure at urban schoolyards. Each school's plant palette was designed differently, so the planting strategies can be compared over time. The plantings are designed to be an educational centerpiece for each school and additionally provide wildlife food and habitat in addition to stormwater cleansing benefits. The planting designs are entirely comprised of low-maintenance plants to minimize weeding, irrigation and long-term maintenance inputs over time once the plants established.

The Hernandez school landscape is modeled after the movement of water within the Charles River Basin Watershed which is the "most densely populated watershed in New England" containing 35 towns within its 308 miles.[1] Urban watersheds typically suffer from non-point source pollution and warm water caused by stormwater runoff from parking lots and streets. Urban stormwater then inundates waterbodies in surges when a storm hits because it is all channeled away into drains. This process is on display at the Hernandez schoolyard.

The upper paved area of the schoolyard represents the urban and impervious watershed typical in much of the Charles River basin. Rain falls on the impervious paved urban condition and the watered is channeled through paved cobble swale. Small islands of planting throughout the paved schoolyard are planted with ornamental species commonly found in urban areas including *Pachysandra* and *Liriope* groundcovers, *Cornus sericea* 'Kelseyi', **Rhus aromatica** 'Gro-Low' and River Birch Trees.

The channeled water through the schoolyard then flows into the final raingarden planting bed designed with native plants common to a healthy riparian Charles River edge. These native plants include low-land, herbaceous species in the center of the planting that will survive both water inundation and drought events, including *Iris versicolor, Eupatorium dubium* 'Little Joe', *Aster novae-angliae, Asclepias syriaca, Carex muskingumensis and Carex amphibola*. Native woody upland shrubs and trees are found on the slopes, banks and upland areas of the rain garden including *Salix discolor, Viburnum dentatum, Vaccinium corymbosum, Clethra alnifolia, and Ceanothus americanu*s. These plants grow together to form a thick root zone and vegetated mat that stabilize steeper areas of soil preventing erosion. The roots of these species

[1] Charles River Watershed | Charles River Watershed Association. (2014). Retrieved November 22, 2016, from http://www.crwa.org/charles-river-watershed

additional perform rhizofiltration, helping to remove contaminants from the stormwater that infiltrates in the garden.

NOTE: Some of these plant species listed can be found in the schoolyard planting and final plant list, but they are not indicated on the original drawings/planting plan because some plant species were substituted during construction.

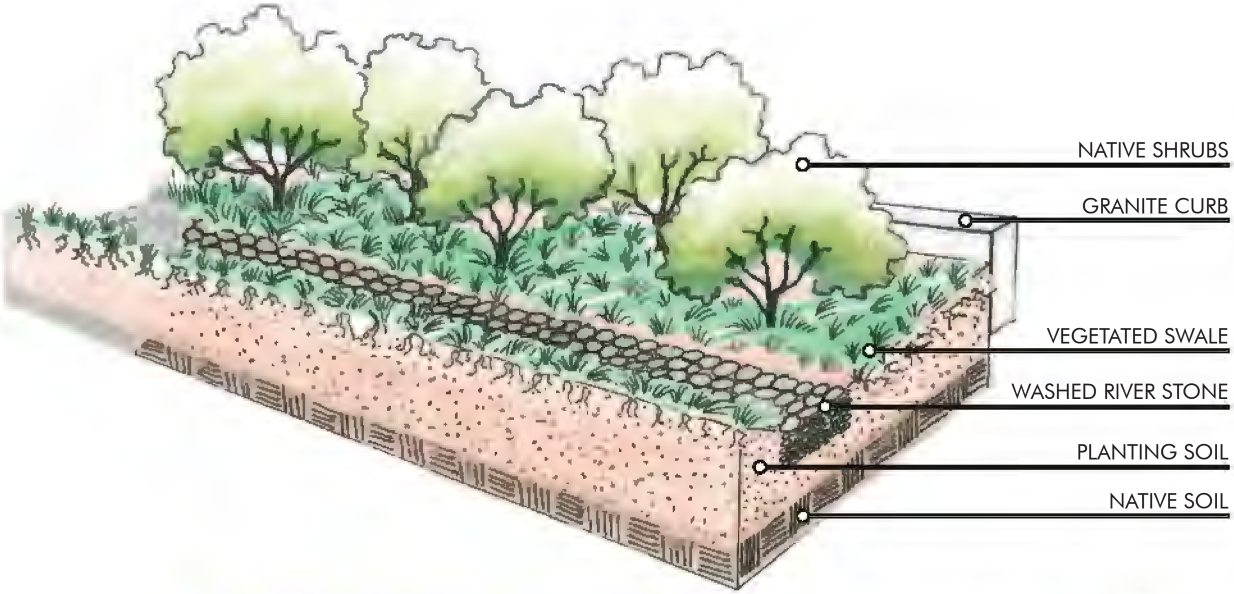
Ideas for how teachers/ students can engage with the plantings at Hernandez:

- What is the difference between a 'herbaceous' (non-woody plant species) and a 'woody' plant (shrub). Point out the herbaceous plant species in the rain garden and contrast those to the woody plants.
- Which of the plants in the rain garden look like "weeds?" Were they originally planted as part of the garden? What is the definition of a "weed?"
- *Amelanchier* (June Berry or Serviceberry) Trees & *Vaccinium* (blueberry) bushes: Harvest the June berries in June. Explain how these are edible and how they can be eaten and cooked with just like blueberries. Harvest the blueberries in July. Record observations and compare the taste, size and appearance of the berries. Discuss the different native animals that use these berries for food.

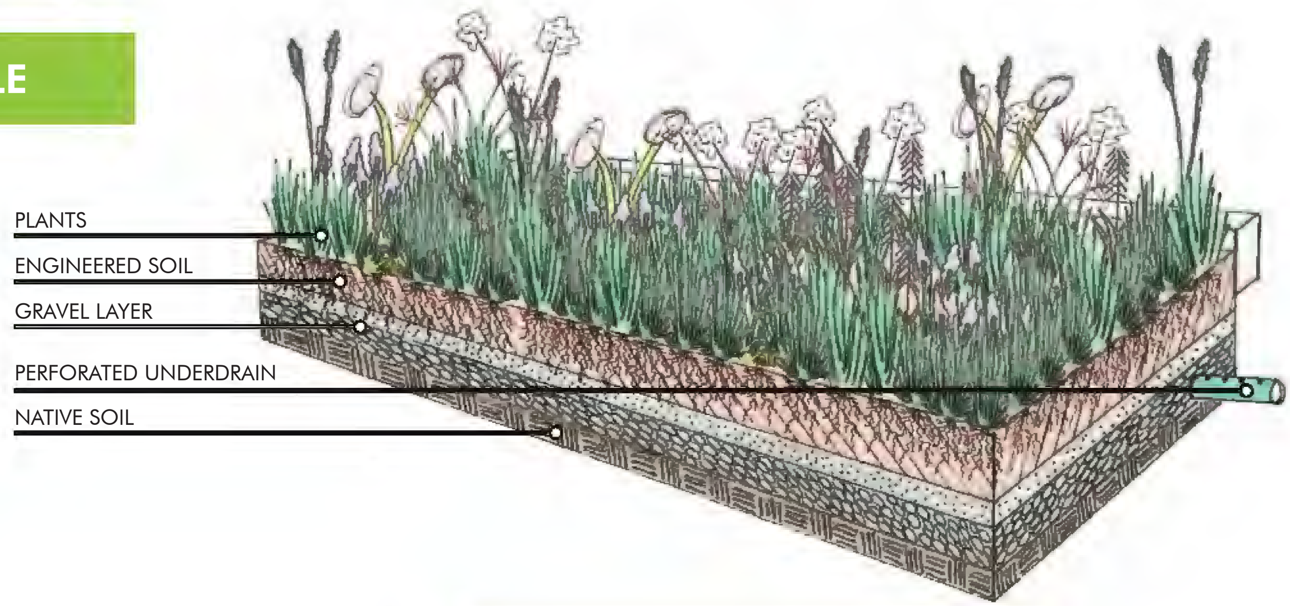
Suggested GI Activities

- ❑ Measure and compare water flow rates across different surfaces.
- ❑ During dry weather, use pump for tanks, and valve at cistern to generate water flow. Use sluice gate to temporarily back up flows into bowl area.
- ❑ Illustrate transport feasibility of floatables (trash and debris) by floating common city trash (e.g., styrofoam cups, plastic bags, and cigarette butts) down channel.
- ❑ Compare sediment and trash collected in weirs and gates.
- ❑ Open observation well in bioretention area to see how much water is sitting in chambers below and how long it takes to infiltrate.
- ❑ Open manhole for drywell and look at pipes. Where are they coming from and where are they draining to?
- ❑ Paint a watershed mural of the Charles River on the building wall facing the courtyard.
- ❑ Use rain paint on the concrete walkway as an art project that only appears when its raining.
- ❑ Calculate storage volume of cistern and tank. Delineate drainage area to each.
- ❑ Measure rainfall volumes from a storm.
- ❑ Compare level of water in the cistern before and after a storm.
- ❑ Experiment with the best way to manage cisterns (is it better to empty it before or after a storm?)
- ❑ Tank next to the ramp collects water drained off the impervious surface in the schoolyard through catch basins and pipes. Students determine ways to measure the amount of water they can pump out with hand pump. Test and compare water volume before and after a storm.
- ❑ Open manhole in pump tank. Why do you think there is a short weir wall inside?

JACKSON-MANN SCHOOL



VEGETATED SWALE



BIORETENTION

List of GI Features at Jackson-Mann:

1. Vegetated Swale
2. Bioretention

Plantings at the Jackson-Mann

A unique plant community was created at each of the five (5) Boston Schoolyards to test and compare how various matrixes of plants would perform in green infrastructure at urban schoolyards. Each school's plant palette was designed differently, so the planting strategies can be compared over time. The plantings are designed to be an educational centerpiece for each school and additionally provide wildlife food and habitat in addition to stormwater cleansing benefits. The planting designs are entirely comprised of low-maintenance plants to minimize weeding, irrigation and long-term maintenance inputs over time once the plants established.

The green infrastructure improvements at Jackson-Mann school are split into two discrete treatment zones that mimic eco-systems - a river's edge and a wetland.

Water from the parking lot flows through the forebay and into a vegetated swale modeled after a riparian bank. Water flows through the center channel which is engulfed in a thick planting of shrubs with phytoremediation (pollution removal) capabilities (Native - *Cornus sericea,* non-native- *Cornus alba, Cornus sanguinea, Salix purpurea*)[2] underplanted with a dense mat of native sedges (*Carex platyphylla, Carex plantaginea*). The dogwood and willow shrub planting scheme is supplemented with non-native dogwoods and willows that will help ensure the swale has a diverse plant palette to handle urban conditions, provide year-round interest, and facilitate pollutant removal from the stormwater. Once the water has meandered through the swale, it flows through a second forebay before dropping into the second system.

Water that hasn't infiltrated or been taken up into the thick mat of roots stabilizing the riparian bank will flow into a bioretention area designed to mimic an herbaceous wetland planting. This system has two unique wetland mixes to create visual interest and diversity of plant species. The first mix, a large swath down the center of the system, is a mix of native Milkweed species (*Asclepias incarnata, Asclepias speciosa, Asclepias syriaca, Asclepias purpurascens*) creating a display of orange, pink, and purple flowers that will provide food and habitat value for pollinators. *Asclepia* is an especially important species to include since they are host plants for the Monarch butterfly, of which populations of this once-common black and orange iconic insect have plummeted by about 90% in just the last two decades[3]. Around the edges, the second native wetland mix (Amsonia 'Blue Ice', E*upatorium dubium, Pycanthemum muticum,* and *Veronicastrum virginicum*) provides additional seasonal blooms to provide pollinator food

[2] Kennen and Kirkwood 2015. P*HYTO: Principles and Resources for Site Remediation and Landscape Design*, Routledge, New York, NY
[3] http://blog.nwf.org/2017/02/new-numbers-show-monarch-butterfly-populations-still-in-trouble/

sources throughout the spring and summer. This portion of the system is designed to retain water and allow it to slowly infiltrate, the plants are all uniquely suited to this environment.

The Jackson-Mann green infrastructure system is in an exposed sunny area and will be supplemented with hybrid tree species that will provide shade, spring blooms, and fall color. The two shade trees, Acer x *freemanii* 'Jeffersred' (Autumn Blaze Maple), are a hybrid cultivar of the native Red Maple and Silver Maple which are commonly found along rivers and wetlands throughout the Northeast. The smaller ornamental trees, *Amelanchier x grandiflora* 'Autumn Brilliance', a hybrid of native Serviceberries will provide very early spring flowers, and berries that attract birds throughout the summer. These trees will be underplanted with a thick mat of Comfrey, a dynamic nutrient accumulator commonly used in organic gardening to both keep weeds down and provide pollution removal benefits.

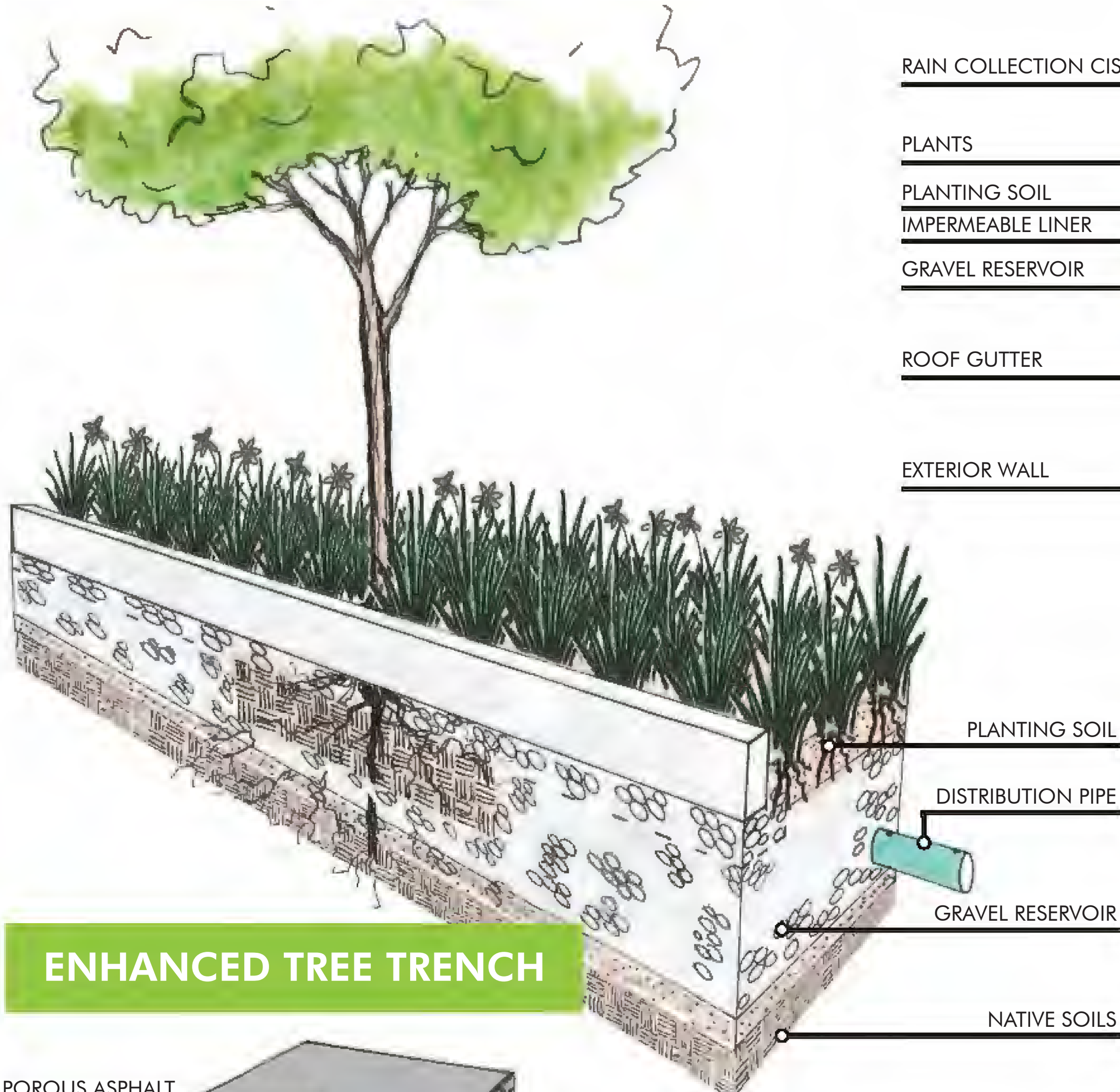
Ideas for how teachers/ students can engage with the plantings at Jackson Mann:

- Count the number of pollinator insects (butterflies, bees) on the plantings 1) in the Riparian Zone Areas 2) in the Wetland Zone area. How do they differ? Why? Are there more pollinators where certain plants are flowering? Complete this at different times of the year when different plants are flowering.
- Look carefully at the Asclepias species. Do any of they have Monarch larvae living on them or are adults eating the nectar of the plants? Explain the life-cycle of the Monarch and how it needs a specific species of plant for reproduction.
- Amelanchier (June Berry or Serviceberry) Tree: Harvest the berries in June. Explain how these are edible and how they can be eaten and cooked with just like blueberries. Try some/ make jam and explain how birds and wildlife use these berries for food.

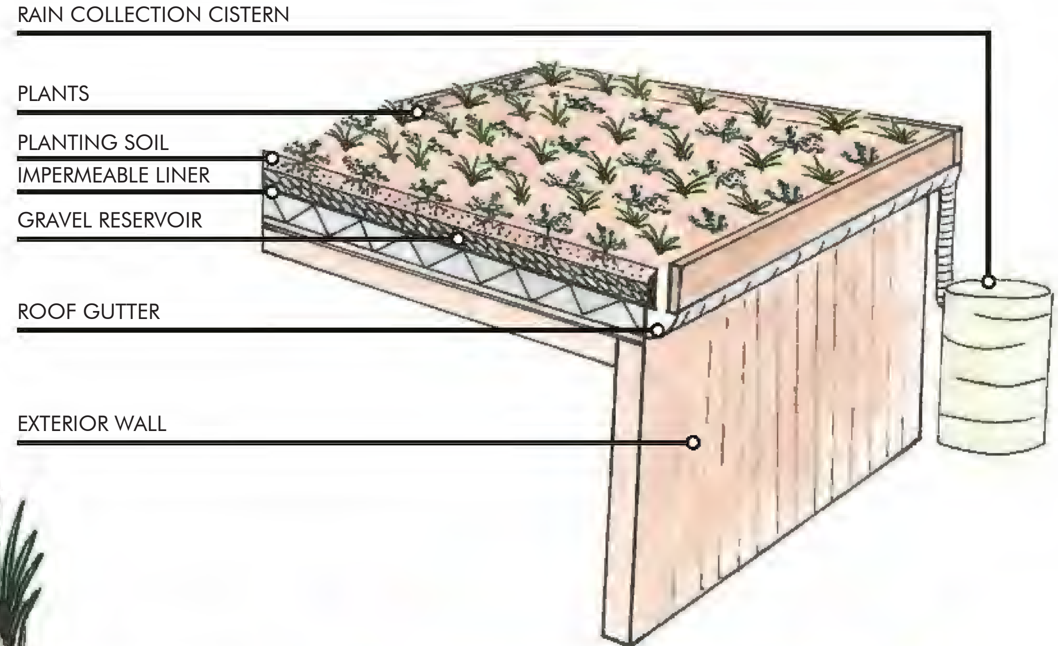
Suggested GI Activities

- ❑ Compare flows in trench drain vs. vegetated swale vs. gutter line on street.
- ❑ Delineate and measure drainage area to bioretention feature (two inlets).
- ❑ Measure sediment, organic and trash accumulation in sediment forebay, compare seasonally, because phosphorus binds to sediment, you can equate sediment to phosphorus.
- ❑ Measure chloride levels—compare summer to winter in runoff and soil.
- ❑ Compare authentic wetland edge in bioretention area to woodland stream in bioswale.

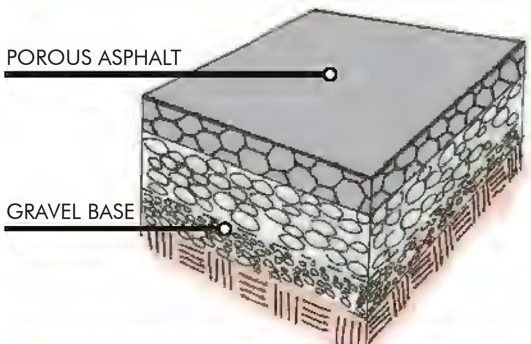
EDWARD M. KENNEDY ACADEMY



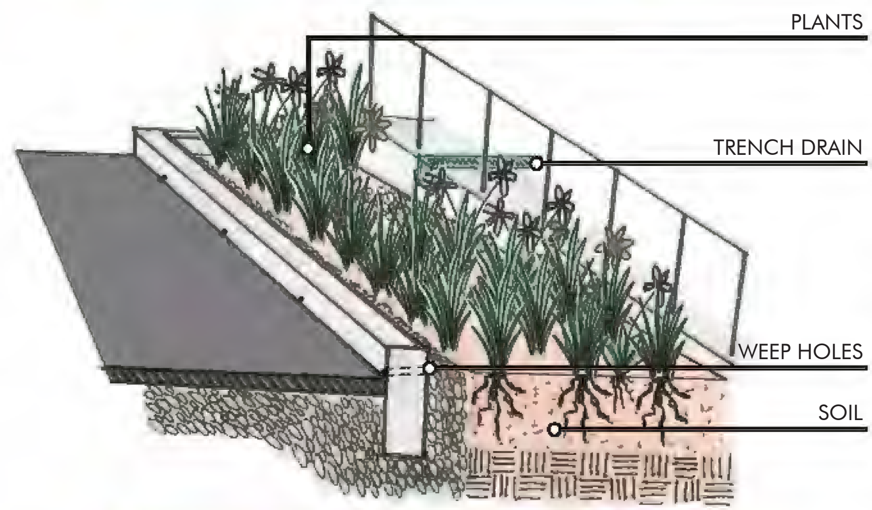
ENHANCED TREE TRENCH



GREEN ROOF & CISTERN



POROUS ASPHALT



STORMWATER PLANTER

List of GI Features at Kennedy:

1. permeable pavement
2. tree trench
3. stormwater planter
4. green roof
5. Rain barrel

Plantings at the Kennedy School:
A unique plant community was created at each of the five (5) Boston Schoolyards to test and compare how various matrixes of plants would perform in green infrastructure at urban schoolyards. Each school's plant palette was designed differently, so the planting strategies can be compared over time. The plantings are designed to be an educational centerpiece for each school and additionally provide wildlife food and habitat in addition to stormwater cleansing benefits. The planting designs are entirely comprised of low-maintenance plants to minimize weeding, irrigation and long-term maintenance inputs over time once the plants established.

All of the plants installed in the new Kennedy School green infrastructure systems are medicinal plants and were at some point in history used for medicinal purposes. The planting design concept stemmed from the fact that the Kennedy High School is a college preparatory school for health careers, and that medicinal plants may be of interest to students. All of the plant species were also selected because of their ability to grow in harsh urban conditions, remove contaminants from stormwater, and survive adjacent to a parking lot that is salted during the winter months. The plant species utilized, and their medicinal uses are described below.

SCIENTIFIC NAME	COMMON NAME	MEDICINAL USES
TREES		
Hamamelis x intermedia 'Arnold Promise'	Arnold Promise Hybrid Witchhazel	Twigs & Bark - Astringent, tonic, sedative
Ginkgo biloba 'Autumn Gold'	Male Ginkgo Cultivars	Leaf- Memory disorders, asthma, allergies, bronchitis
Ginkgo biloba 'Halka'		Leaf- Memory disorders, asthma, allergies, bronchitis
Ginkgo biloba 'Magyar'		Leaf- Memory disorders, asthma, allergies, bronchitis
Ginkgo biloba 'Presidential Gold'		Leaf- Memory disorders, asthma, allergies, bronchitis

SCIENTIFIC NAME	COMMON NAME	MEDICINAL USES
SHRUBS		
Hamamelis x intermedia 'Diane'	Diane Hybrid Witchhazel	Twigs & Bark - Astringent, tonic, sedative
Juniperus sabina var. tamariscifolia	Tamarix Juniper	Young Shoots- Diuretic & used for skin ointments
Morella pensylvanica 'Morton'	Silver Sprite (Morton Female) Bayberry	Root Bark- Astringent & Emetic, Tea from Leaves- fevers & skin wash
Morella pensylvanica 'Morton Male'	Morton Male Bayberry	Root Bark- Astringent & Emetic, Tea from Leaves- fevers & skin wash
Rhus aromatica 'Grow Low'	Dwarf Fragrant Sumac	Root Bark- Astringent & treatment of diabetes and kidney diseases
Rosa rugosa 'Purple Pavement'	Beach Rose	Rose Hip- High in Vitamin C, antioxidants
Salix purpurea 'Nana'	Dwarf Arctic Willow	Bark- Anti-inflammatory, Antiseptic, Ciuretic, Sedative
Sarcococca hookeriana var. humilis	Himalayan Sweet Box	Leaves- laxative, blood purifier and muscular analgesic

PERENNIALS		
Vinca minor	Periwinkle	Alkaloids- Treatment of leukemia, Hodgkin's disease, high blood pressure
Viola labradorica	Labrador Violet	Flowers- Respiratory problems
Viola odorata	Sweet violet	Flowers- Respiratory problems

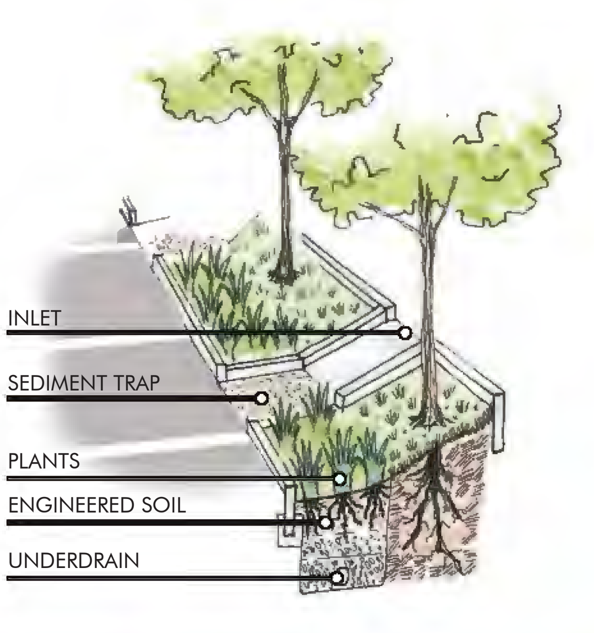
Ideas for how teachers/ students can engage with the plantings at Kennedy:

- Identify the different medicinal plants utilized in the landscape. What medicinal uses were they historically used for? What portion of the plant was utilized?
- How did each particular medicinal plant species arrive in the US? Why do you think it was brought here? Which plants are native to Massachusetts?

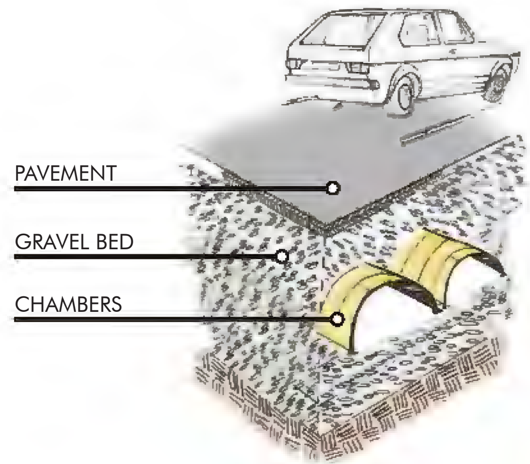
Suggested GI Activities

- ❑ ID plants and research medicinal properties of landscape plants and those in raised beds
- ❑ Rain paint to show underground pipes and flow paths
- ❑ Compare drainage on tradition pavement vs porous pavers
- ❑ Use rain gauge, gutter, and cistern to measure green roof runoff vs hardscapes area of similar size.

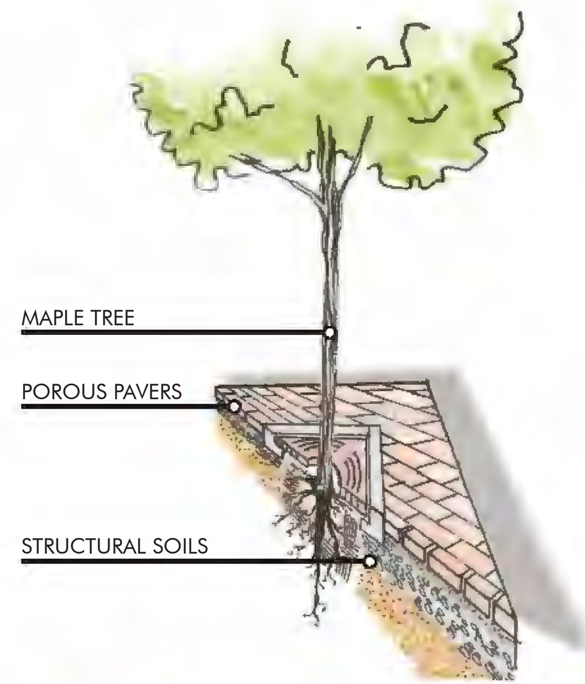
WASHINGTON IRVING MIDDLE SCHOOL



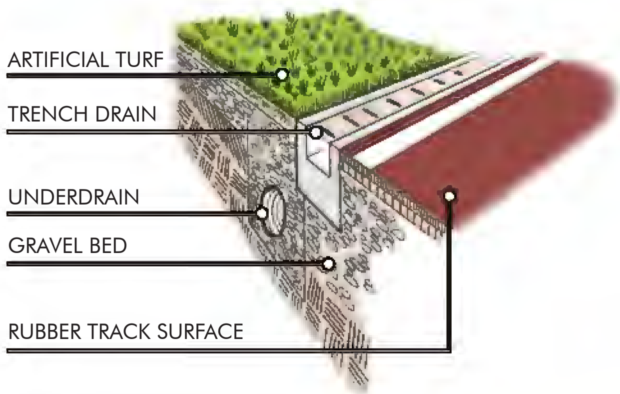
BIOSWALE



UNDERGROUND CHAMBERS



TREE PIT



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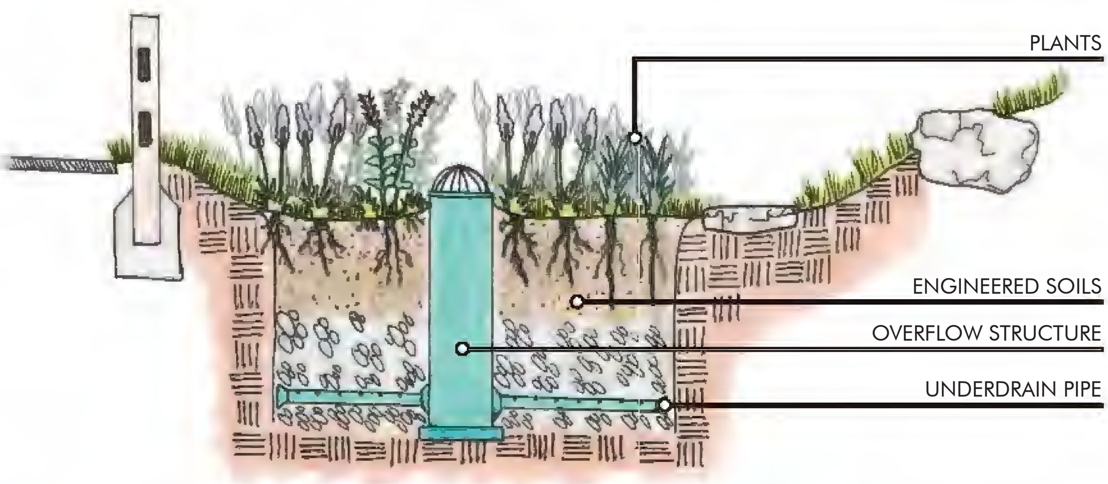

BIORETENTION


Infiltration Chambers
Bioswale
Tree Filter
Bioretention
Washington Irving Middle School
Permeable Turf Field

STORMWATER GREEN INFRASTRUCTURE
Curriculum Packet

WASHINGTON IRVING MIDDLE SCHOOL
105 CUMMINS HIGHWAY
ROSLINDALE, MA

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1.0 Introduction

The purpose of this report is to provide guidance materials for the 7th grade curriculum exercises related to site evaluation and stormwater practice selection for green infrastructure (GI) at the Washington Irving Middle School. GI were designed to:

1. Capture and treat the first 1-inch of stormwater runoff from contributing impervious surfaces, where practicable.
2. Maintain or improve runoff water quality when compared to existing conditions.
3. Reduce total impervious surface area if practicable to minimize runoff volumes.
4. Provide stormwater educational opportunities

We provide information from the engineering assessment and design of GI at the school that can be used to assist students:

- ☑ Delineate drainage areas;
- ☑ Calculate drainage area size and cover type;
- ☑ Evaluate site usage, constraints, and opportunities; and
- ☑ Select green infrastructure practices
- ☑ Interact with GI on site

2.0 Delineating Drainage Areas

Students can delineate general drainage area boundaries at their school using topographic maps and by walking around the property to identify low points (such as drain inlets, areas where water ponds) and the "watershed" that contributes to those points (i.e., high points creating the "rim of the bowl"). Once delineated, students will need to estimate the square footage of that drainage area in order to calculate annual phosphorus load and the volume of runoff generated by the first inch of rain. Stormwater practices are sized to manage this first inch of runoff. **Figure 1** is an example of the type of map that will be provided for each school showing the site aerial and topography. Students should use this map when they walk around outside. **Figure 2** shows what students might create as their drainage area map when they walk around the site. **Figure 3** is the corresponding engineering drainage area map showing catch basins and drainage pipe network for comparison.

3.0 Calculating Total Size of Drainage Area and Cover Types

Once the areas have been delineated on a map, students will need to estimate the size of each area. This can be done by pacing in the field and tapping into some geometry lessons, by using a scale on the map, or digitally on the computer in google earth (pro version allows you to calculate size of polygons). Adobe Acrobat also allows you to calculate the area of a polygon in PDF files. Just make sure you know the scale of the map. Students can also breakdown the total drainage area into impervious cover (roof or parking) or pervious area (trees or grass) if desired. Rough estimations of percent coverage can be used to generate a square footage (i.e., 50% of the area is grass, so divide total area in half to generate square footage of grass. **Table 1** provides the square footage information for each drainage area based on what was actually surveyed.

Table 1. Existing (Pre-GI) Drainage Area Summary (from Engineer)

Pre-GI Drainage Area ID	Total Area (sq ft)	Impervious Area (sq ft)	Impervious Area (%)	Pervious Area (sq ft)	Runoff Volume 1" storm (cf)
DA1	12,900	12,900	100%	0	1,075
DA2	18,230	15,660	86%	2,570	1,305
DA3	16,670	14,690	88%	1,980	1,224
DA4	17,140	15,400	90%	1,740	1,283
DA5	19,540	8,510	44%	11,030	709
DA6	9,240	7,640	83%	1,600	636
DA7 (6b)	5,080	2,560	50%	2,520	213
Roof	37,400	37,400	100%	0	3100
Front	12,880	6,725	52%	6155	560
Total	**149,080**	**121,485**	**81%**	**21,440**	**10,105**

1 cubic foot = 7.5 gallons; 1 acre=43,560 sf

It should be noted that post-GI, the individual drainage boundaries on site changed slightly due to rerouting and regrading. Overall site impervious cover was reduced by over 15,000 sf, which is 12% of total site impervious cover. This reduction also reduced the total volume of runoff that must be managed by 2,300 cf (or 17,200 gallons). Overall, almost 60% of the total impervious cover on the school property is now being managed by green infrastructure. The roof and the front of the school are not being managed. A final summary of the post-GI drainage area management is provided in **Table 2**.

In addition, the impervious cover area is reduced by over 15,000 sq ft (0.35 ac), which is equal to about 20% of the drainage area at the site. Furthermore, the volume of runoff needed to be treated has been reduced by 1,270 cf, also a 20% reduction.

Table 2. Post-GI Drainage Area Summary

Post-GI Drainage Area ID	Total Drainage Area (sf)	Impervious Area (sf)	Impervious Area (%)	Runoff Volume from 1" storm (cf)	GI	% 1" Runoff treated
DA1	26,740	16,420	61%	1,370	Tree Pits/Sports Field	100%
DA2	23,920	7,020	30%	600	Bioretention	100%
DA3	16,680	14,070	84%	1,150	Concrete Swale/ Underground Chambers	100%
DA4	17,140	14,390	84%	1,200	Bioswale	100%
DA5	14,320	10,200	71%	850	Underground Chambers (BPS)	100%
Roof	37,400	37,400	100%	3100	N/A	N/A
Front	12,880	6,725	52%	560	N/A	N/A
Total	**149,080**	**106,250**	**71%**	**8,830**	**--**	**59%**[1]

[1] 59% of the school is managed by green infrastructure for 1" of runoff from impervious surfaces. All of the paved areas where site improvements were made are now managed by green infrastructure (5,170 cf). The roof and the front of the school are not managed.

Figure 1. Washington Irving aerial prior to 2017 stormwater improvements, topography, and soils

Figure 2. Field sketch of catch basins and drainage boundaries (THIS NEEDS TO BE TO SCALE FOR STUDENT USE)

Figure 3. Engineering drainage area map of pre-GI conditions

4.0 Evaluating Site Uses and Constraints

There was no existing stormwater management at this school. One of the most important parts of designing a new stormwater management approach at an existing building is understanding how different parts of the site are currently being used, what the constraints may be for stormwater improvement, and where the opportunities are. The students should document what is happening at the site including parking needs, areas where kids play, known flooding problems, and locations where snow is piled in the winter. They may want to interview the Principal, PE teachers, and maintenance staff. How can stormwater retrofits improve site uses?

To give you an idea of what site information is relevant, **Table 3** summarizes site usage, grounds maintenance, and parking information collected during the preliminary site assessment and in meetings with school officials. Based on this initial evaluation, three specific locations at the school were identified for focusing green infrastructure design efforts on: 1) the rear parking lot; 2) the interior courtyard; and 3) the existing low point on the east side of the school between the stage and the interior courtyard. Each of these locations was then evaluated based on site constraints and opportunities:

- Adequate available space for siting surface and/or subsurface practices;
- Safety
- Aesthetics
- Educational opportunity and public visibility;
- How site is currently used by students and staff;
- Existing drainage pathways;
- Existing utilities, buildings and other structures;
- Potential disruption to existing facilities, adjacent land uses/activities and traffic; and
- Operational or maintenance conflicts (e.g. snow removal) or opportunities for improvement.

Table 4 summarizes the land use constraints, the potential space improvements through the use of green infrastructure, and the potential educational opportunities for each of three locations.

Other key data include soils and floodplain information. Based on the USDA web soil survey the two major soil types at Washington Irving include:

- 626B Merrimac-Urban Land Complex: 0-8 % slope, HSG A-D, with >80 inch depth to groundwater.
- 627C Newport-Urban Land Complex:3-15% slopes, HSG B, with 18-30 inch depth to groundwater

Soil type and depth to groundwater is important to determine if increasing stormwater infiltration is feasible and are included in **Figure 1**. In real life, the Engineer dug test pits to actually classify soil type and measure depth to groundwater, but for concepts and for this exercise, the web soil survey is fine. BWSC will be providing these maps for all schools.

Table 3. Preliminary Site Assessment for Washington Irving

Assessment Parameters	Comments
Existing "available" space–documenting unused or underutilized land, either unpaved or paved, that does not currently have a building or other structure (i.e. play equipment).	• Opportunities exist for pavement removal in the back. The area is used mostly for play and is not typically accessed by vehicles (except medium-sized bus pickups/drop offs). • For PE classes, the school can have 70 students in courtyard at one time playing soccer, kickball etc. Home plate is in western corner. The majority of the courtyard space should remain open for running kids and flying balls. • Tenacity currently has 16 students in the program with 3 to 4 courts set up at 60-ft lengths with 18-ft wide portable nets. The setup uses about half the available courtyard space. Tenacity would prefer a hard surface
Parking lot configuration/traffic flow – documenting current existing parking and traffic flows to evaluate whether GI practices can be installed with minimal or no impact on existing parking and traffic.	• One entrance exists from Hawthorne St. and one on Sycamore St. The co-principals indicated that parking is not a problem and could reduce available parking spaces if lot was to be reconfigured. BPS noted that a loss of up to 8 spaces would be acceptable. Compact parking stalls acceptable. • Need to maintain fire access and handicapped accessibility, particularly from sidewalk to ADA-compliant door into building. Easy access should be maintained in multiple locations with proposed parking lot reconfiguration. • Snow disposal area is currently on north side of rear parking lot. • Full-sized buses use front of school for pickup/drop-offs. Half buses load in interior courtyard. Moving bus pickup from interior courtyard to the rear building entrance will improve safety. Buses need to have approximately 300 ft to line up, with space to pull around. Bus dimensions are 26ft long x 8 ft wide. Students exit from multiple doors and load onto buses during the same time that Tenacity is meeting in interior space. The school is open to rerouting suggestions. • Reconfiguration of the rear parking lot could be considered, including new curb cuts to Hawthorne Street and access to Sycamore Street. However, there was not much support from the school or BPS for a new curb entrance on Hawthorne. Exiting out of the side onto Sycamore Street would be viable—delivery trucks go that way. • Must maintain firetruck access to interior courtyard area
Site visibility and viewsheds – identifying educational opportunities and evaluating whether GI practices can be readily observed by most individuals entering/leaving the site and/or buildings.	• Parking lot may not be easiest spot for classes to be out looking at GI unless there is a “viewing platform” or sidewalk space • Interior courtyard visible from classrooms. Evaluate way to incorporate trees or other perimeter vegetation without blocking light into windows. • Consider bioretention in low point in the back. Karen discussed her vision of the outdoor classroom—20 kids at a time, distributed area where kids can all walk around and not be clumped together. Suggested elements: visible line of sight; opportunities to interact and observe; water quality testing.
Site context – identifying unique site features, elements, vegetation and assess the context of the surrounding neighborhood.	• Soils indicate relatively high potential to infiltrate. Groundwater Adjacent community is walkable neighborhood. • At low capacity right now, likely to be identified for additional growth. • Community group may be interested in landscape maintenance.
Existing Landscaping and grounds maintenance—documenting the types of vegetation and level of care currently provided.	• Floods in the back by the stage due to clogged catchbasin • Fix the stairs back by the stage when redoing that area. • Minimal existing landscaping (small grass area out front and in back by main entrances). • School co-principal asked about maintenance of surface GI practices and classroom areas. BPS is adding the GI pilots to their outdoor classroom maintenance list, which is a 3 times/yr maintenance plan. BWSC will maintain GI for first few years.

Table 4. Summary of Site Constraints, Improvements and Opportunities

GI Location	Constraints	Potential Improvements	Educational Opportunities
1. Parking Lot in the Rear	• BPS proposing to manage this area; potential to reduce size of underground storage chambers • Full sun • No utility conflicts; can use existing drainage infrastructure • Highly visible • Not particularly safe for kids to be standing around GI without dedicated space • Reduction of existing parking count (56 stalls); requires designated on-street parking • 300 ft line up length for buses may not be easily met in rear lot • Snow disposal may result in temporary loss of additional spaces. Snow storage along eastern boundary.	• Safety benefit to reconfiguration for busing that makes sense with building access • Add landscaping and canopy cover to open parking lot; Potential for air quality improvement in location where vehicles idle. • Potential to disconnect drainage from sewer (not as currently proposed)	• Observe stormwater runoff across paved and vegetated cover • Compare BMP performance • Comparable drainage areas
2. Interior Courtyard	• BPS proposing to manage this area; • Partial shading • Visible from all interior facing classrooms (three sides of 3-story building) • Main drain line • Limited potential for landscaping (e.g., trees potential hazards to running children)	• Safety benefit to reconfiguration for busing-makes sense with building access • Improving the play space and aesthetics is primary driver • Surfacing and sizing should be compatible with PE classes and Tenacity program	• Some related to permeable vs impervious surfaces • Arboretum
3. Low point in eastern back corner	• Shady, integration potential with sloped, treed area • Poor drainage at low point • Utility poles	• Improve drainage conditions • Opportunity for pavement removal • Need to maintain fire access • Close to door	• Outdoor classroom space • Transition between paved and natural area

5.0 Practice Selection

Once site constraints and opportunities are known, students will next identify the type of green infrastructure they want to use for a given drainage area(s). There is a fun spreadsheet that can be used for this activity that groups typical practices into 5 groups and assigns a generic TP removal efficiency (**Table 5**). While design and sizing of these practices varies greatly, this complexity can be ignored at the 7^{th} grade level.

Table 5. Simplified groupings of stormwater practices

GI Group	Practices	Assigned % TP removal efficiency	Assigned 20-yr $ per acre treated	Comments on selection criteria
Infiltration practices (subsurface)	basin, chambers, dry well/leachers, trench	80%	$160,000	Need permeable non-contaminated soils and sufficient distance to groundwater
Biofilters (surface, vegetated)	bioretention, bioswale, tree pits, organic filters	60%	$150,000	Acceptable landscape area, understanding of sun vs shade for plant selection
Pervious pavement (surface with subsurface base)	porous concrete, permeable pavers, porous asphalt, pervious synthetic turf	70%	$280,000	Replacement for impervious hardscapes; no deicing
Ponds/wetlands (surface)	constructed wetlands, wet ponds, gravel wetlands	50%	$50,000	Take up a lot of space. Considerations for standing water on site. Could be cool for habitat
Cisterns	above ground, underground tanks, rain barrels	--	--	

The proposed green infrastructure practices at Washington Irving include a bioswale and underground chambers in the parking lot and alley; tree pits and pervious synthetic turf field in the interior courtyard; and a large bioretention in the eastern corner. Specific GI components are shown in **Figures 4** and **5** and described below. **Table 5** summarizes the benefits of the GI used. **Figure 6** shows the new, post-GI drainage boundaries from engineer's modeling.

Table 5. Summary of GI practices

GI	Post-GI DA managed	Benefits
Bioswale	half of rear parking lot (DA4)	• Some phosphorous removal capability • Increase biodiversity- phytoremediation • Some infiltration • Helps with improved traffic flow • Educational comparison with concrete swale
Underground chambers	half of rear parking lot (DA3) and alley (DA5, *formerly DA6*)	• Good phosphorus removal • Increased infiltration • Can drive/park on top, allows for traffic reconfiguration • Reduces ponding issues
Tree Pits/Synthetic Field	Interior courtyard (DA1, formerly DA1 and DA2)	• Reduced impervious cover • Some phosphorus removal • Improved recreation • Increased biodiversity and shade • Some infiltration
Bioretention	Eastern corner between stage and courtyard (DA2, formerly DA5)	• Reduced flooding • Some phosphorous removal capability • Increase biodiversity-pollinator meadow • Some infiltration • Educational

Figure 4. Green infrastructure at Washington Irving

Figure 5. Cartoons of GI practices used at Washington Irving

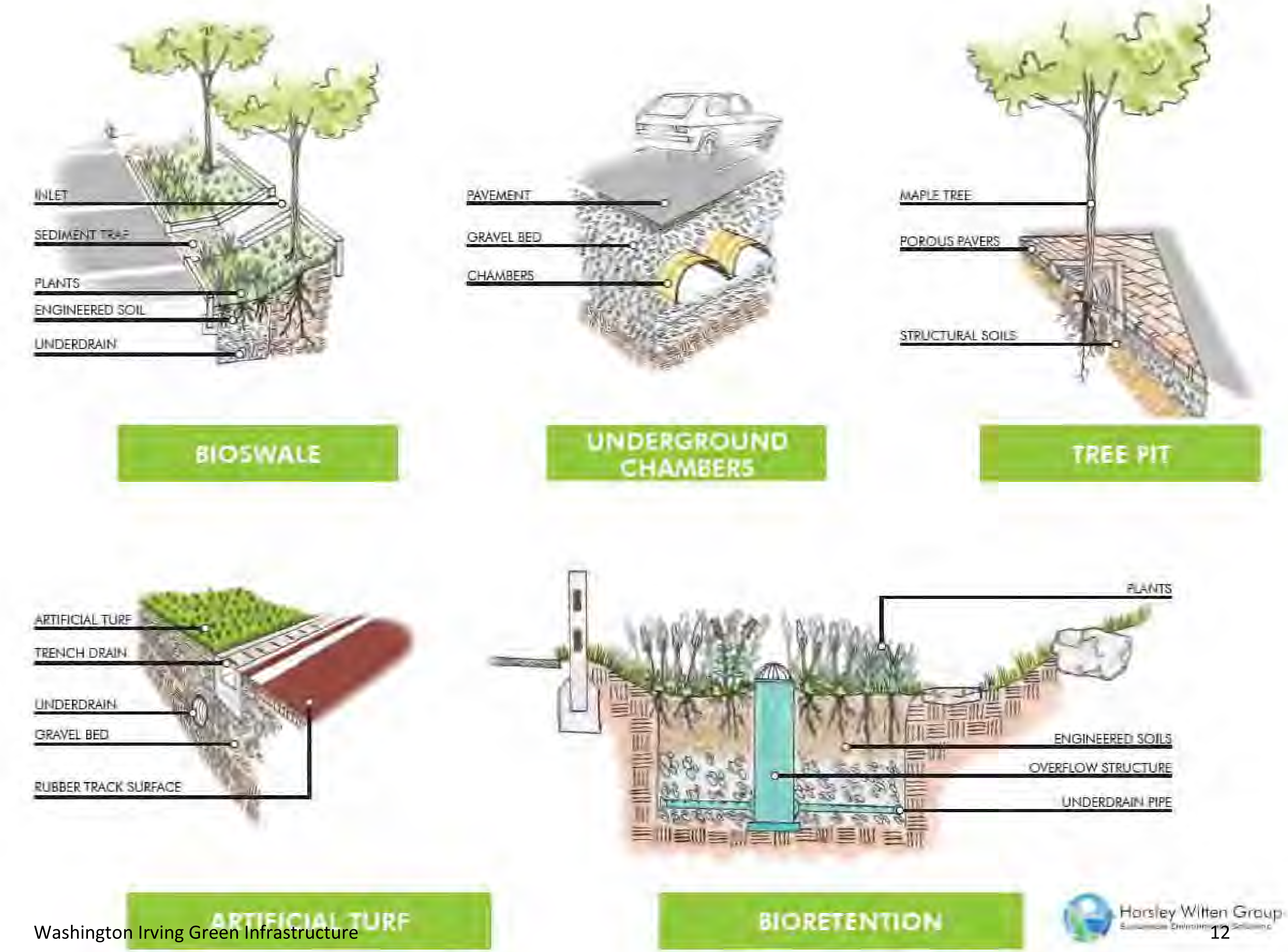

Figure 6. Engineering drainage area map of post-GI conditions (note slight changes from original drainage boundaries in courtyard and eastern corner)

Rear Parking Lot
The green infrastructure was designed to manage stormwater runoff from DA3 and DA4. The design splits the parking lot in half. Half of the lot drains to a concrete swale and underground chamber system, and the other half drains to a bioswale. This split was done explicitly to provide an educational opportunity to compare stormwater runoff between traditional (concrete channel) vs the "green infrastructure" approach (bioswale). The chambers used actually provide treatment for the runoff from the concrete swale. The total number of parking stalls was reduced, however the parking lot was reconfigured to create a designated bus loading zone to improve safety (rather than using the interior courtyard). Pedestrian access between the parking lot and the school is provided through a sidewalk crossing between the two swales, and buses now exit through the alley on the north side of the building to Sycamore St. See **Figure 7** for photos and illustrations of the GI in the parking lot. The Washington-Irving school has three unique interventions with plant communities suited to each application. There is a bioswale at the parking lot, shade trees at the sports field, and a pollinator meadow at the outdoor classroom.

<u>Bioswale Design</u>
The parking area drains to the bioswale through curb inlets while the designated loading zone and drive aisle drains to the bioswale through concrete inlet channels. Runoff to the bioswale is managed for the first 1-inch of runoff from impervious surfaces for water quality; excess runoff enters the existing drainage system through an overflow structure. Due to limited infiltration capacity in the soils, the bioswale is under-drained to ensure the practice will drain within 40 hours. The bioswale uses bioretention soil media and vegetation to promote infiltration, filtering and uptake of pollutants. A ponding depth of no more than 4-inches is used to maximize management of stormwater runoff, but minimize any safety concerns for students, teachers or staff.

The bioswale is planted with salt tolerant species as well as species that provide air quality benefits to minimize impacts from bus idling. The selection of plants is diverse to maximize water quality benefits through pollutant uptake and minimize required maintenance. Plants include Creek and Ice Dance Sedges, Blue Flag Iris, Slender Rush, Creedping Lilyturf, and Varigated Liriope. Trees (Sycamore, London Plain Tree, Tulip Poplar, and Little Leaf Linden) provide shading for the parking lot and pedestrains.

<u>Concrete Swale and Underground Chambers Design</u>
Similar to the bioswale design, the concrete swale manages stormwater runoff from the parking area through curb inlets while runoff from the designated loading zone and drive aisle would enter through concrete inlet channels. Unlike the bioswale, the concrete swale design is for conveyance only; runoff would ultimately be conveyed to underground storage chambers that would manage the 1-inch water quality event. The underground system includes 30, 16-inch StomrTech chambers laid out in two rows sitting in a 34-inch bed of gravel. It is equipped with an overflow mechanism to safely convey runoff from larger storm events to the existing catch basin that will be converted to a drain manhole structure.

Figure 7. Before and after photos of bioswale and underground chambers in the rear parking lot.

Interior courtyard

The green infrastructure in the interior courtyard involved replacing pavement with a porous sports field and tree pits that manage stormwater runoff from both original drainage areas DA1 and DA2 (see **Figure 8** photos). The sports field was specifically selected to improve recreational uses of this space. Five tree pits were added around the perimeter to improve aesthetics, shade, and to create an educational opportunity related to comparing different types of maple trees. The tree pits maintain a 10-ft setback from the building to avoid impacts to the building foundation and to allow access around the perimeter of the courtyard. The surface of the tree pits are a permeable paver block. Tree pits are spaced to avoid blocking windows and sightlines, minimize interference with PE class activities (e.g., kickball).

<u>Sports Field Design</u>

The sports field design includes a porous, synthetic playing surface (e.g., artificial turf) with a shallow gravel storage area to manage runoff from rainfall that falls on the field itself, the surrounding track, and asphalt. A small portion of the asphalt areas surrounding the sports field would also be captured through individual tree pits. The sports field's storage will be directed to trench drains which will then connect into existing 54-inch drain line.

<u>Tree Pits</u>

The tree pits manage stormwater runoff from surrounding impervious surfaces and allow for filtering of pollutants using a structural based soil. The trees at the sports field showcase a gradient of native tree species and their cultivars to create a visualization of the differences between Red Maples, Fraser Maples and Silver Maples.

Low Point on East Side (Between Interior Courtyard and Stage Area)

The green infrastructure manages runoff from the original drainage area DA5 and a portion of DA2. It involved removing portions of existing pavement and installing a large bioretention facility with a pretreatment sediment forebay. The practice was specifically selected and designed to eliminate flooding. The bioretention area and surrounding landscaping are configured to provide an outdoor space for teachers and students to observe drainage, bees, and plants. A section of existing pavement was cut and planted to mimic a river pattern. Site features, such as stepping stones, allow students to interact with the space. There is a sampling port cut into the inlet flume that allows for the collection of water samples if needed. The area is configured to ensure fire access between the rear parking lot and the stage area and protect existing overhead utilities along the edge of the existing asphalt area. See **Figure 9**.

<u>Bioretention Design</u>

The bioretention area includes a curb cut to a sediment forebay with paver stones that can be easily shoveled. From the sediment forebay, flows overtop a weir structure into a vegetated swale that discharges into the bioretention. Flows are then directed through a spillway to the bioretention area, which uses engineered soil media and vegetation to promote infiltration, filtering and uptake of pollutants. Runoff to the bioretention area manages 1-inch of rainfall on contributing impervious surfaces; excess runoff would enter the existing drainage system through an overflow structure. Due to limited infiltration capacity in the soils, the bioretention is under-drained to ensure the practice will drain within 40 hours. The bioretention has a maximum ponding depth of 4-inches to maximize management of stormwater runoff while minimizing safety concerns for students, teachers and staff that will be observing and interacting with the practice. The plants selected for the bioretention area mimic a small pollinator meadow comprised of primarily MA native Little Bluestem, joe pyweed, and Creek Sedge, and supplemented with additional North American native meadow species (e.g., yarrow, hyssop, milkweed, asters, indigo, coneflowers, sunflowers, spike gayflower, iron weed, and little bluestem) to create a pollinator garden to provide food and habitat to butterflies and bees throughout the growing season.

Figure 8. Before and after photos of the interior courtyard conversion to field with perimeter tree pits.

Figure 9. Before and after photos of the eastern corner conversion to bioretention.

In addition to these GI practices, pavement was also removed around the side door entrance in the interior access lane. These areas were planted with Red chokeberry, spurge, and little leaf linden (**Figure 10**).

Figure 10. Before and after photos of the side entrance.

6.0 Additional Activities

This pilot site will be set up with real-time monitoring equipment, including

- Two monitoring panels powered by solar (one in front bioswale and one in back bio)
- 4 or 5 flow measuring devices (using weirs and pressure transducers) will be located in the outlet structures for concrete and bioswale so you can compare, and one at recharge chamber. Also one in the bio in the back. Not sure they will be measuring inflow into systems, so it would be great to be able to have kids go actively measure surface flows so they can compare with what is leaving.
- Two soil saturation sensors, one will be placed in the bio in the back and one in the swale in the front.
- Not sure if there are multiple rain gauges at the site. We put a post in the back by fence, but they may opt to put it out front.

Activities suggested for interacting with the GI on site include:

1. At bioswale: Paired catchment study. Delineate drainage areas. Compare traditional drainage vs GI features and how each works. Measure volume, rate, quality of inflow and outflow from each system. See opti on-line, real-time measurements.
2. At recharge chambers: Apply rain paint on surface to show location of recharge chambers and underground pipes/flow direction. Open observation port/maintenance cleanout and measure height of water in system.
3. At bioretention: Apply rain paint to showing actual or representative watersheds and flow paths to each bio inlet. Could paint Charles River on wall of building. Students could use street chalk to draw and calculate drainage areas. Can sample inflow,

measure how much rain it takes to overflow system via under drains or overflow pipe. Open maintenance cleanout port and see if there is water in the system. See opti on-line, real-time measurements.

4. All GI: Plant identification and co-benefits: in pollinator meadow garden; trees in tree pits; pollution reduction by plants in bioswale
5. Impervious cover reduction- calculate how much impervious cover was removed from the site (measure footprint of field, landscape islands, and bio).

List of GI Features at Washington Irving:

1. Bioswale/concrete channel in parking lot
2. Infiltration chambers (underneath parking lot managing drainage from concrete swale)
3. Tree pits
4. Turf Field
5. Bioretention

Plantings at the Washington-Irving

A unique plant community was created at each of the five (5) Boston Schoolyards to test and compare how various matrixes of plants would perform in green infrastructure at urban schoolyards. Each school's plant palette was designed differently, so the planting strategies can be compared over time. The plantings are designed to be an educational centerpiece for each school and additionally provide wildlife food and habitat in addition to stormwater cleansing benefits. The planting designs are entirely comprised of low-maintenance plants to minimize weeding, irrigation and long-term maintenance inputs over time once the plants established.

The Washington-Irving school has three unique green infrastructure interventions with plant communities suited to each application. The bioswale plantings at the parking lot are designed to both cleanse the stormwater from the parking lot and remove large particulate matter from any air pollution generated from idling cars and buses. Around the sports fields/ track, several varieties of maple trees were planted in the tree filter boxes so that students can compare and contrast different species of maple leaves. Lastly, a pollinator meadow was created at the outdoor classroom to provide both stormwater infiltration benefits while providing food and habitat for bees and butterflies.

<u>Parking Lot Bioswale:</u> The bioswale that runs along the parking lot is planted with a cohesive mix of low maintenance, spiky textured plants including *Iris versicolor*, *Liriope*, Iris "Caesar's Brother' and *Carex morrowii* 'Ice Dance' among others. The aggressive plant varieties selected will grow together, mix and spread by seed or rhizomes creating very little visible soil at ground level and thereby smothering out weeds and creating a lower-maintenance planting. The leaves of all the native and non-native plant varieties selected are vertical and spiky in appearance, creating an overall pleasing aesthetic composition, even when the species are mixed together. The idea is for the planting to have a neat, unified appearance, but to be comprised of many different plant species to maximize the variety of microbiology present in the bioswale root zone. Different varieties of plants support different kinds of microbiology in the root zone and the microbes help mitigate contaminants introduced with the stormwater. The row of trees along the edge of the parking lot swales consists of species selected for their ability to remove large particulate matter from the air[4]. The intention is for these trees to help mitigate the air pollution impacts caused by buses and cars idling at the drop off circle. These tree species, including *Tillia cordata, Platanus occidentalis, Liriodendron tulipifera* and *Platanus* hybrids all have waxy leaf surfaces or leaf hairs that help remove particulate matter from the surrounding air.

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[4] Kennen and Kirkwood 2015. P*HYTO: Principles and Resources for Site Remediation and Landscape Design*, Routledge, New York, NY

Sports Field/ Track: The trees planted in the tree filter pits around the sports field/ track area showcase two native maples and a hybrid that has the best attributes of each: *Acer rubrum* (Red Maple), *Acer x fremanni* (Freeman Maple, a hybrid of red and silver) and *Acer saccharinum* (Silver Maple). These maples can survive in harsh urban growing conditions and the roots help remove contaminants from stormwater. A gradient of different types of maples was utilized so students can compare the different leaf shapes and consider the physical differences in the shape, color and size of the tree canopy between multiple varieties of the same kind of plant.

Bioretention: The plantings in the bioretention are all native species and create a pollinator meadow garden to provide food and habitat to butterflies and bees throughout the growing season.

The primary grass species in the meadow is *Schizachyrium scoparium* (Little Bluestem) which is paired with supplemental flowering North American perennial species. These forbs, including but not limited to, *Agastache* 'Blue Fortune', *Achillea millefolium, Baptisia, Helenium* and *Helianthus* provide flowers throughout the entire spring and summer so that pollinators have a constant source of high-quality nectar. Various seed pods will develop on the plant species for student collection and exploration.

Ideas for how teachers/ students can engage with the plantings at Washington-Irving:

- How many different kinds of plants do you see in the parking lot bioswale? Many of the plants have a similar leaf-shape, but the kinds of plants are actually different. Which plants do you think were planted as part of the original planting? Which do you think might have invaded as 'weeds'?
- Compare and contrast the different varieties of maple trees around the sports field/ track area. Which trees are similar? Which are different? How are the leaf shapes of the different varieties of maples different even though they are the same species? How are the cultivars different? Explain the difference between plant family, species, variety and cultivar.
- Count the number of pollinator insects (butterflies, bees) on two different kinds of flowering plants in the outdoor classroom area. How do they differ? Why? Are there more pollinators on certain kinds of plants? Why do you think this is? Complete this at different times of the year when different plants are flowering.

Suggested GI Activities

- ❑ See 7th grade lesson plans and case study.
- ❑ Paired catchment study between bioswale and concrete channel. Delineate drainage areas. Compare traditional drainage vs GI features and how each works. Measure volume, rate, quality of inflow and outflow from each system. Visit BWSC website for link to real-time monitoring.
- ❑ Apply rain paint in parking lot to show recharge chambers and underground pipes/flow direction and watershed divide.
- ❑ At bioretention: Apply rain paint to showing actual or representative watersheds and flow paths to each inlet. Could paint Charles River on wall of building. Students could use street

chalk to draw and calculate drainage areas. Can sample inflow, measure how much rain it takes to overflow system via under drains or overflow pipe.

- ❑ Rain gauge measurements, compare open vs canopy area
- ❑ Impervious cover reduction- calculate how much impervious cover was removed from the site (measure footprint of field, landscape islands, and bio.

Suggested Activities for GI Schools by GI Feature

Bioretention Feature

- ❑ Measure soil saturation: how much water comes into a bioretention feature and how much is taken up by plants compared to how much is taken up by the soil?
- ❑ During or immediately after a rain, compare water flow on impervious surfaces aimed at moving water out as fast as possible to water flow in bioretention features which mimic the natural hydrologic process: slowing water down so plants, soil and microbes can remove phosphorus and the water can slowly absorb into the ground.
- ❑ Look for patterns in the types of plants that are used in the bioretention features. Can you find plant species that you think typically grow in wet areas? Compare riparian (on or near river banks) vs upland transition zones.
- ❑ Research the plants on your site to identify the species, and learn about what plants were chosen and why. Each species has a different function.
- ❑ Look for evidence of biodiversity in different areas of the schoolyard. Compare number of species in grassy areas to bioretention features.

Infiltration Practices

- ❑ Underground so hard to see, unless you can open manholes or observation wells/clean outs.
- ❑ Open observation well and look down inside. If there is water in the chambers, you should be able to see it. You can use measuring sticks and fishing bobbers to keep track of the water level to see how quickly it fills after a rain event and how long it takes for water to infiltrate (dry out).

Permeable Pavement

- ❑ Look for evidence of ponding water on street or in parking lot (impervious surfaces) compared to porous surfaces (permeable pavers, bioretention features) used in GI.
- ❑ Poor water on different surfaces and see what happens.

Rain Gauge

- ❑ Collect and record data over time to compare volume of rainfall from: rain gauge in the schoolyard, online real-time data, and weather reports.

Tree Pits

- ❑ Analyze how much water trees uptake when they're leafed out to compared to when they're bare.
- ❑ Measure canopy density of different tree species and make correlations with canopy interception rates and shade.

Stormwater and Green Infrastructure Curriculum for Boston Public Schools

Curriculum Appendix C
Print Materials for Lessons 7.1-7.4

Lesson 7.1

NUTRIENT POLLUTION: READINGS from the EPA

EPA text: 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.

Nutrient Challenges in the Charles River

EPA text: https://www.epa.gov/charlesriver/environmental-challenges-charles-river

Blue-green algae bloom along the banks of the Charles River in Boston.
Nutrients, primarily phosphorus, are a chief culprit for dramatic algae blooms that plague the River with blue-green algae during the summer months.

These "blue green" algae blooms, are a form of bacteria known as Cyanobacteria, whose cells may release a toxin when they die. Exposure to the toxin can cause skin rashes and irritate the nose, eyes or throat, and if ingested can lead to serious liver and nervous system damage. Other harmful effects of the algae include reduced water clarity, nuisance scum, and reduced oxygen in the water, which is necessary for a healthy fish habitat.

EPA's goal is to reduce phosphorus discharges to the lower Charles by 54 percent to restore the river to a healthy state. In order to meet that goal, EPA must reduce the amount of stormwater runoff entering the River.

EPA Finds: More Than Half of The Nations Streams and Rivers Will Not Adequately Support Aquatic Life

Ryan Locicero / April 23, 2013

A recent news release from the EPA finds that more than half, (55%) of the nations streams and rivers are in poor conditions for aquatic life. The major contributing factor: excess nutrients.

This comprehensive survey, collected with the help of university scientist, state, and local officials investigated the water quality of approximately 2,000 sites across the United States. They found twenty-seven percent of the nation's rivers and streams to be significantly impacted as a result of excess nitrogen and forty percent to have high phosphorus levels.

Results from this study will be used to inform decision makers about the critical need for addressing the issue of nutrient over-enrichment and enhance the ability of states to manage water quality and protect sensitive ecosystems.

Photo Montage of Charles River Water Quality Over Time

Cars in river near Wellesley, near South Natick, April 22, 1966 Credit: Charles River Watershed Association

Dumping in Charles River at Cow Island-Flora Epstein and Arthur Brownell Credit: H. Shippen Goodhue, 1963

West Medway Dye Co. Discharge

Credit: Charles River Watershed Association

Town Dump in Milford, Cedar Swamp Pond, July 1968

Credit: Charles River Watershed Association

Fish kill near Perkins School for the Blind, Watertown--June 1964

Credit: Charles River Watershed Association

Credit: Lamar Gore/USFWS

Credit: Charles River Watershed Association

Credit: Rob Lerman

Heron in nest, feeding young, Charles River, Millenium Park

Credit: Rob Lerman

Millenium Park: What animal might have done this? Credit: Rob Lerman

Credit: Lamar Gore/USFWS

Credit: Lamar Gore/USFWS

CHARLES RIVER--ALGAL BLOOMS

Credit: Lamar Gore/USFW

CAUTION

POSTED ________________: Based on counts of the cyanobacteria (blue-green algae), MDPH thresholds for recreational waters have been exceeded.

- Water which looks like the pictures above may contain algae capable of producing toxins that can be dangerous to humans and pets.

- People and pets should avoid contact in areas of algae concentration

- Do not swallow water and rinse off after contact

For further information call:

MA Department of Public Health at 617-624-5757

Credit: MA Department of Public Health

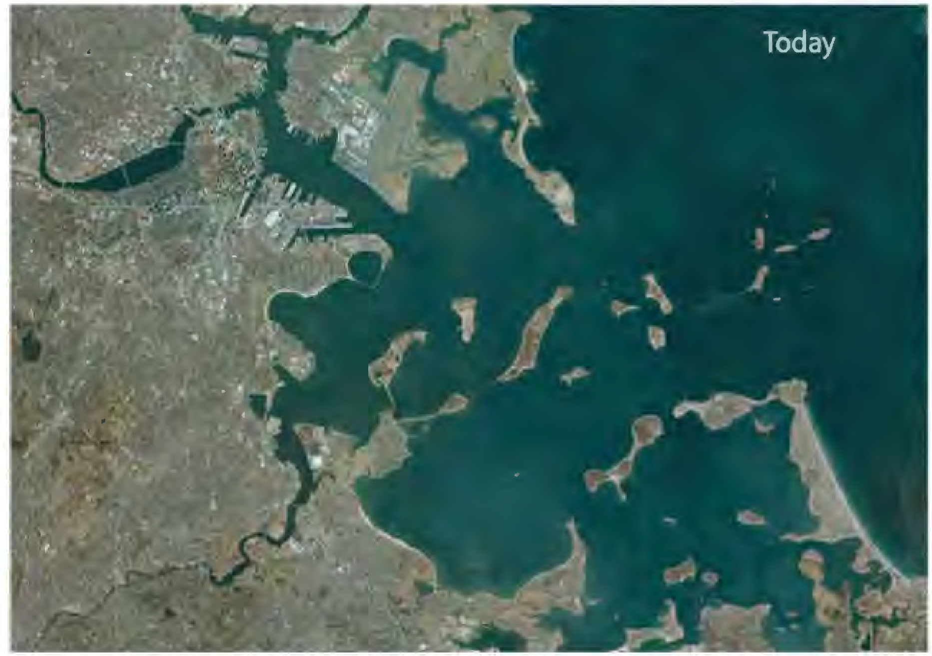
Algal Blooms Near the Esplanade

Credit: Charles River Watershed Association

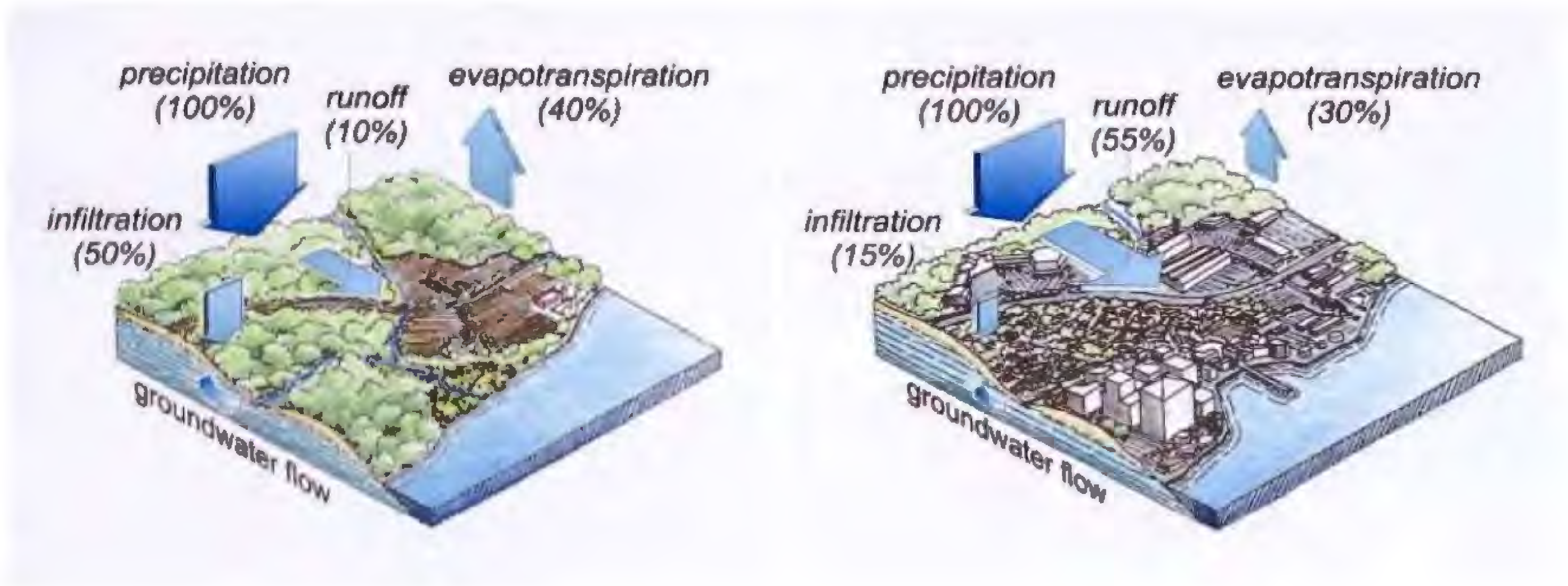
Algal Blooms

Credit: Charles River Watershed Association

LAND COVER IN BOSTON: 1630 to TODAY

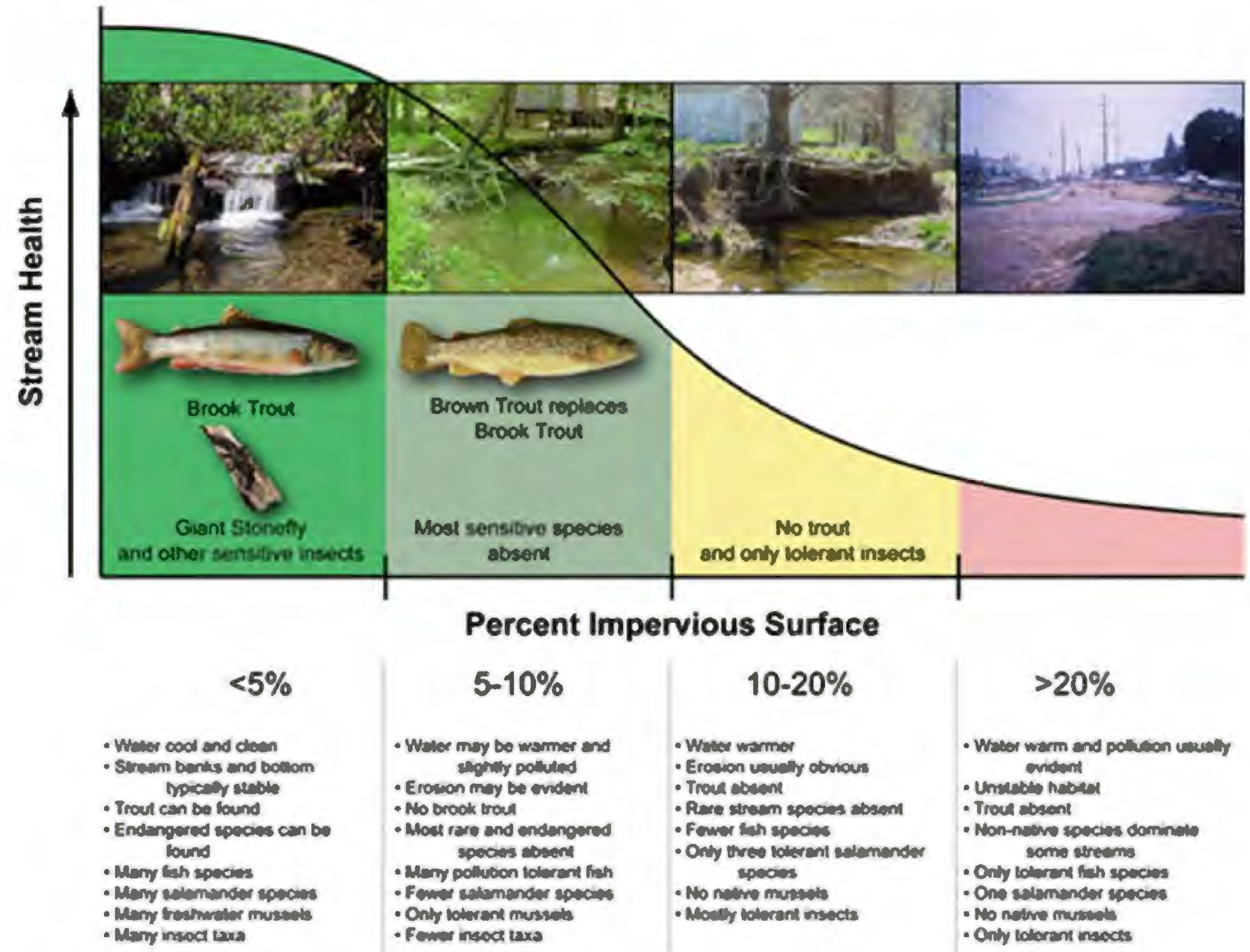


WATER CYCLE: PRE- AND POST-DEVELOPMENT



Mass.gov - https://www.teachengineering.org/content/usf_/lessons/usf_stormwater/usf_stormwater_lesson01_image1web.jpg

IMPERVIOUS COVER AND BIODIVERSITY IN STREAMS



Maryland.gov - http://dnr.maryland.gov/streams/PublishingImages/imp_graph.gif

Lesson 7.2

FOUR WATERSHED PHOTOS

Forest

Credit: Michael Roebbers

Farmland

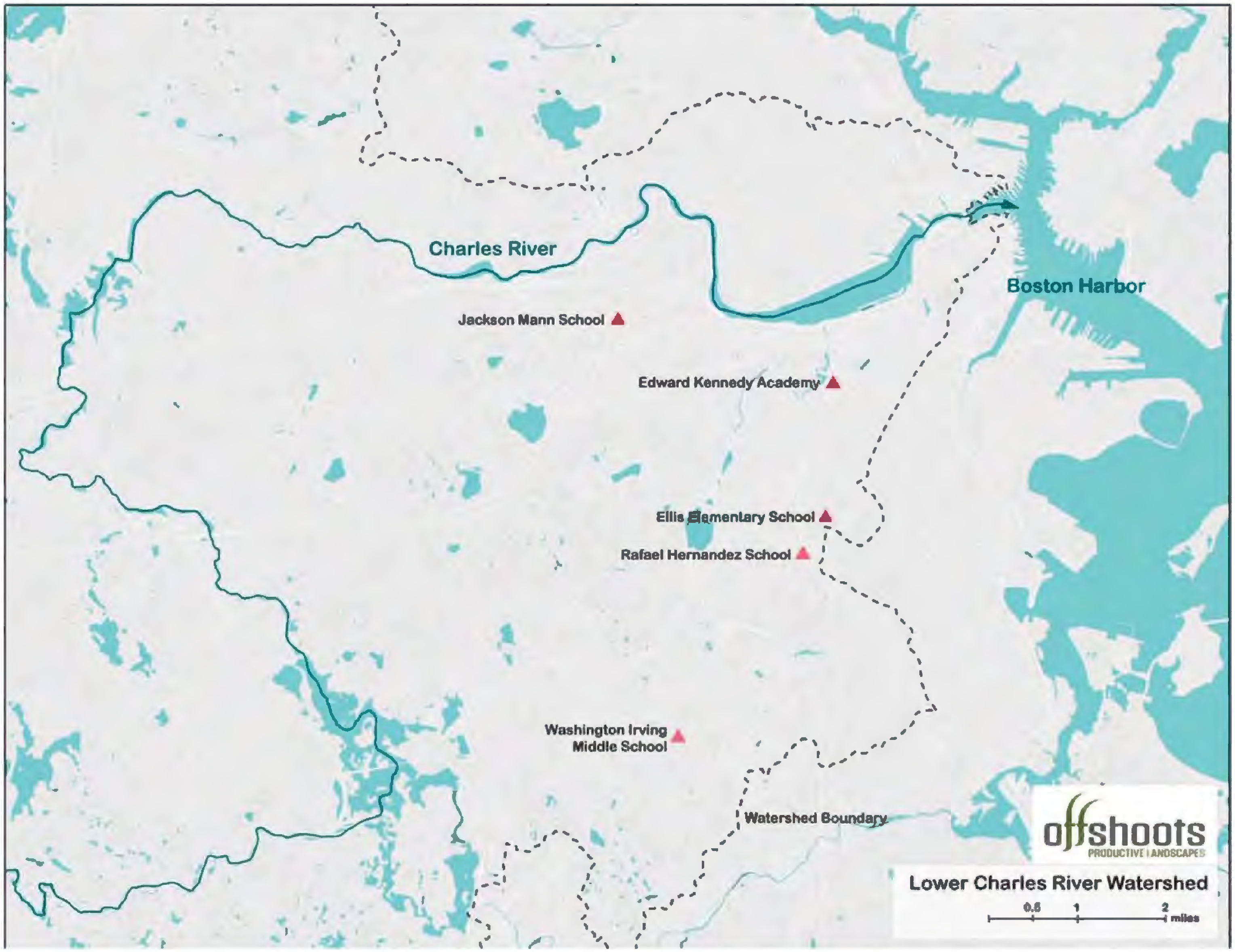
Town/Suburban

Credit: Max Pixel http://maxpixel.freegreatpicture.com/Inn-Old-Town-City-Historically-Passau-River-296797

Large City

Credit: Myrna Kassem

CHARLES RIVER WATERSHED MAP WITH GI SCHOOLS



IRVING SCHOOL PARKING LOT | "BEFORE" AERIAL VIEW

IRVING SCHOOL PARKING LOT | SCHOOLYARD WATERSHED MAP

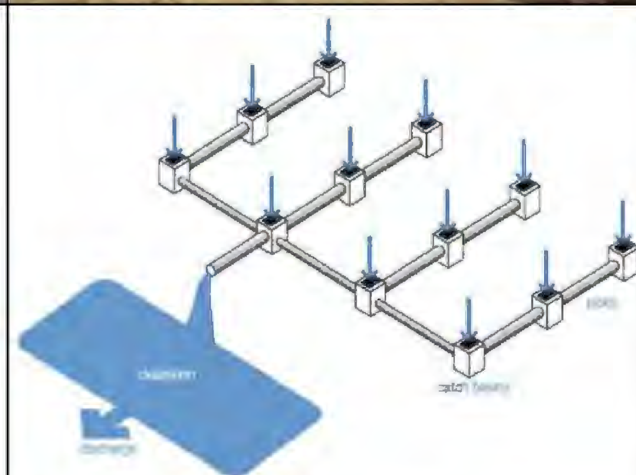
Grey Infrastructure

Grey infrastructure uses catch basins and pipes to quickly get runoff away from buildings and people; provides temporary storage in large ponds or underground storage tunnels/tanks; and carries stormwater to a single downstream location (pond or river outfall) while still carrying pollutants. It is the opposite of green infrastructure, which reduces runoff and promotes infiltration, evapotranspiration, and pollutant removal through small practices located close to where the actual rain falls.

Large underground stormwater storage tunnel.

Considerations

- Mostly used to control flooding at a large, watershed-scale with catchbasins and pipe networks (see diagram on left).
- Goal is to move water away quickly and safely
- Pipes carry stormwater to storage (detention) ponds or tanks to be released at a later time (once flood concerns are over).
- Can be installed underground (see upper right photo)
- Not always designed to clean water or to encourage infiltration
- Does not use vegetation or increase evapotranspiration
- Can be expensive to construct.
- Out of sight, out of mind.



UACDC, 2010

Grey infrastructure uses catch basins and pipes to collect rainwater and move it away from city streets and neighborhoods so they won't flood. Pipes carry stormwater to ponds and tanks for temporary storage or to outfalls into rivers.

Lesson 7.3

BIORETENTION FEATURES

Shallow, landscape depressions that promote natural filtering, evapotranspiration, and infiltration using plants and soil. Stormwater flows into the bioretention practice and ponds for a short period of time. Plants absorb water and phosphorus, microbes around roots take up pollutants. The soil layer is designed to filter pollutants and, in some cases, can promote infiltration. There are different types of bioretention (e.g., simple rain gardens, bioswales, stormwater planters, green roofs, and tree filters).

Siting Considerations

- Takes up surface space.
- Can be installed in existing landscaped areas such as lawn, parking lot islands, road medians, flower beds, etc. or can replace unused areas of impervious cover.
- Ponding is only temporary, generally less than 2 days.
- In general, do not eat the plants (unless only roof runoff going into practice).
- Need salt tolerant plants that can handle winter road salts if used to manage road or parking lot runoff.
- Green roofs can be expensive.

Benefits

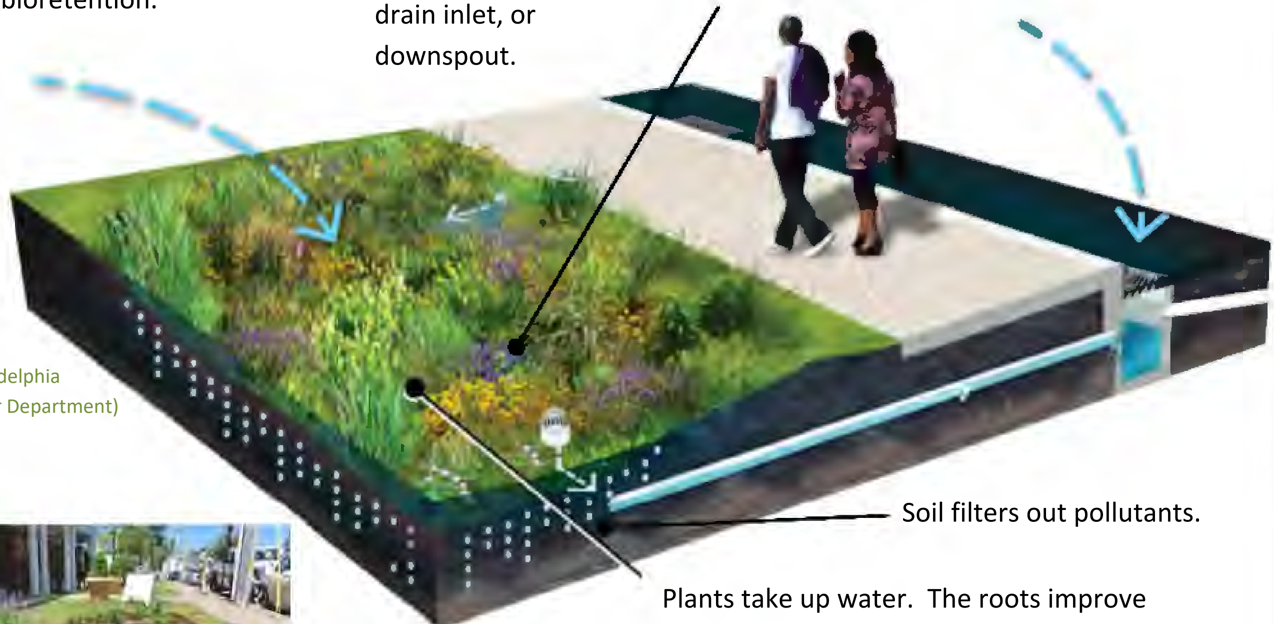
- 60% phosphorus removal from stormwater.
- Can be integrated with play spaces.
- High visibility for educational purposes.
- Promotes biodiversity.
- Can help provide shade and better air quality if trees are incorporated.
- Green roofs can help with building cooling
- Helps with water conservation by reducing need for watering.
- Can help provide infiltration (optional).

Bioretention/Rain Garden - Planted depressions with modified soils. Rain gardens are generally smaller, have a simpler design, and include minor amendments to existing native soils. Bioretention facilities often treat larger drainage areas than rain gardens, have engineered soils, and include an underdrain pipe system.

Stormwater runoff from surrounding landscape flows into bioretention.

Stormwater is piped from a catch basin/ drain inlet, or downspout.

Runoff can be piped back to drainage network after it has been cleaned, or it can infiltrate into the ground.



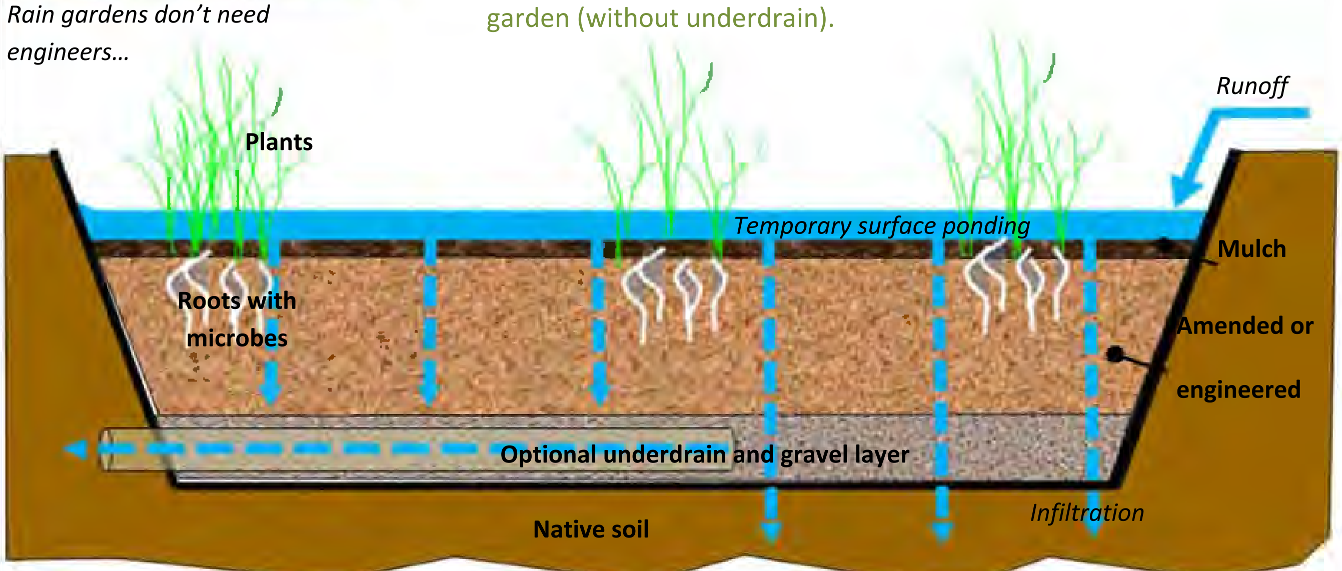
(Philadelphia Water Department)

Soil filters out pollutants.

Plants take up water. The roots improve infiltration and provide surface area for microbes that can breakdown pollutants.

Rain gardens don't need engineers…

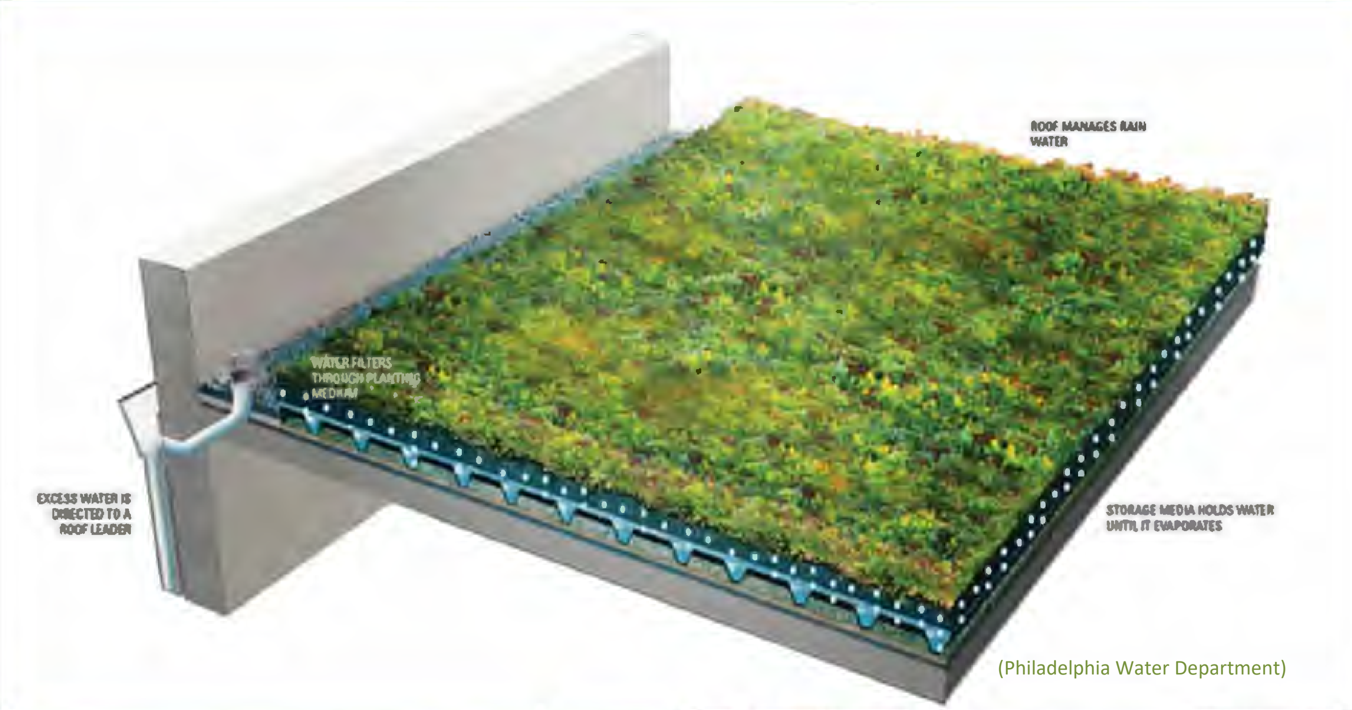
Cross section showing shallow ponding, cleaning, and infiltration in a bioretention cell (with underdrain) or a rain garden (without underdrain).



Bioswales - Linear bioretention that also helps move runoff downhill. Commonly used in parking lot landscaped islands and between streets and sidewalks.

(Philadelphia Water Department)

Green Roof - Using plants on the roof to manage runoff and cool buildings.



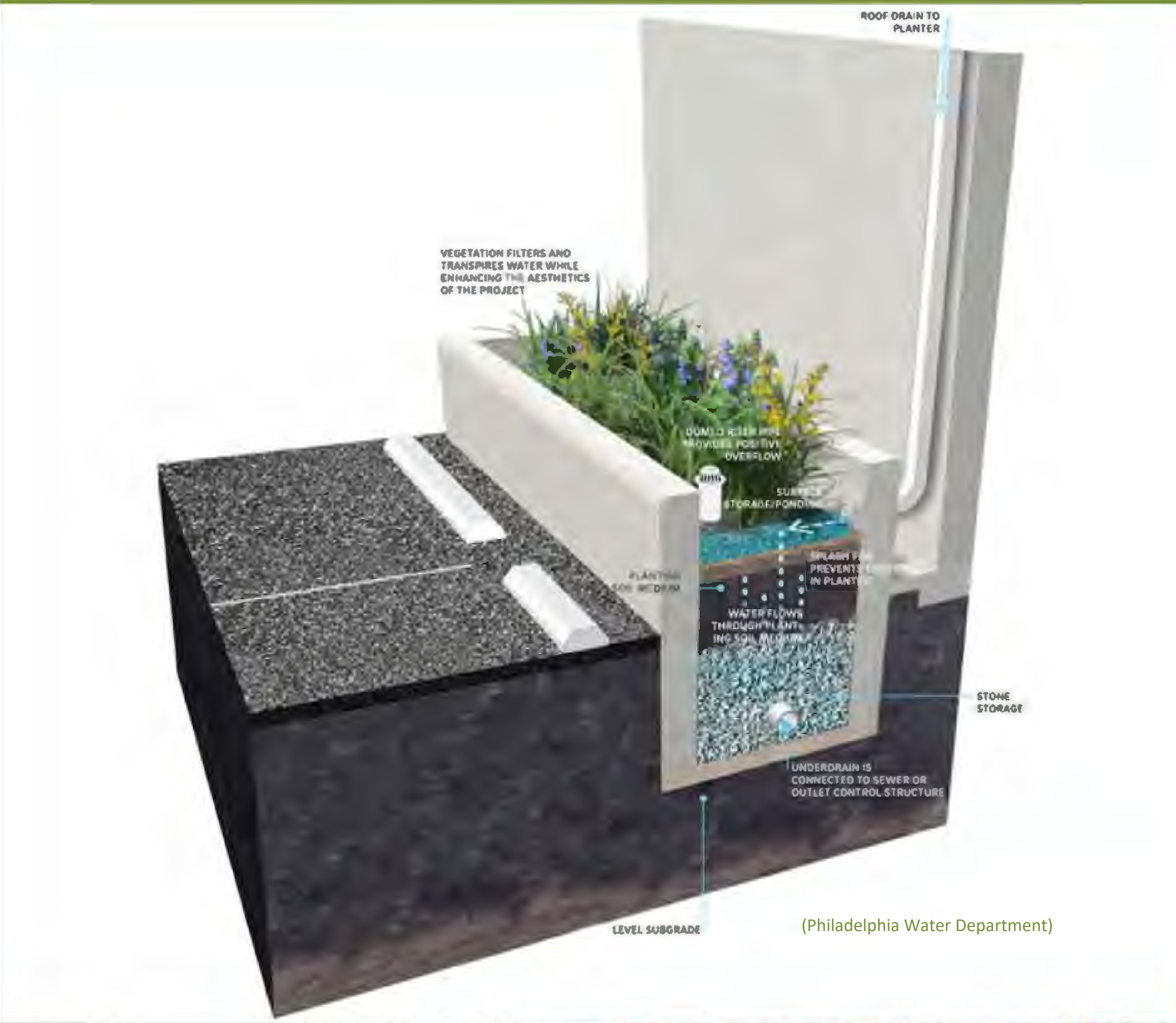
(Philadelphia Water Department)

Tree Filter - Street trees designed to accept stormwater runoff. They have large area of soil to hold runoff and promote root growth, uptake by the tree, and infiltration.

(Philadelphia Water Department)



Stormwater Planter - Vegetated box installed next to buildings to intercept rooftop runoff.



(Philadelphia Water Department)

PERMEABLE PAVEMENTS

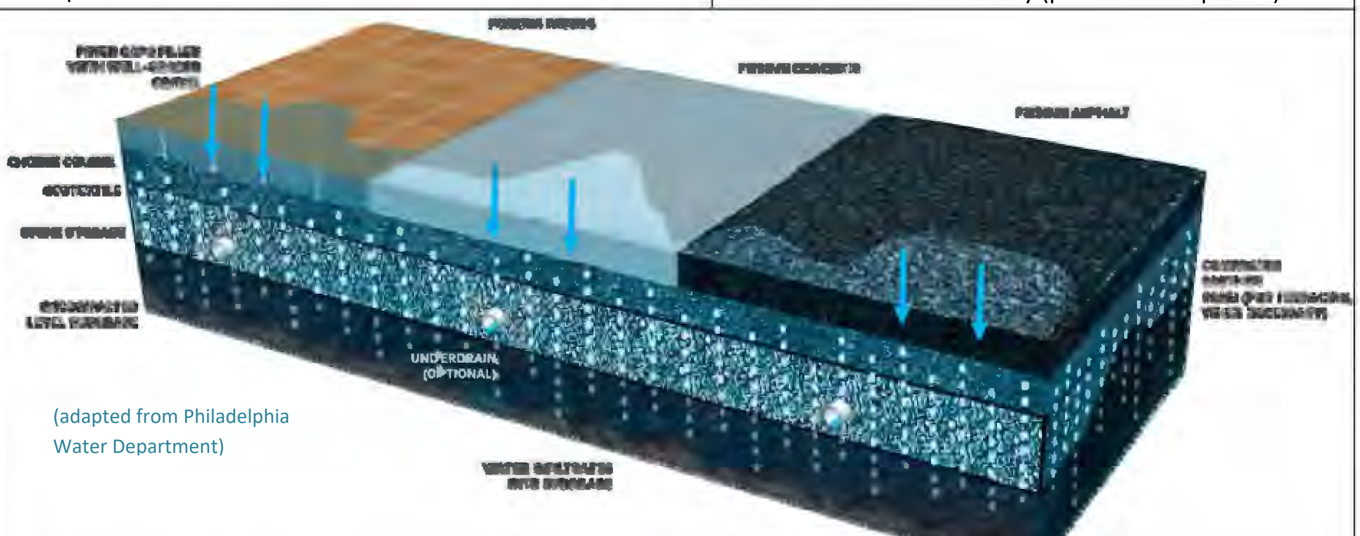
Hard surface materials used on roads, parking lots, sidewalks, basketball courts, etc. that allow water to pass through. These include permeable asphalt, concrete, and pavers. They can be made from a variety of recycled materials (rubber tires, glass, etc). You can still use the surface just like an impervious surface. The stone storage layer below the permeable pavement serves as a temporary reservoir to give water time to slowly infiltrate.

Siting Considerations

- Use in places where hard surfaces are needed (parking lots, playgrounds, sidewalks, basketball courts, etc).
- Needs adequate separation distance from groundwater table.
- Permeable native soils preferred.
- Do not allow off-site run-on to pavements. You really just want to handle the rain that falls directly on the surface.
- Can be an expensive alternative compared to other GI options.

Benefits

- 70% phosphorus removal from stormwater
- Reduces the amount of stormwater generated by removing/replacing impervious cover.
- Allows for normal uses on surfaces (parking, basketball, etc)
- Promotes infiltration.
- Don't need to apply winter deicing chemicals.
- Good opportunities for stormwater education, as well as artistic creativity (patterns with pavers).



(adapted from Philadelphia Water Department)

Porous paver, gravel fill

Porous concrete

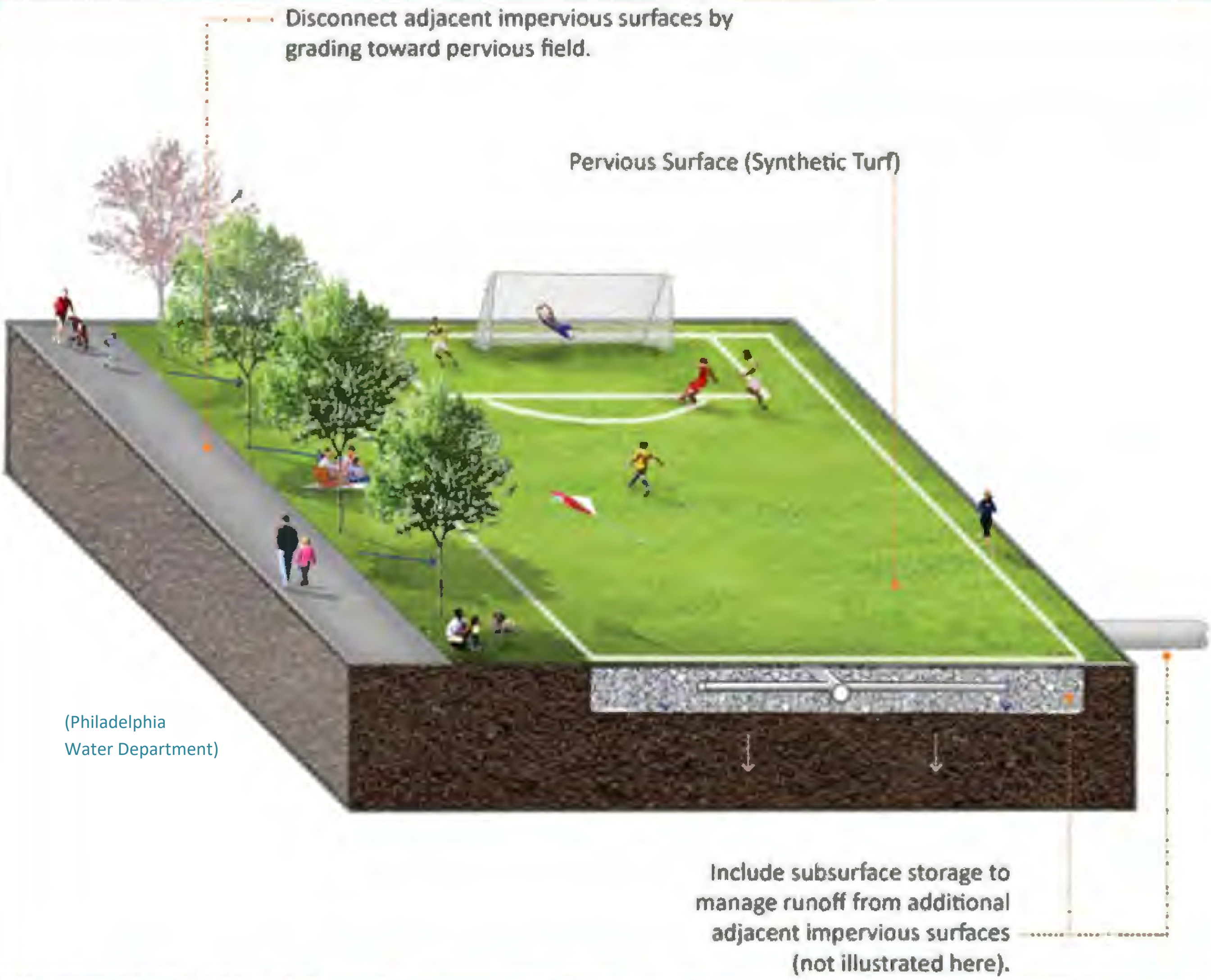
Porous asphalt

Porous paver, grass fill

Runoff can pass through holes and gaps in the surface and drain down into and filling up the stone reservoir below.	Porous asphalt used here in parking stalls (on right) and traditional asphalt used in drive aisle (on left).

Examples of Permeable Surfaces at Schools

Pervious Turf Field



(Philadelphia Water Department)

Rafael Hernandez K-8 School

Washington Irving Middle School

INFILTRATION PRACTICES

Group of engineered practices designed to hold runoff underground and slowly release it into the surrounding soils. This group of practices includes underground chambers, infiltration basins infiltration trenches, and dry wells. These practices only work if the underlying native soils are permeable. They typically are installed within a stone bedding layer, include internal pipes to help distribute flows evenly, and have a structure to trap sediment and debris that might otherwise clog the system.

Site Considerations

- Can be installed below parking lots, fields, or other locations where a change in land use is not desired.
- Needs adequate separation distance from groundwater table in order to infiltrate.
- Permeable native soils required. Avoid infiltrating into contaminated soils.
- Don't want to be too close to steep slope, buildings, and underground utilities.

Benefits

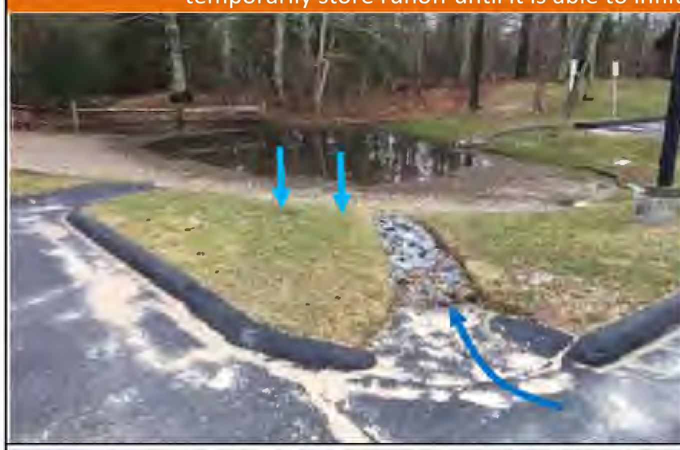
- 80% phosphorus removal efficiency.
- Promotes infiltration and can help recharge groundwater supplies.
- Can be used where parking or surface play space cannot be lost for surface GI practice.
- Can provide some educational benefit, but not easily seen from surface.

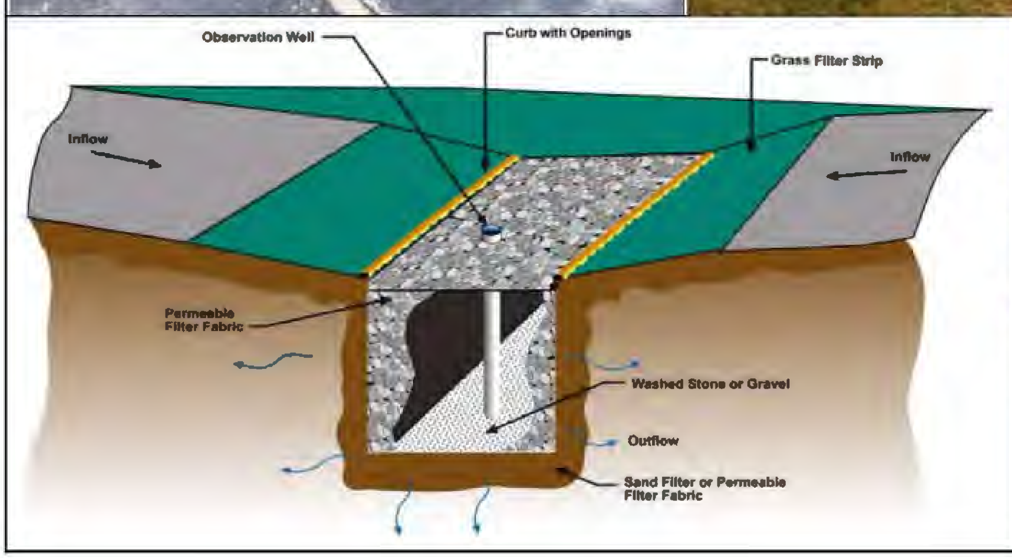
(Philadelphia Water Department)

Example of a dry well (also called a recharger) used to infiltrate water collected in a catch basin/storm drain inlet.

Infiltration Chambers - Underground pipes, boxes, or other structure with an open bottom and perforated sides surrounded by stone. Chambers will fill up with runoff between storms and, slowly over time, infiltration out of the bottom and sides of the system into the native soils.

Infiltration Basins/Trenches - Underground stone bed below a depressed area with vegetation (top right) or stone surface (top left). Basins are generally wider than they are long. Trenches are linear (longer than they are wide). Both use a perforated pipe system to help distribute flows evenly underground (bottom right). Both practices are designed to temporarily store runoff until it is able to infiltrate out into the into surrounding native soils.





RAIN WATER HARVESTING

A storage structure, such as a rain barrel, cistern, or rain tank used to hold runoff for subsequent reuse--primarily for non-potable purposes such as irrigation or washing cars. Generally includes a filtering mechanism and a pump for distribution. In Massachusetts the plumbing code is very restrictive when it comes to rainwater reuse inside buildings. In other places, if treated with chlorine or UV light, rainwater can be used for washing clothes/dishes, toilets, showers, sprinkler systems, and even drinking.

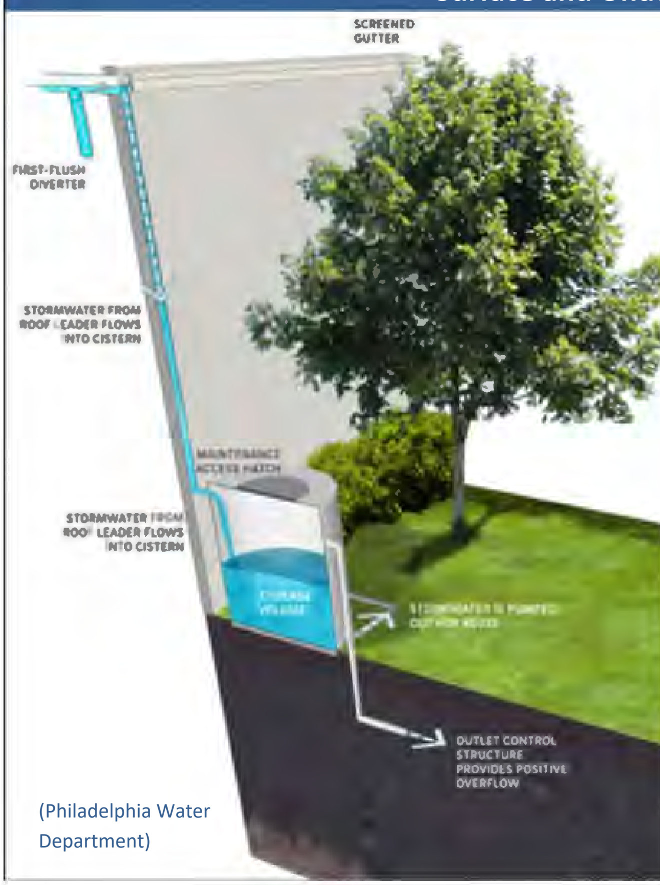
Site Considerations

- Great for collecting rooftop runoff (can be installed above ground and water is relatively clean for reuse).
- Depending on where located, it may require pumps to move water.
- Be careful when reusing to water edible plants.
- Underground storage is generally more expensive than aboveground storage.

Benefits

- If completely reused, then 100% phosphorus reduction.
- Water reuse helps meet water conservation goals and provides cost savings on water bill.
- Could be used to help plants grow (irrigation), which could contribute to greater evapotranspiration and infiltration.
- Great educational opportunity.

Surface and Underground Cisterns

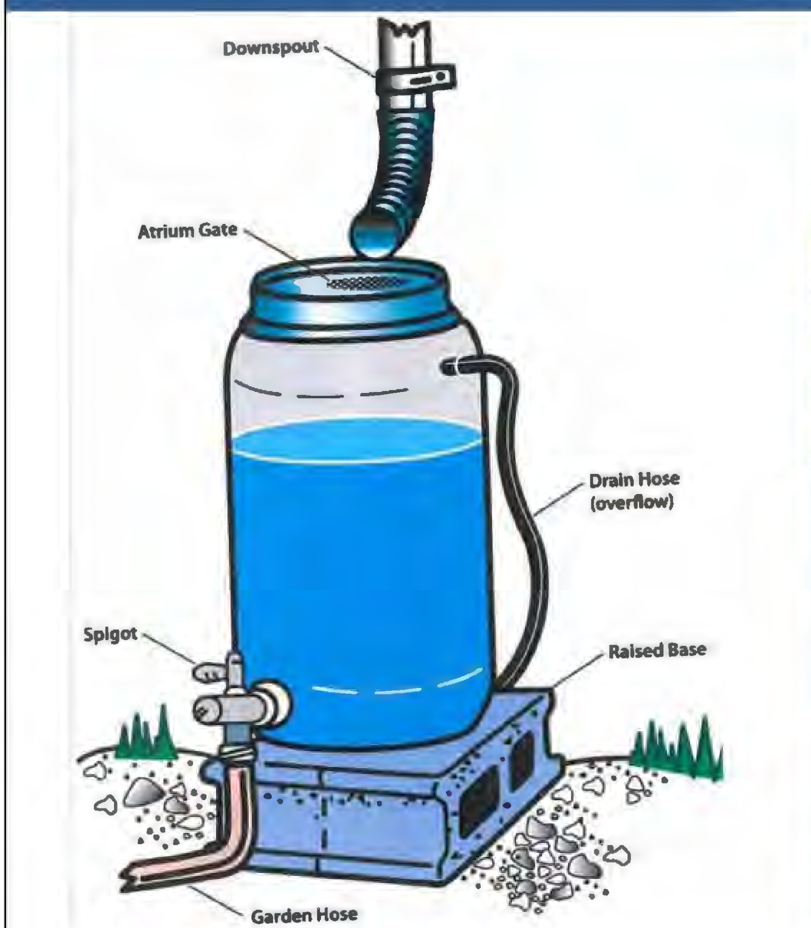


(Philadelphia Water Department)

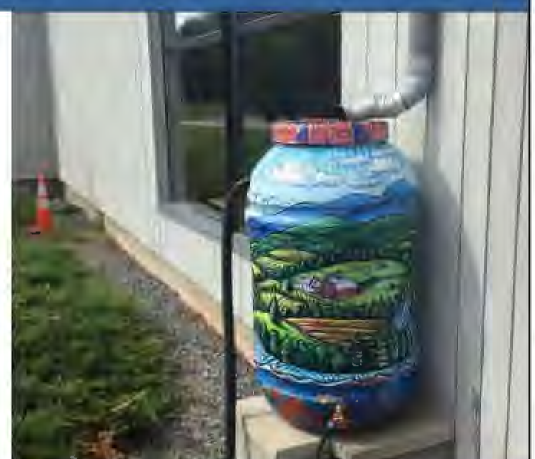
(Philadelphia Water Department)

Rain Tank - Underground modular, plastic cells surrounded by impermeable liner to prevent loss of water through infiltration. Water is pumped from tank to watering lawn.

Rain Barrels - Small storage tanks used by homeowners to collect rainwater for watering plants



Monaghan Township, Dillsburg, Pennsylvania



IRVING SCHOOL PARKING LOT | AFTER--DIAGRAM WITH GI

IRVING SCHOOL PARKING LOT | "BEFORE" GROUND VIEW

IRVING SCHOOL PARKING LOT | CONCRETE SWALE

IRVING SCHOOL PARKING LOT| BIOSWALE

Claims, Evidence, Reasoning Template

Question:

Claim:

Evidence:

Evidence:

Evidence:

Reasoning:

Reasoning:

Reasoning:

Fill in the order you prefer.

Lesson 7.4

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**

Washington Irving Case Study Scenario A

Scenario Name (optional)	Washington Irving Scenario A
Location	parking lot
Priority Co-benefits	education, parking, and groundwater

Decision Matrix

GI Practice Options	Catchment Area (sq ft)	Runoff Volume (gallon)	Phosphorus (lbs/acre/yr)		Construction Cost ($/cu ft)	Co-benefits Score
			Before GI	Remaining After GI		
No GI	30,000	17,054	0.82	0.82	N/A	N/A
Infiltration practices	30,000	17,054	0.82	0.16	$ 73,000	70
Bioretention practices	30,000	17,054	0.82	0.33	$ 61,600	10
Permeable pavements	30,000	17,054	0.82	0.25	$ 228,000	70
Rainwater harvesting	30,000	17,054	0.82	0.00	$ 45,600	0

Priority Co-Benefits

Co-benefits of GI	Explain Your Ranking	**Rank** (out of 100 points)	Considerations
Parking	teachers and parents generally complain about finding enough parking, so we don't want to reduce the number of spaces	30	*If parking is limited or there are traffic issues with bus loading and parent pickup, you don't want your GI installation to make things worse. Maybe it can make it better!*
Impervious Cover			*If you have wasted areas of impervious cover (not really used by cars or buildings or people), then maybe you can remove it and convert to a bioretention or other landscaping. This would reduce the amount of stormwater runoff generated.*
Playspace			*If playspace is limited or unattractive, you don't want to make it worse. Opportunities to expand playspace or improve existing areas as part of GI construction could be great!*
Groundwater	recharging groundwater is a priority for us since our schoolyard is almost 100% impervious area, meaning we have NO infiltration at our school anymore.	30	*A main goal of GI is to get water back into the ground rather than discharing it offsite in a pipe. (This is an especially good choice if you know that the soils on your site have a high permeability, i.e. HSG A and B soils.)*
Biodiversity			*If your schoolyard or neighborhood lacks vegetation or habitat areas for birds, insects, etc., then you may want to use GI to help bring some biodiversity back to your school. Using native plants that flower and fruit in GI features is a good start.*
Tree Canopy			*Trees promote evapotranspiration and provide shade during the summer which helps reduce air temperatures in the city --for people and parked cars.*
Air Quality			*Trees can help clean pollutants out of the air and can make a measureable difference at the city-scale. At the school site, consider planting trees in locations where car or bus exhaust is most concentrated.*
Stormwater Education	Has to be good for educational purposes	40	*Since it is a school, maybe providing opportunities for stormwater and watershed education with your GI feature is a priority for you. Look for locations with high visibility (e.g., front of school) and choose GI practices you can see.*
Total		**100**	

Co-benefit Scores for GI Practices

Infiltration practices

Co-benefits	Rank (% of 100 total points)	Evaluation Options (select from drop down menu)	Score
Parking	30	No change to parking count	0
Impervious Cover	0	None Selected	0
Playspace	0	None Selected	0
Groundwater	30	Increases infiltration a lot	30
Schoolyard Biodiversity	0	None Selected	0
Tree Canopy	0	None Selected	0
Air Quality	0	None Selected	0
Education	40	Excellent teaching opportunity	40
Total	**100**		**70**

Bioretention practices

Co-benefits	Rank (% of 100 total points)	Evaluation Options (select from drop down menu)	Score
Parking	30	Reduces number of parking spaces	-30
Impervious Cover	0	None Selected	0
Playspace	0	None Selected	0
Groundwater	30	Increases infiltration a little	0
Schoolyard Biodiversity	0	None Selected	0
Tree Canopy	0	None Selected	0
Air Quality	0	None Selected	0
Education	40	Excellent teaching opportunity	40
Total	**100**		**10**

Permeable pavements

Co-benefits	Rank (% of 100 total points)	Evaluation Options (select from drop down menu)	Score
Parking	30	No change to parking count	0
Impervious Cover	0	None Selected	0
Playspace	0	None Selected	0
Groundwater	30	Increases infiltration a lot	30
Schoolyard Biodiversity	0	None Selected	0
Tree Canopy	0	None Selected	0
Air Quality	0	None Selected	0
Education	40	Excellent teaching opportunity	40
Total	**100**		**70**

Rainwater harvesting

Co-benefits	Rank (% of 100 total points)	Evaluation Options (select from drop down menu)	Score
Parking	30	No change to parking count	0
Impervious Cover	0	None Selected	0
Playspace	0	None Selected	0
Groundwater	30	Increases infiltration a little	0
Schoolyard Biodiversity	0	None Selected	0
Tree Canopy	0	None Selected	0
Air Quality	0	None Selected	0
Education	40	Some teaching opportunity	0
Total	**100**		**0**

Washington Irving Case Study Scenario B

Scenario Name (optional)	Washington Irving Scenario B
Location	parking lot
Priority Co-benefits	education, air quality, and impervious cover reduction

Decision Matrix

GI Practice Options	Catchment Area (sq ft)	Runoff Volume (gallon)	Phosphorus (lbs/acre/yr)		Construction Cost ($/cu ft)	Co-benefits Score
			Before GI	Remaining After GI		
No GI	30,000	17,054	0.82	0.82	N/A	N/A
Infiltration practices	30,000	17,054	0.82	0.16	$ 73,000	40
Bioretention practices	30,000	17,054	0.82	0.33	$ 61,600	100
Permeable pavements	30,000	17,054	0.82	0.25	$ 228,000	65
Rainwater harvesting	30,000	17,054	0.82	0.00	$ 45,600	35

Priority Co-Benefits

Co-benefits of GI	Explain Your Ranking	Rank (out of 100 points)	Considerations
Parking			*If parking is limited or there are traffic issues with bus loading and parent pickup, you don't want your GI installation to make things worse. Maybe it can make it better!*
Impervious Cover	Convert some impervious cover to landscape islands where we can separate cars from where kids walk into the school or wait to be picked up	25	*If you have wasted areas of impervious cover (not really used by cars or buildings or people), then maybe you can remove it and convert to a bioretention or other landscaping. This would reduce the amount of stormwater runoff generated.*
Playspace			*If playspace is limited or unattractive, you don't want to make it worse. Opportunities to expand playspace or improve existing areas as part of GI construction could be great!*
Groundwater			*A main goal of GI is to get water back into the ground rather than discharing it offsite in a pipe. (This is an especially good choice If you know that the soils on your site have a high permeability, i.e. HSG A and B soils.)*
Biodiversity			*If your schoolyard or neighborhood lacks vegetation or habitat areas for birds, insects, etc., then you may want to use GI to help bring some biodiversity back to your school. Using native plants that flower and fruit in GI features is a good start.*
Tree Canopy			*Trees promote evapotranspiration and provide shade during the summer which helps reduce air temperatures in the city --for people and parked cars.*
Air Quality	Bring in plants that can help clean the air where all the cars are	35	*Trees can help clean pollutants out of the air and can make a measureable difference at the city-scale. At the school site, consider planting trees in locations where car or bus exhaust is most concentrated.*
Stormwater Education	Has to be good for educational purposes	40	*Since it is a school, maybe providing opportunities for stormwater and watershed education with your GI feature is a priority for you. Look for locations with high visibility (e.g., front of school) and choose GI practices you can see.*
Total		**100**	

Co-benefit Scores for GI Practices

Infiltration practices

Co-benefits	Rank (% of 100 total points)	Evaluation Options (select from drop down menu)	Score
Parking	0	None Selected	0
Impervious Cover	25	No change in amount of impervious cover	0
Playspace	0	None Selected	0
Groundwater	0	None Selected	0
Schoolyard Biodiversity	0	None Selected	0
Tree Canopy	0	None Selected	0
Air Quality	35	No improvement	0
Education	40	Excellent teaching opportunity	40
Total	**100**		**40**

Bioretention practices

Co-benefits	Rank (% of 100 total points)	Evaluation Options (select from drop down menu)	Score
Parking	0	None Selected	0
Impervious Cover	25	Reduces impervious cover (e.g. removal of some pavement)	25
Playspace	0	None Selected	0
Groundwater	0	None Selected	0
Schoolyard Biodiversity	0	None Selected	0
Tree Canopy	0	None Selected	0
Air Quality	35	Improves air quality (e.g., trees planted at bus loading zone)	35
Education	40	Excellent teaching opportunity	40
Total	**100**		**100**

Permeable pavements

Co-benefits	Rank (% of 100 total points)	Evaluation Options (select from drop down menu)	Score
Parking	0	None Selected	0
Impervious Cover	25	Reduces impervious cover (e.g. removal of some pavement)	25
Playspace	0	None Selected	0
Groundwater	0	None Selected	0
Schoolyard Biodiversity	0	None Selected	0
Tree Canopy	0	None Selected	0
Air Quality	35	No improvement	0
Education	40	Excellent teaching opportunity	40
Total	**100**		**65**

Rainwater harvesting

Co-benefits	Rank (% of 100 total points)	Evaluation Options (select from drop down menu)	Score
Parking	0	None Selected	0
Impervious Cover	25	No change in amount of impervious cover	0
Playspace	0	None Selected	0
Groundwater	0	None Selected	0
Schoolyard Biodiversity	0	None Selected	0
Tree Canopy	0	None Selected	0
Air Quality	35	Improves air quality (e.g., trees planted at bus loading zone)	35
Education	40	Some teaching opportunity	0
Total	**100**		**35**

Stormwater and Green Infrastructure Curriculum for Boston Public Schools

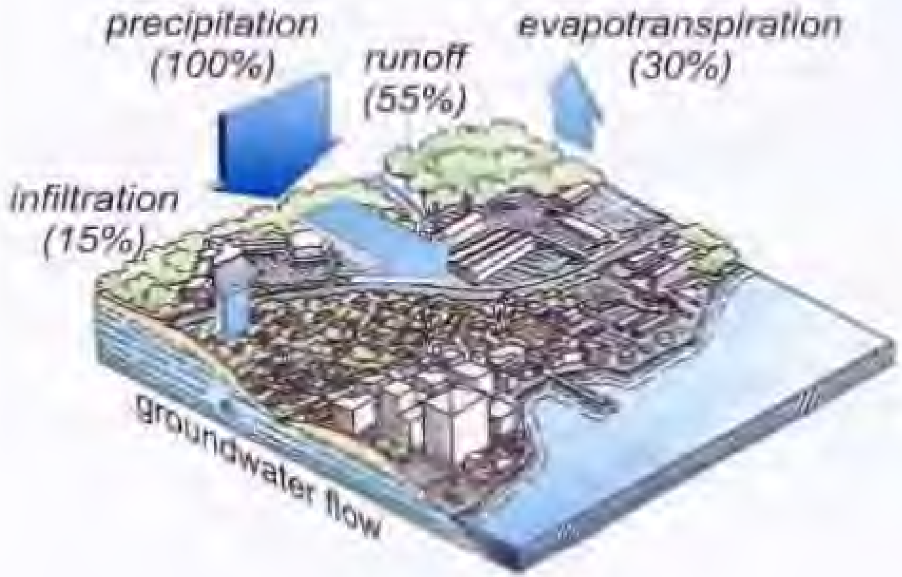
Curriculum Appendix D

Captioned Slideshow

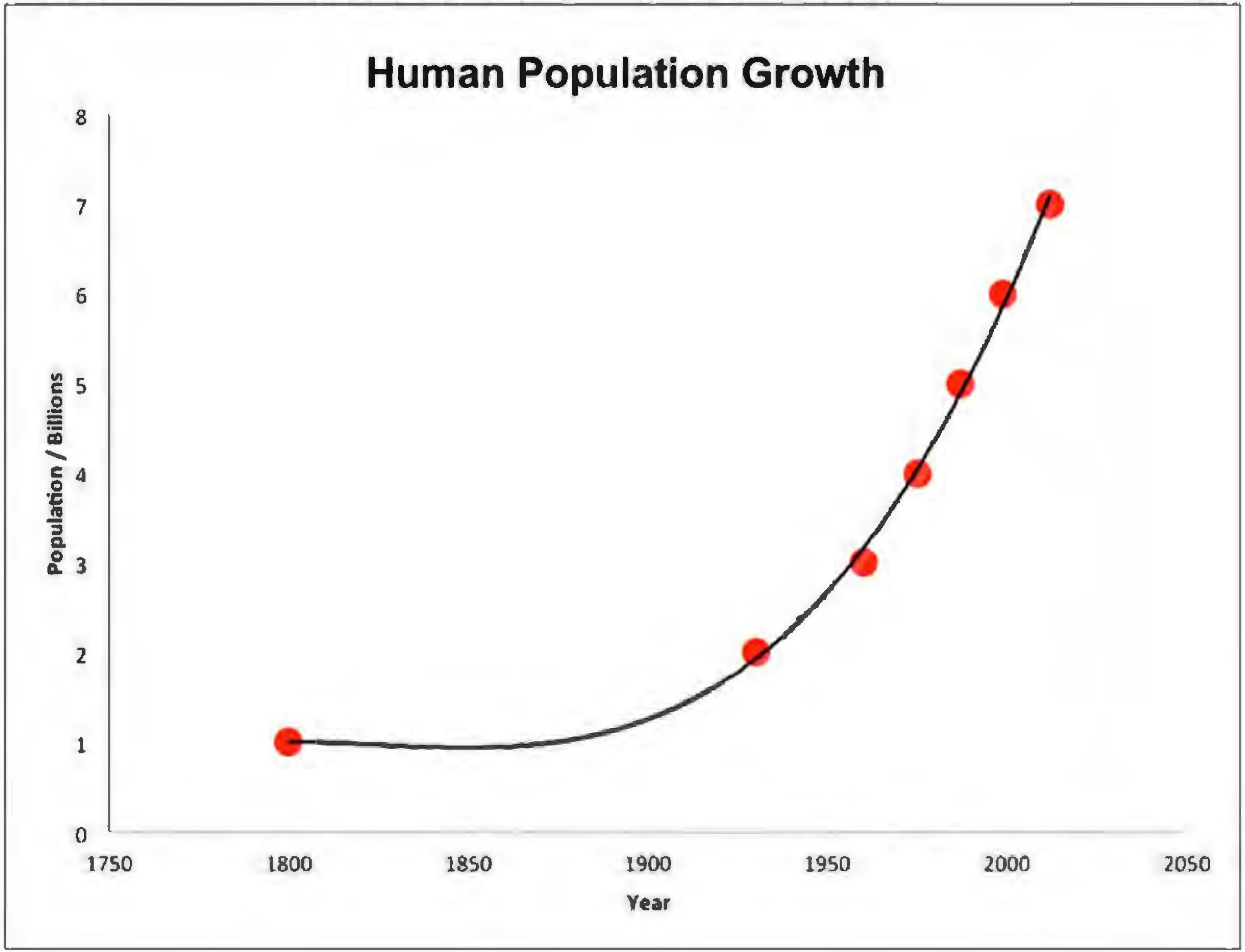
Lesson number (e.g. 7.1.2) indicates the lesson where the image is first introduced. You may want to return to these images at other points as well.

Boston Land Cover 1630 | Today

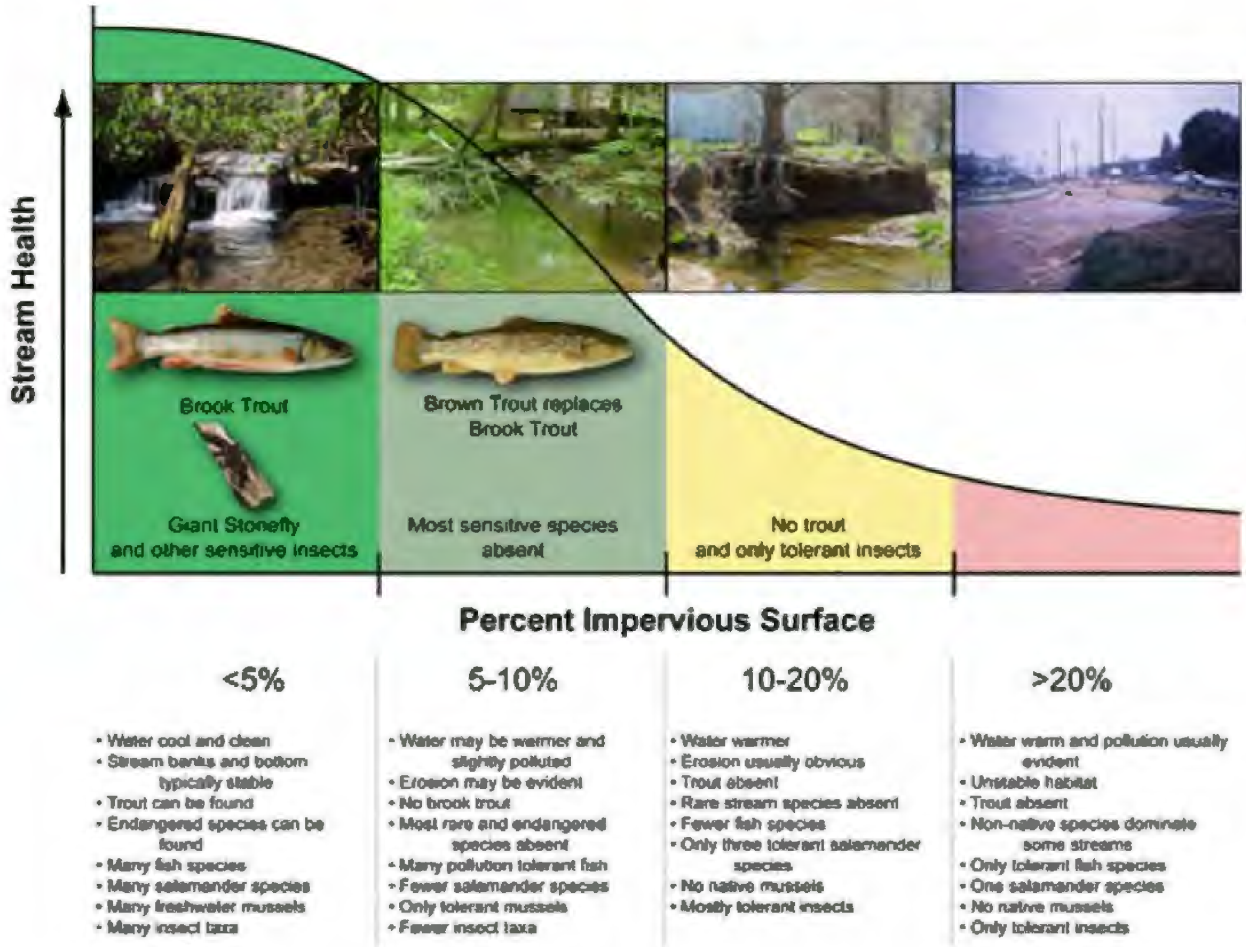
The Natural Water Cycle | The Urban Water Cycle



Mass.gov - https://www.teachengineering.org/content/usf_/lessons/usf_stormwater/usf_stormwater_lesson01_image1web.jpg



https://upload.wikimedia.org/wikipedia/en/thumb/3/3a/Human_population_growth_from_1800_to_2000.png/800px-Human_population_growth_from_1800_to_2000.png



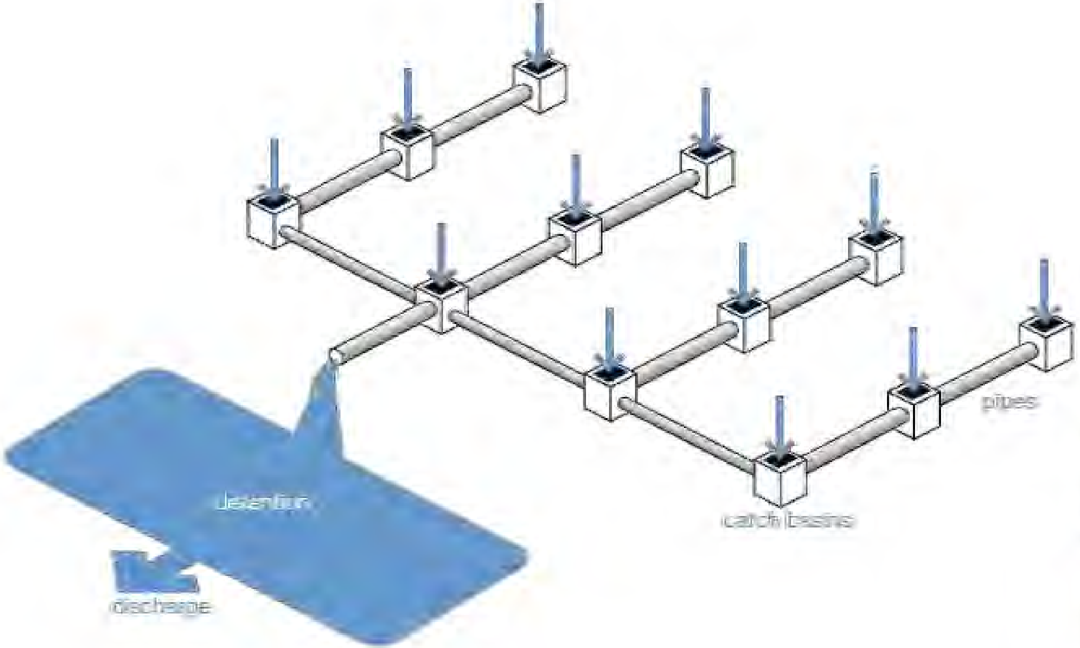
Maryland.gov - http://dnr.maryland.gov/streams/PublishingImages/imp_graph.gif

How Can We Make the Landscape on the Right Work More Like the Landscape on the Left?

Credit: Michael Roebbers

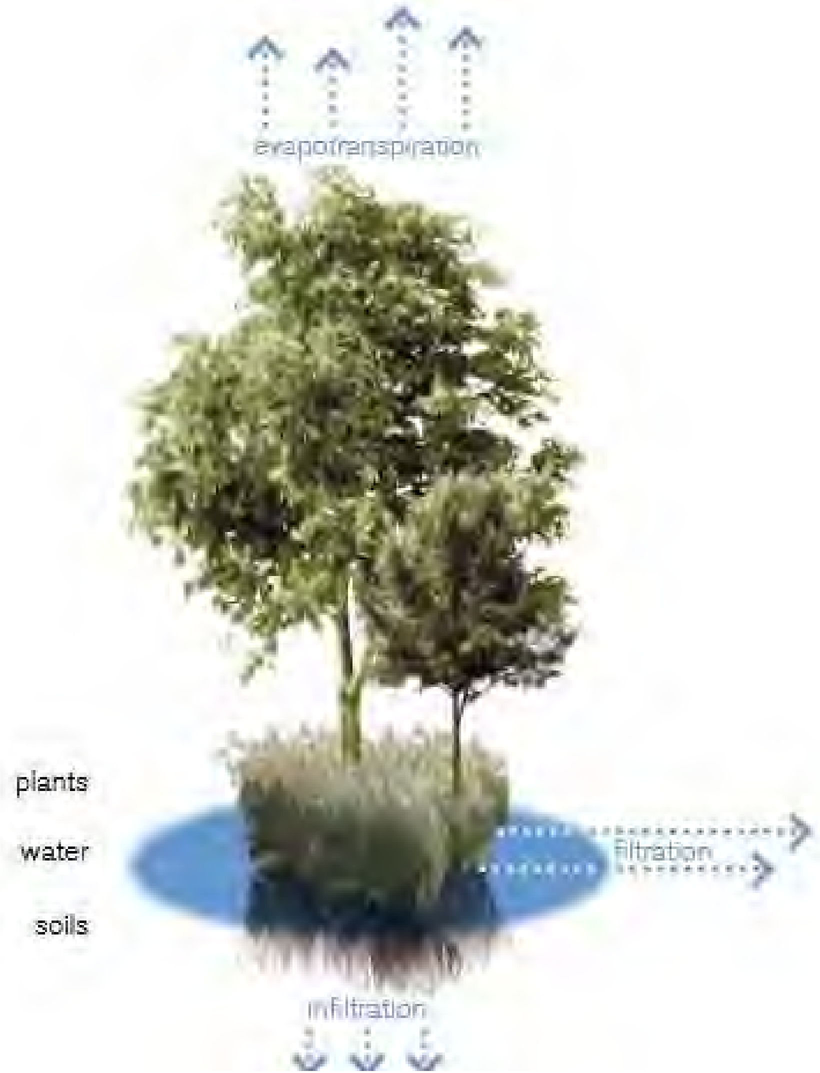
Credit: Myrna Kassem

Stormwater Infrastructure: Managing Rain in the City



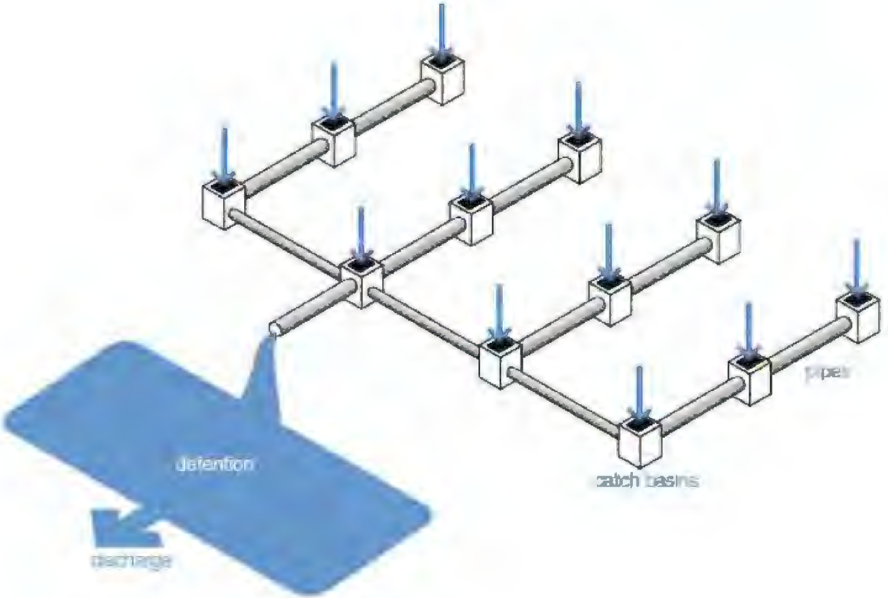
University of Arkansas – Community Design Center
Low Impact Development: a design manual for urban areas
http://www.bwdh2o.org/wp-content/uploads/2012/03/Low_Impact_Development_Manual-2010.pdf

Could We Use Plants Instead of Pipes to Manage Stormwater Runoff?

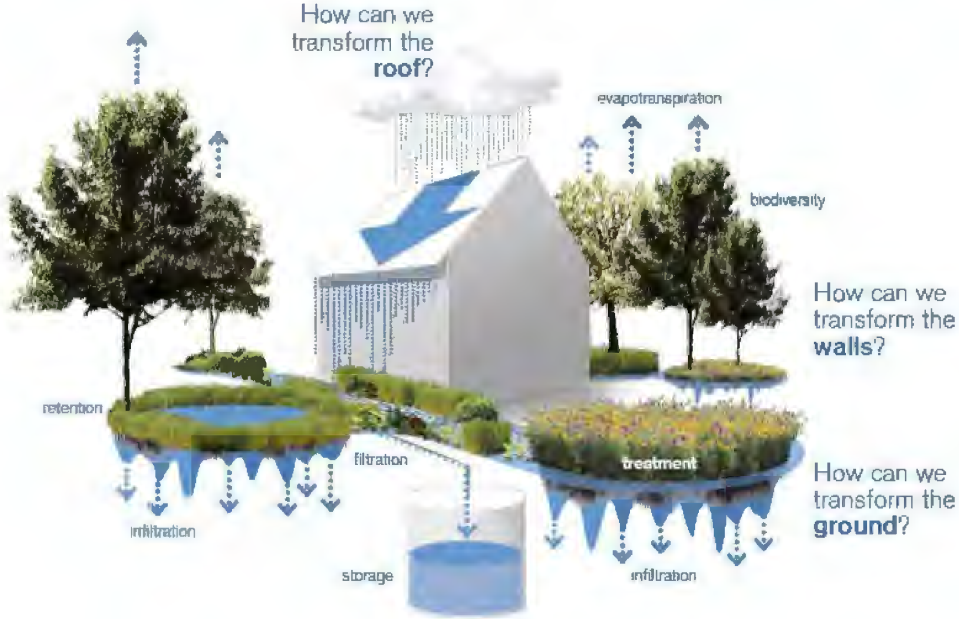


University of Arkansas – Community Design Center
Low Impact Development: a design manual for urban areas
http://www.bwdh2o.org/wp-content/uploads/2012/03/Low_Impact_Development_Manual-2010.pdf

Grey Infrastructure



Green Infrastructure

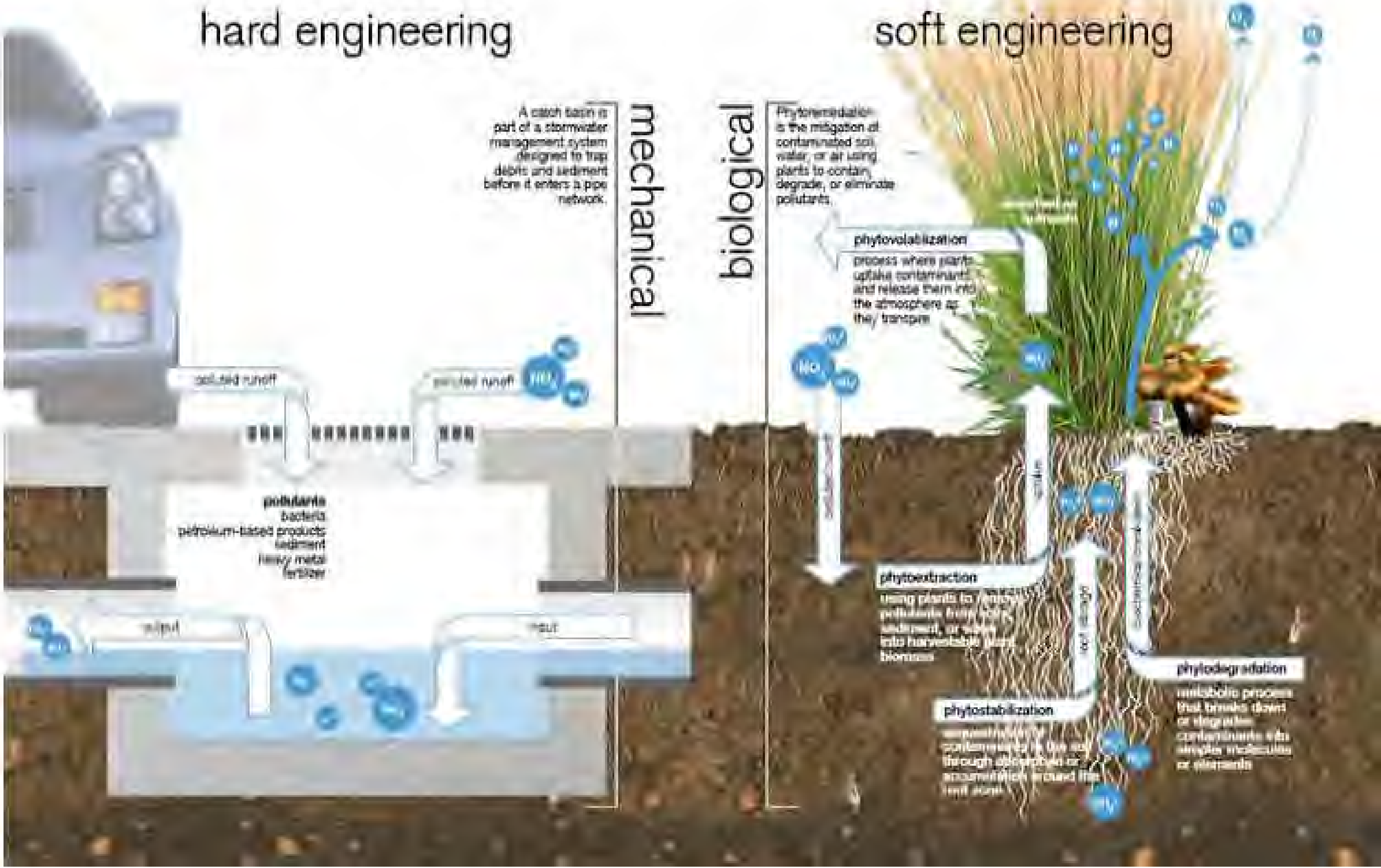


University of Arkansas – Community Design Center
Low Impact Development: a design manual for urban areas
http://www.bwdh2o.org/wp-content/uploads/2012/03/Low_Impact_Development_Manual-2010.pdf

Grey Infrastructure

Green Infrastructure

University of Arkansas – Community Design Center
Low Impact Development: a design manual for urban areas
http://www.bwdh2o.org/wp-content/uploads/2012/03/Low_Impact_Development_Manual-2010.pdf



University of Arkansas – Community Design Center
Low Impact Development: a design manual for urban areas
http://www.bwdh2o.org/wp-content/uploads/2012/03/Low_Impact_Development_Manual-2010.pdf


Downspout planter
Porous paving
Stormwater bumpout
Stormwater tree
Stormwater planter
Stormwater inlet
Stormwater inlet
Stormwater tree trench
Rain garden
Philadelphia Water Department


Infiltration Chambers
Bioswale
Tree Filter
Bioretention
Washington Irving Middle School
Permeable Turf Field

APPENDIX E. SCHOOLYARD DATA SPREADSHEET

This worksheet was developed to accompany the 7th Grade Green Infrastructure Curriculum

This spreadsheet contains four worksheets: Stormwater Runoff, Priority Co-benefits, Co-benefits Score, and a Decision Matrix. Use of each worksheet is described in the accompanying lesson plans, as they are intended to help students better understand how impervious cover influences runoff and phosphorus and to compare the pollutant removal efficiency, costs, and other benefits of different GI features.

Teachers and students should **fill in the yellow boxes** with site specific drainage area and GI information. Remaining values and formulas are locked in the worksheet (**Password= GI**). Default values used in the spreadsheets for Phosphorus loading, cost, pollutant removal, etc are shown below.

Summary of input variables used in this spreadsheet

Land Cover Type	**Phosphorus Loads (lbs/acre/yr)**	**Runoff Factor**
Roofs	0.7	100%
Pavement	1.3	100%
Woods/landscaping/gardens	0.1	8%
Lawn/grass fields	0.2	12%

NOTE: these values are linked to other worksheets. If needed, changes should be made here.

The preassinged phosphorus loads for different land cover types are derived from stormwater runoff studies around the country. Runoff factor is how much of the 1" rain is converted to runoff. This information is used in the " ***Stormwater Runoff*** *" worksheet.*

GI Options	**GI Features**	**Phosphorus % Removal**
Infiltration Practices	basin, chambers, dry well/rechargers, trench	80%
Bioretention Features	bioretention, rain garden, bioswale, tree pits	60%
Permeable Pavements	porous concrete, porous asphalt, permeable pavers, synthetic turf	70%
Rainwater Harvesting	rain barrels, cisterns, tanks	100%

NOTE: values are linked to other worksheets. If needed, changes should be made here.

The assigned removal rates are within the range of acceptable efficiencies assumed for various features within that GI group. Many factors play into the how well individual features are at removing phosphorus from stormwater runoff leaving a site. This information is used in the " ***Decision Matrix*** *."*

GI Construction Cost	**$/cu ft treated**	
Infiltration Practices	$ 32	*(chambers)*
Bioretention Features	$ 27	*(bios; green roofs are $250)*
Permeable Pavements	$ 100	*(general)*
Rainwater Harvesting	$ 20	*(above ground)*

NOTE: values are linked to other worksheets. If needed, changes should be made here.

The assigned costs for construction of each GI type are roughly based on average estimates from the Upper Charles River Sustainable Stormwater Funding project (2011) and do not include long term maintenance. This information is presented in the " ***Decision Matrix*** *."*

Co-benefits	GI Evalaution Options	**Raw Score** (not shown in worksheet)
Parking	Increases number of parking spaces	1
	No change to parking count	0
	Reduces number of parking spaces	-1
Impervious Cover	Reduces impervious cover (e.g. removal of some pavement)	1
	No change in amount of impervious cover	0
	Increases impervious cover	-1
Playspace	Adds playspace	1
	No change to playspace	0
	Takes away playspace	-1
Groundwater	Increases infiltration a lot	1
	Increases infiltration a little	0
	No increases to infiltration	-1
Schoolyard Biodiversity	Increases plant diversity and wildlife habitat	1
	No change at school	0
	Decreases diversity and habitat (e.g. removes trees)	-1
Tree Canopy	Increases canopy (i.e., shade, evapotranspiration)	1
	No change in canopy	0
	Reduces canopy (e.g., tree loss to install GI)	-1
Air Quality	Improves air quality (e.g., trees planted at bus loading zone)	1
	No improvement	0
	Reduces air quality (e.g. loss of trees)	-1
Education	Excellent teaching opportunity	1
	Some teaching opportunity	0
	No teaching opportunity	-1

NOTE: changes to these inputs should be made in hidden columns G, H, and I of "GI Evaluation" worksheet.

*There are dozens of selection factors in addtion to the ones shown here that can be used to help compare GI options. You can change the factors or change the weight applied to each factor as needed in the "**Priority Co-benefits**" and "**Co-benefits Score**" worksheets.*

Instructions: *For schoolyard or catchment of interest, enter estimated area of each land cover type into yellow boxes. The volume of runoff generated by 1 inch of rain and the resulting phosphorus load will be calculated automatically. Unit conversions are automatic. Refer to lesson plan.*

Enter your values into yellow cells. Grey and white cells are locked.

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**

*if your drainage area includes permeable pavement, assign it to the lawn cover type

Useful conversions and formulas

Area

1 acre= 43,560 sq ft

Runoff Volume

Volume= area*runoff factor * 1/12 *(in. to ft conversion)*

1 cubic ft=7.48 gallons

see "Intro" tab for runoff factor

Phosphorus

Load=acres*loading rate or = (sq ft/43560)*loading rate

see "Intro" tab for loading rates

Instructions: *This Table lists eight areas in which GI can offer co- benefit on top of removing phosphorus from stormwater. 1) Decide as a group which of these are* ***most important*** *at your location. <u>Limit your choice to the three or four co-benefits that you think should be prioritized.</u> 2) Delete the sample text in the yellow boxes and write a brief explanation of why you think this benefit should be a top priority at your location (see Considerations for ideas). 3) Assign a numerical value to each benefit you selected (up to a total of 100 available points). The higher the priority, the higher the number of points you'll want to give it.*

Enter your values into yellow cells. Grey and white cells are locked.

Priority Co-Benefits

Co-benefits of GI	**Explain Your Ranking**	**Rank** (out of 100 points)	**Considerations**
Parking			*If parking is limited or there are traffic issues with bus loading and parent pickup, you don't want your GI installation to make things worse. Maybe it can make it better!*
Impervious Cover			*If you have underutilized areas of impervious cover (not really used by cars or buildings or people), then maybe you can remove it and convert to a bioretention or other landscaping. This would reduce the amount of stormwater runoff generated.*
Playspace	*Sample:* The playground is all aspalt and there's nothing to do when we're out there. Plus all the asphalt is just creating stormwater runoff.	30	*If playspace is limited or unattractive, you don't want to make it worse. Opportunities to expand playspace or improve existing areas as part of GI construction could be great!*
Groundwater			*A main goal of GI is to get water back into the ground, rather than discharing it offsite in a pipe. (This is an especially good choice If you know that the soils on your site have a high permeability, i.e. HSG A and B soils).*
Biodiversity	*Sample:* We think we should create more habitat for plants and animals on the schoolyard because there is so little wildlife habitat in our neighborhood.	30	*If your schoolyard or neighborhood lacks vegetation or habitat areas for birds, insects, etc., then you may want to use GI to help bring some biodiversity back to your school. Using native plants that flower and fruit in GI features is a good start.*
Tree Canopy	*Sample:* It gets too hot to play games in the schoolyard because there is no shade anywhere. When the schoolyard temperature is high it also makes the city hotter.	40	*Trees promote evapotranspiration and provide shade during the summer which helps reduce air temperatures in the city --for people and parked cars.*
Air Quality			*Trees can help clean pollutants out of the air and can make a measureable difference at the city-scale. At the school site, consider planting trees in locations where car or bus exhaust is most concentrated.*
Stormwater Education			*Since it is a school, maybe providing opportunities for stormwater and watershed education with your GI feature is a priority for you. Look for locations with high visibility (e.g., front of school) and choose GI features you can see.*
Total		**100**	

Instructions: *in your Expert Groups, score your GI feature to show how well it addresses the co-benefits that you identified as the top priorities for your location. (Notice that the rank you gave them has automatically carried over from the previous worksheet). Click in the yellow boxes to make arrows appear to the right, then click on arrow--a menu of answers will appear. Select the answer that best fits your GI feature. The total score for each GI feature will automatically carry over into the Decision Matrix.* ***[TEACHER NOTE:*** *Hidden columns G,H,& I contain information for dropdown menus and raw score input data].*

Enter your values into yellow cells. Grey and white cells are locked.

Co-benefit Scores for GI Features

Infiltration Practices

Co-benefits	**Rank** (% of 100 total points)	**Evaluation Options** (select from drop down menu)	Score
Parking	0	None Selected	0
Impervious Cover	0	None Selected	0
Playspace	30	None Selected	0
Groundwater	0	None Selected	0
Schoolyard Biodiversity	30	None Selected	0
Tree Canopy	40	None Selected	0
Air Quality	0	None Selected	0
Education	0	None Selected	0
Total	**100**		**0**

Bioretention Features

Co-benefits	**Rank** (% of 100 total points)	**Evaluation Options** (select from drop down menu)	Score
Parking	0	None Selected	0
Impervious Cover	0	None Selected	0
Playspace	30	None Selected	0
Groundwater	0	None Selected	0
Schoolyard Biodiversity	30	None Selected	0
Tree Canopy	40	None Selected	0
Air Quality	0	None Selected	0
Education	0	None Selected	0
Total	**100**		**0**

Permeable Pavements

Co-benefits	**Rank** (% of 100 total points)	**Evaluation Options** (select from drop down menu)	Score
Parking	0	None Selected	0
Impervious Cover	0	None Selected	0
Playspace	30	None Selected	0
Groundwater	0	None Selected	0
Schoolyard Biodiversity	30	None Selected	0
Tree Canopy	40	None Selected	0
Air Quality	0	None Selected	0
Education	0	None Selected	0
Total	**100**		**0**

Rainwater Harvesting

Co-benefits	**Rank** (% of 100 total points)	**Evaluation Options** (select from drop down menu)	Score
Parking	0	None Selected	0
Impervious Cover	0	None Selected	0
Playspace	30	None Selected	0
Groundwater	0	None Selected	0
Schoolyard Biodiversity	30	None Selected	0
Tree Canopy	40	None Selected	0
Air Quality	0	None Selected	0
Education	0	None Selected	0
Total	**100**		**0**

Instructions: *A Decision Matrix provides a way to compare different GI options. There is no one answer for which GI feature is best for a given location. The GI you choose to install will depend on the criteria and constraints you have to work with at your site. Will you choose the one that: a) removes the most phosphorus; b) costs the least; or c) has the best co-benefits score, showing that it is the best one to meet the co-benefits you prioritized; or d) some combination of these?*

Enter the senario name, location, and the co-benefits you thought were the most important into the yellow cells (optional). The numbers in the Decision Matrix have all carried over automatically from the other worksheets.

Scenario Name (optional)	
Location	
Priority Co-benefits	

Decision Matrix

GI Practice Options	**Catchment Area** (sq ft)	**Runoff Volume** (gallon)	**Phosphorus** (lbs/acre/yr)		**Construction Cost** ($/cu ft)	**Co-benefits Score**
			Before GI	Remaining After GI		
No GI	-	-	0.00	0.00	N/A	N/A
Infiltration Practices	-	-	0.00	0.00	$ -	0
Bioretention Features	-	-	0.00	0.00	$ -	0
Permeable Pavements	-	-	0.00	0.00	$ -	0
Rainwater Harvesting	-	-	0.00	0.00	$ -	0

Useful conversions and formulas

1 cu ft = 7.48 gallons conversion used to estimate cost

Stormwater and Green Infrastructure Curriculum for Boston Public Schools

Curriculum Appendix F

Additional Resources

The Charles River

Live Water Quality Data for the Charles River

EPA Buoy in Charles River: Live water quality data for the Lower Charles River. Measurements taken every 15 minutes from a buoy outside the Museum of Science include turbidity, chlorophyll, temperature, and dissolved oxygen.

https://www.epa.gov/charlesriver/live-water-quality-data-lower-charles-river

A History of the Charles River

http://bujournalism.com/charlesriver/

Annual Earth Day Charles River Cleanup:

Join more than 3,000 volunteers from local schools, businesses, scout troops, and civic groups every April to pick up litter, remove invasive species, and assist with park maintenance along the Charles River and its tributaries. For more information or to register for this year's cleanup, visit: http://www.crwa.org/charles-river-cleanup

Museum of Science Yawkey Gallery on the Charles River

https://www.mos.org/exhibits/yawkey-gallery-on-the-charles-river

Changing Cities

"Sponge Cities"

https://www.theguardian.com/world/2017/dec/28/chinas-sponge-cities-are-turning-streets-green-to-combat-flooding, accessed 3/24/18
http://worldwaterday.org/app/uploads/2018/02/fact_sheet_WWD2017_EN_2.pdf, accessed 3/24/18

Blue Cities

https://www.crwa.org/blue-cities, accessed 3/24/18

Climate Change

K-12 Science Lessons on Climate Change

https://www.climatecurriculum.com/

Climate Ready Boston

Report on Boston's climate readiness and proposed actions with a short explanation of interactive maps on climate change, includes stormwater runoff

http://www.greenovateboston.org/crb-maptool

newsela "Climate Change in the U.S. Northeast"

https://newsela.com/read/govt-EPA-climate-northeast/id/28810/

Mapping Boston

Maps showing changes in sea level in Boston: 9,000, 6,000, and 3,000 years ago, 1630, today, and projections for 2100. Created by the City Archaeologist. Sasaki Krieger and Cobb, 2001. Institute of Maritime History.

http://i.giphy.com/3o7ablb2JqPmab2s92.gif

Green Infrastructure

Online Engineering Activities on Green Infrastructure

Just Breathe Green: Measuring Transpiration Rates:
https://www.teachengineering.org/activities/view/usf_stormwater_lesson02_activity1

Students put small native plants under plastic domes and measure the condensation over time. Then they calculate and graph the rates at which the plants breathe—their transpiration rates—and compare transpiration rates among different plant species.

Does Media Matter? Infiltration Rates and Storage Capacities
https://www.teachengineering.org/activities/view/usf_stormwater_lesson02_activity2

Students gain a basic understanding of the properties of media such as soil, sand, compost and gravel, and how these properties affect the movement of water (infiltration/percolation) into and below the surface of the ground. They design and test their own material mixes.

Making "Magic" Sidewalks of Pervious Pavementhttps://www.teachengineering.org/activities/view/usf_stormwater_lesson02_activity3

Students use sand, pea gravel, cement and water to create and test pervious pavement. Groups create their own pervious pavement mixes, experimenting with material ratios to evaluate how infiltration rates change with different mix combinations.

A Guide to Rain Garden Construction

https://www.teachengineering.org/activities/view/usf_stormwater_lesson02_activity4

This activity culminates the unit (see activities above). Groups create personal rain gardens planted with native species that can be installed on the school campus, in the community, or at students' homes to provide a solution for flooding areas.

Don't Runoff video
Engineering Everywhere Special Report: Runoff video developed by Engineering is Elementary®, Museum of Science, Boston, used with permission. Also on YouTube
https://www.youtube.com/watch?v=3zmp4UXomaU

Role of Plants in Water Filtration

https://www3.epa.gov/safewater/kids/pdfs/activity_grades_4-8_plantsinwaterfiltration.pdf

Stormwater Runoff

LID | Low Impact Development: A Design Manual For Urban Areas
Clear visuals, and succinct description of the environmental costs of urban sprawl; the need for better stormwater management; and the benefits of green infrastructure.
https://s3.amazonaws.com/uacdc/LID-Manual_Excerpt.pdf

Massachusetts Clean Water Toolkit, Urban Stormwater Runoff
Excellent description of stormwater runoff, causes, effects etc.

National Academies Press, Urban Stormwater in the United States

Lengthy, detailed, and highly informative report on stormwater.

Stormwater Center instructions on calculating pollution reduction loads
http://www.stormwatercenter.net/monitoring%20and%20assessment/simple%20meth/simple.htm

Water

Concord Consortium:

Will There Be Enough Fresh Water? http://authoring.concord.org/sequences/98

Groundwater simulation. http://has.concord.org/groundwater-movement.html

Students explore the permeability of different layers and how water moves through these layers.

newsela: "The Water Cycle"

A database of current event reading material that can be adjusted for different lexile levels, in English or Spanish.
https://newsela.com/read/lib-nasa-water-cycle/id/24072/

Waterworks Museum

www.WaterworksMuseum.org
Tours, hands-on engagements, and curriculum-connected programs on the history of clean drinking water in Greater Boston. Learn about the legacy of engineering and science behind Boston's drinking

water system stretching back into the mid 19th century and how this history shaped the public health and urban development of Boston.

World Water Day

World Water Day, on 22 March every year, is about focusing attention on the importance of water. The theme for World Water Day 2018 is '**Nature for Water**' – exploring nature-based solutions to the water challenges we face in the 21st century.