Understanding the Urban Watershed

A Regional Curriculum Guide for the Classroom

A compilation of successful lessons and activities

Fairmount Water Works

Supported in part by the *Green Schools, Clean Waters* Initiative of the Philadelphia Water Department

The Fairmount Water Works, a national historic engineering landmark, is currently the Philadelphia Water Department's Urban Watershed Education Center. Now celebrating its 10th anniversary as a Center and 200 years in potable water delivery , it has become the "go-to" place for urban water education in the region. This regional guide is based on the original Philadelphia guide created by the Fairmount Water Works.

THE MISSION OF THE FAIRMOUNT WATER WORKS

To foster stewardship of our shared water resources by encouraging informed decisions about the use of land and water. We educate citizens about Philadelphia's urban watershed, its past, present and future, and collaborate with partners to instill an appreciation for the connections between daily life and the natural environment. Administered by the Philadelphia Water Department, the Fairmount Water Works and its partners transform the way people think and live by making them aware of how individual actions on the land impact the quality of water for all living things.

Core Values

- We care about ***Clean Water*** for all living things. We recognize that clean water starts with each individual's actions and we nurture a sense of personal responsibility for the conservation of our watersheds and the health of the planet.

- We take a ***Personal Approach*** to guide visitors in thoughtful exploration of our historic site and to engage their intellect. Every visitor is warmly greeted and treated with courtesy.

- We believe that ***Collaboration*** is the way to bring creative people, sound science, and great ideas together to cultivate excellence in all we do. We accomplish this by developing ***Strategic Partnerships*** with those individuals and groups who share our values and aspirations.

- We provide ***Experiential Learning*** that engages all visitors in understanding the concepts that pervade our messages, programs, and exhibits. Our approach is both "hands on" and "minds on," for all audiences, recognizing that people come to us through different "gateways."

- We value the ***History*** that has shaped our lives, informs our messages, and inspires our future. Our National Historic Landmark setting, exhibits, and programs celebrate Philadelphia's past and the engineering marvel that was and is the Fairmount Water Works.

- We care about ***Our People***, value their individual contributions and seek to attract and retain the very best staff, volunteers, and advisors.

Environmental Education (EE) increases public awareness and knowledge about environmental issues and provides the participants in its programs the skills necessary to make informed environmental decisions and to take responsible actions. EE is based on objective and scientifically sound information and does not advocate a particular viewpoint or a particular course of action. EE teaches individuals how to weigh various sides of an issue through critical thinking, problem solving and decision making skills on environmental topics. EE covers the range of steps and activities from awareness to action with an ultimate goal of environmental stewardship. EE involves lifelong learning; its audiences are of all age groups, from very young children through senior citizens. EE can include both outdoor and in-classroom education, in both formal and informal settings.

— EPA Definition of Environmental Education

ACKNOWLEDGEMENTS

Philadelphia Water Department
Fairmount Water Works
Partnership for the Delaware Estuary
Environmental Protection Agency
The City of Wilmington, Department of Public Works,
Water Division
Berks County Planning Commission
Camden County Municipal Utilities Authority
Camden County Historical Society
Philadelphia Parks and Recreation
Schuylkill Action Network
Eco Express
George W. Nebinger School Principal and Staff
Greenfield Elementary School Principal and Staff

This regional curriculum guide is based on the Philadelphia guide, which grew out of the Education and Outreach programs of the Fairmount Water Works / Philadelphia Water Department. It was first tested as a pilot project during the academic year 2012-13 in partnership with the George Nebinger School Faculty and Principal, made possible with partial funding from the Environmental Protection Agency and administered by the Partnership for the Delaware Estuary. An advisory committee comprised of the PDE, PWD, FWWIC, and Eco Express was formed to review and revise content.

The Lessons and Activities herein are meant to enhance lessons already being taught in the classroom by any classroom teacher. The Lessons and Activities take a interdisciplinary, hands-on approach to learning and are aligned with the Common Core State Standards for grades K through 8. This guide will help teachers create hands-on as well as project-based learning opportunities for their students.

CONNECTING THE DOTS: Expanding our Understanding of the Urban Watershed

We developed this regional guide for the classroom students of our upstream and downstream neighboring cities within our watershed. The lessons and activities in this Regional Guide share the same learning objectives as the Philadelphia version because we have common environmental goals and challenges. We also have similar stories to tell about the history of our water infrastructures. -- the development of our public drinking water and wastewater systems and how we are managing stormwater in the 21st century. Although political boundaries may define municipalities, natural boundaries define the watershed and our connection to each other. Long-term protection of our water resources is all of our work and our responsibility.

Using this guide with your students will lead then to a broader understanding of the complete urban water use cycle. They will not only explore present and future urban watershed issues and challenges but also the history of engineered solutions and an understanding of how our infrastructure delivers tap water and cleans what we flush.

What we have in common is the fact that burgeoning 19th manufacturing cities like Philadelphia, Reading, Wilmington and Camden relied on collective solutions for basic needs. This led to the notion of providing and insuring a clean water supply as a public responsibility. As population and industry in these cities exploded, so did the public health and engineering challenges related to keeping up with demand.

In the 21st century, we all face challenges of a different sort that are threatening our public water supply related to stormwater runoff. Philadelphia has taken the lead role in implementing a land-based solution to the problem with its Green City Clean Waters program, transforming the land to accept, collect, absorb and replenish our water supply in ways that are mimicking the natural water cycle. The future of our cities and our water resources depends on individual and collective action to insure the success of this approach. Young people can play a leading role in ensuring that success. We are all connected.

THE URBAN STORY

This is intended to be a practical guide for K-8 educators interested in making a connection for their students between one of the most fundamental elements in all living things — water — and the complexities and responsibilities associated with accessing it, using it, cleaning it up and returning it to our waterways and managing it as a city.

Most of us turn on the tap or flush the toilet without much thought about how the water got there or where it goes, about its drinkability, supply or cost. Many of us do not know anything about the people and the processes that make a citywide water system "hum" along on a daily basis in order to ensure public health or the balanced ecology of our streams.

Historically, the development of urban water supply systems, essential to the life and economy of cities, were born out of necessity and inventiveness. Finding a reliable and plentiful supply of water often required technological engineering to collect and convey it. As cities grew (no doubt in part because of a clean and reliable water supply), so did the demand and challenges to keep up with "thirsty" customers.

Today, whereas many cities draw their source water from the same creeks and streams of 100 (or 200) years ago, growth and development continues to challenge those resources. Public policy and regulations along with environmental stewardship practices of organizations and utilities exist to protect our water.

Individual actions also have a significant role to play; In truth, individuals have the ability to protect the ecology of our waterways for all living things and to advocate for a healthy environment. The activities that follow will help your students gain a greater understanding of their connection to the urban watershed and the urban water use cycle. Urban watershed education is about understanding the delicate balance between land and water, how we are supplied with abundant safe drinking water, proper sanitation and the management of stormwater runoff and healthy ecosystems.

Ben Franklin's adage that we do not know the value of water until the well is dry speaks to our goals. Ultimately, the activities in this guide will encourage students of all ages to discuss, assess, calculate and evaluate the worth of water.

WHY LEARN ABOUT WATER?

The need for water is something that unites all living things. Abundant fresh water may cause a region to flourish whereas the lack of access to clean water can destroy a community. It is every human's most basic need and yet it is rarely discussed or even considered in most developed regions. In an age where potable (drinkable) water simply appears from the tap, it is quite possible for a person to be unaware of where that water originated or how it was made to be safe enough to drink.

This disconnect becomes a problem when water resources are threatened, making urban water education vital. Urban watershed education helps re-connect us to the life and health of our waterways, helping us learn where drinking water comes from, how it gets to the consumer, where it goes next, how it can be threatened, and how to take better care of it. Once "consumers" begin to understand that they have an impact on this precious natural water resource, they can make informed decisions about the best way to take care of these resources.

Simply put, effective urban water education is essential to transforming the way people think and live by making them more aware of how individual actions on the land impact the quality of water for all living things.

INNOVATION AND SOLUTIONS: A CAPTIVATING STORY

This guide presents a variety of ways to help you engage your students in the fascinating and yet complex narrative, with its twists and turns, describing the story of the urban water system. As with any good story, it has a theme, a plot—with conflict and struggle as well as resolution, interesting characters, and a familiar setting. The style and tone of how you tell the story is up to you, but the content is compelling and real. The only difference between this narrative and the one found in a book is that it has no ending. It is up to your students to write the next chapters and to pass it on.

ABOUT THIS URBAN WATERSHED CURRICULUM

It is designed as a series of thematic units that build on each other, starting with the personal perspective. Ultimately, the learning experience will provide students with the broadest view of the development of urban water delivery systems and help them become active participants in 21st – century solutions to urban water issues. The final thematic unit, focused on stewardship, will be project based at the school or in the neighborhood community. Students, faculty, administrators, families and community members will help shape it to be sustainable and valuable.

Each thematic unit includes broad learning objectives, a "What You Should Know" section to begin to inform the educator, and a series of lessons with activities to follow. Each lesson provides activities to be done in and around the classroom in an open and flexible style, knowing that the classroom teacher will be able to make the appropriate connections to student learning styles, subject areas and assessment tools.

HOW TO USE THIS GUIDE

This guide is designed to draw upon the expertise and creativity of the teacher practitioner as well as the student experience. Learning begins in the classroom or in the after-school environment but should spread beyond the building walls to the urban environment itself.

The activities are presented in sections to help students explore water in their own home, neighborhood or community and the city as a whole. Ideally, activities within each section should be done sequentially. Each activity suggests appropriate age-ranges and subject areas. They should take, on average, one or two class periods and can be integrated into what is already being taught in the classroom.

Thematic Unit 1: Water in Our World

OBJECTIVES:

First we (you and your students) must develop an understanding of the value of water in our lives and the way the natural water cycle (the hydrologic cycle) functions. It is important to embrace this basic level of appreciation before exploring subsequent thematic units, which address the growth of cities, and how people adapted and innovated to meet the challenge of providing clean water as the population grew.

LESSONS:

1. Water for Life (or My BFF)
2. The Natural Water Cycle
3. Landforms and Watersheds
4. Ecology of Waterways: Diverse and Abundant Communities
5. Plants, Trees and other Buffers
6. Wetlands and Wildlife: Nature's Filters
7. Life Aquatic: The Ecology of Microscopic Organisms and Macroscopic Invertebrates

Thematic Unit 2: Drinking Water and You

OBJECTIVES:

Students will learn about the **urban water use cycle** and how this is both different and similar to the **natural water cycle**. They will explore their individual connection to it as well as their human impact on it. They will develop a basic understanding of safe and reliable urban water systems, infrastructure and management of drinking water (supply). Many cities approach access to a clean drinking water supply as a civic responsibility for the public good.

LESSONS:

1. My Daily Water Use Log
2. Water for the City: Civic Responsibility for the Public Good
3. Technology and Innovation: Engineering a Public Water System
4. Clean Water and Public Health: Consider the Source
5. Public Drinking Water Treatment Process Explained
6. Testing the Waters: Making it Safe

Thematic Unit 3: Down the Drain, or Out of Sight, Out of Mind

OBJECTIVES:

Just as cities developed a collective drinking water supply system to ensure the public health of its citizens, they also develop ways to collect and dispose of its waste or "used" water. Students will discover that it was no small task to engineer an effective system of drains and pipes to carry human and industrial waste away from where people lived.

LESSONS:

1. The Growth of the City: Population and Wastewater Systems
2. Industrial Revolution and Environmental Devolution
3. Streams to Sewers: Creating an Underground Infrastructure
4. Sinks, Pipes and Mains: Make the Connection
5. Public Wastewater Treatment Process Explained

Thematic Unit 4: Land and Water: A Delicate Balance (or Can't We All Just Get Along?)

OBJECTIVES:

Homes, markets, factories, parks and roadways – these are many of the ways land has been transformed to create our cities and affect water quality. Students will learn how the relationship of land to water is an ecological balancing act, both for humans and for the natural environment. At many points throughout the last two centuries, the balance has been tipped, equilibrium lost. They will discover not only the consequence of pollution (making people sick), but also how public health safety was restored.

LESSONS:

1. The Rain Drain: Stop Trash in its Tracks
2. What's the Point: Exploring Point Source and Non-point Source Pollution
3. Plants and Pavement: Pervious and Impervious Surfaces
4. What is Combined Sewer Overflow?
5. The Clean Water Act: A Policy Solution

Thematic Unit 5: Green Plan for the Future: Playing a Part

OBJECTIVES:

The greatest threat to our water resources in the 21st century is created by stormwater runoff. As students have learned by now, past solutions and innovations for the collective good have moved the story forward. Next they will explore how individuals and communities can play a key role in shaping the future environmental health and well-being of their city. Words like "sustainability," "greening" and "stewardship" will take on greater meaning – a vocabulary that becomes an integral part of our story.

LESSONS:

1. Green Infrastructure: Following Nature's Lead
2. Calculating Rainwater
3. Restoring Urban Waterways
4. A "Model" Schoolyard

Thematic Unit 6: Environmental Stewardship

PROJECT-BASED APPROACH

Green stormwater infrastructure project development and implementation for school and/or neighborhood community

OBJECTIVES:

It is important to the health of our waterways to implement projects that restore and maintain a natural balance between stormwater runoff and infiltration by capturing on the land the first one inch of rainfall. This will reduce both quantity and quality issues related to pollutants in our streams. The Philadelphia Water Department's "Green City, Clean Waters" program encourages Philadelphians to think about various creative and common sense practices for reducing stormwater runoff. Explore what your city is doing to adopt this approach as well. These practices, called Green Stormwater Infrastructure (GSI), range from simple to complex.

Common Core State Standards (CCSS)

Turn to page 69 to see how the Lesson plans align with CCSS for Literacy and Math.

Thematic Unit 1:

Water in Our World

Objectives:

First we (you and your students) must develop an understanding of the value of water in our lives and the way the natural water cycle (the hydrological cycle) functions. It is important to embrace this basic level of appreciation before exploring subsequent thematic units about the growth of cities, and how people adapted and innovated to meet the challenge of providing clean water as the population grew.

What you should know:

We use water all the time in our daily lives. We drink it, clean with it, cook with it, water plants, and even swim in it. The tap water that your city relies on originates from a creek or stream. A public utility is responsible for making the water clean and safe to drink and for collecting it after we have used it. This now polluted water is cleaned once more and returned to the river. We call this the **urban water use cycle**; it connects all citizens to the rivers and gives us all a reason to care about protecting them. It is a public responsibility all around – to supply it, clean it up, and protect it at its source.

Water is essential to life and the freshwater resources on Earth are limited. Only about 3% of the water on Earth is freshwater and about 2/3 of that is frozen into icebergs and much of the remaining 1% of available freshwater is being polluted.

The Earth has a very efficient method of cycling water through the atmosphere and the land. As precipitation falls from the sky, it takes one of many different routes: some infiltrates, replenishing ground water, some is taken up by plants keeping them healthy, and some runs into waterways refreshing surface water. The heat from the sun warms the water in oceans and turns it into a gas, causing it to rise back into the atmosphere, a process called evaporation. Transpiration, or "sweating", releases water from plants as a gas into the atmosphere. These steps make up what we call the **natural water cycle**.

Precisely because of the way the **natural water cycle** functions, there is an inseparable connection between water and the land that surrounds it. All of the land that sheds its water to a particular water body when it rains is called a **watershed**. Unfortunately, if waterways are not cared for and become polluted, the wildlife will suffer also.

There are two main ways that what happens on the land can affect the water it drains into. The first way is caused by the hard surfaces that cover our cities and towns (e.g. roads, sidewalks, parking lots, and buildings). These hard, **impervious surfaces** are unable to absorb water, so rain and melted snow run right off them into storm drains. In some cities, a large percentage of stormwater runoff from the street drains into the same underground pipes, sending collected rainwater and sewage directly to a wastewater treatment plant. In a heavy rain event, these pipes may get too full of this rainwater-sanitary waste mixture and need to overflow into the rivers.

The second way water pollution occurs is from different types of pollution that get washed into waterways in a rainstorm. Rainwater rushes over our streets and carries with it the animal waste, litter, fertilizer, and oil that someone has left behind. This combination problem of too much polluted water running off our streets and into storm drains is called **stormwater runoff**.

Looking for ways to change the way water is collected, captured or runs off the land is one of the best ways to mitigate this stormwater runoff pollution problem. By integrating more natural surfaces into the urban landscape (hardscape), more water will be allowed to collect and infiltrate slowly into the ground. Specially engineered projects designed to manage stormwater make up what is called **Green Stormwater Infrastructure**. By planting street trees, installing stormwater planters and green roofs, starting a community garden, or attaching a rain barrel to homes, this water can renew and replenish our waterways and, at the very least, will prevent harmful pollutants from ever getting into them in the first place.

One way to determine the health of our waterways is for scientists to observe nature itself by using **biological indicators**. Biological indicators are plant and animal species that tell us, by their very nature, about the health of an **ecosystem**. In the Schuylkill River, for example, scientists will look at species like the American Shad, a delicate fish species, to infer how healthy or polluted the water is. Other species that can be used as indicators include the Great Blue Heron and macro-invertebrates like the Mayfly.

Another way to help ensure the protection of our waterways is to help citizens understand their connection to the urban water use cycle. Unlike the natural water cycle, this cycle relies on people to ensure source water becomes drinkable tap water and cleaned wastewater and runoff returns to that source after we use it.

The story of many public water systems in our watershed are similar in that the narrative spans two centuries. As the city's population expanded rapidly during the industrial era and tap water was seemingly abundant, the city faced increasing engineering and political challenges to keep up with demand; the city was in a constant struggle to find new ways to provide a clean water supply and engineer a reliable system to provide it conveniently to a growing and ever-thirsty populous. Often it begins in the early 1800s when the depleted or contaminated spring water (ground water) supply is abandoned for the fresh and flowing (surface) water of a creek or stream.

One way to understand and appreciate how the municipal drinking water systems actually work is to deconstruct its various component parts. Like many urban water systems, two simple factors are considered -- the natural force of gravity (that enables water to run downhill without an energy supply needed--it comes for free!) and potability (ultimately our urban drinking water supply needs to be safe for human consumption). Now add in collection and storage (reservoirs, tanks or standpipes) and a way to deliver it (pipes and tunnels) and you have a basic understanding of how the system works. If the topography of the land does not fully "cooperate" with where you want the water to go, you may need to employ some pumps to help gravity along; moreover, if your watershed neighbor is a farm or factory that may pollute the water upstream then you may need filtration. These parts working together require complex engineering solutions to ensure that a safe and adequate supply of water flows from your tap.

As the water is used, it becomes dirty again and must be collected as wastewater at the treatment plants, where it is cleaned so it can be returned to the waterways. Sewage treatment today is managed by Wastewater Treatment Plants. The cleaned-up water or effluent (often cleaner than the river itself) discharges to the waterways and allows the cycle to continue downstream. Clean and healthy waterways contribute to a healthy and balanced ecosystem for the diverse and abundant fish and wildlife populations that live in and around its waters.

It is also important to begin any stewardship effort by nurturing a basic appreciation for our natural resources. "Because environmental education, like much education, often fails to acknowledge the crucial role of emotions in the learning process, activities that both inform the mind and engage the heart proved to be a powerful and effective combination…Helping children fall in love with earth is what we do. Because people protect what they love, this is a powerful prescription for stewardship and ultimately, we hope kinship."

- MK Stone and Z Barlow (eds) Ecological Literacy: Educating Our Children for a Sustainable World. San Francisco, CA: Sierra Club Books (2005). P 116.

Sequence of Lessons

1. Water for Life (or My BFF)
2. The Natural Water Cycle
3. Landforms and Watersheds
4. Ecology of Waterways: Diverse and Abundant Communities
5. Plants, Trees and other Buffers
6. Wetlands and Wildlife: Nature's Filters
7. Life Aquatic: The Ecology of Microscopic Organisms and Macroscopic Invertebrates

Lesson 1: Water for Life (or My BFF)

All living things need water to live and all living things contain a certain percentage of water. From the President of the United States to the clams at the beach, everything living in this world needs water to survive. Although this is true, there is another part to this story. There are aspects of water that may not seem integral to life itself, but without which our world would be transformed into a dry, thirsty environment around us. Consider living without rivers and lakes or the summer thunderstorms that refresh the air.

VOCABULARY

Water *(noun and verb)*

Collect in a notebook or post in the classroom as many definitions as you can find to describe this word. Write as many sentences as possible using the word. See who can write the most. Research and post the word "water" in many languages.

ACTIVITIES

a. Compare how much water exists in a variety of everyday living things. Have students choose anything from the mundane (something related to what they bring everyday for lunch) to something outside their school that they can see or pass by. (K-5)

b. Write a love letter to water. Illustrate it. (K-5)

c. Write a story using rivers as symbolism. Discuss such terms as flow, rhythm, light, grace, fluidity or even rushing, raging and flooding. Use the landscape as metaphor. (6-8)

d. Survey the landscape paintings of 19th century "plein air" artists. Analyze composition and color before having students copy a master's work or create their own outside. (3-8)

e. Research, collect and compare data related to how much water we use as individuals, in manufacturing and in agriculture by assigning one item to each student (e.g. a shower, a hamburger, growing soybeans on a family farm) also called your "Water Footprint." Chart and graph. (6-8)

CONSIDER AND DISCUSS

- What is a water footprint?
- Where there is water there are life forms:

  When we explore other planets, water is the first indication that there is life. Find articles that describe the most recent space expeditions.
- Water in rituals/Rivers as sacred:

  We have rituals that include water to connect us with the spiritual world. Have your student's name at least two faith-based rituals. Find images or written descriptions. Find examples of secular rites of passage that use water. For younger students, talk about their own personal rituals around water, usually related to bath or shower time.

SUGGESTED READINGS

Kephart, Beth. Flow: The Life and Times of Philadelphia's Schuylkill River (Philadelphia: Temple U Press, 2007)

Michael, Pamela, Editor. River of Words: Young Poets and Artists on the Nature of Things (Berkeley, CA: Heyday Books, 2003)

Rodriguez, Susan. Travels with Monet (Glenview, IL: Crystal Productions, 2010).

ASK THE QUESTION

How do we know the worth of water?

Lesson 2: The Natural Water Cycle

Technically called the "hydrologic" cycle, the natural water cycle is the ultimate sustainable process. As human beings we absolutely depend on getting and using clean, safe fresh water to sustain us. We can't make new water on the planet, so the water we do depend on exists in a closed system, an endless loop from land to sky and back again. Getting students to understand this fundamental concept will serve as the foundation for any study of the topic of water and will help them explore and understand the value of water in their world.

VOCABULARY

Hydrology *(noun, from Latin hydrologia)*
A science dealing with the properties, distribution, and circulation of water on and below the earth's surface and in the atmosphere.

ACTIVITIES

a. Create simple icons on cards depicting each stage and place in the proper order on a pre-drawn circle. With younger students, write a script and perform a play demonstrating the natural water cycle (consider calling it "Birth of Small Cloud"). (K-2)
b. Seek out the root of the word "evaporation" to discuss vapor and states of matter. (3-5)
c. Read *Water Dance* by Thomas Locker aloud to students and discuss the images and first-person style of narration (e.g. "I am rain"). Have students write additional lines of poetry elaborating on the statements (e.g. "I am rain, and I give life." or "I am rain, I fall from the sky and make rivers."). (2-5)
d. Memorize/review the different stages of the hydrological cycle by creating a song, a poster, or a computer graphic. (4-8)

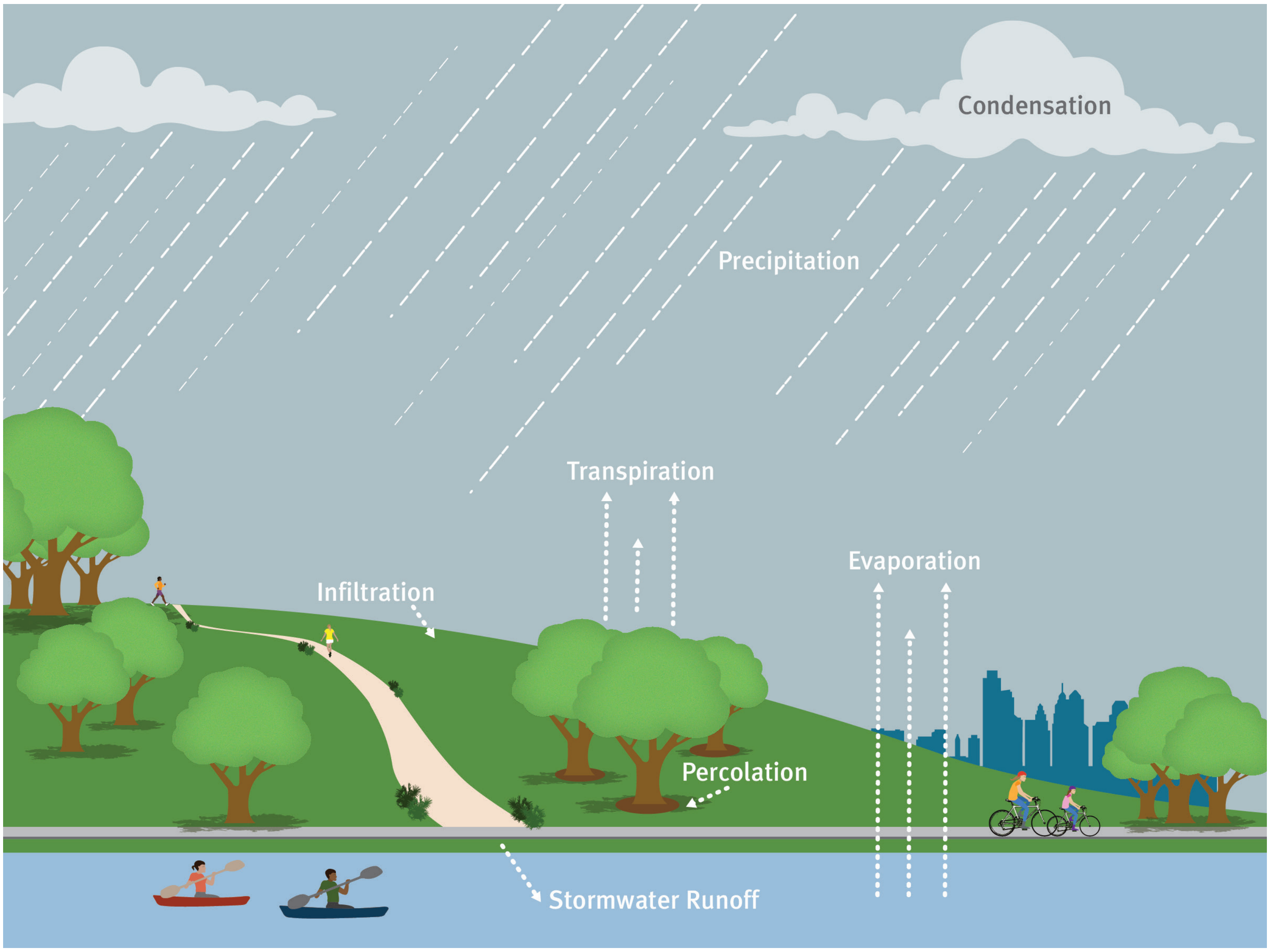
CONSIDER AND DISCUSS

- Water as a finite resource

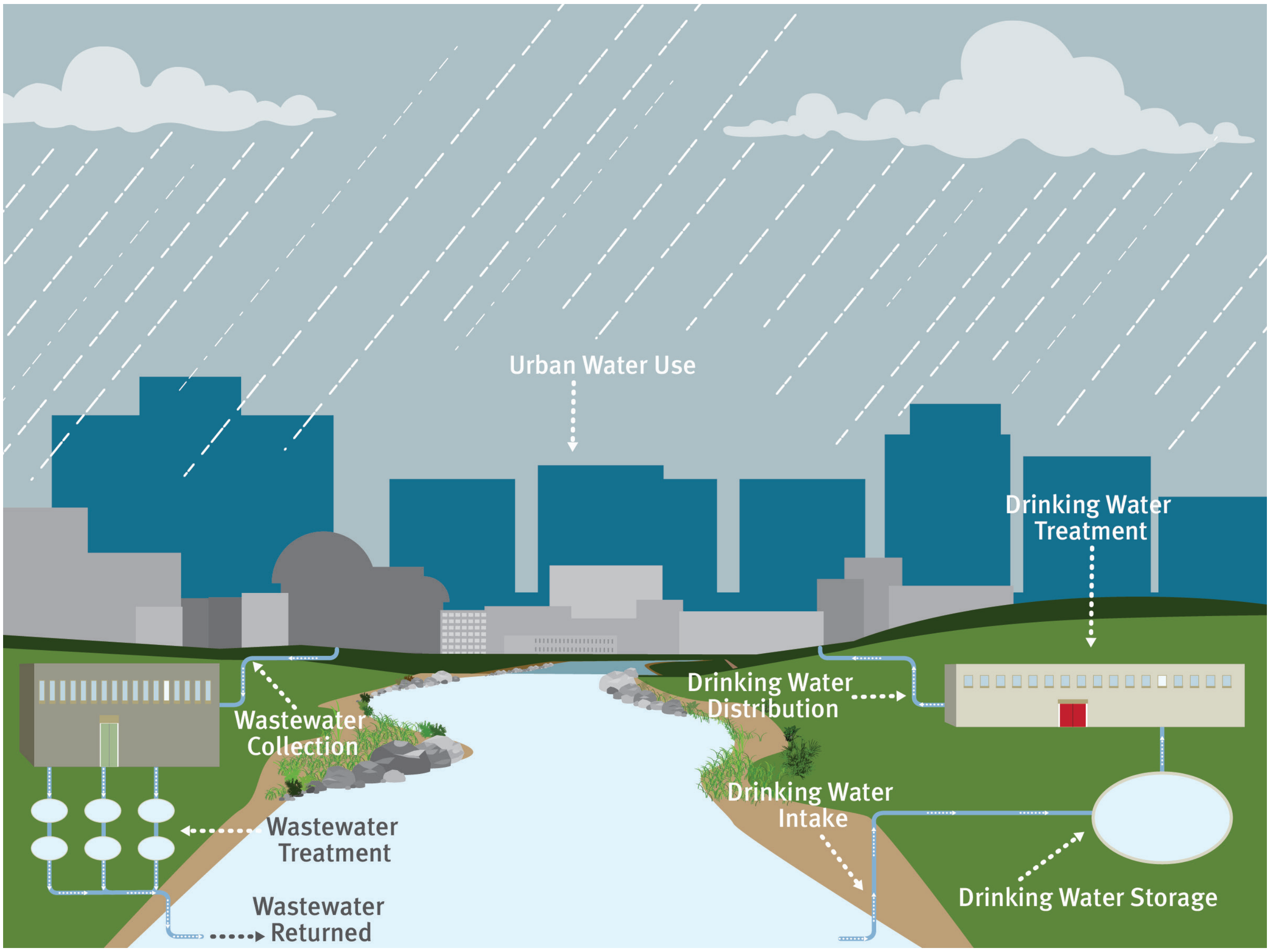
  Fresh water exists in a limited quantity. Approximately 3% of the planet's water is fresh and only 1% of that fresh water supply is accessible—the remaining 2% is trapped in glaciers or rocks underground. We can't make new water!

ASK THE QUESTION

Have you "seen" the water cycle at work?



NATURAL WATER CYCLE



URBAN WATER CYCLE

Lesson 3: Landforms and Watersheds

All of the land that sheds its water to a particular body of water when it rains is called a watershed. We can think of watersheds as big sinks – because of their slope, the water flows down its sides to the drain. Before we can discuss the urban watershed with students, help them understand this fundamental relationship amongst water, land, and drainage. Scale it up, or scale it down, it is all the same.

VOCABULARY

Topography *(noun, from Greek topographein -- to describe a place; topos, place and graphein, write)*
The art or practice of graphic delineation in detail usually on maps and charts of natural and man-made features of a place or region especially in a way to show their relative positions and elevations

ACTIVITIES

a. Using clay, have students create mountains and a river (hint: create enough slope in both the land and water to allow for "runoff"). Use water or beads dropped as rain on the mountaintop. (K-2)

b. Make a working watershed model, in a carton or plastic bin, of land and water to demonstrate the concept from crumpled paper, foil, paper mache or insulation foam. (3-5)

c. Locate and share varying scales of topographical maps of your state or region, showing the abundance of rivers. Trace the rivers. Compare to a topographic map of the United States. Overlay a watershed map to illustrate the defining nature of a watershed. (6-8)

CONSIDER AND DISCUSS

- The relationship of geography, geology and landforms:

  Name various local and regional natural geological landmarks. Discuss the geological formation of streams.

ASK THE QUESTION

How do you know you live in a watershed?

Lesson 4: Ecology of Waterways: Diverse and Abundant Communities

There is an integral connection between the health of the stream and the diversity of living things in it. Diversity and abundance are the "watchwords" of our scientists who test and monitor fish and wildlife to measure the health of our waterways. A simple walk along the streambank can give us an idea of how we're doing. How many birds do you see? Can you see turtles of all sizes? Wait for that surprise splash on the surface that tells us—there are fish in there!

VOCABULARY

Ecology *(noun, from Latin hydrologia)*
A branch of science concerned with the interrelationship of organisms and their environments.

ACTIVITIES

a. Choose an activity such as cleaning up the classroom in which every student's participation is essential in meeting the goal: a clean classroom. Give each student a job to do (if one student seems to "take over" talk about invasive species here) to demonstrate interdependence within a community as it relates to the goal. You can even name the students different species and have the classroom become a waterway. (K-2)

b. Assign a journaling activity for your students during a visit to the nearest waterway. Consider having them document what they observe in 5, 10, and 20-minute intervals. (6-8)

c. Characterize the diversity and abundance of fish species in the nearest accessible (and safe) waterway using real data to help students understand the work of aquatic biologists. Set up a simulation of the fish census, characterizing the species into pollution tolerant, moderately tolerant and intolerant. Make simple graphs of the data. (K-8)

CONSIDER AND DISCUSS:

- What is a biological or wildlife indicator? Why do we use wildlife to measure ecological health? Fish, migratory birds, reptiles and amphibians are all visual indicators of the health of our waterways.

ASK THE QUESTION

Why is diversity a positive ecological indicator?

Lesson 5: Plants, Trees and other Buffers

Nature had its own method for filtering pollutants from water long before people began building infrastructure. Plants and trees have a sophisticated and vital role to play in the water cycle related to infiltration and transpiration. Along the banks of our waterways, plants act as buffers by catching sediment, keeping things in place or preventing erosion and by using up nitrogen and phosphorous before they reach our waterways.

VOCABULARY

Riparian *(adjective, Latin, riparius first known use c.1841)* Relating to or living or located on the bank of a natural watercourse (as a river) or sometimes of a lake or a tidewater.

Buffer *(noun)* Something that serves as a protective barrier.

ACTIVITIES

a. Create your own riparian buffer (birds-eye view line drawing of stream bank and river mural). Ask students to imagine their own natural world by populating the stream bank with their own plants and animals. Create pre-cut pieces (bugs, flowers, mammals, trees, etc.) and glue them to the sheet of paper. Use cut flowers and food coloring to demonstrate capillary action. (K-2)

b. Make a model depicting three different kinds of surfaces on a slope with a catch-basin – a planted area, a grassy area (low lawn-type setting) and a paved surface. Use something to represent water such as beads, beans or rice. Predict and compare the runoff of each of the surfaces. (3-5)

c. Research native species and their properties. Create a how-to booklet to accompany a walk in the park for identifying natives/invasives. Make leaf rubbings in the field and display/chart in the classroom. (6-8)

CONSIDER AND DISCUSS

- What other benefits are there to creating and maintaining riparian buffers along our waterways?

ASK THE QUESTION

What happens in a heavy rainstorm if a stream does not have any 'buffer'?

Lesson 6: Wetlands and Wildlife: Nature's Filters

Wetlands can clean stormwater runoff, replenish ground water, reduce flooding risks and provide a home for wildlife. They act like sponges by capturing, storing and releasing water. Much of our natural wetlands have been lost due to urban land development; however, they are one of those tools in the green infrastructure toolbox being used to manage pollution from runoff—both in quantity and quality.

VOCABULARY

Permeable *(adjective)*

Capable of being permeated especially having pores or openings that permit liquids or gases to pass. (opposite: impermeable)

ACTIVITIES

a. Pour a measured quantity of water into sloped foil pans filled with a sponge (wetland), a reusable dishcloth (lawn) and nothing (paved surface), respectively to demonstrate the different properties of land use and wetlands. (K-2)

b. Read aloud Meadowlands: *A Wetlands Survival Story* by Thomas Yezerski. Have students discuss the images, ideas, and narrative of the book. (K-3)

c. Collect images of wetlands throughout the United States and make a photo magazine with captions. (K-5)

d. Research the different kinds of wetlands in your area and the communities they serve. Broaden the scope of research to include other regions and scales of wetlands.. (e.g. New Orleans, Everglades). Turn student research into a newsmagazine and call it something clever and alliterate like "Wetlands World" or write a newspaper article or editorials. (6-8)

e. Research various wetland restoration projects, including their plant species and habitat. Learn what metrics are being used to evaluate the benefits. (6-8)

CONSIDER AND DISCUSS

- Discuss environmental policy and wetlands in current events.
- Plan a field trip – engage an expert to give a tour (preferably during or just after a rainstorm).

ASK THE QUESTION

Do wetlands benefit the urban environment in other ways besides managing stormwater runoff?

Lesson 7: Life Aquatic: The Ecology of Microscopic Organisms and Macroscopic Invertebrates

Fish, migratory birds, reptiles and amphibians, riparian and aquatic plants are important indicators of the health of our waterways. In addition, with the benefits of a microscope, we can examine the diverse world of living things through a new lens. Even the smallest drop of water has a story to tell.

VOCABULARY

Plankton *(noun, From Greek, neuter of planktos drifting, from plazesthai to wander, drift, middle voice of plazein to drive astray; akin to Latin plangere to strike. First known use: 1891)*
The small and microscopic plant and animal organisms that float or drift in sea or freshwater.

Macro *(adj)*
Of, involving, or intended for use with relatively large quantities or on a large scale.

Macroscopic *(adj)*
Large enough to be observed by the naked eye.

Micro *(adj)*
Involving minute quantities or variations.

ACTIVITIES

a. Create an exhibit of images showing the variety of shapes and sizes of this world of macros and micros. Make an exhibit label that describes the relationship of the organism or plant to water quality. Use pencil, pen and ink and/or watercolors or crayons to create a gallery in your classroom. Scale this activity up or down depending on the age of your students. (K-8)

b. Write a research paper on environmentalists like Dr. Ruth Patrick, ALdo Leopold and Rachel Carson. (6-8)

CONSIDER AND DISCUSS

- Which microorganisms are indicators of the health of a stream?
- How do we use macro-invertebrates as water quality indicators?
- What is a diatom and why do environmentalists care about them?

ASK THE QUESTION

What kind of scientist researches and studies water quality issues?

Thematic Unit 2:

Drinking Water and You

Objectives:

Students will learn about the **urban water use cycle** and how this is both different and similar to the **natural water cycle**. They will explore their individual connection to it as well as the human impact on it. They will develop a basic understanding of safe and reliable urban water systems, infrastructure and management of drinking water (supply). Prominent cities in our region approached access to a clean drinking water supply as a civic responsibility for the public good.

What you should know: Philadelphia

Philadelphia began using the river (surface water) for drinking water supply over 200 years ago. The City's first public water supply system, which opened in 1801, pumped water from the Schuylkill River at 24th and Chestnut Street by steam engine to a water works at Centre Square. From here it was distributed to the city through wooden pipes made from hollowed out logs. Difficulties with the machinery and management of the facility hampered the operation of the Center Square Water Works and improvements were needed. The banks of the Schuylkill were chosen as the ideal location for a new and improved system.

The engine house was constructed at Centre Square and housed two steam engines –there was a low-pressure design built by Samuel Richards and a new high-pressure engine, designed by Oliver Evans. Both engines were made locally. The reservoir had a 3 million gallon capacity. Five wooden distribution mains, each six-inches in diameter, led to the cast-iron distribution chest at the Center Square works where water continued to flow to hydrants, pumps, businesses and dwellings.

Very soon, the demand for water exceeded the capacity of this first pumping station, cast iron replaced wood pipes and construction began on a newer, larger capacity pumping works at Fairmount. The site was chosen for its close proximity to the river and more importantly to Faire Mount, one of the highest points in the city to create a gravity-fed system, where reservoirs were constructed. The high cost of fuel and increasing demand for clean water led the Watering Committee to find a new and less expensive technological solution. Water both as energy to pump and supply for drinking was the solution. On October 24, 1822, the steam engines were stopped and by the 1830s the old engine house was converted to a public saloon.

From 1815 through 1854 Fairmount Water Works was the sole pumping station, supplying Philadelphia with water, and for part of that time it also supplied the districts of Spring Garden, Northern Liberties, and Southwark. After water power replaced steam power, which used expensive fuel to power the pumps, the financial rewards for the city were considerable. In 1854, the City boundaries grew, incorporating all the outlying and adjacent districts and their accompanying pumping stations, diminishing the City's sole dependence on water from Fairmount.

This "What you should know" section of the regional guide offers summary histories of the drinking water infrastructure in some of the major cities in our watershed. Individually, they will help your students understand how the public drinking water system in their own city was developed, but collectively, help them understand civil engineering and the "magic" behind their tap water.

See resourcewater.org for reference maps and diagrams for a greater visual understanding of this topic

People notable for the creation and operation of the Water Works were Frederick Graff (1774-1847) and his son Frederic Graff, Jr. (1817-1890). As a young man, the elder Graff was an assistant to the architect and engineer Benjamin Henry Latrobe. Graff served as superintendent of the first water works at Center Square and continued at Fairmount until his death in 1847. He is responsible for designing the buildings, most of the machinery, the distribution system, and the gardens immediately surrounding the water works. His son continued to serve as civil engineer and played a major role in the development of Fairmount Park.

The technological innovations that were employed at Fairmount to pump water from the river to the reservoirs were: steam power (1815-1822), waterwheels (1822- late 1860s), and hydraulic turbines (early 1860s- 1909) until the Fairmount Water Works was decommissioned.

What you should know: Wilmington

Like many colonial settlements in America, Wilmington first relied on wells for supply fresh water. The city's first effort to create a municipal drinking water supply system from springs was initiated in 1804 by a the Wilmington Spring Water Company who was chartered to tap a spring at high ground and convey it through wooden pipes to cisterns where subscribers pumped it by hand. This was around the same time that Wilmington's upstream neighbor, Philadelphia initiated its first public water supply system using the Schuylkill River as its source water, which was conveyed in wooden pipes to a pumping station at Centre Square (where City Hall stands today) and delivered to subscribers in their homes and businesses or to public pumps on the street for free.

In less than a decade, the city acquired the Spring Water Company to meet the challenges of an increasing demand and diminishing water table. This marked the beginning of nearly a century of public debates about how to create a system for reliable, safe and affordable drinking water. In 1820 a plan to build an economical and reliable infrastructure like Philadelphia's in which surface water from a river was pumped to a high reservoir was debated.

The milling industry had already been harnessing the power of the Brandywine Creek for more than a century. Large merchant grist mills lined both sides of the Brandywine Creek upstream.

At the height of mill operations, two raceways were located on each side of the river. It seemed prudent to adapt this infrastructure for the new water system. The borough bought John Cummings' mill just below Market Street Bridge on the south side of the Brandywine Creek was chosen as a site for the first pumping station.

Two reservoirs were constructed at the site of present day Rodney Square. Water was then conveyed by gravity down Market Street in an iron "main" until it reached Water Street along the Christina River. Piped connections from the "main" to homes and public cisterns in every part of town were completed.

As in many 19th century industrialized cities, the growing population in Wilmington made necessary an ongoing series of improvements in efficiency and capacity to the drinking water system. Overtime, the town introduced more sophisticated methods for water conveyance and storage to meet public demand, challenged to keep up with political pressures politics, public health concerns and an overly thirsty populace, which seemed to grow exponentially during the 19th century's industrial age. At the same time, consumers of water took for granted a seemingly abundant and endless public supply. Take note that this is a story repeated in many 19th century industrialized American cities, not just Wilmington. Increasing storage, installing larger capacity pipes and tunnels and more efficient pumps with greater capacity was only half the equation; upstream pollution of the water supply was also posing ever-increasing challenges. In Wilmington, relatively flat areas or parts of the landscape that serve a large geographical region depend on water towers or standpipes to deal with water pressure. The township also uses "purpose built" reservoirs and dammed stream valleys or water impoundments for drinking water supply.

The introduction of a water filtration system did not occur until 1892. Raw (unfiltered) water arrives at the Brandywine Pumping Station from the Brandywine Creek and is either be pumped to the Porter Reservoir to be filtered or taken through the filtration process to remove industrial pollution and sewage on site and distributed to consumers directly.

What you should know: Reading

Like many colonial settlements in America, the citizens of Reading first relied on groundwater for supply fresh water either from wells or from springs. Reading's first public water supply came from a spring near 11th and Court Streets in 1821. As the City developed, so did the challenges of keeping up with an increasing demand and diminishing water table for a clean, reliable supply of water. Like Wilmington, the City of Reading adapted the 18th century water-powered technology of the milling for its 19th century for water supply system. In 1865, Reading purchased a dam and gristmill on Antietam Creek as the beginning of its new public water infrastructure. (Antietam Lake was officially taken offline in 1974). To protect the water supply, land surrounding the reservoir or impoundment was purchased. This was nearly a half-century after Reading's more populous downstream neighbor, Philadelphia, initiated its first public water supply system using the Schuylkill River as its source water, which was conveyed in wooden pipes to a pumping station at Centre Square (where City Hall stands today) and delivered to subscribers in their homes and businesses or to public pumps on the street for free.

The growing population in Reading made necessary an ongoing series of improvements in efficiency and capacity to the drinking water system. From 1926 to 1933 a new water supply system was completed which required the construction of Maiden Creek Dam that backed up water from ten streams to create the man-made Lake Ontalaunee. Fifty properties were flooded to form the lake, which holds nearly 4 billions gallons. It is 1,000 acres and spans from 7 to 28 feet deep. It serves about fewer than 100,000 customers in the City of Reading and about 8 adjacent townships. When first completed, Lake Ontalaunee was considered the largest man-made lake in Pennsylvania. Water is treated in a nearby filtration plant before being delivered to consumers.

What you should know: Camden

Camden's first successful water works used the Delaware River to supply drinking water. The Camden Water Works Company, a private company, was incorporated on April 2, 1845 and was familiarly known as the "Henry Allen Company". An iron pipe drew water from the Delaware River. The original plant was located on a lot 30 by 90 feet at what was then the foot of Cooper Street (later the center of the Esterbrook Pen Works), and was purchased from William D. Cooper for $400. The supply of water was turned into the mains on November 1, 1846.

In 1854 by a supplement to its charter the company was authorized to increase its capital stock and to hold lands outside the city limits, and it build a plant at Pavonia, which continued to supply water to the city until 1870, when under an act of the Legislature Camden purchased all of its rights and appurtences for the sum of $200,000. The plant was described as a two-story high brownstone structure with a mansard roof 30 x 40 feet and housed 2 steam-powered pumps. The supply pipe extended into the river and conveyed water to a forebay located under the pumps in the basement of the engine house. This water was screened and filtered before being pumped to a standpipe 5 feet in diameter, 120 feet high. Water flowed from the standpipe, which was above the level of a reservoir basin that held up to 8 million gallons and was situated 47 feet higher than the city of Camden. This water supply served Camden "rate-payers" as well as the Fire Department.

By the late 19th century, human and industrial waste dumped into the Delaware River from both sides of the river and deadly outbreaks of typhoid, a water-borne illness led Camden to seek a cleaner, more reliable source for its drinking water supply than the polluted water of the Delaware. Unlike its "river" neighbor Philadelphia which constructed filtration plants as a solution, Camden turned to its unadulterated groundwater for a new water supply.

Today Camden still supplies its citizens with water from groundwater relying on an extensive series of artesian wells (in what is called a wellfield) and individual ones as well (pun intended). After being pumped to the surface, this water is processed at the treatment facility and conveyed to the consumer through an extensive 145-mile pipe system using water mains ranging from 16 inches to 36 inches. The water infrastructure also includes a series of pumps and elevated tanks to maintain water pressure throughout the system.

Currently the water system in the City of Camden is owned and managed as a public/private partnership.

Sequence of Lessons

1. My Daily Water Use Log
2. Water for the Federal City: Civic Responsibility for the Public Good
3. Technology and Innovation: Engineering a Public Water System
4. Clean Water and Public Health: Consider the Source
5. Public Drinking Water Treatment Process Explained
6. Testing the Waters: Making it Safe

Lesson 1: My Daily Water Use Log

Most American cities enjoy abundant clean water resources for drinking, cooking, and bathing. There is no doubt that the seemingly endless supply is, in fact, a finite resource. The simple act of tracking and logging personal gallons used will enlighten, inform and perhaps modify how and what we take for granted.

VOCABULARY

Hygiene *(noun)*

A science of the establishment and maintenance of health. Conditions or practices (as of cleanliness) conducive to health.

ACTIVITIES

a. Start with a group discussion about how we use water every day and make a list and/or simple icons to depict the basic uses of water. Put these uses into larger categories (e.g. bathing, cooking, cleaning) based on the active use of water. Use something to represent gallons as counters and begin to develop different piles or even "buckets" of gallons used. (K-2)

b. Develop with your students a water use log sheet to be completed by them in a 24-hour time period. Brainstorm about what to include on that sheet as part of the activity. (3-8)

c. Have students figure out not only how to track and display the data, but use bar graphs, pie charts and other visual displays of information. Compare water usage of cities in the United States by population, geography and climate, and access to supply (source water). Compare usage globally. (6-8)

CONSIDER AND DISCUSS

- Have a conversation with students about where their water comes from before they use it. How aware are they of how much water they use, compared to other people in the class, other cities, or other countries?

ASK THE QUESTION

Why should we care about how much water we use?

Lesson 2: Water for the City: Civic Responsibility for the Public Good

The development of any first public water supply system was the city's attempt at meeting the challenges of providing every citizen with safe and reliable water. Exploding population and industrial growth coupled with topography and source water led to challenges that could only be solved by political will and sound engineering. Providing reliable and abundant water the help individuals and businesses thrive is a source of civic pride for any city. This is in evidence too as we see the influences of the City Beautiful Movement in the public works buildings built in major industrial cities in our watershed around the turn of the century.

VOCABULARY

Civic *(adjective)*
Of or relating to citizen, a city, citizenship or community affairs.

ACTIVITIES

a. Find images of public buildings and institutions from the City Beautiful Movement, including the World's Columbian Exposition, said to be the Movement's inspiration. Label their function and talk about their significance in a city. Talk about their surroundings. Using blocks or a kit of geometric shapes, have students design their own landmark. (K-5)

b. Have each student or group of students research the life and work of a well-known architect, engineer or designer for public projects and create an exhibit. They should be able to articulate what the impact of the innovation or institution had on society. Present to each other and if there is time, to other classes. Research the person who the school is named for. Explore and discuss current day innovations and innovators. (6-8)

CONSIDER AND DISCUSS

- Speculate as to why early 20th century Water Plant, Filtration Plants and Pumping Stations were designed to be both beautiful and functional. Compare to similar types of functional public buildings from that time period or today like airports, railway stations, public libraries or public schools.

ASK THE QUESTION

Can you identify any current day public utility buildings?

Image: Shaun Bailey

Lesson 3: Technology and Innovation: Engineering a Public Water System

In the early 1800s, people benefitted from an engineered solution to their drinking water problem socially and economically. Engineering a system of pumps, pipes, waterwheels, gears, hydrants and reservoirs made water delivery convenient and abundant.

VOCABULARY

Engineering *(noun)*
The application of science and mathematics by which the properties of matter and the sources of energy in nature are made useful to people.

ACTIVITIES

a. Set up a model joining two water-tight containers with a flexible tube. Fill one of the containers and raise it up to a higher elevation to regulate the flow into the empty container at a lower elevation. This demonstrates the fundamentals of a gravity-fed system. (K-2)

b. Illustrate and caption, on separate cards, component parts of a water system such as tank, reservoir, pump, waterwheel, aqueduct, and pipe. Arrange sequentially. (3-5)

c. Add to the above activity by introducing the source water component (surface, stream, ground) and its accessibility. Demonstrate and/or fabricate a simple pump and waterwheel that both have a simple function. (3-5)

d. Research and report on other public works projects related to water such as canal systems (e.g. Erie, Morris, Schuylkill, public baths in ancient Rome). (5-8)

e. Identify and describe various fields of study and skills needed for civil, sanitary and environmental engineering professions. (7-8)

f. Add the innovation piece to the two activities above by having your students design a simple machine or a "Rube Goldberg" for fun or make it a contest. Examine the original underground pipe plans for your city or another city of its age and discuss infrastructure. Check with your Public Works Department or public Water Utility. (6-8)

CONSIDER AND DISCUSS

- Discuss the pros and cons of a public water supply vs. private. Relate this to fire-fighting, public health, cost, etc.
- Discuss comparable public engineering projects such as roads and bridges (transportation systems).

ASK THE QUESTION

Do you know what the average household pays for 1 gallon of public water?

Lesson 4: Clean Water and Public Health: Consider the Source

Have you heard the expression "Consider the source"? This applies to the water we drink, whether it is from our rivers and lakes (surface), from an underground aquifer (groundwater) or from a spring. Its drinkability is dependent on many complex factors. One thing we can be certain about is that human beings need clean, fresh water to live.

VOCABULARY

Potable *(noun)*
A liquid that is suitable for drinking.

ACTIVITIES

a. Read various fables, such as Aesop's Fable *The Crow and the Pitcher*, and other stories about wells and drinking water with magic powers. Discuss and list ways we keep ourselves healthy (include hydration in this discussion). (K-2)

b. Write a fable or other kind of story about a well or drinking water with special properties. (5-8)

c. Interview the physical education teacher about the importance of hydration after physical activity. (5-8)

d. Discuss concepts related to contagion, epidemics, water-borne illnesses as well as prevention, immunization and why these are all part of a discussion about water and our collective public health. (3-5)

e. Research and present information that compares various public urban water systems in various locations throughout the United States; identify their drinking water source. Compare to farming communities, and suburban as well as ex-urban communities. (6-8)

CONSIDER AND DISCUSS

- Discuss the relationship of drinking water sources to the people that use it considering such factors as proximity, population, and technology.

ASK THE QUESTION

Do you know the source of your drinking water?

Lesson 5: Public Drinking Water Treatment Process Explained

Access to clean, safe drinking water is considered by many to be a public service, managed by what we call utilities (from the word useful). We know Philadelphia was one of the first cities in the nation to succeed at this civic responsibility. Today public water suppliers are regulated under the Federal Safe Drinking Water Act to keep tap water safe by monitoring and testing the product continuously. Many water utilities, including the Philadelphia Water Department, use the multi-step process for cleaning source water as follows: Sedimentation, Coagulation, Flocculation, Filtration and Disinfection. It is an important responsibility to provide and distribute potable (drinkable) water. Additionally, the regulatory agencies that are involved in keeping tap water safe to drink are the Environmental Protection Agency and the state's Department of Environmental Protection or Environmental Quality. These agencies, along with the Safe Drinking Water Act, require drinking water utilities to monitor about 100 parameters (coli form bacteria, disinfectant and disinfectant by-products, lead, turbidity, etc.) on a consistent basis. All before you turn on the faucet!

VOCABULARY

Screening *(noun)*
The process of liquid passing through a perforated surface to help remove large floating debris as well as animal life from entering the system.

Sedimentation *(noun)*
The process of matter settling to the bottom of a liquid by gravity.

Coagulation *(noun)*
The process of changing from a liquid to a semi-solid state. (Chemicals are added to the water to bind smaller particles together to encourage them to settle).

Flocculation *(noun)*
The formation of small clumps. (In this process, water is gently mixed to make sure that the chemicals added in coagulation have bonded and that particles combine to form "floc" which will settle).

Filtration *(noun)*
The act of capturing impurities from the water as it passes through a layer of sand, gravel and charcoal now called rapid sand filtration. Many cities first used a slow sand filtration process in the early 1900s using sand and gravel only.

Disinfection *(noun)*
The process of introducing a chemical or other product added to kill disease causing organisms.

ACTIVITIES

a. Introduce your students to the idea of scientific experimentation. Investigate sedimentation by using items of varying weight to see how they settle in water. Do some float to the top, some sink to the bottom and others float around (suspended)? Predict, observe and record what happens in a clear glass container. Look at the items under a magnifying glass. (K-2)

b. Discuss and define rocks and minerals. Investigate the relationship of geology and drinking water. What does it mean to have hard water? Make a solution (solvent, solute) of baking soda and water. Measure alkalinity and hardness. Talk about how minerals can dissolve in nature. Next make a supersaturated solution of baking soda and water. Have students paint on black paper with the solution. Do they see anything? Let it dry. What happened? (3-5)

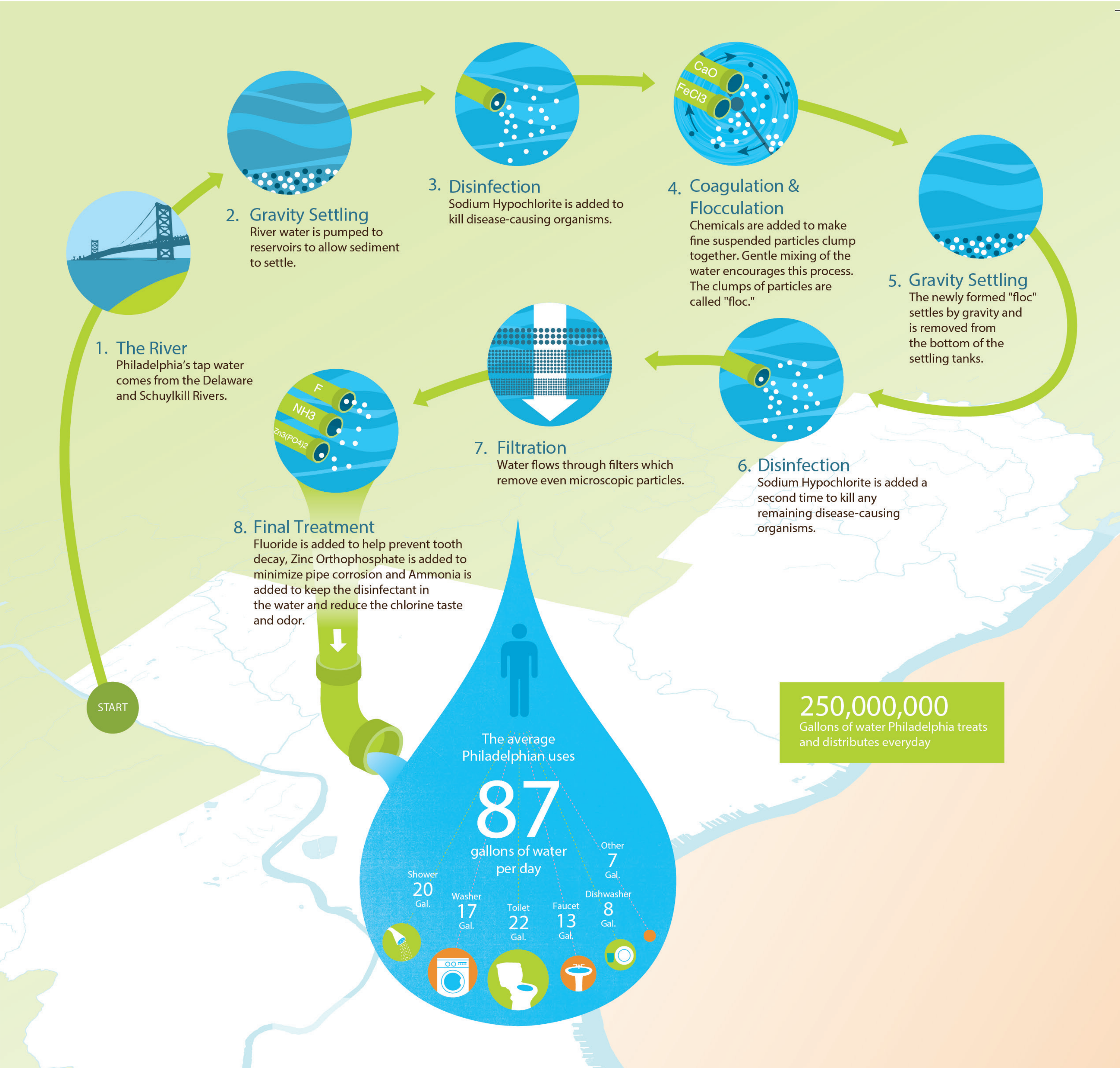
c. Plan a field trip to your local drinking water treatment facility. Obtain copies or go online to get a copy of the Annual Drinking Water Quality Report and discuss. Reach out to a water department in a different region and compare and contrast data included in their water quality report. What technologies are being used at your local Drinking Water Treatment Plant? Who works there and what is their training (career path)? (6-8)

CONSIDER AND DISCUSS

- When did your city start treating its drinking water? How and why? Compare to other cities your watershed or in the United States and/or globally.

ASK THE QUESTION

What Federal and State Agencies regulate private and bottled water industries? Ask the same question related to public water utilities?



PHILADELPHIA'S DRINKING WATER TREATMENT PROCESS

Lesson 6: Testing the Waters: Making it Safe

Public agencies responsible for pubic health and safety use a variety of scientific tests to determine the quality of the water before it is determined safe to drink. Measures of pH, alkalinity and chlorine are some measures of the quality of a sample. Using simply prepared solutions and store bought test strips (like those you use to test the water in pools), students can see how chemistry is used to determine if water is safe to drink.

VOCABULARY

Chemistry *(noun)*
A science that deals with the composition, structure and properties of substances and with the transformations that they undergo.

ACTIVITIES

a. Public utilities conduct taste and odor tests at their central labs. Have your students conduct their own taste and odor tests using two different samples (tap water/bottle water or tap water from two sources) and using a scientific method of observation, hypothesis, prediction, experimentation and conclusion. (K-8)
b. Using store bought pool test strips and several "mystery" samples, have students predict and confirm which sample is drinking water and why. Demonstrate using four sample cups of water (1: Tap water; 2: Tap water with a drop or two of vinegar (pH); 3: Tap water with a drop or two of chlorine bleach (chlorine); 4: Tap water with dissolved antacid tablet (alkalinity or hardness). Record data and determine which one is tap water based on data collected. (3-8)

CONSIDER AND DISCUSS

- Using your local Drinking Water Quality Report (required by law to publish), which can be found online on the website of your local utility, talk about the myriad of parameters that are used (required) to determine if water is safe to drink. If you can get two different area reports or past reports, compare.

ASK THE QUESTION

What kind of test would you like your water to take before you drink it?

Thematic Unit 3:

Down the Drain or Out of Sight, Out of Mind

Objectives:
Just as cities developed a collective drinking water supply system to ensure the public health of its citizens, they also develop ways to collect and dispose of its waste or “used” water. Students will discover that it was no small task to engineer an effective system of drains and pipes to carry human and industrial waste away from where people lived.

What you should know: Philadelphia

As in many urban areas, most of Philadelphia's surface streams, encompassing many square miles of watershed, were systematically obliterated over the course of the city's development. Diverted into pipes -- their valleys leveled with millions of yards of fill and overlaid with a grid of streets -- these streams now flow in some of the largest sewers in the city's 3,000-mile drainage system. In most cases, these projects were designed as combined sewers, carrying raw sewage along with the stream flow and stormwater runoff. For this reason alone (and there are many others), it would be prohibitively expensive to "daylight" such streams (that is, uncover the streams and restore them to something akin to a natural state), since it would mean building a completely separate system of pipes to carry the sewage.

This "What you should know" section of the regional guide offers summary histories of the wastewater infrastructure of some of the major cities in our watershed. Individually, they will help your students understand how the this system developed in their own city , but collectively, help them understand civil engineering and reveal the "magic" of their flush.

See resourcewater.org for reference maps and diagrams for a greater visual understanding of this topic.

Use of urban streams for sewage disposal and, ultimately, as the beds of actual sewers, was standard practice for 19th and 20th century engineers. Initially, stream pollution and its deleterious effect on human health was the main reason for undertaking such drastic measures. When a section of the Cohocksink Creek in Philadelphia was "culverted" (or enclosed in a tunnel) in 1860, the Board of Health applauded the project as "one of the most valuable sanitary improvements ever to be undertaken by the corporate authorities."

However, by the second half of the 19th century, as epidemic diseases (in particular typhoid fever) killed thousands of Philadelphians, the provision of proper sewerage and drainage became a subject of great concern, and city engineers began planning the culverting of creeks in advance of development. As early as 1853, city surveyor Samuel H. Kneass acknowledged that natural watersheds would have to be utilized to provide proper drainage for the city. In the 1880s, when the city engineers drew up their preliminary drainage maps for Philadelphia's 129 square miles, converting many of the city's smaller streams into sewers was an integral part of the plan.

By doing this work in advance of development, the engineers hoped to solve several problems. Since it was then standard sewage disposal practice to direct branch sewers downhill into the nearest stream, they knew that even pristine surface streams would become polluted once the areas around them were developed. Culverting the streams before they became polluted was seen as a positive step to protect the public health.

In undertaking these projects, the engineers also hoped to reduce the cost of the city's infrastructure in a number of ways. Sewage, being mostly liquid, flows most cheaply by gravity--pumping it up a slope is expensive in terms of fuel costs, and is only as reliable as the pumping equipment. By placing sewers in the natural stream valleys, the engineers got the gravity flow they needed, and in the process they managed to avoid the high cost of making extensive, deep excavations. Once the valleys were filled in over the newly built pipes--in some stream valleys in Philadelphia, more than 40 feet of fill was used--the cost of building a bridge each time a main street crossed the stream was avoided as well.

Building sewers in advance of development also gave engineers more freedom in their designs. Since most of the land the sewers traversed was open farmland or woodland, the cost of paying out land damages to property owners was less. Often, building a sewer in a creek bed was to the advantage of private landholders, especially in areas of the city where the rectangular grid system of streets prevailed. A piece of land with a creek cutting through it was impossible to subdivide into regular slices, but with the creek in a sewer, and the grid laid over the valley, real estate speculators could divide their property into the tightly fitted rectangular lots so common throughout Philadelphia. Since the streets were built on top of the new sewers, with water and gas lines put in as well, the developers had a ready-made infrastructure that tended to speed up the sales of these lots. The city, in return, could count on a quick return on its investment in infrastructure from the resulting increase in tax revenue from all the new buildings.

In some watersheds, it took many years to culvert the main stream and its tributaries. The Mill Creek conversion from creek to sewer took more than 25 years. The city's largest such project, the burying of both branches of Wingohocking Creek, took about 40 years. Early in the 20th century, city planners realized the benefits of creating parks in stream valleys, but it was too late for most. The modern map of the city's surface streams is now disturbingly blank.

From Creek to Sewer: A historical Overview by Adam Levine http://www.phillyh2o.org/creek.htm

What you should know: Wilmington

Like many industrializing cities after the Civil War, Wilmington had no infrastructure in place to safely rid the city of the growing problem of accumulating industrial and human waste. The inevitable consequence of poor drainage was the increased number deaths from water borne diseases like cholera and typhoid; waste from upstream mills, slaughterhouses, cesspools, privy vaults, cemeteries and factories were draining directly into the Brandywine and fouling the water supply. This was due in great part to the rapid population explosion after the Civil War. In 1864 the city's population exceeded 22,000 and by 1880 the population had grown to more than 42,000. The size, location, and composition of Wilmington's population had changed dramatically. By the 1870s, after much public debate (some characterize it as bickering), a Sanitary Engineer named Rudolph Hering was hired by City Council to survey the situation and make recommendations for a solution. He urged the city to build an interceptor sewer along the Brandywine to convey waste away from the water supply but nothing was done. Additionally, Wilmington's varying topography also posed challenges for devising a drainage system; the west side was hilly and drained well but the low-lying east side, where worker housing was developed was difficult. By 1887, a Sewer Commission was established and by 1896 nearly 48 miles of sewer lines were laid, emptying waste directly into the Delaware. Combined sewers were installed in the hilly areas as well as some separate systems in the flat areas. Other quality of life improvements in Wilmington initiated in the late 19th century were the paving of the streets and the development of a park system.

By the mid-20th century, Wilmington constructed the Cherry Island Treatment Plant and a system of interceptor sewers that conveyed waste the treatment plant. Today there are two sewer districts and 3 pumping stations to serve an 8.5 square mile area. In heavy rainstorms, water is collected in a combined system (pipes that collect sanitary waste and stormwater in the same conveyance) and, if at capacity, overflows into the Brandywine Creek, the Christina River, and other tributaries of the Delaware River but nearly 90% of runoff is collected in the treatment system during wet weather events. Today, the City of Wilmington still has only one Wastewater Control Plant, which has the capacity to process 105 million gallons per day (average dry weather capacity is 75 mgd). One sustainable solution in the works is Wilmington's planned completion of a facility that will take gases from wastewater plant and from the nearby Cherry Island Landfill and turn it into electricity. The excess heat from the electricity will be used to reduce the amount of sludge or biosolids produced by the wastewater treatment process.

What you should know: Reading

By the late 19th century, Reading developed a system for collection and treatment of its wastewater from homes, businesses and industry. Originally built on an island out in the Schuylkill River between a landform called Mifflin Arm and Angelica Creek, a pumping station at 6th and Canal conveyed the waste by steam power to the plant. By 1929, to add steps to the process, a larger facility was constructed on Fritz Island to receive the clarified effluent by pipe from the original location for further processing steps. Subsequent upgrades to the process as well as capacity were made in 1959 and in 1986, parallel to upgrades being made by other municipalities in the watershed. Fritz Island Plant currently operated by the City has a capacity of 28.5 million gallons a day (MGD) (Philadelphia processes about 471 million gallons a day).

Unlike its downstream neighbors Philadelphia and Wilmington, Reading does not have a system of combined sewers (the collection of wastewater and stormwater in the same pipe). To manage stormwater as it lands and runs off the city streets, Reading constructed an infrastructure system of 70 miles of pipes and over 3,000 catch basins and drop inlets that drain to various outfalls and open drainage ditches. Much of this system was installed between the 1880s and the 1920s. This rainwater discharges to either the Schuylkill River or to absorption areas. Either way, the current challenge to the City is how to deal with high volumes of rainwater in a short amount of time that causes flooding and damage to properties and is also is a threat to public health and safety.

What you should know: Camden

Camden's sewer infrastructure was constructed during the late 19th century when its population and industry were booming. Like many 19th century cities in the northeast United States, Camden relied on a combined sewer system conveying both sanitary wastewater and stormwater runoff in the same pipes that emptied to the local creeks and rivers.

Camden's first wastewater treatment facility was constructed in the 1950s; in 1972, a regional authority was formed, which led to the construction of wastewater management system that served a broader geographic area, including Camden and its surrounding municipalities. The system is made up of interceptor sewer pipes, pumps and 28 combined sewer outfalls (CSOs) Like the drinking water system, the drainage system is extensive, made up of 150 mile of combined sewer pipes, 25 miles of sanitary sewers and 5 miles of storm sewers.

Today, in dry weather, that combined flow is directed to the treatment facility and cleaned before being discharged (as clean effluent) to the Delaware River. Over 90 percent of the brick and mortar "pipes" was built before 1930 and include a series of pumping stations to help keep the system operational. In wet weather, the combination wastewater and stormwater may overflow into the river, especially during intense rain events combined with high tide. To help prevent this overflow condition in heavy rainstorms, Camden is adopting a sustainable approach to stormwater management through green stormwater infrastructure (GSI) projects. Capturing the first one inch of rainwater in rain gardens, tree trenches, bioswales, rain barrels, green roofs and other GSI tools, Camden hopes to prevent flooding on the land and pollution in the waterways.

Sequence of Lessons

1. The Growth of the City: Population and Wastewater Systems
2. Industrial Revolution and Environmental Devolution
3. Streams to Sewers: Creating an Underground Infrastructure
4. Sinks, Pipes and Mains: Make the Connection
5. Public Wastewater Treatment Process Explained

Lesson 1: The Growth of the City: Population and Wastewater Systems

Building upon the students' understanding of natural watersheds, they can explore how early drainage systems in cities tried to meet the demands of a growing population. It seemed logical to use the natural flow and order of the streams as a way of dealing with human and industrial pollution.

VOCABULARY

Collect *(transitive verb)*
To bring together into one body or place.

Drain *(verb)*
To flow off gradually.

ACTIVITIES

a. Compare waterways to the branches of a tree. Create a box filled with sand, tilt it and pour water from the high spot to the low spot to see how "hills and valleys" form as water meanders to find a path of least resistance. Introduce houses and streets using Legos or other available toys to demonstrate the challenges of land development imposed onto natural topography. (K-3)

b. For the older students, also explore the idea of branches, stream order, slope and velocity (speed). You can create the same type of model as above or re-visit the watershed model in Thematic Unit 1: Lesson 3 but populate it with houses and "paved" surfaces using an impervious material like wax paper, tin foil or plastic recyclables. (3-8)

c. Research and print out maps and create overlays to determine where the historic streams were located in relation to the school or community. Find historic photographs of farms and mills that now are in city neighborhoods. Explore the names of streets and neighborhoods as clues to the past (Are any of the streets named after the original creeks?). Research other cities to see how they developed to find similar patterns of development. (6-8)

CONSIDER AND DISCUSS

- Imagine what the city looked like with natural rolling hills. Ask your students to identify a place that still retains its original topography or why/how some streets in the city feel and/or act like streams?

ASK THE QUESTION

Do you know the name of the stream or creek nearest your school?

Lesson 2: Industrial Revolution and Environmental Devolution

The way we use land *can* impact water quality. Farms, factories, shopping centers, and homes are all examples of how we change the natural landscape to meet human needs. Sometimes that means paving over the natural landscape to build streets, houses, and sidewalks, and creating surfaces that are designed to shed rainwater quickly and easily to prevent flooding on the land but may cause flooding and erosion downstream.

VOCABULARY

Industrialization *(noun)*

The large-scale introduction of manufacturing, advanced technical enterprises and other productive economic activity in an area, society, country, etc.

ACTIVITIES

a. Start a conversation about different ways people use land to live, work and play. Have students talk about what a community of the future might need. With a large sheet of mural paper, and a handful of pre-cut color-coded squares representing these kinds of land use (introduced as places we live -red, places we work-purple, places we play-green), have your students design their own planned community. Start them off with a waterway and few roads. Assign roles and discuss placement and consequences of individual actions on the community. (K-2)

b. Make the above activity more complex by introducing more parameters such as starting out with an agrarian community that becomes industrialized. Create a modern day, densely populated city. Introduce controversy. Explore different time periods and create a chronology of polluters of water through time. (3-5)

c. Add to the above activities by introducing a discussion about zoning. Divide the class into neighborhood or community groups with connecting waterways. Discuss the impact on upstream/downstream neighborhoods. (6-8)

CONSIDER AND DISCUSS

- The balance (and imbalance) between growth and health of cities and its impact on the natural environment

ASK THE QUESTION

What changes are happening in your neighborhood that may impact water quality?

Lesson 3: Streams to Sewers: Creating an Underground Infrastructure

Streets, buildings and rooftops, along with the creeks and streams, become part of what we call the watershed in an urban setting. Cities, notoriously densely populated and developed, constructed widespread systems of underground pipes (hidden/out-of-sight) to collect and drain the water used by its citizens from homes and workplaces. Cities also developed systems for draining rain water from its streets. Sometimes these two systems are COMBINED, other times they are SEPARATE.

VOCABULARY

Infrastructure *(Infrastructure)*

1. The underlying foundation or basic framework (as of a system or organization);
2. The system of public works of a country, state or region.

ACTIVITIES

a. Begin this exploration of underground systems through fictional characters in books or movies that live or travel by sewer. Create a character that lives in such a place. Write a picture book or narrative story about this character. The character can even be an object (such as a bag of chips) that goes down the storm drain. (K-5)

b. Research and compare other examples of urban infrastructure ("works") such as electricity, gas, and transportation and the idea of public/private management of these systems locally and in other cities. Make a photo-montage or inventory of the clues/evidence of these systems on the street and in our neighborhoods. (6-8)

CONSIDER AND DISCUSS

- Why do cities choose to create certain underground infrastructure?

ASK THE QUESTION

What are some of the ways a city can deal with an aging infrastructure?

Lesson 4: Sinks, Pipes, and Mains: Make the Connection

There are many component parts of the underground sewer that are molded, manufactured and engineered to create this urban system. They all fit together to keep the city's wastewater flowing, relying on gravity to keep everything moving "downhill".

VOCABULARY

Conduit *(noun)*

A pipe, tube or the like for conveying water or other fluid.

ACTIVITIES

a. Find objects in everyday life that can be used to demonstrate how a conduit works (e.g. bendable or straight straws, paper towel rolls) using beads or water. (K-2)

b. Make a kit of parts using various diameter tubing, complex profiles, shapes and forms to create conduits that can accept water and test the velocity using the variables of shape and slope. (3-8)

c. Create individual homes on a street using a collection of shoeboxes. Configure them to create the sidewalk and street. Elevate the model to create some space under the street. Use blue (drinking water) and red (waste water) pipe cleaners to represent the path of water coming into the house from a pipe underground and the waste going to another pipe under the house. Connect the pipes from each house underground to each other. (3-8)

d. Identify films in which the majority of the action/plot takes place/is based on the setting of a sewer (e.g. Phantom of the Opera (1925/2004), The Third Man (1949), Flushed Away (2006)). Write an original story or play of the same.

CONSIDER AND DISCUSS

- How are these conduits constructed today, as well as in the past? How are they inspected? Maintained?

ASK THE QUESTION

Where does your wastewater go after you flush?

Lesson 5: Public Wastewater Treatment Process Explained

Wastewater treatment is the process of collecting wastewater and removing pollutants before returning the clean final outflow to a body of water. In any city, it is a big and sophisticated process that runs 24/7 without much notice or fanfare. Everything washed down a drain is collected -- from toilets, sinks, tubs, washing machines, dishwashers and floor drains in homes, schools and businesses everyday. Sometimes stormwater runoff collected from streets and properties in underground pipes combines with this wastewater to travel to a Wastewater Treatment Facility. Treating wastewater and returning the cleaned-up water back to the river is a critical step in the urban water use cycle and imperative for protecting the health of our waterways.

VOCABULARY

Influent/Effluent *(noun)*
Inflow/outflow

Permit *(noun)*
An official document authorizing permission to do something.

Sludge *(noun)*
Solids that settle by gravity in the wastewater treatment process made up of organic materials such as food, feces, paper fibers, etc.

Scum *(noun)* A layer of grease and oil that rises to the surface of the liquid.

Dissolution *(noun)*
The act or process of dissolving into parts or elements or to disintegrate.

WASTEWATER TREATMENT PROCESS

- **Pretreatment** involves a physical removal such as screening and sedimentation.
- **Primary Treatment** focuses on clarifying sedimentation tanks water by removing heavy solids (sludge) and oil/grease (scum).
- **Secondary Treatment** uses local microorganisms to help remove dissolved organics and suspended particles. Once the microorganisms have been removed through a settling process a disinfectant is often added before the clean effluent, final out flow, is released into a body of water.
- **Tertiary Treatment** is an additional level of treatment that may use microfiltration, lagoons, clarification, chemical or physical removal.

ACTIVITIES

a. Discuss the idea that people make this process work! Have students learn about various jobs and what gets sent to their Wastewater Treatment Plant. Recreate the journey of your flush verbally by having each student add to the story to create a suspenseful narrative from the perspective of something you flush, what it feels like to be in a sewer, or your arrival at the Plant. Next, let them illustrate or record their story. (K-2)

b. To help demonstrate the wastewater treatment process, fill up a container with water and add things such as a few sheets of toilet paper, dirt, rocks, foods, and oil – shake it up. Do things separate? What sinks? What floats? What stays suspended? Collect information and create a poster display of animals and plants that act as natural filters. (3-5)

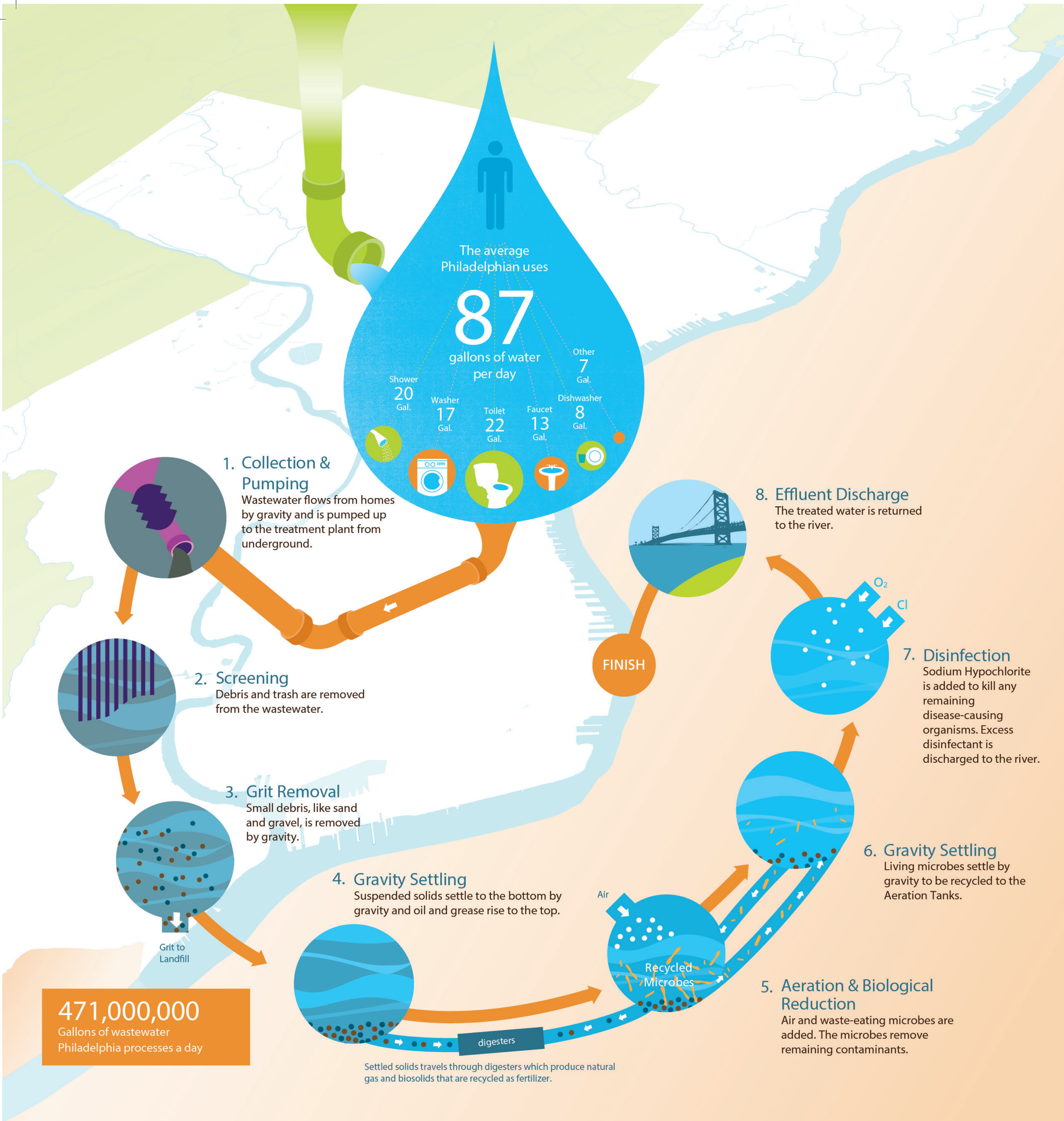
c. Plan a visit to your local Wastewater Treatment Facility. Research a current event related to severe weather events and sewage or wastewater. Investigate the microorganisms that ingest suspended particles and dissolved organics in secondary treatment. What do they look like? What do they need to survive? (6-8)

CONSIDER AND DISCUSS

- Discuss the history of wastewater and its treatment in your city.
- Discuss or have students research what changes they can personally make to help the process at the wastewater treatment plants to improve overall water quality (organic cleaners, picking up after dog, not littering)

ASK THE QUESTION

What industries near your neighborhood qualify for a waste water permit?



PHILADELPHIA'S WASTEWATER TREATMENT PROCESS

Thematic Unit 4:

Land and Water: A Delicate Balance (or Can’t We All Just Get Along?)

Objectives:

Homes, markets, factories, parks and roadways – these are many of the ways land has been transformed to create our cities and affect water quality. Students will learn how the relationship of land to water is an ecological balancing act, both for humans and for the natural environment. At many points throughout the last two centuries, the balance has been tipped, equilibrium lost. They will discover not only the consequence of pollution (making people sick), but also how public health safety was restored.

What you should know:

"Simply said, the health of a stream depends on the quality of the land surrounding it, which in turn relies on the people charged with the care for that land." –Cobbs Creek Integrated Watershed Management Plan June 2004

The watershed of a stream is all the land that sheds water to that stream when it rains or when snow melts.

There has always been an inseparable connection between people and water. Personally, we need to drink water to keep us healthy. We also need it to keep ourselves clean, to cook with, and to carry our waste away. Collectively, we use water to keep our streets clean, and to keep our homes and businesses safe from damaging fires. We enjoy the beauty of our waterways for fishing, boating, and picnicking. In earlier times, we depended on our waterways to transport vital (and luxury) goods and to power our mills. Water was an integral part of the industrial age, used in the manufacture of everything from clothing and blankets to beer and locomotives. Since the beginning of the 1800s, many cities in our watershed have depended on its rivers and their tributaries to supply its citizens with drinking water and to carry its wastewater away. Originally, settlers could rely on nature to take care of keeping that supply clean. Now nature needs help man-made solutions because as the population grew, so did pollution, and the city became more and more dependent on an engineered treatment process to keep things healthy.

Ironically, the rapid growth and development of the city in the industrial age both helped its citizens prosper and posed a grave threat to their health as the very source of healthy drinking water became contaminated with industrial waste. By looking at the watershed during this time period, students will see how the land use changed from a predominantly agricultural use, with scattered farms and small water-powered mills along the creek to residential use, with densely packed neighborhoods of row houses as we see it today. They will discuss what impact the land use changes had on the health of the creek.

We now have important laws and regulations in place for industries and public water and sewer departments that help ensure that we keep our streams healthy. Today, the biggest source of water pollution is stormwater runoff, pollution that is carried by rainfall off the land into the nearest stream. Agricultural runoff upstream of a city can be one of the the greatest perpetrators of water pollution in the waterways. We can be optimistic about the future if we understand the dependent relationship between land use and water quality.

Sequence of Lessons

1. The Rain Drain: Stop Trash in its Tracks
2. What is the Point: Exploring Point Source and Non-point Source Pollution
3. Plants and Pavement: Pervious and Impervious Surfaces
4. What's Combined Sewer Overflow?
5. The Clean Water Act: A Policy Solution

Lesson 1: The Rain Drain: Stop Trash in its Tracks

One of the greatest threats to water quality today is pollution from stormwater runoff. This happens when rain washes whatever is on our streets and sidewalks into the rivers either directly or through the storm drains that lead right to the river. This is a current day issue and therefore one of the best ways to engage your students in this topic is through observation in and around their neighborhoods and schools.

VOCABULARY

Pollute, pollution, pollutants

Discuss these words and what they mean in relation to each other and themselves. Give examples. Collect images of examples.

ACTIVITIES

a. This activity requires a walk around the block or simple checklist for students to take home with them to identify the location of storm drains in and around their school. (K-2)

b. In addition to the above activity, have students assess the condition of these drains in dry weather and in the rain. Have students write letters home about the problem and the solution. Collect rainfall data and graph. (3-5)

c. Also discuss and develop an anti-trash campaign and storm-drain marking project to raise awareness. Investigate how other cities mark their storm drains; propose a design for a new way to mark your city's and have a design contest. Have students make posters, write slogans and create public service announcements for the school community defining the problem and advocating for the solution. (6-8)

CONSIDER AND DISCUSS

- We all live in a watershed

ASK THE QUESTION

What is the relationship between trash on my street and my watershed?

Lesson 2: What's the Point: Exploring Point Source and Non-point Source Pollution

Before we can work at stemming pollution in our waterways, we need to identify its source. Sometimes it is easy to tell the source—something dumped directly into the water would be considered point source pollution. Other times it is not as obvious—some kind of waste deposited on the land makes its way into the water indirectly – this is considered non-point source pollution.

VOCABULARY

Point Source Pollution

The term "point source" means any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agricultural storm water discharges and return flows from irrigated agriculture. (Clean Water Act, from EPA.gov Website). In other words, pollution you can see being dumped directly into the water like factories used to do by dumping untreated wastewater directly into the waterways.

Non-point Source Pollution

The term "non-point source" is defined to mean any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act. (EPA.gov). In other words, if you see pollution but can't see where it came from, like leaking oil that a passing car left behind.

ACTIVITIES

a. Brainstorm and make a list of things that can cause pollution in our waterways. Now ask students to separate this list into point source and non-point source pollutants. Ask them to describe the difference. Illustrate the items or cut out pictures from magazines. Create a story about the travels of a character named "Non-point Source Pollution". (K-2)

b. Using the checklist they created in Lesson 1, create an inventory of all the non-point source pollution they can identify in one block around the school. Discuss the issues and plan and implement a solution. (3-5)

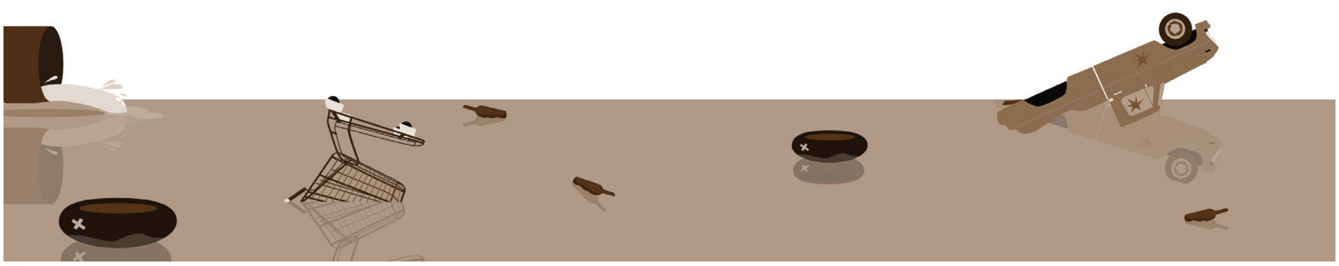
c. Develop a school campaign to raise awareness about water pollution and how individuals can make a difference (e.g. reduce dog waste, clean-up plan). (6-8)

CONSIDER AND DISCUSS

- Do you think other cities are working to reduce water pollution?

ASK THE QUESTION

How do I play a part in solving the problem?



Lesson 3. Plants and Pavement: Pervious and Impervious Surfaces

Changing an urban *streetscape* to an urban *landscape* is one of the long-term goals of water quality protection. The transformation of streets, rooftops and parking lots (or impervious surfaces) to green roofs, tree trenches, rain gardens and porous paving (or pervious surfaces) requires some understanding of the key components of success – soil and plants.

VOCABULARY

Vascular *(noun)*
Of or relating to a channel for the conveyance of a fluid.

ACTIVITIES

a. Students can explore how soil affects the rate of water infiltration by creating some simple soil compositions and timing water flow through these soil types (sand, silt and clay). Use a funnel, coffee filter and conical tube or clear measured container to catch the water. Add compost to your soil and observe and record what happens. (K-8)

b. In tandem with the soil infiltration tests also have students explore how water gets transported through a plant through some simple experiments. (K-8)

c. Grow simple vascular plants (bean plants work well) in your classroom in small test tubes by the window or with a grow light and observe and record the emerging root and leaf systems. (K-8)

d. Have students observe the growing plants once a week and write poetry from observation. (K-8)

CONSIDER AND DISCUSS

- What are our perceptions of nature in the urban environment?

ASK THE QUESTION

What is the benefit of a "green" schoolyard?

Lesson 4. What is Combined Sewer Overflow?

In Thematic Unit 3, students learned about the vast infrastructure system engineered to convey waste, both stormwater and sanitary sewage (In many older cities, they are often carried in the same pipe called a "combined sewer) away from where we live, work and play. During dry weather, the combined sewer system and waste water treatment plants have the capacity to transport and treat all the sanitary sewage entering the system. However, when flow in the sewer increases as a result of rainfall and/or snowmelt, the treatment plants may reach their capacity. When system capacity is reached, the sewer system allows for combined sewage to discharge to nearby water bodies from combined sewer outfalls to prevent and protect neighborhoods and these wastewater plants from flooding. Although agricultural runoff is the greatest water pollution concern in Wilmington, overflow from combined sewers this is a major concern for upstream Philadelphia and the Delaware River Basin of which Wilmington is a part.

VOCABULARY

Outfall *(noun)*
The outlet of a body of water.

Convey *(verb)*
To move in a continuous stream or mass.

ACTIVITIES

a. Ask students to share examples of something overflowing – the bathtub, the sink, a glass of milk or juice. What were the consequences? How did they or someone they know deal with the clean up? Relate this to our waterways during a heavy rainstorm. (K-2)

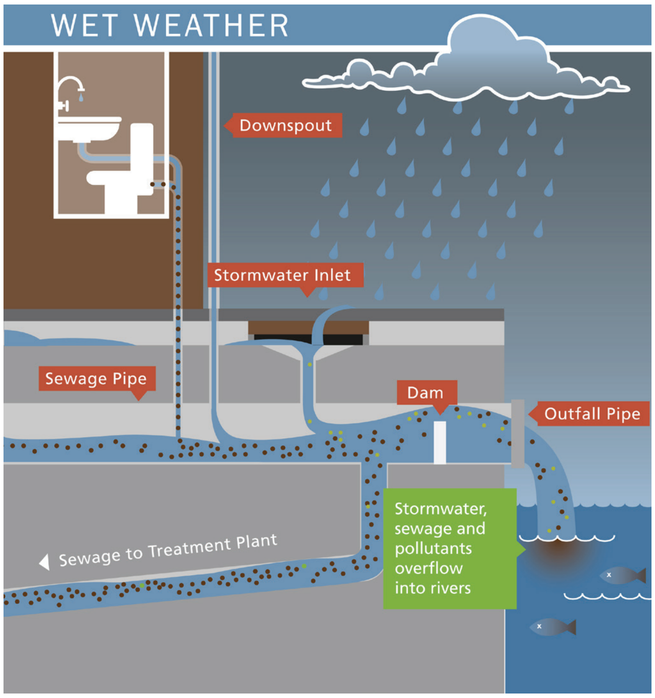
b. Set up a demonstration (or have the older students work in teams to create a model themselves) of combined sewer overflow. Start with two separate plastic tubes outfitted with a funnel on top. These two tubes are connected to another larger tube. Pour water dyed with food coloring – blue for rain water and red for waste water—into the separate tubes and see the water turn purple and spill out the bottom. You can now divert some of the water from the larger tube (simulating the journey to the treatment plant). Now pour larger quantities of water down the stormwater tube and simulate overflow. (3-8)

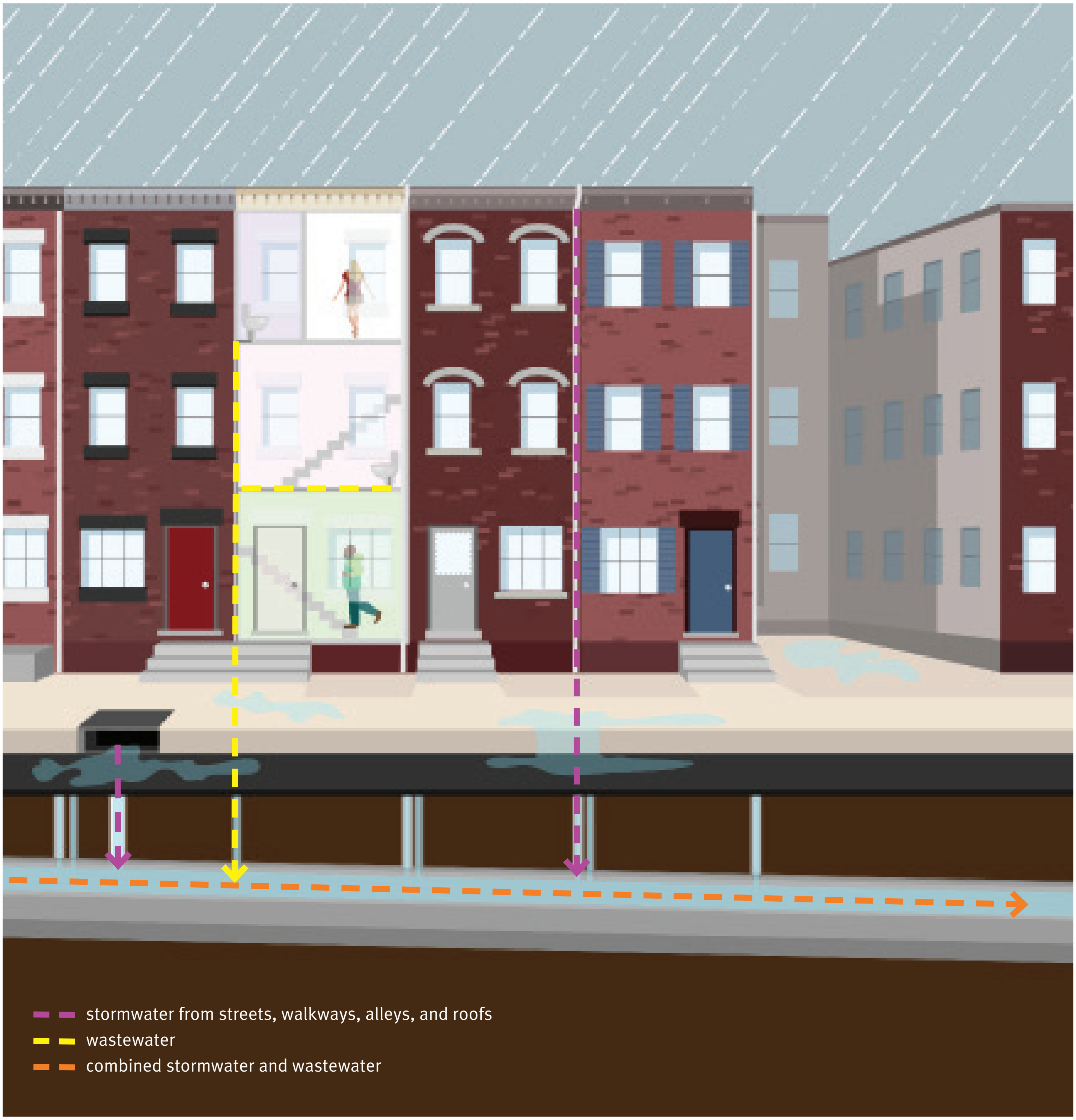
CONSIDER AND DISCUSS

- Speculate as to why the combined sewer infrastructure exists in older neighborhoods

ASK THE QUESTION

How many drains (or outfalls) are there along the Schuylkill and Delaware Rivers and why are they numbered?





COMBINED SEWER SYSTEM

A combined sewer system (CSS) is simply a single sewer system that carries both sewage and stormwater in one pipe, to a water pollution control plant for treatment before being released to a waterway. During moderate to heavy rainfall events, the system will reach capacity, overflow, and discharge a mixture of sewage and stormwater directly to our streams and rivers from Combined Sewer Over - flow (CSO) outfalls within the City. For example, just 2% of water pollution in Wilmington comes from Combined Sewers, and 59% from Agricultural runoff, 20% from stream modification and about 10% from both surburban stormwater runoff and municipal/ industrial point sources. What is the drainage infrastructure system in your city?

Lesson 5: The Clean Water Act: A Policy Solution

The Clean Water Act, as we commonly call it today, was enacted in 1972. It set up regulations for controlling pollution and maintaining water quality in America's waterways. The Environmental Protection Agency has put into place regulations that make it unlawful to discharge any pollutant directly (point source) into navigable waters without a permit. This generally applies to industrial, municipal and other facilities that dump wastewater directly into surface waters.

VOCABULARY

Regulation *(noun)*

A rule or order issued by an executive authority or regulatory agency of a government and having the force of law.

ACTIVITIES

a. Have students brainstorm, develop and "enact" a regulation for the classroom that benefits the entire group. Determine how and who will enforce the regulation, and what, if any consequences there will be for violations. (K-2)

b. Add to the activity above with role-play as citizens and lawmakers. Review how a bill becomes a law. Have students perform the song from "I'm Just a Bill" from Disney's Schoolhouse Rock. (3-5)

c. Research the Environmental Protection Agency and other regulatory agencies that oversee and protect public health. (6-8)

d. Connect the role of the Clean Water Act and the construction of sewage treatment plant facilities. (6-8)

CONSIDER AND DISCUSS

- What other laws help protect the public's health and well-being; Are there any rules school-wide/as a class that are made to help protect all students

ASK THE QUESTION

How do such big laws come about? How are they enforced?

Thematic Unit 5:

Green Plan for the Future: Playing a Part

Objectives:

The greatest threat to our water resources in the 21st century is created by stormwater runoff. As students have learned by now, past solutions and innovations for the collective good have moved the story forward. Next they will explore how individuals and communities can play a key role in shaping the future environmental health and well-being of their city. Words like “sustainability”, “greening” and “stewardship” will take on greater meaning – a vocabulary that becomes an integral part of our story.

What you should know:

The earth has a very efficient method of cycling water through the atmosphere and the land. As precipitation falls from the sky, it takes one of many different routes: some **infiltrates**, replenishing ground water, some is taken up by plants keeping them healthy, and some runs into waterways refreshing surface water. The heat from the sun warms the water and turns it into a gas and it rises back into the atmosphere, a process called **evaporation**. **Transpiration**, similar to"sweating", releases water from plants as a gas into the atmosphere. These steps make up what we call the natural water cycle.

Modern towns and cities are full of **impervious surfaces**, like roads, sidewalks and parking lots, which cannot absorb rain water. Because infiltration is inhibited, stormwater will flow downhill until reaching a waterway or a man-made storm drain. This water that does not infiltrate, but runs off the land is called **stormwater runoff**. As stormwater runoff flows over impervious surfaces, it gathers pollutants like litter, pesticides, fertilizers, animal waste, loose dirt, and motor oil as it drains.

When it reaches our waterways the ecological balance suffers. Trash creates a risk for wildlife that might mistake it for food. Chemicals, such as motor oil and pesticides, can be toxic to those same animals. Fertilizers can cause algae to grow out of control and hog the oxygen supply in the water. Too much animal waste can introduce unhealthy levels of bacteria into the water system. These are considered water quality issues.

A combined sewer system (CSS) is simply a single sewer system that carries both sewage and stormwater in one pipe, to a water pollution control plant for treatment before being released to a waterway. During moderate to heavy rainfall events, the system will reach capacity, overflow, and discharge a mixture of sewage and stormwater directly to our streams and rivers from the regulated and monitored outfalls as Combined Sewer Overflow (CSO). This is a water quality and quantity issue.

A separate sewer system collects stormwater in a **storm sewer** pipe and discharges it directly to a waterway, while the sanitary sewage collected from homes, businesses, and industry is collected in a **sanitary sewer** pipe and taken to the water pollution control plant for treatment before being released to the waterways.

If we think about watersheds or areas of land that share the same drain, the problems caused by stormwater runoff impact everything and everyone who depends on that drain or waterway, and that includes humans.

Protecting the environmental health of watersheds is a local, state and federal responsibility. To keep stormwater runoff from polluting our waterways, the Environmental Protection Agency (EPA) implemented practices that change the way water runs off the land by absorbing or holding water, rather than having it rush into our creeks and rivers at high speed and volumes. These practices that mimic the natural water cycle and therefore help **mitigate**, or reduce the impact of stormwater were formerly called **Best Management Practices (BMPs)** but now are referred to as **Green Stormwater Infrastructure (GSI)**. Trees and plants are especially good at absorbing these large volumes of water and they are used in these projects. PWD has become a model for other cities in the use of these GSI.

With these GSIs in mind, the PWD has created the "Green City, Clean Waters" program. This program encourages property owners to implement different projects on their land to help capture the first one inch ("first flush") of stormwater that carries the most pollutants. The more of these GSI we have on our land, the healthier our waterways will be – upstream and downstream.

Sequence of Lessons

1. Green Infrastructure: Following Nature's Lead
2. Calculating Rainwater
3. Restoring Urban Waterways
4. A "Model" Schoolyard

Lesson 1: Green Infrastructure: Following Nature's Lead

The Environmental Protection Agency (EPA) encourages city's to adopt green practices in the urban landscape to help transform the places we live, work, go to school and play into vibrant, green communities. By merging the vision of a "green city" with "clean water" we can benefit not only our watershed environment, but the region's economic health, quality of life and sustainability.

VOCABULARY

Mitigation *(noun)*

Measures taken to reduce adverse impacts on the environment (US EPA glossary).

ACTIVITIES

a. Use this opportunity to talk about the benefits of plants by growing some from seed in the classroom and keeping a log tracking watering schedule and growth. Plant outside in the appropriate season and location. (K-2)

b. Take a walk outside for one block directly across from the school entrance. Take individual photos to capture the entire block when "stitched" together. In the classroom, create a mural streetscape drawing of the block outside of school using the photos (figure out a method for viewing them before venturing outside). Highlight any green practices on the street (street trees, window boxes, rain barrels, etc.) and add if needed. Discuss the benefits. (3-8)

CONSIDER AND DISCUSS

- What is green stormwater infrastructure and how does/can it benefit the street/neighborhood?

ASK THE QUESTION

Why is all this planting and greening and collecting of rain called "infrastructure"?"

GREEN STORMWATER INFRASTRUCTURE

Green stormwater infrastructure manages the first inch of rainfall which would normally flow along its street gutters and into its storm drains. These vegetated features, such as those pictured above, manage rain where it hits the ground similar to the way a natural system such as a forest or a meadow would handle the rain runoff.

Lesson 2: Calculating Rainwater

Rainwater landing on the city streets and rooftops is often measured in volume. Help students visualize just how much water falls on a single row home by calculating gallons of rain. There are different categories of storms, some which will drop more water than others. If this water is not kept on the land, gallons of polluted water may end up in our waterways.

VOCABULARY

Pervious/Permeable *(adjective)*
Surfaces that allow the penetration of water into the ground.

Impervious *(adjective))*
A hard surface area that either prevents or slows the entry of water into the soil as under natural conditions prior to development.

ACTIVITIES

a. Use the chart below to help students understand stormwater and that it all adds up along one street, in one neighborhood, across one city…and on and on. (K-8)

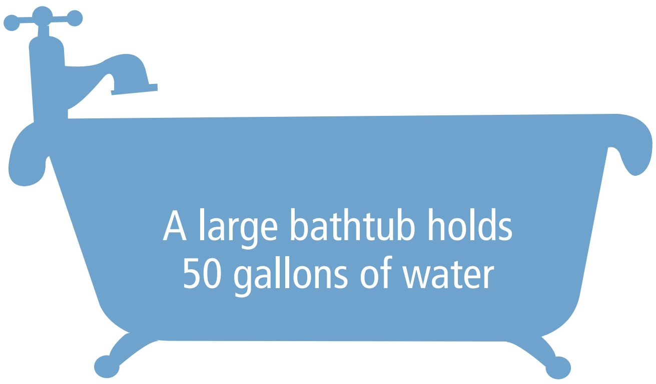
Row Home Calculations:					
Rain Event (in)	Square Footage (ft2)	Rain (ft)	Cubic Feet (ft3)	Conver-sion (ft3/gal)	Gallons
1/10	1000	0.008	8	7.5	60
1/4	1000	0.021	21	7.5	157.5
1/2	1000	0.042	42	7.5	315
1	1000	0.083	83	7.5	622.5
2	1000	0.166	166	7.5	1245

CONSIDER AND DISCUSS

- Did you ever envision rain as a volume of water?

ASK THE QUESTION

Why is capturing the first one inch of rainfall on the land so important in this discussion about water quality?



Lesson 3: Restoring Urban Waterways

Urbanization is responsible for many of the sources that contribute to waterway degradation in our streams. Increases in impervious surface area and runoff have negative effects on stream flow.

Once the natural physical condition of a waterway is compromised by pollution or excessive runoff, it sets off a chain of degradation from erosion to water temperature changes to habitat loss.

VOCABULARY

Erode *(verb)*
To wear away by the action of water, wind or glacial ice.

ACTIVITIES

a. Create a very simple stream by filling a plastic container with sandbox sand and have students "make it rain"using a spray bottle or other gentle method. You can start with a light rain shower. At first they will see how channels naturally form. Now introduce heavier rain conditions by more aggressive pouring and see how that erodes the "banks" of your stream. Discuss what could be done to keep the stream from eroding (plants, trees). (K-2)

b. Take a field trip to the nearest stream and observe and record its condition. Key points to consider are flow, water temperature, habitat, erosion, pollution, etc. Connect with community groups or environmental scientists. Organize volunteer efforts to clean up the stream and a plan for long-term stewardship of the stream. (3-8)

c. Create a story, a photographic essay, or a documentary video about life in and around the stream. (K-8)

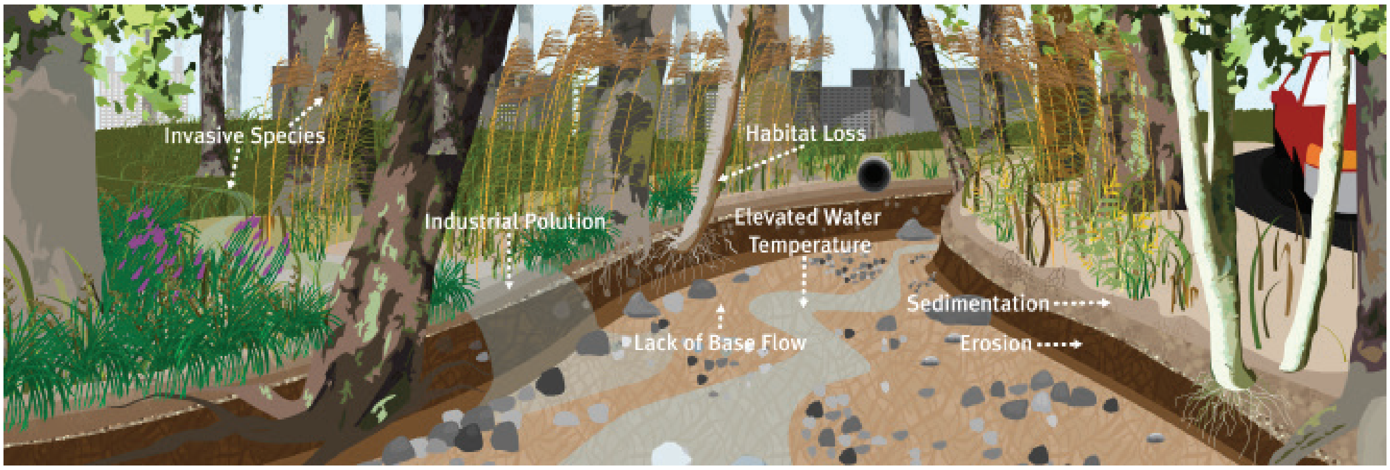
CONSIDER AND DISCUSS

- Review the riparian buffer lesson and discuss the function as well as the beauty of the bank of a river.

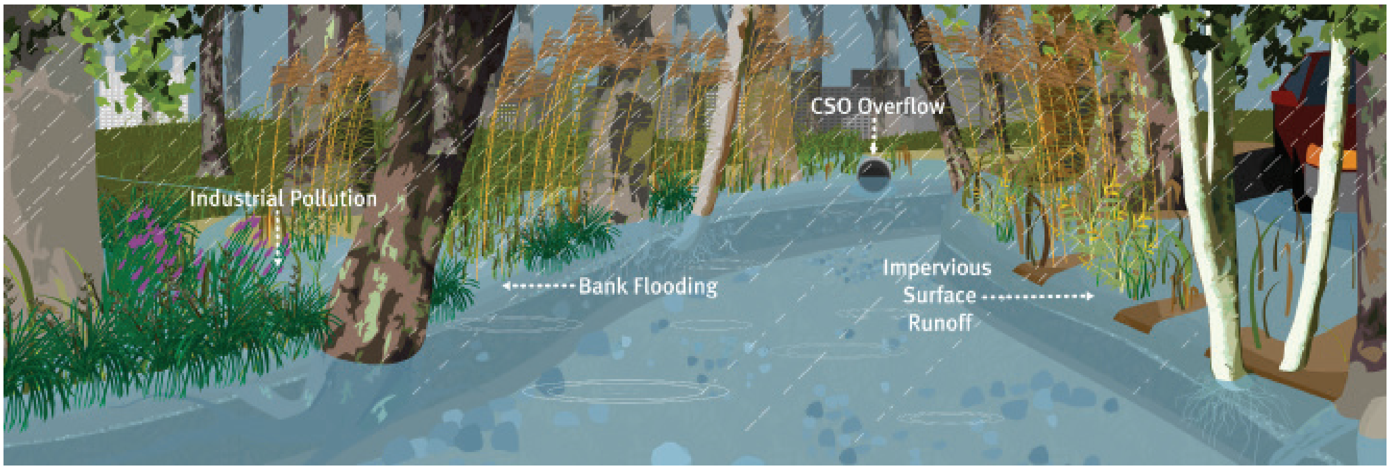
ASK THE QUESTION

What are the long-term benefits for people as well as wildlife of restoring urban streams?

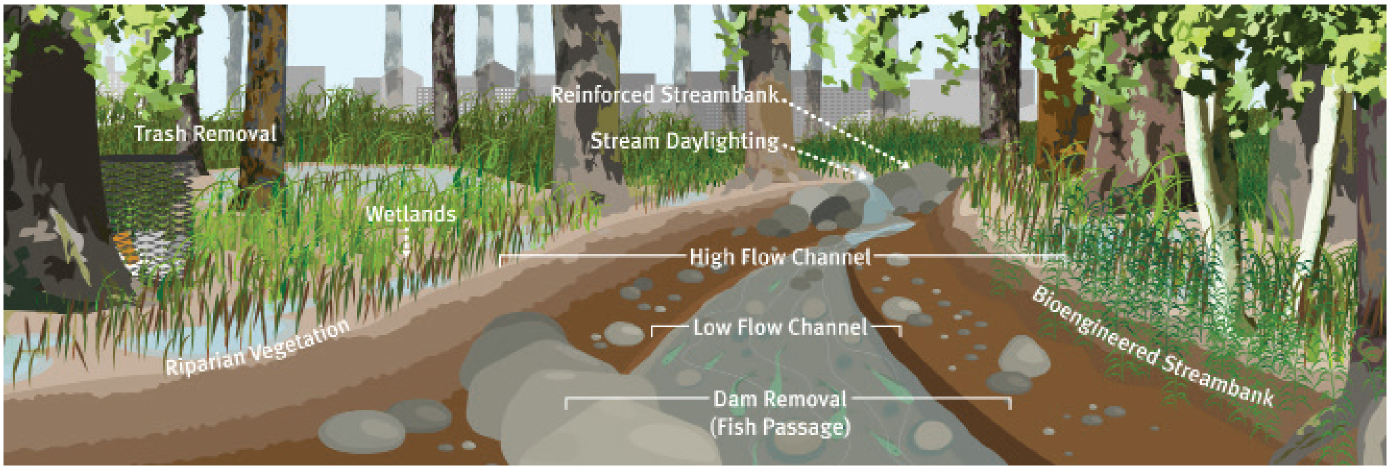
DEGRADED WATERWAY IN DRY CONDITIONS



DEGRADED WATERWAY IN STORM CONDITIONS



WATERWAY RESTORATION TOOLS



Lesson 4: A "Model" Schoolyard

This is the bridge between all that your students have learned and explored in the classroom (and outside) and becoming an active environmental steward. The goal of this lesson is to document the built environment, record how water behaves on the surfaces of your schoolyard and create some green space to capture/collect the water and help it infiltrate into the ground. This lesson is for dreamers. The next thematic unit will be for the roll up your sleeves/how are we going to create a real project, fund it, monitor its benefits and insure its long-term care.

VOCABULARY

Swale/bioswale *(noun)*

A long, gently sloped vegetated ditch designed to filter pollutants from stormwater.

ACTIVITIES

a. Measure and draw a plan of your school yard. Use your own body or the entire class as units of measure. (K-2)
   1. Use your own feet and relative units of measure and proportion. (3-5)
   2. Find a scale drawing of the school and have students duplicate or scale up or down, depending on the drawing.

b. After completing **activity a** with your students, transfer to a base. First with a pencil, label the base to locate all prominent features, including the school building, the play area, the parking lot up to the sidewalk and the middle of the street.

c. Make this three-dimensional using whatever building materials are best suited to the model, age and abilities of your students (e.g. shoeboxes, foam board, cardboard, blocks).

d. Using crumpled tissue paper, straws, pipe cleaners, etc., make your green areas. (6-8)

CONSIDER AND DISCUSS:

- How will changes to the schoolyard change your feelings toward the outside space of the school? What are the benefits to the environment (source water)?

ASK THE QUESTION

How would you like to change your schoolyard?

Thematic Unit 6: Environmental Stewardship

Objectives:

It is important to the health of our waterways to implement projects that restore and maintain a natural balance between stormwater runoff and infiltration by capturing on the land the first one inch of rainfall. This will reduce both quantity and quality issues related to pollutants in our streams. The Philadelphia Water Department's "Green City, Clean Waters" program encourages Philadelphians to think about various creative and *common sense* practices for reducing stormwater runoff. Citizens in other cities in the region are adopting this approach as well. These practices, called Green Stormwater Infrastructure (GSI), range from simple to complex.

What you should know:

This thematic unit is about designing and implementing GSI projects with your students for their school or neighborhood community. By now, students should have a better understanding of the water quality problems caused by stormwater runoff; through project-based learning in this thematic unit, they will become part of the solution.

Stormwater management is a critical issue for many cities with predominantly impervious land cover. Like many older cities, Philadelphia utilizes a combined sewer system. Most properties were designed to quickly remove water from the site, causing many of our local waterways to suffer from flash flooding on rainy days. We've all seen those days when the our local creeks and streams are high and brownish from high volumes of stormwater which churn up stream sediments and sometimes overwhelm municipal treatment facilities. During periods of heavy rainfall, combined and separate sewers carrying a mixture of pollution and rainwater overflow into city waterways causing increased levels of non-point source pollution. A good way to reduce the impacts of this stormwater runoff pollution is by changing hard surfaces (believe it or not that even includes hard turf grass), such as roadways, schools, homes and parking lots, so they can absorb, slowly filter, and cleanse naturally as much polluted rainwater as possible. The goal is to have clean and reliable waterways not only for fishing and swimming but ultimately to protect the purity and affordability of our drinking water supply in a sustainable, long-term way.

To combat this growing issue, the Philadelphia Water Department has developed Green City, Clean Waters, a 25-year plan to protect and enhance our watersheds by managing our stormwater with innovative green infrastructure. The plan has become a model for other cities. Find out what your community, water or wastewater department, or school is doing to manage stormwater in a sustainable way.

Philadelphia is about 135 square miles
640 acres is ONE square mile.
According to the USGS Water Science School calculator (find a link in your online Toolbox), a 1 inch rainfall on 1 acre = 27,000 gallons of water and a 1 inch rainfall on Philadelphia's 135 square miles adds up to about 2,348,000 gallons of water. Wow!

This final thematic unit connects the experiential and classroom learning of this *Understanding the Urban Watershed* Curriculum to a real world project. The project's goal will be to transform impervious land into porous or "green" space that reduces (in even the smallest way) the amount of stormwater that ends up in our combined sewer system. Each project adds up to the overall goal of decreasing the number of overflows and making our watersheds cleaner and healthier.

In this Thematic Unit, rather than Lesson Plans, you will see a menu of ideas to help catalyze your creative thinking about practical and impactful projects for your site. Keep in mind, although implementing your project will be a critical step in improving the quality of water in your watershed, always remember in the broader context that watershed problems do not begin or end at the outfall. Bank and streambed erosion, litter along the creeks, degraded aquatic and riparian habitats and limited diversity of fish and other aquatic life are some of the many issues city agencies together with many public and private partners are working to improve, which affects the quality of life for all urban dwellers, young, middle and old.

CONSIDER AND DISCUSS

It all adds up! Consider the impact of the student's actions on our waterways block-by-block, school by school. Discuss the different ways you will measure success (quantitative and qualitative measures). One acre receives one million gallons of rainfall each year. Today, if the land is impervious, it all runs off into the sewer and becomes polluted. A Greened Acre will stop 80–90% of this pollution from occurring.

Consider how aging infrastructure as well as the impact of climate change on human health and our ecosystems will impact our present and future decisions related to our urban water resources.

ASK THE QUESTION

How do I know I am making a difference in my watershed/ subwateshed?

GREEN SCHOOLS

Schools make up 2% of all impervious cover in the combined sewer drainage area but are highly visible, thereby offering excellent opportunities to educate the local community on green stormwater infrastructure. An array of stormwater measures can be implemented on school properties, such as rain gardens, green roofs, porous pavement, trees, rain barrels and cisterns. For example, porous pavement and trees on both parking and recreational facilities on school campuses can transform what are now heat-trapping asphalt surfaces into more welcoming, cooler, green havens.

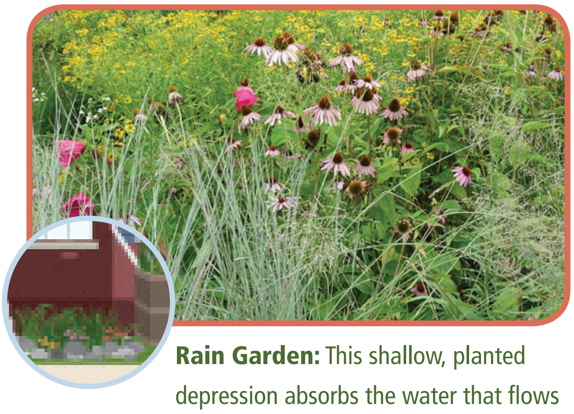
GREEN STORMWATER INFRASTRUCTURE (GSI) TOOLS

Green stormwater infrastructure includes a range of soil-water-plant systems that intercept stormwater, infiltrate a portion of it into the ground, evaporate a portion of it into the air, and in some cases release a portion of it slowly back into the sewer system.

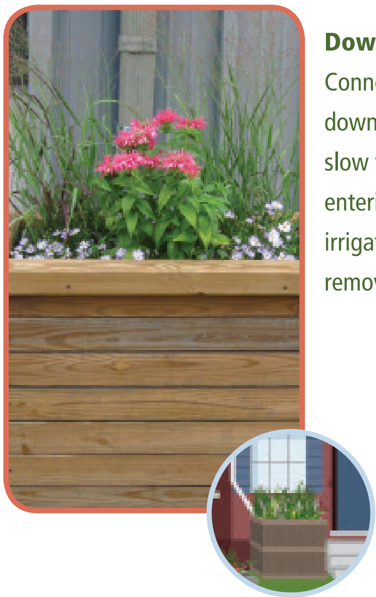
Trees, shrubs, and flowers help manage rain, or stormwater, through catching rain drops on their leaves and branches before the stormwater becomes runoff, as it hits the ground. The stormwater collected on these surfaces can easily evaporate into the air. Additionally, plants help manage stormwater runoff not only by allowing water to infiltrate into the soil, but also by a process called evapotranspiration, in which water is taken up by plant roots and transpired through their leaves. Plants and soil also help in filtering stormwater runoff.

Stormwater Tree Trench
Downspout Planter
Green Roof
Rain Barrel
Pervious Paving
Bump-out
Stormwater Planter
Rain Garden
Stormwater Wetland

EXAMPLES OF GREEN STORMWATER INFRASTRUCTURE (GSI) TOOLS



Rain Garden: This shallow, planted depression absorbs the water that flows from a roof, patio, or yard.



Downspout Planter: Connected to the roof downspout, these planters slow water down before entering the sewer while irrigating plants and removing pollutants.

Pervious Paving: Specially designed paving stones, bricks, or pavers that allow water to soak into the ground below.

GREEN STORMWATER INFRASTRUCTURE (GSI) PROJECT IDEAS:

Edible garden/agriculture zones
Above ground planters
Trees, trees and more trees
Re-designed playground — equipment and surfaces
Outdoor classrooms
Urban forests
Rain garden
Art projects
Swales

GREEN STORMWATER INFRASTRUCTURE (GSI) MONITORING (DATA COLLECTION)

Monitoring and testing various green stormwater infrastructure systems (stormwater tree trenches, porous pavement, rain gardens) are essential steps in Philadelphia's 25-year plan to reduce combined sewer overflows. Assessing the performance of green projects can verify the impact on the sewer system and identify problems that require maintenance or cleaning. The Water Department uses a variety of methods to test its green infrastructure, including simulated runoff testing (hydrant testing) and the measurement of infiltration rates, soil moisture, and water level. As data is collected, it is analyzed and used as feedback for more efficient and improved designs. You can develop your own simple soil and temperature sensing monitoring system with your students using the simple instructions provided in the companion online resources.

EXAMPLE OF A GREEN SCHOOLYARD


STOP

The Common Core State Standards (CCSS) indicate that all content-area teachers need to plan for and implement a variety of literacy strategies. Reading, writing, speaking, and listening are the four areas emphasized in the standards. "Understanding the Urban Watershed" (UUW) aligns most of its program with the specific anchors and standards of CCSS. Each of the lessons in the various units have a literacy element: students will be reading appropriate and challenging content area texts; students will be writing as they respond to and think about water related issues; students will be preparing for one on one, pair share, teacher-led, and group conversations; and students will be gaining experience in how to listen to their peers and teachers. UUW has been designed to facilitate teachers who want to align their own practice with CCSS and it will aid K-8 teachers in their implementation of CCSS while educating students about water in their world. Whereas we have provided what we believe is a useable framework, we know that the ability to make those connections work successfully ultimately relies on the expertise and energy of the educator.

As teachers work with students to engage with complex ideas related to urban water systems, we believe that incorporating activities that speak to the CCSS will help create a learning environment conducive to the goals of UUW. This curriculum guide aims to incorporate best literacy practices across content areas. The guide is intended for all classroom teachers K-5, as well as subject area teachers 6-8. As an interdisciplinary approach to urban watershed education, this guide will facilitate collaboration among science, history, language arts, art, and math teachers.

An important note: at times we have chosen one particular grade to show the explicit connection between CCSS and UUW; given that the standards build from one grade to the next, teachers should go directly to the standards to see their particular grade level if it is not represented in the connection.

CCSS OVERVIEW OF LITERACY:

"The Standards set requirements not only for English language arts (ELA) but also for literacy in history/social studies, science, and technical subjects. Just as students must learn to read, write, speak, listen, and use language effectively in a variety of content areas, so too must the Standards specify the literacy skills and understandings required for college and career readiness in multiple disciplines….Students who meet the Standards readily undertake the close, attentive reading that is at the heart of understanding and enjoying complex works of literature [and nonfiction]. They habitually perform the critical reading necessary to pick carefully through the staggering amount of information available today in print and digitally. They actively seek the wide, deep, and thoughtful engagement with high-quality literary and informational texts that builds knowledge, enlarges experience, and broadens worldviews. They reflexively demonstrate the cogent reasoning and use of evidence that is essential to both private deliberation and responsible citizenship in a democratic republic."[1]

OVERVIEW OF WRITING:

"Each year in their writing, students should demonstrate increasing sophistication in all aspects of language use, from vocabulary and syntax to the development and organization of ideas, and they should address increasingly demanding content and sources…[2] To build a foundation for college and career readiness, students need to learn to use writing as a way of offering and supporting opinions, demonstrating understanding of the subjects they are studying, and conveying real and imagined experiences and events. They learn to appreciate that a key purpose of writing is to communicate clearly to an external, sometimes unfamiliar audience, and they begin to adapt the form and content of their writing to accomplish a particular task and purpose. They develop the capacity to build knowledge on a subject through research projects and to respond analytically to literary and informational sources. To meet these goals, students must devote significant time and effort to writing, producing numerous pieces over short and extended time frames throughout the year."[3]

AN EXAMPLE OF A WRITING STANDARD THAT UUW MEETS:

"CCSS.ELA-Literacy.W.4.1 Write opinion pieces on topics or texts, supporting a point of view with reasons and information."[4] [see Unit 1, Lesson 4b]

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1 http://www.corestandards.org/ELA-Literacy
2 http://www.corestandards.org/ELA-Literacy/W/introduction
3 http://www.corestandards.org/ELA-Literacy/CCRA/W
4 http://www.corestandards.org/ELA-Literacy/W/4

READING OVERVIEW:

"One of the key requirements of the Common Core State Standards for Reading is that all students must be able to comprehend texts of steadily increasing complexity as they progress through school…By reading texts in history/social studies, science, and other disciplines, students build a foundation of knowledge in these fields that will also give them the background to be better readers in all content areas. Students can only gain this foundation when the curriculum is intentionally and coherently structured to develop rich content knowledge within and across grades. Students also acquire the habits of reading independently and closely, which are essential to their future success."[5]

AN EXAMPLE OF A READING STANDARD THAT UUW MEETS:

"CCSS.ELA-Literacy.RI.1.3 Describe the connection between two individuals, events, ideas, or pieces of information in a text."[6] [see Unit 1, Lesson 7b]

SPEAKING AND LISTENING OVERVIEW:

"To build a foundation for college and career readiness, students must have ample opportunities to take part in a variety of rich, structured conversations—as part of a whole class, in small groups, and with a partner. Being productive members of these conversations requires that students contribute accurate, relevant information; respond to and develop what others have said; make comparisons and contrasts; and analyze and synthesize a multitude of ideas in various domains.[7]

New technologies have broadened and expanded the role that speaking and listening play in acquiring and sharing knowledge and have tightened their link to other forms of communication. Digital texts confront students with the potential for continually updated content and dynamically changing combinations of words, graphics, images, hyperlinks, and embedded video and audio."[8]

AN EXAMPLE OF A SPEAKING AND LISTENING STANDARD THAT UUW MEETS:

"CCSS.ELA-Literacy.SL.5.1a Come to discussions prepared, having read or studied required material; explicitly draw on that preparation and other information known about the topic to explore ideas under discussion."[9] [see Unit 2, Lesson 1a]

Literacy Standards developed by Christopher Singler, Department Head, English, Middle and High School, Germantown Friends School.

5 http://www.corestandards.org/assets/Appendix_A.pdf
6 http://www.corestandards.org/ELA-Literacy/RI/1
7 http://www.corestandards.org/ELA-Literacy/CCRA/SL
8 http://www.corestandards.org/ELA-Literacy/CCRA/SL
9 http://www.corestandards.org/ELA-Literacy/SL/5

WRITING STANDARDS	Lesson Connection (Coded by Thematic Unit #, Lesson #, Activity Letter)
CCSS.ELA-Literacy.W.2.7 Participate in shared research and writing projects (e.g., read a number of books on a single topic to produce a report; record science observations). (K-5)	1.1.e, 4.3.b
CCSS.ELA-Literacy.W.2.3 Write narratives in which they recount a well-elaborated event or short sequence of events, include details to describe actions, thoughts, and feelings, use temporal words to signal event order, and provide a sense of closure. (K-5)	1.2.c,d
CCSS.ELA-Literacy.W.3.4 With guidance and support from adults, produce writing in which the development and organization are appropriate to task and purpose. (Grade-specific expectations for writing types are defined in standards 1–3 above.) (K-5)	4.1.b
CCSS.ELA-Literacy.W.5.3 Write narratives to develop real or imagined experiences or events using effective technique, descriptive details, and clear event sequences. (K-5)	1.1.c, 2.4.b, 4.2.a, 5.3.c
CCSS.ELA-Literacy.W.4.3a-eWrite narratives to develop real or imagined experiences or events using effective technique, descriptive details, and clear event sequences. (K-5)	3.3.a, 3.4.d
CCSS.ELA-Literacy.WHST.6-8.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (6-8)	1.4.c, 1.6.d, 4.1.c, 4.2.c
CCSS.ELA-Literacy.WHST.6-8.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.	4.1.c, 4.2.c
CCSS.ELA-Literacy.WHST.6-8.5 With some guidance and support from peers and adults, develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on how well purpose and audience have been addressed.	4.1.c, 4.2.c
CCSS.ELA-Literacy.WHST.6-8.1b Support claim(s) with logical reasoning and relevant, accurate data and evidence that demonstrate an understanding of the topic or text, using credible sources. (6-8)	1.5.c
CCSS.ELA-Literacy.WHST.6-8.2b Develop the topic with relevant, well-chosen facts, definitions, concrete details, quotations, or other information and examples. (6-8)	1.5.c
CCSS.ELA-Literacy.W.7.2 Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content. (6-8)	2.1.c, 2.2.b, 2.3.c
CCSS.ELA-Literacy.W.7.3d Use precise words and phrases, relevant descriptive details, and sensory language to capture the action and convey experiences and events. (6-8)	4.3.d

CCSS.ELA-Literacy.W.7.7 Conduct short research projects to answer a question, drawing on several sources and generating additional related, focused questions for further research and investigation. (6-8)	1.6.d,e, 1.7.b, 2.1.c, 2.2.b, 2.3.c, 2.4.e, 3.1.c, 3.5.c, 4.5.d
CCSS.ELA-Literacy.W.7.9 Draw evidence from literary or informational texts to support analysis, reflection, and research. (6-8)	1.7.b, 2.1.c, 2.2.b, 2.3.c, 2.4.e, 3.1.c, 3.5.c, 4.5.d
CCSS.ELA-Literacy.W.7.10 Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences. (6-8)	1.6.d
READING STANDARDS	**Lesson Connection (Coded by Thematic Unit #, Lesson #, Activity Letter)**
CCSS.ELA-Literacy.RL.2.1 Ask and answer such questions as who, what, where, when, why, and how to demonstrate understanding of key details in a text. (K-5)	1.6.b
CCSS.ELA-Literacy.RL.2.2 Recount stories, including fables and folktales from diverse cultures, and determine their central message, lesson, or moral. (K-5)	2.4.b
CCSS.ELA-Literacy.RL.2.3 Describe how characters in a story respond to major events and challenges. (K-5)	2.4.a
CCSS.ELA-Literacy.RI.1.3 Describe the connection between two individuals, events, ideas, or pieces of information in a text. (K-5)	1.7.b
CCSS.ELA-Literacy.RI.4.1 Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text. (K-5)	1.6.b
CCSS.ELA-Literacy.RI.6.7 Integrate information presented in different media or formats (e.g., visually, quantitatively) as well as in words to develop a coherent understanding of a topic or issue (6-8)	1.1.d,c
CCSS.ELA-Literacy.RST.6-8.2 Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions. (6-8)	1.2.d
CCSS.ELA-Literacy.RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. (6-8)	2.6.b, 4.1.b, 5.3.b
CCSS.ELA-Literacy.RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (6-8)	1.2.d, 2.1.c, 3.3.b
CCSS.ELA-Literacy.RST.6-8.8 Distinguish among facts, reasoned judgment based on research findings, and speculation in a text. (6-8)	2.1.c

Math Standards developed by Betsy Biernat, Senior Mathematics Major and Education Minor, Bryn Mawr College

CCSS OVERVIEW OF MATH:

Because "Understanding the Urban Watershed" (UUW) aims to be interdisciplinary and utilized by teachers of all subject areas, UUW also includes activities that link to the subject area of math. These activities are then linked to Common Core State Standards (CCSS) for math so that teachers can utilize UUW while also creating lessons that align with CCSS. The math activities included here are a sampling of the ways in which teaching about the urban watershed can be linked to math and CCSS math standards. In addition to being useable activities for teachers, these activities can also be used as a springboard from which to brainstorm other creative ways to teach math concepts in relation to the urban watershed systems.

STANDARDS FOR MATHEMATICAL PRACTICE: MODEL WITH MATHEMATICS

The CCSS practice standards for mathematics are a set of eight practices that "describe varieties of expertise that mathematics educators at all levels should seek to develop in their students"[1]. UUW provides a unique and rich opportunity for math educators to engage with the math practice standard "CCSS.Math.Practice.MP4 Model with mathematics,"[1] which asserts that "Mathematically proficient students can apply the mathematics they know to solve problems arising in everyday life, society, and the workplace."[1] Specifically, UUW allows students to engage with the issues of urban watershed systems, which has a direct and meaningful connection to their lives as residents of Philadelphia. All of the math activities presented in UUW thus create opportunities for students to use and develop math skills to model, investigate, and problem-solve real-world issues related to the urban watershed and its effects on students' everyday lives.

CONTENT STANDARDS FOR MATHEMATICS

The range of math activities represented in UUW are linked to the following mathematical domains that CCSS provides content standards for: Counting & Cardinality, Numbers & Operations in Base Ten, Numbers & Operations—Fractions, Measurement & Data, Geometry, Ratios & Proportional Relationships, Functions, and Statistics & Probability. Below are examples of standards in each of these mathematical domains with which an activity or activities in UUW is aligned.

- **Counting & Cardinality** "CCSS.Math.Content.K.CC.C.6 Compare two numbers between 1 and 10 presented as written numerals."[2] [see Unit 1, Lesson 1e]
- **Numbers & Operations in Base Ten** "CCSS.Math.Content.4.NBT.A.2 Read and write multi-digit whole numbers using base-ten numerals, number names, and expanded form. Compare two multi-digit numbers based on meanings of the digits in each place, using >, =, and < symbols to record the results of comparisons."[3] [see Unit 2, Lesson 1c]
- **Numbers & Operations — Fractions** "CCSS.Math.Content.3.NF.A.3 Explain equivalence of fractions in special cases, and compare fractions by reasoning about their size."[4] [see Unit 1, Lesson 1a]
- **Measurement & Data** "CCSS.Math.Content.5.MD.C.5 Relate volume to the operations of multiplication and addition and solve real world and mathematical problems involving volume."[5] [see Unit 5, Lesson 2a]
- **Geometry** "CCSS.Math.Content.7.G.B.6 Solve real-world and mathematical problems involving area, volume and surface area of two- and three-dimensional objects composed of triangles, quadrilaterals, polygons, cubes, and right prisms."[6] [see Unit 3, Lesson 4b]
- **Ratios & Proportional Relationships** "CCSS.Math.Content.6.RP.A.3d Use ratio reasoning to convert measurement units; manipulate and transform units appropriately when multiplying or dividing quantities."[7] [see Unit 5, Lesson 4a]
- **Functions** "CCSS.Math.Content.8.F.B.4 Construct a function to model a linear relationship between two quantities. Determine the rate of change and initial value of the function from a description of a relationship or from two (x, y) values, including reading these from a table or from a graph. Interpret the rate of change and initial value of a linear function in terms of the situation it models, and in terms of its graph or a table of values."[8] [see Unit 3, Lesson 1b]
- **Statistics & Probability** "CCSS.Math.Content.6.SP.B.4 Display numerical data in plots on a number line, including dot plots, histograms, and box plots."[9] [see Unit 4, Lesson 1b]

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[1] http://www.corestandards.org/Math/Practice
[2] http://www.corestandards.org/Math/Content/CC
[3] http://www.corestandards.org/Math/Content/NBT
[4] http://www.corestandards.org/Math/Content/NF
[5] http://www.corestandards.org/Math/Content/MD
[6] http://www.corestandards.org/Math/Content/G
[7] http://www.corestandards.org/Math/Content/RP
[8] http://www.corestandards.org/Math/Content/F
[9] http://www.corestandards.org/Math/Content/SP

MATH STANDARDS	Lesson Connection (Coded by Thematic Unit #, Lesson #, Activity Letter)
CCSS.Math.Content.K.CC.C.6 Compare two numbers between 1 and 10 presented as written numerals	1.1.e
CCSS.Math.Content.K.G.B.5 Model shapes in the world by building shapes from components (e.g., sticks and clay balls) and drawing shapes.	2.2.a
CCSS.Math.Content.K.MD.A.2 Directly compare two objects with a measurable attribute in common, to see which object has "more of"/"less of" the attribute, and describe the difference.	1.1.a
CCSS.Math.Content.1.MD.A.2 Express the length of an object as a whole number of length units, by laying multiple copies of a shorter object (the length unit) end to end; understand that the length measurement of an object is the number of same-size length units that span it with no gaps or overlaps.	5.4.a
CCSS.Math.Content.2.MD.D.10 Draw a picture graph and a bar graph (with single-unit scale) to represent a data set with up to four categories. Solve simple put-together, take-apart, and compare problems1 using information presented in a bar graph.	1.1.e, 1.4.c, 2.1.c
CCSS.Math.Content.3.NF.A.3 Explain equivalence of fractions in special cases, and compare fractions by reasoning about their size.	1.1.a
CCSS.Math.Content.4.MD.A.2 Use the four operations to solve word problems involving distances, intervals of time, liquid volumes, masses of objects, and money, including problems involving simple fractions or decimals, and problems that require expressing measurements given in a larger unit in terms of a smaller unit. Represent measurement quantities using diagrams such as number line diagrams that feature a measurement scale.	5.2.a
CCSS.Math.Content.4.NBT.A.2 Read and write multi-digit whole numbers using base-ten numerals, number names, and expanded form. Compare two multi-digit numbers based on meanings of the digits in each place, using >, =, and < symbols to record the results of comparisons.	1.1.e, 2.1.c
CCSS.Math.Content.5.MD.C.5 Relate volume to the operations of multiplication and addition and solve real world and mathematical problems involving volume.	5.2.a
CCSS.Math.Content.6.SP.B.4 Display numerical data in plots on a number line, including dot plots, histograms, and box plots.	1.1.a, 1.1.e, 1.4.c, 2.1.c, 4.1.b
CCSS.Math.Content.6.SP.B.5 Summarize numerical data sets in relation to their context.	1.1.a, 1.1.e, 1.4.c, 2.1.c, 4.1.b
CCSS.Math.Content.6.RP.A.3d Use ratio reasoning to convert measurement units; manipulate and transform units appropriately when multiplying or dividing quantities.	5.2.a, 5.4.a

CCSS.Math.Content.7.G.A.1 Solve problems involving scale drawings of geometric figures, including computing actual lengths and areas from a scale drawing and reproducing a scale drawing at a different scale.	5.4.a
CCSS.Math.Content.7.G.B.6 Solve real-world and mathematical problems involving area, volume and surface area of two- and three-dimensional objects composed of triangles, quadrilaterals, polygons, cubes, and right prisms.	3.4.b, 5.2.a
CCSS.Math.Content.8.F.B.4 Construct a function to model a linear relationship between two quantities. Determine the rate of change and initial value of the function from a description of a relationship or from two (x, y) values, including reading these from a table or from a graph. Interpret the rate of change and initial value of a linear function in terms of the situation it models, and in terms of its graph or a table of values.	3.1.b, 4.3.a
CCSS.Math.Content.8.G.C.9 - Know the formulas for the volumes of cones, cylinders, and spheres and use them to solve real-world mathematical problems.	3.4.b

Funding for this curriculum was provided in part by the U.S. Environmental Protection Agency in support of the National Estuary Program