Understanding NYC's Water Story

A Curriculum Guide for the Classroom

A COMPILATION OF SUCCESSFUL LESSONS AND ACTIVITIES

NYC Environmental Protection

Acknowledgements

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New York City Department of Environmental Protection

The mission of the New York City (NYC) Department of Environmental Protection (DEP) is to enrich the environment and protect public health for all New Yorkers by providing high quality drinking water, managing wastewater and stormwater, and reducing air, noise, and hazardous materials pollution.

DEP is a New York City agency of nearly 6,000 employees that strives to be a world class water and wastewater utility, while building a sustainable future for all New Yorkers. DEP's Education Office, which developed this guide, provides free education programs and resources to pre-Kindergarten through college students and educators on these important environmental topics. Through experiential learning, field trips, engaging resource materials, and collaboration with agencies and organizations throughout NYC and the NYC Watersheds, we aim to connect with young water consumers and foster appreciation and stewardship of our shared water resources.

Introduction

The New York City Department of Environmental Protection (DEP) is delighted to present this new curriculum guide, developed in partnership with the Fairmount Water Works, the acclaimed Watershed Education Center of the Philadelphia Water Department. You will find, nestled between the covers of this relevant and comprehensive resource, a variety of lessons and activities to enhance your teaching and learning about the New York City water cycle.

These lessons and activities are focused on STEM concepts and humanities subjects and designed to support your interdisciplinary, hands-on approach to teaching. They are also aligned with the New York State Science Learning Standards and Amplify Curriculum for Kindergarten through 8th grade students. Within the units, links to online resources, including those featured on DEP's website, allow for quick classroom access to videos, reading lists, primary source material, historic and contemporary photographs, technical information, and maps. You can also find other online education modules designed to help you create teaching resources that complement your curriculum and the needs of your students. We appreciate receiving your feedback to help improve this guide in the future. Please contact educationoffice@dep.nyc.gov.

Philadelphia's Curriculum Guide, *Understanding the Urban Watershed*, was first published in 2013 as a compilation of tested ideas and activities for K-8 students. It grew from more than a decade of classroom experiences, fieldwork and field trip experiences by school groups visiting the Fairmount Water Works, a National Historic Landmark, celebrated for engineering a venerated public drinking water system in the early 19th century. Subsequently, a regional version was created, focusing on its neighboring cities of Camden, Reading and Wilmington. The first Understanding the Urban Watershed was a partnership project made possible, in part, through the contributions and expertise of both public and private organizations and institutions. The New York City DEP and the Fairmount Water Works are pleased to provide this companion resource, a significant step in building a deeper understanding and broader context related to the impressive, important, and complex story of the water cycle.

The New York City Water Story

This guide will help your students make connections between one of the most fundamental elements in all living things – water – and the complexities and responsibilities associated with its availability, use, treatment, protection, and its return to the water cycle.

Most of us turn on the tap or flush the toilet without much thought about how the water got there, where it goes, or how much we use. We do not think about the people who sacrificed their homes and livelihoods so reservoirs could be built on land held for generations. It is important to think about these people and the engineers and laborers who created the New York City water supply system long ago, when science and technology were so different from what we experience today. As you read this right now, there are people working within watershed communities and deep below ground, to enhance and maintain our precious water supply system so it can continue flowing on a daily basis, so that you, and 9 million other people, can benefit from this life-giving resource.

Not only will students learn of the story of our precious drinking water, naturally filtered by protected watershed forests, but they will also discover the complex system of sewer pipes and wastewater treatment facilities that collect and clean our used water, recovering resources and contributing to sustainable initiatives. Making these important connections between these two vast systems will help students recognize the value of New York Harbor and the many surrounding waterways.

The activities that follow were designed to help your students explore their relationship with tap water and watersheds, with flushing toilets and wastewater treatment, and rainfall and local water ecology. Water education is about exploring the delicate balance between land, water, human behavior, and environmental protection. Our hope is that, ultimately, the activities and lessons will encourage youth of all ages, and educators, to study, discuss, assess, and experience our shared water resources.

Why Learn about Water?

The need for clean 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 may simply appear from the tap, it is quite possible for a person to be unaware of where that water originated, how it was transported, or why it is clean and safe to drink.

Understanding watersheds helps us learn where our drinking water comes from, about the people who live and work there and what they do as stewards of this land, how water gets to the consumer and ways it is used, where it goes next, how it can be threatened, and how to take better care of it. In an urban watershed, we also connect to the life and health of our local waterways. We learn that as water consumers and water lovers, we have a tremendous impact on this precious natural resource and through education, we have the power to make informed decisions about how best to preserve and protect it.

About this Water Curriculum

This resource for K-8 students and educators is designed as a series of thematic units that build on each other, starting with a personal perspective of water. Ultimately, the learning experience will provide students with the broadest view of the entire New York City water cycle which can help them become active participants in 21st century solutions to water issues. The final thematic unit, focused on stewardship, is project-based and meant to encourage critical thinking and action. As with any important project, students will need the support of many people, including school and community members to shape their projects to be sustainable and meaningful.

Each thematic unit includes broad learning objectives, a “What You Should Know” section designed to inform educators, and a series of lessons. These lessons are packed with ideas for activities that can be done 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 as well as the student experience. Learning, which takes place in the classroom or in an after-school environment, can spread beyond the building walls to the outdoor environment, such as the playground, the city sidewalk, the park, the neighborhood, the home, the beach, or a nearby waterway.

The activities are presented to help students explore water at home, in their schools, and neighborhoods throughout New York City and watershed communities. Lessons include vocabulary, essential questions, a “consider and discuss” prompt, and a note about careers. Ideally, units and lessons should be done sequentially. Activities could take, on average, one or two class periods and are designed to be integrated into multiple disciplines. For information on how the activities can relate to academic standards, an overview can be found at the end of the guide.

Visit nyc.gov/dep/education for more DEP education resources and program opportunities.

Thematic Unit 1: Water in Our World

By exploring where our water comes from, students will begin to develop an understanding of water in their lives, and the way the water cycle functions. Embracing this fundamental level of awareness, students will also begin to appreciate adaptations and innovations designed to meet the challenge of protecting our shared water resources in the past, present, and future.

LESSONS

1. Water for Life
2. The Water Cycle
3. Landforms and Watersheds
4. Trees, Plants, and other Buffers
5. Ecology of Waterways: Diverse and Abundant Communities
6. Life Aquatic: Microscopic Organisms and Macroscopic Invertebrates

Thematic Unit 2: Drinking Water and You

By learning about the history of the New York City water supply system and its creation as one of the greatest engineering marvels of modern times, students will explore both historical and personal connections to New York's special water. Students will begin to understand New York's water story from source to tap and develop an understanding of the protection, operation, maintenance, and conservation of a safe and reliable drinking water system for millions of New Yorkers.

LESSONS

1. My Daily Water Use Log
2. Water for New York City: Creating a Public Water Supply System
3. Technology and Innovation: Engineering New York City's Water Supply System
4. Clean Water and Public Health: Consider the Source
5. Drinking Water Treatment Explained
6. Testing the Waters: Making it Safe
7. Water for the Future: The Big Fix

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

Just as our city developed a collective drinking water supply system to ensure the health of residents, we also developed ways to dispose of our wastewater or "used" water. Students will discover that it is no small task to engineer an effective and safe system to manage human and industrial waste and to make sure clean water is returned safely into the environment.

LESSONS

1. The Growth of the City: Population and Wastewater Systems
2. Industrial Revolution and Environmental Devolution
3. Under our Noses: Creating an Underground Infrastructure
4. Sinks, Pipes, and Systems: Making the Connection
5. Wastewater Treatment Explained
6. A Healthy Harbor: Keeping Pollution at Bay

Thematic Unit 4: Land and Water: A Delicate Balance

Homes, schools, businesses, parks, and roadways are all part of the essential fabric of our urban life. When our built environment grows, development can overwhelm the natural environment and impact surrounding waterways. Students will learn how this relationship between land and water is a delicate balancing act for humans and nature. Periodically, throughout the last two centuries, human activities have tipped the balance leading to a loss in equilibrium. Finding and maintaining this balance in order to protect public health and sustain ecological well-being is a commitment we must make for our future.

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 Movement

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

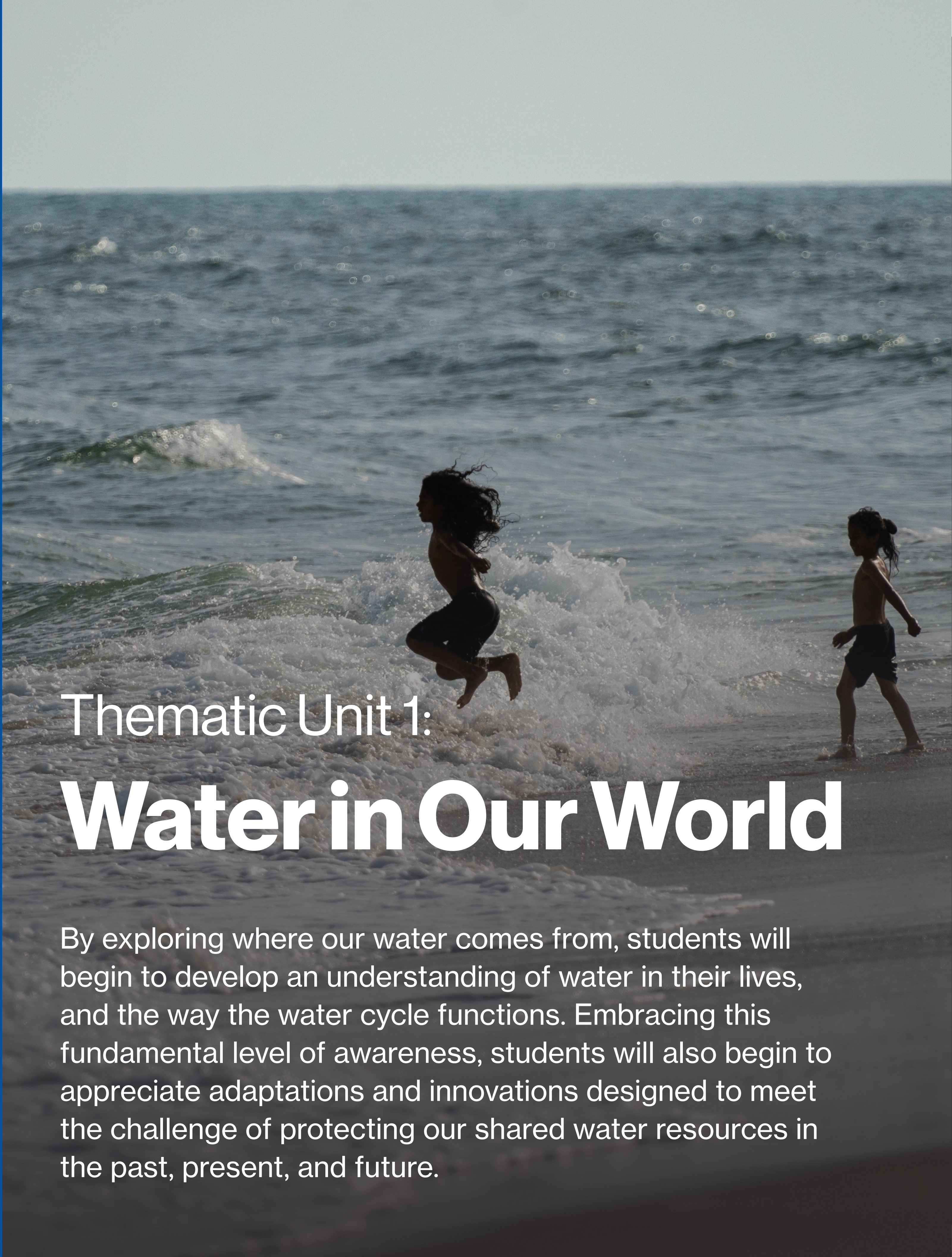
Some of the most challenging threats to water quality in the 21st century are created by stormwater runoff and exacerbated by climate change. As students have learned, solutions and innovations to monitor and improve the environment have helped move our water story forward. Now, your students will explore how individuals, communities, and public agencies continue to play key roles in shaping the future health and well-being of water for New York City. Words like sustainability, resiliency, and stewardship will become actions as we plan for the future of our shared water resources.

LESSONS

1. Green Infrastructure: Following Nature's Lead
2. Calculating Rainwater
3. Restoring Urban Waterways
4. A "Model" Schoolyard
5. Climate Change: Engaging in Action

Thematic Unit 6: Environmental Stewardship

We all have the power to affect positive environmental change! Through education, we can help students realize their potential for conserving and protecting New York City's shared water resources and the environment. By understanding that both the small individual actions we take at home and school and the larger service projects we initiate in our communities have an impact, students can become empowered as agents for change in their own neighborhood, city, and beyond.



Thematic Unit 1:

Water in Our World

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What you should know:

We use water all the time in our daily lives. We drink it, bathe with it, cook with it, water our plants, give it to our pets, and also flush and brush with it. Did you know that New York City's drinking water, considered some of the best quality water in the world, can travel from as far as 125 miles away to reach your faucet? It starts as rain and snow falling on the mostly forested mountains and valleys north of New York City. This vast, 2000-square mile area of protected and managed land that collects and stores our drinking water is called the New York City **Watershed** and is delineated both geographically and topographically into three regions -- the Croton, Catskill, and Delaware – located on both the east and west sides of the Hudson River.

Water flows downhill through a complex, interconnected system of streams, lakes, reservoirs, aqueducts, and tunnels to New York City's nearly nine million consumers. When it reaches the city, drinking water is distributed into nearly 7,000 miles of pipes to homes, schools, and businesses throughout the five boroughs. The New York City Department of Environmental Protection (DEP) is the public agency responsible for protecting, operating, and maintaining this supply, but it is ultimately our collective responsibility to care for all the water in our world.

WATER: EARTH'S PRECIOUS RESOURCE

Water is essential to life and **freshwater** resources on Earth are limited. While 70% of the world is covered by water, only about 3% of the water on Earth is freshwater (97% is saltwater). Most of the Earth's freshwater is found frozen or trapped underground, which means the less than 1% of freshwater that is actually available is in high demand.

The Earth has a very efficient method of cycling water through the atmosphere and the land. As **precipitation** falls from the sky and hits the Earth's surface, it takes one of many different routes: some soaks into the ground (**infiltrates**), replenishing groundwater; 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 streams and turns it into a gas (**water vapor**), 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. Water vapor collects to form clouds through **condensation**. These steps make up the **water cycle**, or **hydrologic cycle.** When it rains, the land that drains (or sheds) this water to the nearest water body is called a **watershed.** A watershed can be thought of as a big bowl or basin, collecting all the surface and groundwater within a specific area and draining it from the highest to the lowest point.

NYC'S WATER HISTORY

Precisely because of the way the water cycle functions, there is an inseparable connection between water and land. Indigenous communities developed near fresh, clean, and reliable water sources. As populations grew, so did the demands on freshwater ponds, rivers, and groundwater sources. With the rise of cities, these sources grew foul with human and animal waste. Without access to clean water, and a yet to be discovered scientific understanding about water pollution, cities could not thrive.

By the early 1800s, New York City's polluted water supply led to dire consequences of disease, filth, and a lack of a plentiful supply to fight fires. In the interest of public health and safety, we needed to find a new, reliable source of drinking water. Like other ancient and modern cities facing similar challenges, we searched for clean water in the less populated areas beyond city boundaries, and that's where we found the Croton River. By 1842, a remarkable system was engineered to collect and convey water by **gravity** through a system of **reservoirs** and **aqueducts.** This was the beginning of a continuous and ever-growing dependence on New York City's watershed neighbors for our abundant and consistent water supply.

Although the waterways surrounding our city are not the source of drinking water, they have always been an integral part of the commercial, industrial, and recreational fabric of our city. In the 21st century, protecting beaches, wetlands, rivers, canals, bays, and the harbor has been an ongoing collective effort. After all, these areas are home to native New Yorkers of other kinds--birds, fish, reptiles, amphibians, and small mammals.

Artwork by Lindsay Espana, Hillside Arts and Letters Academy, Queens

In the past, water flowing into New York Harbor could be effectively filtered and cleaned by nature because pollution existed on a small scale. In modern times, in order to keep up with the daily flushing, brushing, showering, and other healthy habits of millions of busy New Yorkers and visitors, we needed to engineer a wastewater system. Our **wastewater** is now carried in pipes called **sewers** to one of 14 **wastewater resource recovery facilities (WRRF)** in the city. In just 8-10 hours, harmful waste is removed and clean water is returned to the waterways surrounding New York City. DEP manages and monitors this process to make sure that the treated water from these facilities is safe to discharge into local waterways and the water cycle. Additionally, nearly two-thirds of rainwater from our streets is collected in sewers and carried to these same facilities for treatment. Processing and treating the wastewater of New York City is no small task!

WATER PROTECTION & STEWARDSHIP

New York City has many buildings, as well as paved (**impervious**) sidewalks and streets that are unable to absorb water when it rains, disrupting the natural processes of the water cycle. Catch basins and a network of underground sewer pipes, were designed to help drain the rain quickly. Rainwater rushing over streets, rooftops, and other impervious surfaces picks up pollutants in its path, such as pet waste, litter, lawn fertilizer, and oil. This is referred to as **stormwater runoff.** About 40% of our sewer system collects and drains stormwater runoff directly to waterways through the **municipal separate storm sewer system (MS4).** The other 60% of our sewers convey stormwater runoff and wastewater together to a wastewater resource recovery facility through the **combined sewer system**. On most rainy days, the combined sewage goes to a facility to be cleaned. During heavy downpours, the sewers and facilities may reach capacity, and a mixture of untreated stormwater and wastewater can overflow to the nearest waterway.

One way to fix this problem is through **grey infrastructure,** or the building of large underground tanks and tunnels to hold untreated wastewater until the rain ends. Another, more innovative solution is **green infrastructure,** or the use of natural systems that divert rainwater into planted areas. Rain gardens and green roofs are examples of green infrastructure that help absorb stormwater like a sponge. The engineered wetlands on Staten Island, called **Bluebelts**, are another form of green infrastructure, designed to help filter and absorb stormwater naturally, enhance habitats for wildlife, create public green spaces, and help with flood control.

In order to determine the health of our waterways and effectiveness of our water systems, scientists observe nature by using biological and chemical indicators. Biological indicators are plant and animal species that tell us about the health of the **ecosystem**. DEP scientists monitor the health of the rivers, streams, and tributaries that comprise the New York Harbor through ongoing water sampling and testing of bacteria, chlorophyll, turbidity, temperature, and dissolved oxygen.

This is our New York City water story; its narrative connects people in New York City to each other and to our watershed neighbors, and gives us all a common purpose in protecting our shared water resources. Students and teachers play a key role in ensuring the future of clean water by exploring our water story and connecting to **stewardship** opportunities. You can start this unit by asking your students what the value of fresh water means to them. Student observations and experiences can help segue the conversation from a personal level of understanding to a more holistic perspective on their community, city, and the world.

"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
2. The Water Cycle
3. Landforms and Watersheds
4. Trees, Plants, and other Buffers
5. Ecology of Waterways: Diverse and Abundant Communities
6. Life Aquatic: Microscopic Organisms and Macroscopic Invertebrates

L1 Water for Life

All living things need water to live and all living things contain a certain percentage of water. From your students to the clams at the beach, everything living in this world needs water to survive. We should also consider aspects of water that we simply enjoy, such as running through the sprinkler, jumping in waves at the beach, and ice-skating with friends at the park.

ESSENTIAL QUESTION

How can we understand and appreciate the importance of water?

VOCABULARY

Water *(noun and verb)*
The liquid that descends from the clouds as rain or snow, forms streams, lakes, and seas. Water is a major component of all living matter. When pure it is odorless and tasteless; freezes at 0° C (32°F) and boils at 100° C (212°F). It is the only substance that can naturally occur as a solid, liquid, and gas.

SUGGESTED IDEAS AND ACTIVITIES

a. Compare how much water exists in a variety of everyday living things. Have students choose something related to what they bring for lunch, something larger that helps your school function, or even their bodies! Research and illustrate in diagrams.
b. Create a chart of water words around the room. Record new and important words shared during class activities, discuss and define as a class.
c. Research the word "water" in many different languages. For example, in Spanish (agua), French (eau), and Chinese (shuĭ). How do other cultures and communities relate to and value water? Interview family members.
d. How have you used water today? Why do we need water in our life (what else relies on water)? Write a love letter to water. Illustrate the love letters on droplet-shaped blue paper; hole punch and thread string through to create a hanging display (like a rainstorm!).
e. Write a story using rivers as symbolism. Discuss terms like flow, rhythm, light, grace, fluidity or even rushing, raging, and flooding. Use the landscape as metaphor.
f. Survey the landscape paintings of 19th century "plein air" or Hudson River School of artists. Analyze composition and color before having students copy a work or create their own artwork outside.
g. Have students collect water in jars from different locations (sink, bathtub, rainwater, stream, beach, puddle, garden hose), and in different states of matter (ice cube, water vapor from breath or living plant); observe and record similarities and differences (color, smell, temperature, chemical phase, salinity, and more). Discuss how water from different sources is the same and different. What factors influence these water samples?

CONSIDER AND DISCUSS

- Where there is water, there are lifeforms. When we explore other planets, water is the first indication that there may be life. Find articles that describe the most recent space expeditions.
- Many communities have often celebrated water through rituals, annual events, artwork, and writing. Look at civilizations that developed near waterways and their dependence on the availability of water. Find past and present poetry, passages in literature, and music that reflect this theme and discuss. For younger students, talk about their own personal rituals around water – how is it used every day at home?

ASK THE EXPERT

The love of water does not require a professional degree! Ask yourself, and talk to family and friends about the importance of water in their lives from work and chores to hobbies and play.

L2 The Water Cycle

Technically known as the "hydrologic" cycle, the water cycle is the ultimate sustainable process. As human beings, we depend on clean, safe freshwater. We can't make new water. The water we depend on exists in a closed system--an endless loop from land to sky and back again. Encouraging students to understand this fundamental concept will serve as the foundation for any study of water and will help them explore and understand the value of water in their world.

ESSENTIAL QUESTION

How does water cycle through the environment?

VOCABULARY

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

H_2O *(noun)*
The chemical formula for water; each water molecule consists of two hydrogen atoms bonded to one oxygen atom.

SUGGESTED IDEAS AND ACTIVITIES

a. Create simple icons on cards depicting each stage of the water cycle and place them in the proper order on a pre-drawn circle. With younger students, write a script and perform a song or play, acting out with sounds and movement of the water cycle (use DEP's New York City Water Cycle Rain Dance activity as an example).

b. Read *The Magic School Bus: Wet All Over* by Joanna Cole aloud to students and discuss the stages of the water cycle. Have students write and illustrate a list of the many ways they find H2O as a solid, liquid, and gas.

c. Read *Water Dance* by Thomas Locker aloud to students and discuss the images and first-person narrative (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.").

d. Seek out the root of the word "evaporation" to discuss vapor and states of matter. Make observations using classroom demonstrations (e.g., put plastic wrap over a cup of water and place in the sun; watch as water evaporates and forms condensation). Go outside after a rainstorm or to see morning dew.

e. Using pennies and pipettes, see how many droplets students can add and count on the surface of the penny. Demonstrate and discuss cohesion (H2O molecules sticking to each other) and adhesion (H2O molecules sticking to other surfaces).

f. Put water in a clear bin, and mark and measure the height of the water. Place the bin outside on a sunny day and monitor how the water level changes over time. Have students make hypotheses beforehand and calculate the difference afterwards.

g. Memorize and review the different stages of the hydrologic cycle by creating a song, a dance, a poster, or a computer graphic.

CONSIDER AND DISCUSS

- Water as a finite resource. Fresh water exists in a limited quantity. We can't make new water, but we can deplete existing freshwater resources.
- Where does water come from? After we use it, where will it go next? Will it rejoin the hydrologic cycle?
- Are we responsible for thinking about where our water comes from and what happens to it after we use it?
- Can the water cycle be altered?

ASK THE EXPERT

Hydrologist – a scientist who studies water by sampling and analyzing the properties of waterbodies and examining the environmental impacts of pollution.


The Water Cycle
Condensation
Precipitation
Transpiration
Infiltration
Evaporation
Stormwater Runoff


DEP

L3 Landforms and Watersheds

Our natural landscape consists of many features, including mountains, valleys, forests, and bodies of water. A watershed is the area of land where rain and snow collects and drains, or "sheds," into rivers, lakes, streams, and underground. We can think of a watershed as a big sink – because of its slope and gravity, the water flows down its sides to the drain. Before discussing the concept of watersheds, help students understand the fundamental relationship between water and land, whether you observe a "stream" forming in the parking lot during a rainstorm, wonder where all the water in the Hudson River originates, or consider the quality of water at your local beach.

ESSENTIAL QUESTION

What is a watershed?

VOCABULARY

Topography *(noun)*
The art or science of making maps that show the height, shape, or other features of the land in a particular area. The arrangement of the natural and artificial physical features of an area of land.

Watershed *(noun)*
An area of land that drains and collects water, by gravity, in rivers, lakes, streams, and underground.

SUGGESTED IDEAS AND ACTIVITIES

a. Start by having students hold their hands palm side up with their fingers together. Spray water on hands using a spray bottle and observe how water moves and where it collects. Why does this happen? Discuss how the whole hand is the watershed and the palm is where the puddle (lake, pond, or reservoir) collects and holds the rain.

b. Using clay or papier mache, have students create mountains and a river (hint: create enough slope to allow for "runoff"). Use water or beads dropped on the mountaintop to model rain.

c. Make a working model, in a carton or plastic bin, to demonstrate the different landforms and watersheds (use DEP's What is a Watershed? lesson). After working in small groups, bring the class together to create a larger watershed model using backpacks piled centrally and draped with a sheet; add in beads, ribbons, and blue fabric to show where rain falls, drains, and collects.

d. Locate and share varying scales of topographic maps (check out USGS maps). Trace ridgelines, major waterways, and tributaries. Predict and then show the direction of the flow. Compare to a topographic map of the United States. Compare or overlay varying kinds of maps such as a watershed and municipal boundary map to consider the defining nature of a watershed.

e. Use Google Earth to further study the topography and landscapes of the New York City watershed. Map out the path that water takes from high points to low points.

f. Take a rainy day hike around your school grounds or plan a field trip to a local park to observe water flow, slope, and land use. Discuss how activities on land may impact the quality of water.

g. Using a blank sheet of paper, or a simple map, draw and label the waterbodies that surround New York City or your local community. Discuss student experiences on or near these waterways.

h. Plan a field trip to a local museum exhibiting water and watershed education. Visit the Queens Museum's Watershed Model to view a large-scale relief map of New York City's water supply system, which was constructed for the 1939 World's Fair. Experience more hands-on, interactive exhibits, including "Connected Worlds" at the NY Hall of Science and "Dynamic H2O" at the Children's Museum of Manhattan.

i. Apply for a Watershed Forestry Bus Tour grant from the Watershed Agricultural Council or funding for a class trip to the New York City watersheds from the Catskill Watershed Corporation. Education opportunities supported by these grants vary, but all are designed to enhance student understanding of the New York City water supply system and watersheds, urban and rural landforms, and community partnerships.

CONSIDER AND DISCUSS

- Discover the relationship of geography, geology, and landforms. Explore your community and identify various local geological landmarks. Use Google Earth or other maps to explore regional geological landmarks. Discuss the geological formation of rivers.
- What can impact the quality of water in a waterbody? Who is responsible for ensuring our water is clean and safe? Explore DEP's NYC Watershed Virtual Tour for video interviews, maps, and more activities on the importance of watershed protection.
- How can a fluctuation or change in weather and climate affect a watershed? Consider local and regional rainfall data and study the impacts of droughts and floods.

ASK THE EXPERT

Geologist – a scientist who studies the solid and liquid matter that constitute the Earth.

L4 Trees, Plants, and Other Buffers

Nature has filtered pollutants from water long before people began building infrastructure to do the same. Trees play a vital role in the water cycle related to infiltration and transpiration. Along the edges of our waterways, trees and other plants act as buffers by catching sediment, keeping soil in place to prevent erosion, and by absorbing and using nitrogen and phosphorous as nutrients before they reach our waterways. In upstate watersheds where our drinking water flows from, forested areas make up nearly 75% of the land and play an essential role in watershed protection.

ESSENTIAL QUESTION

How do forests protect a watershed?

VOCABULARY

Forest *(noun)*
A dense growth of trees and underbrush covering a large area.

Riparian *(adjective)*
Relating to, living or located on the bank of a natural waterway.

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

Filter *(verb)*
To pass or move through in order to separate out or hold back elements.

SUGGESTED IDEAS AND ACTIVITIES

a. Meet a tree! Go outside to a nearby park or green space, have students find a tree that intrigues them and spend a few minutes observing its unique aspects including leaf and branch patterns, trunk texture, roots, and growth location. Share out as a group, introducing everyone to your tree.

b. Observe trees planted along the street or growing in a local park throughout the seasons. Keep a journal of sketches, and leaf and bark rubbings. Research and identify native species and their properties. Consider the impacts of invasive species on native plants; learn about invasive species that are common to your local ecosystem.

c. 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 plants and animals. Create pre-cut pieces (insects, flowers, mammals, trees) and glue them to the sheet of paper.

d. Demonstrate capillary action by placing fresh cut flowers (white carnations work well) into cups of warm water and adding different color food dye to each cup. Make observations and discuss the changes. Discuss absorption and consider how plants can prevent pollution from getting into waterways.

e. Make a model depicting four different kinds of surfaces on a slope with a drain and collection container at the bottom. Surfaces may include a planted area, a forested area, a grassy or sandy area (low lawn-type setting), and a paved surface. Use something to represent water such as beads, beans, or rice. Predict and compare the amount and speed of the runoff from each of the surfaces.

f. Research and delineate maps of streams, and their surrounding landscape, that lead directly into New York City reservoirs. How do forests play a role in stream flow, shade, water quality, and wildlife habitat?

g. Plant native seedlings in the classroom and monitor plant needs and activity over the course of the season in order to understand what plants require to live. Create a plan to transfer plants outside.

h. Go outside and identify areas with abundant plant-life or permeable surfaces and other open areas with little plant life and hard, impervious surfaces. Pour water on these surfaces and observe how it moves (consider slope and amount of runoff). Stick a wooden tongue depressor or stake into the ground in different places where dirt, grass, and other plants grow. Pour water on the ground in front of the stake to see how water (and soil!) splashes up. What role do plants play in keeping the soil in place?

i. After spending time outside observing trees, use your bodies to identify the benefits of trees – fingers as leaves (intercept rain), arms as branches (with leaves that provide shade for habitat), legs as trunks (absorb water), and feet as roots (stabilize tree, reduce erosion, intake water and nutrients that might otherwise pollute waterways like nitrogen and phosphorous).

j. Visit the [New York Botanical Garden] to explore Thain Family Forest, the largest preserved area of old-growth woodland forest in the city. Take a trip to a [Model Forest] in the New York City watershed to learn about forest management practices that help protect water quality and provide other benefits like biodiversity, recreation, and jobs.

CONSIDER AND DISCUSS

- What other benefits are there to creating and maintaining riparian buffers and large forested areas in our watershed? What is habitat fragmentation?
- How do watershed residents and visitors utilize and value the watershed landscape (forests, farmland, etc.)?
- Why do we need trees? Have students develop a list of forest products and ecosystem services; consider the balance of use and protection.

ASK THE EXPERT

Forester – a professional who plans, manages, and cares for forests.

L5 Ecology of Waterways: Diverse and Abundant Communities

There is an integral connection between the health of a river and the diversity of living things in and around it. Diversity and abundance are indicators for our scientists who test and monitor fish and other wildlife to measure the health of our waterways. A simple walk by a creek or along the beach can give us an idea of how we're doing. How many birds do you see? Can you see insects? Wait for that surprise splash on the surface that tells us—there are fish in there!

ESSENTIAL QUESTION

Why is diversity a positive ecological indicator?

VOCABULARY

Biodiversity *(noun)*
The variation of life in the world or in a specific habitat or ecosystem.

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

Community *(noun)*
An interacting population of various kinds of individuals (as species) in a common location.

SUGGESTED IDEAS AND ACTIVITIES

a. Choose an activity in which every student's participation is essential to meeting a goal, such as a clean classroom. Give each student a job 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. Try again giving each student a role to play; for example, a student who takes over the activity is an invasive species.

b. Assign a journaling activity for your students during a visit to the nearest waterway. Have them document and illustrate what they observe in 5, 10, and 20-minute intervals. Return to the classroom and use guide books to help students identify what they saw.

c. Characterize the diversity and abundance of fish species in fresh and marine waterways using real data to help students understand the work of aquatic and marine biologists. Refer to the New York State Department of Environmental Conservation for information, maps, and photos on the variety, distribution, and status of each of New York's freshwater and marine fishes – some of which can be found in New York City. Make simple graphs and illustrate maps using the data. Create a story about the journey of migrating fish.

d. Learn about the Trout in the Classroom program, a yearlong study that includes raising trout, from eggs to juvenile fingerlings. Students learn about the trout life cycle, watershed protection, stream habitats, and discover how trout are indicative of healthy water quality, before releasing their fish into upstate watershed streams at the end of the school year.

e. Visit the NY Aquarium in Coney Island, Brooklyn to learn more about marine species found in local waterways. Identify a species to research and observe. Take photographs or make sketches while documenting characteristics and behavior. What is required to maintain a healthy marine ecosystem for these species?

f. Adopt oyster beds to study and monitor the habitat and life cycle of oysters in a nearby waterway. Work with the Billion Oyster Project to identify a suitable location for a harvesting, and for teacher and student support throughout the school year.

g. Have students act out an aquatic food web by standing in a circle, assigning each student to represent a different organism. Pass a ball of string from person to person to demonstrate important interrelationships. Have one species drop the string; ask students what happened to their web, discuss what this means for the ecosystem. Make a mural using mixed media to show how these species interact and depend on each other.

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.
- How do we balance the interrelationship of humans (collectively and individually) and the environment (past, present, and future)?

ASK THE EXPERT

Aquatic Biologist – a scientist who studies living organisms in fresh- and saltwater.

L6 Life Aquatic: Microscopic Organisms & Macroscopic Invertebrates

Fish, migratory birds, reptiles, and amphibians, as well as riparian and aquatic plants, are important indicators of the health of our waterways. 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. Both microorganisms and macroinvertebrates help share that story and are often important biological indicators of water quality and food sources for larger aquatic species.

ESSENTIAL QUESTION

Why do scientists rely on smaller living organisms to help diagnose the health of a waterway?

VOCABULARY

Microorganism *(noun)*
An extremely small living thing that can only be seen with a microscope.

Macroinvertebrate *(noun)*
An animal without a backbone that can be seen with the naked eye (mostly aquatic insects).

SUGGESTED IDEAS AND ACTIVITIES

a. Explore a neighborhood park to look for aquatic macroinvertebrates. Collect water samples and look under a microscope. Use mesh bags and old leaves to assemble a leaf pack in the classroom before setting in a stream a few weeks prior to the activity.

b. Create an exhibit of images showing the variety of shapes and sizes of the world of macro- and microorganisms. Make an exhibit label that describes the relationship of the organism or plant to water quality. Create a gallery of artwork in your classroom.

c. Write a research paper on environmentalists such as Dr. Ruth Patrick and Rachel Carson who studied pollution's effects on organisms. Have students present their findings or display in the classroom or hallway for others to read.

d. Visit a freshwater stream or river in the city (Bronx River) or New York City watershed (Cross River in Ward Pound Ridge Reservation) to observe the habitat, and discover macroinvertebrates (check if a permit is necessary ahead of time). Using nets, a bucket, trays, spoons, and a microscope, students can observe organisms found beneath leaf litter and rocks in streams. Use a dichotomous key to identify species before returning them to the stream.

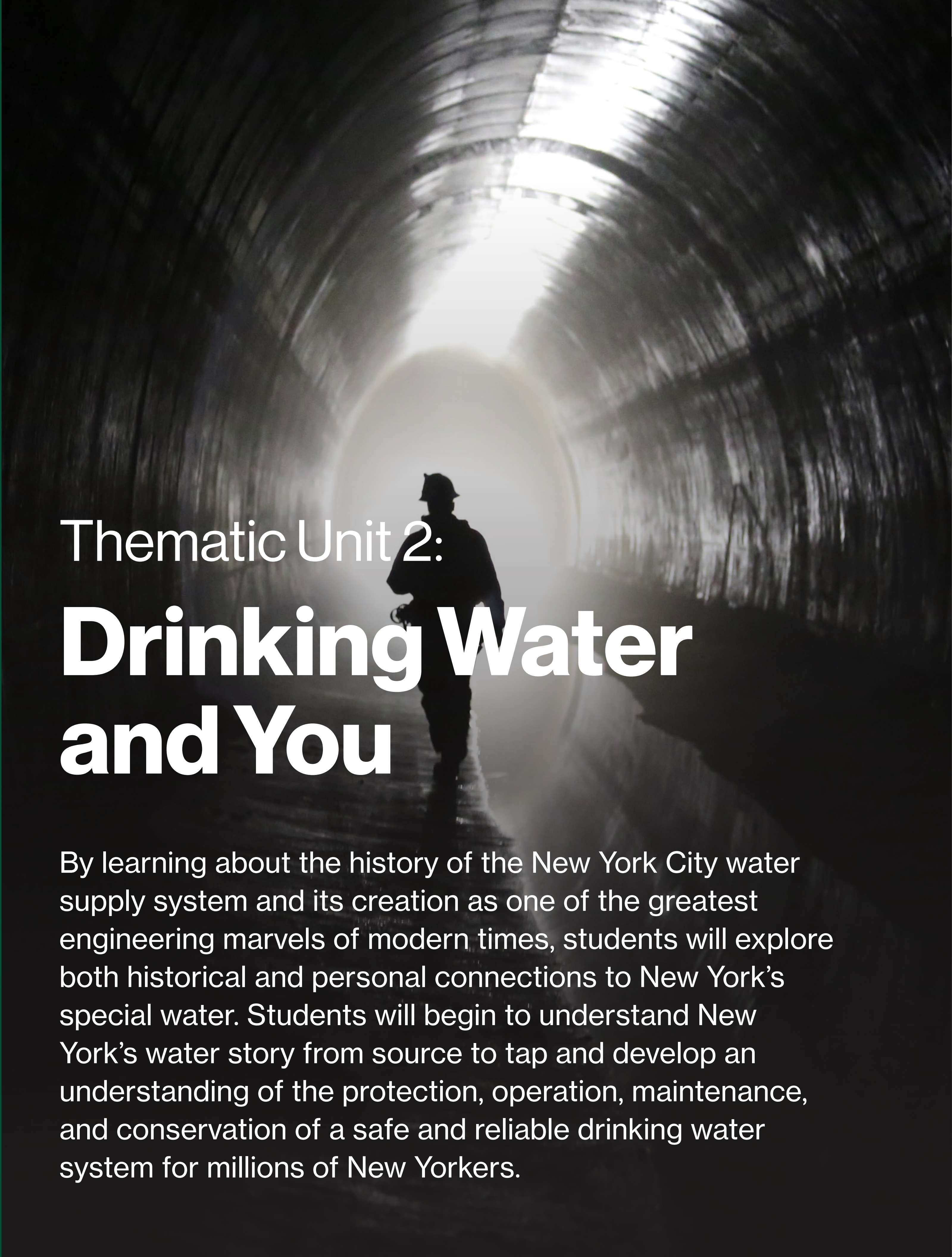
e. After conducting the above biological water quality analyses, use chemical water quality test kits to continue analyzing water quality indicators. Collect data on pH, dissolved oxygen, nitrate and phosphate, turbidity, temperature, and fecal coliform levels. Discuss what each of the different parameters tell us about the health of the waterway.

CONSIDER AND DISCUSS

- Which microorganisms are indicators of the health of a stream?
- How do we use macroinvertebrates as water quality indicators? What is the difference between an abundance of macroinvertebrates and a diversity of species?

ASK THE EXPERT

Research Scientist – a scientist that researches, investigates, and experiments on a wide variety of topics.



Thematic Unit 2:

Drinking Water and You

By learning about the history of the New York City water supply system and its creation as one of the greatest engineering marvels of modern times, students will explore both historical and personal connections to New York's special water. Students will begin to understand New York's water story from source to tap and develop an understanding of the protection, operation, maintenance, and conservation of a safe and reliable drinking water system for millions of New Yorkers.

What you should know:

The development of New York City's public drinking water supply system began in the 19th century and continues today with upgrades incorporating new technologies and innovations. Its history is a complex narrative of civic achievement, community sacrifice, scientific advancement, and brilliant engineering.

EARLY HISTORY

Indigenous populations, such as the Lenape tribal community, relied on abundant fresh water springs, streams, and ponds for a water supply close to where they lived. In what is now known as the borough of Manhattan, a primary source of water for both indigenous peoples and early Dutch colonists was a body of water called the Collect Pond. By the 1600s, early Dutch and British colonists relied on a growing number of public and private **wells** fed by groundwater. As New York's population grew these water supplies were contaminated by unchecked pollution from industry, livestock, and privies that either seeped into the ground, or was dumped directly into surface supplies.

In 1799, a New York State law entitled "An Act for supplying the City of New York with pure and wholesome water" granted a charter to the Manhattan Company to establish itself as the private water company for New York City. A special provision in the law, slipped in at the last minute by New York State Assemblyman Aaron Burr, also allowed the company to use its surplus money to start a bank. To keep its bank in business the Manhattan Company was obligated to supply water, which it did by pumping water from wells to a reservoir on Chambers Street, and then piping it to consumers. But Burr was more interested in running a successful bank than in solving New York City's water woes. In the end, this system was inadequate, supplying water from the same polluted sources and using inferior pipes, some made from hollowed out logs, that only reached parts of the city.

By this time, New York City's population had tripled from 33,000 in 1790 to nearly 96,000 in 1810. Through the early 1800s, diseases such as yellow fever, typhoid, and cholera killed thousands of people. Without reliable water pipes to fight them, large fires also destroyed entire neighborhoods. If the city was going to thrive (even survive), it was critical that we implement a public water supply system.

CROTON WATER SYSTEM

The Croton River, about 40 miles north of the city, was chosen as the best upland source of fresh water for a new water supply. Damming the river created a **reservoir**, or large basin, to store fresh water for use. Up to 90 million gallons of fresh water a day flowed from the reservoir into the Croton Aqueduct, traversing hills and valleys, and crossing the Harlem River over the High Bridge and into Manhattan. The **aqueduct** filled two reservoirs, a receiving reservoir between 79th and 86th Streets (now the site of Central Park's Great Lawn) and a distributing reservoir between 40th and 42nd Streets (today, the location of the New York Public Library). Engineering this water supply system was a massive and complex public works undertaking, built primarily by immigrant and migrant laborers, and unrivaled as one of the greatest engineering projects of its time.

On October 12, 1842, New Yorkers celebrated their new water supply with three consecutive days of festivities that included fireworks, cannon fire, church bells, and a five-mile-long parade. This only marked the beginning of a system that continued to expand to meet the demands of an ever-thirsty, ever-growing New York City population.

CATSKILL AND DELAWARE WATER SYSTEMS

Soon enough demand for water nearly outpaced supply. As the city industrialized, population continued to rise and the ways people used water began to change due to the introduction of indoor plumbing. In 1898, the boundaries of New York City were expanded into the five-borough city we know today. As pressure grew to provide more water, city leaders looked to expand the existing water system. An area 100 miles north of the city, on the west side of the Hudson River, was selected for what would become the new Catskill System. In 1905, the New York State Legislature passed the McClellan Act, creating a Board of Water Supply and allowing New York City to acquire property and develop reservoirs in the Catskills. The first drop of drinking water from the Catskills arrived on December 27, 1915, and by 1917, the new system was in full operation. Starting from the Ashokan Reservoir, the water traveled by gravity through the 92-mile Catskill Aqueduct, into the Bronx and through Manhattan, and under the New York Harbor to Staten Island. The scope of the new Catskill System eclipsed the engineering achievements of the Croton supply, and city leaders declared that it was now the greatest water supply in ancient or modern times.

People living in the Catskill Mountains at this time sacrificed a lot to make way for the new water system. Farms, cemeteries, and entire villages were removed from the region as we built large dams and flooded valleys to create new reservoirs. The city also required watershed communities to meet new sanitary standards that aimed to keep local farms and sewers from polluting the water supply. The forcible acquisition of land through **eminent domain** and the enforcement of watershed regulations would create a tension that lasted for decades between New York City and Catskill Mountain communities. Expansion of the water supply system, however, also meant that New York City had doubled its access to fresh water. The construction of both the Ashokan Reservoir (1915) and Schoharie Reservoir (1927) led some to promise that "water famine was now impossible."

That promise proved to be untrue as our population doubled in the 1920s, forcing another expansion of the already vast water supply system. This time we looked westward toward the tributaries of the Delaware River. But this proposed expansion was contested in court by the State of New Jersey. In May 1931, the U.S. Supreme Court upheld the right of the City to build dams and reservoirs on the headwaters of the Delaware River. Initially, this new Delaware System included the Rondout (1950), Neversink (1954), and Pepacton (1955) reservoirs. Their waters were conveyed to the city through the 85-mile Delaware Aqueduct, which remains the longest tunnel in the world. After another interstate challenge was settled by the U.S. Supreme Court in 1954, New York City was allowed to build the Cannonsville Reservoir in 1967, which was the final reservoir in the Delaware System. Once again, entire communities were removed or relocated at each stage of construction for the Delaware System.

DRINKING WATER PROTECTION

The 1972 Clean Water Act and the 1974 Safe Drinking Water Act set important federal standards to ensure that drinking water is protected from contaminants. Further, the landmark 1997 Watershed Memorandum of Agreement formalized New York City's commitment to work in partnership with our upstate watershed neighbors to protect our drinking water at the source.

This partnership framework between New York City, New York State, the U.S. Environmental Protection Agency, watershed communities, and environmental advocates is considered a worldwide model for watershed protection, designed to both protect clean drinking water and the economic vitality of the Catskills. Due to these watershed protection programs and regulations, the Catskill and Delaware systems remain the largest unfiltered water supply in the United States today (filtered only by nature!). The agreement also provided economic development programs and other incentives to help the Catskills thrive by promoting projects that are consistent with protecting water quality. Many of these protected watershed areas are popular for outdoor recreation, such as fishing, hiking, and boating. By committing to watershed protection programs, New York City ensures safe drinking water quality today and into the future.

NYC'S WATER SUPPLY SYSTEM TODAY

Every day, New Yorkers use one billion gallons of fresh water! Altogether, the Croton, Catskill, and Delaware watersheds cover a vast 2,000-square mile area, collecting water in 19 reservoirs and three controlled lakes that store a total of 570 billion gallons at full capacity. Water flows from upstate reservoirs to the city by **gravity** through three large aqueducts. Water from the Catskill and Delaware systems is then delivered throughout the city by three large tunnels – City Water Tunnels No. 1, No. 2, and No. 3 – that connect to nearly 7,000 miles of underground pipes to deliver water to homes, schools, and businesses. Typically, water from the Croton System is delivered into the Bronx and Manhattan through the New Croton Aqueduct.

In most parts of the city, water is delivered by gravity alone. However, water must be pumped and stored in rooftop tanks to serve buildings that include more than six floors. Once the water is pumped into those rooftop tanks, gravity again takes over to supply the pressure for your shower, sink, and other fixtures. These wooden structures are an iconic sight along our New York City "roofscapes."

WATER FOR THE FUTURE

Today, our water supply faces new challenges. We are currently working on a $1 billion project to repair two leaks in the Delaware Aqueduct. It's the largest, most complex repair in the history of the system. The Delaware Aqueduct is leaking about 20 million gallons of water a day, mostly from a section of the tunnel on the west bank of the Hudson River. To fix the leak, we are building a 2.5-mile bypass tunnel that will be located 600 feet under the Hudson River. The bypass tunnel will be connected to structurally sound portions of the Delaware Aqueduct to convey water around the leaking section. To connect the bypass tunnel, we plan to shut down the Delaware Aqueduct for six to eight months, which will be the first time the tunnel will be shut down and drained since 1958.

Because the Delaware Aqueduct carries about 50% of our water each day, we need to take a number of steps to ensure all New Yorkers have an adequate, reliable supply of water during the shutdown. This involves some upgrades to the Catskill and Croton systems, which will be working at full capacity while the Delaware Aqueduct is out of service. Water conservation is also an important part of the planning for this project. Although New York City's population has grown by about 1.5 million people since 1990, our water consumption has dropped by about 35%. We are already a very water-efficient city.

But what else can we do to conserve our precious resource? This is a great opportunity for your students to brainstorm ideas that can make a difference and spread the word about making a more water-resilient New York!

Sequence of Lessons

1. My Daily Water Use Log
2. Water for New York City: Creating a Public Water Supply System
3. Technology and Innovation: Engineering New York City's Water Supply System
4. Clean Water and Public Health: Consider the Source
5. Drinking Water Treatment Explained
6. Testing the Waters: Making it Safe
7. Water for the Future: The Big Fix

L1 My Daily Water Use Log

Most American cities enjoy abundant clean water resources for drinking, cooking, and bathing, yet severe drought, water quality concerns, and other circumstances in many parts of the country and the world have made us even more aware of the value of clean water. 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 each day will enlighten, inform, and perhaps modify how we use water and what we take for granted.

ESSENTIAL QUESTION

How much water do you use each day?

VOCABULARY

Hygiene *(noun)*
The conditions or practices (as of cleanliness) conducive to health.

Drought *(noun)*
A prolonged period of dryness when there is very little or no precipitation.

SUGGESTED IDEAS AND ACTIVITIES

a. Discuss how we use water every day and make a list. Put these uses into larger categories (e.g., bathing, cooking, cleaning, recreation). Research how many gallons our typical water activities use, including a 5-minute shower or flushing the toilet. Use beans or another item to represent gallons and count up how many gallons we each use, create different piles or even “buckets” of total gallons used each day.

b. Have students calculate their average daily water use using DEP’s Water Use Calculation Worksheet. Consider which daily activities were not included and discuss how this would change students’ total daily amount. With your students, develop a water use log sheet to be completed in a 24-hour time period for all water activities. Discuss the difference between low-flow, high-efficiency plumbing fixtures and older, less-efficient fixtures.

c. Use bar graphs, pie charts, and other visual displays to track water use data. Now, ask students to complete a weeklong log of their water use activities. Determine average daily use from the data collected. Compare water usage of cities in the United States by population, geography and climate, type of supply (surface water or groundwater), and access to supply (source water). Compare usage globally.

d. Discuss what it means to use water “indirectly” or “virtual water” (e.g., for food, materials, energy) and ask students to brainstorm everything in their lives that requires water. Research, collect, and compare data related to how much water we use indirectly, by assigning a particular item or material to each student (e.g., a hamburger, a carton of almond milk, a new pair of jeans).

e. Pass around a full gallon of water as you discuss how much we use on a daily basis, and define what it means to measure our “water footprint.” Have students look up their water footprint, including their direct and indirect water use activities, by using the online Water Footprint Calculator. Discuss results and next steps for reducing our water footprints.

f. Interview family members about their water use, and pose questions about other countries or places they have lived or traveled to where availability of clean water and water use activities may have been different.

CONSIDER AND DISCUSS

- Have a conversation with students about where their water comes from. How aware are they of how much water they use, compared to other students in the class, other cities, or other countries?
- Discuss how much water is required to make different foods or products that students like. Are students surprised? How does our water footprint affect the environment?
- Why is water conservation important? Consider the different ways we can save more water at home and at school; share with families and friends.

ASK THE EXPERT

Natural Resources Conservation Manager - a professional who ensures that all land-related activities comply with government regulations in order to balance the need to use resources with the health of an ecosystem.

L2 Water for New York City: Creating a Public Water Supply System

New York City's water supply comes from three watersheds called the Croton, Catskill, and the Delaware that span nearly 2,000 square miles, both east and west of the Hudson River. The creation of our water supply system began in the 1830s with the construction of the Croton Reservoir and Croton Aqueduct, and the system continues to advance today, nearly 200 years later. Its ongoing protection requires strong community partnerships with a mutual understanding and appreciation of the importance of clean water.

ESSENTIAL QUESTION

Why should keeping our drinking water clean and safe be a public responsibility?

VOCABULARY

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

Eminent Domain *(noun)*
A right of a government to take private property for public use.

SUGGESTED IDEAS AND ACTIVITIES

a. Have students select a photograph or drawing from the large archival collection of images documenting the design and construction of our water supply system (see DEP's "Out of the Archives" albums for examples). Compare features of the image with today. Write a caption, a poem, or a fictional story about the image. Make sure students also select images that include people.

b. Have each student or groups of students research the life and work of one of the many people (architects, engineers, stone masons, or construction crews) who worked on our water supply system, or the history of the immigrant and migrant communities that contributed to the building of the system. Create an exhibit, present to each other and to other classes.

c. Explore and discuss present day public works projects in your neighborhood or in the city. Visit and photograph them several times throughout the school year. Research recent large-scale projects like the construction of Water Tunnel No. 3, the Croton Water Filtration Plant, or the repairs to the Delaware Aqueduct.

d. Watch the film *Deep Water* to hear firsthand and historical accounts of the building of the Ashokan Reservoir, part of the Catskill System. Discuss what eminent domain is and how it greatly shaped watershed communities during the development of the water supply. Discuss the positive and negative impacts of the development of the Catskill System. Consider the different stakeholders and hold a mock town hall to recreate how decisions affected all of the communities involved.

e. Meet with librarians and educators at the central Public Library within your borough to search for, and learn from, primary source documents such as articles, images, and maps depicting New York City's water story over time. Discover research skills to help find, understand, and decipher archival sources.

f. Take a field trip to Central Park to learn about the history of the Croton System while walking around the Central Park Reservoir. Connect with NYC H2O for a guided school program or plan a self-guided walking trip. Refer to a historical map to find the location of the original receiving reservoir, just south of the current body of water. Ask students how many gallons they think fill the reservoir (it's about one day's supply – one billion gallons!).

CONSIDER AND DISCUSS

- Explore DEP's NYC Watershed Virtual Tour for video interviews, maps, and more activities on the history of our water supply.
- Speculate as to why the dams, reservoirs, and other structures were designed to be both beautiful and functional. Compare to similar types of functional public buildings like libraries, railway stations, or public schools then and now.
- What is eminent domain? Think about how past policies and plans shaped both New York City's growth and that of the watershed towns.

ASK THE EXPERT

Historian – an academic researcher who studies events of the past, related to a particular time period, geographical region, or social phenomenon.

L3 Technology and Innovation: Engineering New York City's Water Supply System

From the late 1700s to the early 1800s, the exponential growth of our population drove the search for a reliable source of drinking water beyond the city limits. Innovative engineering and technology played an integral role in developing this remarkable system. Many of the original above-ground structures, such as bridges and gatehouses built in the mid-1800s to support the system, are now historic landmarks. Some are even enjoyed by the public as recreational attractions (past and revived), such as the High Bridge across the Harlem River.

Today, aqueducts, tunnels, and pipes of different sizes and materials carry drinking water mostly by gravity across long distances from the watersheds to the city. Once drinking water goes underground, we can only imagine the vast system of pipes that convey water to every building, or to the "surface" as it enters one of the iconic wooden water towers. None of this would be possible without the tools, materials, and expertise of the engineers and the hands of those who labored to build the system.

ESSENTIAL QUESTION

What are the necessary skills, information, and technology required for developing a water supply system?

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.

Aqueduct *(noun)*
A conduit, or structure, designed to carry water over a long distance, usually by gravity.

Technology *(noun)*
A manner of accomplishing a task especially using technical processes, methods or knowledge.

SUGGESTED IDEAS AND ACTIVITIES

a. Set up a model joining two watertight 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. Play with the heights and distance between the two containers to consider how water travels from upstate watersheds to the city. This demonstrates the fundamentals of a gravity-fed water system.

b. Add to the above activity by introducing the source water component (surface, stream, and ground) and its accessibility. Demonstrate and/or fabricate a simple pump that draws water from a low spot to a high spot; devise a model of a dam that holds back and creates a pool of water behind it (impounds the water into a reservoir).

c. Review New York City's Water Story: From Mountain Top to Tap map (shown on page 43), including the corresponding slides and teacher's guide. Ask students to locate their borough and nearby waterways, then have them trace the path their drinking water took from the watershed to the city. Use the scale to calculate the distance water travels. Write stories of the journey from the perspective of a drop of water. Contact DEP's Education Office to receive a class set of student maps and a wall map to display in your classroom.

d. Read *The Lowdown on the High Bridge* by Sonia Manzano. Take a trip to the High Bridge in northern Manhattan (shown on page 37). Make observations and consider the skilled labor and the people involved in designing and constructing the bridge that spans nearly 1500 feet across the Harlem River. Illustrate what you think once happened above, within, and below the bridge. Discuss how the construction of the city's first bridge impacted a growing city.

e. Illustrate and caption, on separate cards, component parts of a water system such as a reservoir, aqueduct, water tank, pipes, and faucet. Arrange sequentially. Introduce the concept of systems thinking to students and determine the important interconnections within the water supply system (use DEP's Discovering the New York City Water Supply System lesson).

f. Continue researching the important stories of the laborers and specialists hired to build our water system, including where and how they lived, what jobs they had, and their long-term settlement patterns. Introduce the Sandhogs, the urban miners who constructed much of the city's underground infrastructure. Find videos online that share their stories.

g. Research and report on other public works projects related to water such as canal systems (e.g., Erie, Morris, Champlain) or public baths in ancient Rome. Challenge the class to convey water (or a ping pong ball or marble) across the room by constructing a channel or pipe; introduce the concepts of velocity and slope related to distance.

h. Collect photographs of New York City's iconic water towers and ask students to "wrap" one in their own design. Share photos of actual artwork displayed on water towers. Make an exhibit.

i. Make a cross-section drawing or model illustrating both an above and below ground view showing the path of water from the pipes under the street through your school building to one of the bathroom fixtures. Discuss infrastructure and plumbing.

CONSIDER AND DISCUSS

- Discuss comparable public engineering projects such as roads and bridges (transportation systems).
- Learn more about John B. Jervis, the Chief Engineer for the Croton Aqueduct. Consider his career and compare to how engineers play a role in planning and designing infrastructure projects today.
- If you were developing a city today, would you still use similar techniques and technology to supply water to residents? How would you design a sustainable water system?

ASK THE EXPERT

Civil Engineer – a professional who conceives, designs, constructs, and maintains infrastructure projects.

WHAT IS A SANDHOG?

This is the common name given to generations of New York City's underground construction workers responsible for the tunneling and excavation of our underground infrastructure. Sandhogs have played a key role in the construction of New York City's water system, including City Water Tunnels No. 1, No. 2, and No. 3.

L4 Clean Water and Public Health: Consider the Source

Supplying quality drinking water is an essential part of protecting public health, and it all starts at the source. Every day, one billion gallons of drinking water are delivered to the taps of New York City, serving residents, commuters, and tourists as well as over 70 New York State communities along the path of the water system north of the city. New Yorkers value the world renowned reputation of their drinking water, which is attributable in large part to its source among the dense forests and protected natural creeks and streams that feed into large lakes and reservoirs, up to 125 miles away. Farmers, foresters, residents, business owners, and many partner organizations and communities living and working in the watershed help protect our water at its source – this is what makes up the living watershed.

ASK THE QUESTION

How are we connected to the source of our drinking water?

VOCABULARY

Potable *(adjective)*
Safe or suitable for drinking.

SUGGESTED IDEAS AND 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 how we keep ourselves healthy. Write a fable or other kind of story about a source of drinking water with special properties. Discuss how these properties help all living things.

b. Interview the physical education teacher, biology teacher, or school nurse about the importance of hydration before, during, and after physical activity. How much of your body is made up of water? Which parts of your body only function when you are hydrated?

c. Discuss concepts related to drinking water and our public health, such as contagion, epidemics, and water-borne illnesses, as well as prevention and immunization. Discuss the importance of ensuring safe drinking water quality for water consumers.

d. Research and present information that compares different public water systems in various locations throughout the United States; identify their drinking water source. Compare to rural, suburban, and other urban communities. How is water quality protected?

e. Read *The Magic School Bus: At the Waterworks (NYC Edition)* to trace the source of our drinking water, and understand how the entire water supply system is maintained and protected each day. Create a large mural depicting the flow of water from mountain top to tap to replicate how Ms. Frizzle's class traveled through New York City's water cycle. Contact DEP's Education Office for a class set of books.

f. Refer back to lessons in Unit 1 about the relationship between trees and water quality in a watershed. How do forests filter water naturally? Research New York City's watershed protection programs that support the preservation and sustainable development of forests. Plan a trip to the watershed to plant trees along a watershed stream through the Watershed Agricultural Council's Trees for Tribs (tributaries!) program.

g. Connect with watershed neighbors to learn about our living watershed. Research important industries and activities in watershed communities (past and present), including farming, forestry, tourism, outdoor recreation, and more. Participate in the Watershed Agricultural Council's Green Connections program to connect with students and teachers in watershed communities; plan a trip to visit each other.

h. Plan a field trip to the East- or West-of-Hudson supply systems to experience the Croton Dam, Kensico Dam, Cross River Reservoir, or Ashokan Reservoir, to name a few. Consider applying for a Watershed Forestry Bus Tour grant from the Watershed Agricultural Council or a Watershed Education Grant from the Catskill Watershed Corporation to help plan and pay for your trip. While in the watershed, visit nearby environmental education and recreation centers or cultural and historical sites, such as the Time and the Valleys Museum, the Ashokan Center, Frost Valley YMCA, and the Green Chimneys' Clearpool Education Center. Consider planning a longer watershed trip with Operation Explore, a special three-day program at Taconic Outdoor Education Center and Stony Kill Farm.

CONSIDER AND DISCUSS

- Discuss the relationship of the sources of your drinking water to the water that flows from your tap. Consider how far water needs to travel and by what conveyance; is technology needed?
- Discuss the important relationship between watershed communities and New York City.
- How do forests and vegetation act as natural filters in a watershed? Does the land surrounding our source water play a role in providing for clean water?

ASK THE EXPERT

Epidemiologist – a public health professional who investigates patterns and causes of disease and injury in humans.

L5 Drinking Water Treatment Explained

Today drinking water is regulated under the federal Safe Drinking Water Act to keep tap water safe. The New York State Department of Health and the U.S. Environmental Protection Agency also set regulations to protect our water. It is an important responsibility to provide and distribute potable water, and each year water utilities are required to provide an annual consumer report (Drinking Water Supply and Quality Report) to the public.

Water from the Catskill and Delaware systems, approximately 90% of our daily supply, is filtered only by nature and not required to be filtered by technology. New York City has been granted a Filtration Avoidance Determination from the federal government because drinking water quality meets the criteria to remain unfiltered and our rigorous and comprehensive watershed protection program works to ensure nature can effectively filter it now and into the future.

In 2015, a filtration plant for the Croton supply began operating to remove impurities from the water and ensure it met all the regulatory standards. As parts of the Croton watershed have changed from rural to more densely populated suburban areas, the risk of contaminants reaching the water has increased.

ESSENTIAL QUESTION

How is our drinking water treated?

VOCABULARY

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

Filtration *(noun)*
The act of capturing impurities from the water as it passes through a medium like sand and/or charcoal.

DRINKING WATER TREATMENT PROCESS

Most of New York City's drinking water passes through the Catskill/Delaware Ultraviolet Disinfection Plant before it is distributed throughout the five boroughs. Located north of the city in Westchester County, the plant is the largest of its kind in the world.

- **Chlorine -** Water is disinfected with chlorine which is a common chemical disinfectant added to kill germs and stop bacteria from growing on pipes.
- **Ultraviolet (UV) Light -** Exposure to UV light inactivates potentially harmful microorganisms, including Cryptosporidium and Giardia, which are often tolerant to chlorine disinfection. UV treatment does not change the water chemically, as nothing is added except energy.
- **Fluoride -** Added to drinking water to improve dental protection, it is effective in preventing cavities at a federally approved level of 0.7 mg/L.
- **Sodium Hydroxide -** Added to raise the pH, it reduces corrosion of household plumbing.
- **Food Grade Phosphoric Acid -** Added because it creates a protective film on pipes that reduces the release of metals, such as lead, from service lines and household plumbing.

Water from the Croton System is filtered by the Croton Water Filtration Plant, located underground in the Bronx. After filtration, the Croton water goes through the same steps in the disinfection process described above.

- **Coagulation -** Chemicals are added to the untreated water, causing particulates to bunch together (or coagulate) and become larger particles called floc.
- **Dissolved Air Flotation -** Air bubbles are injected into the water to help float the floc to the top of water tanks where it is skimmed off.
- **Sand Filtration -** The water flows through a bed of sand, slowly removing any remaining particles.

SUGGESTED IDEAS AND ACTIVITIES

a. Introduce your students to the idea of scientific experimentation. Introduce turbidity and sedimentation, investigate by using coffee grounds, tea leaves, and powdered drink mix. Do some float to the top, some sink to the bottom, and others stay suspended? Predict, observe, and record what happens in a clear glass container. Use a magnifying glass.

b. Discuss and define local rocks and minerals. Investigate the relationship of geology and drinking water. What does it mean to have hard water? Make a solution 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?

c. Review DEP's annual Drinking Water Supply and Quality Report with your students. Research online water departments or agencies in different regions, and compare and contrast data included in their water quality reports. Are methods and technologies the same in different regions (why or why not)? Which DEP employees work to provide your safe and clean drinking water each day and what is their background (career path, education, training)?

d. Learn more about the treatment process to remove pathogens like Cryptosporidium and Giardia from drinking water. Which cities have been affected? Discuss UV treatment and how innovative science and technology has advanced water treatment processes to ensure safe drinking water.

e. In small groups, build natural filtration models using various materials of different texture, size, and porosity (sand, gravel, soil, coffee filters), or fun materials like different types of candy. Create a water solution with high turbidity (using clay or soil, or cocoa mix) and hypothesize how clean the water will be after seeping through the filter.

CONSIDER AND DISCUSS

- Explore DEP's NYC Watershed Virtual Tour for video interviews, maps, and more activities on watershed protection and the drinking water treatment process.
- How is New York City able to maintain a drinking water supply that is mostly filtered by nature? Compare our water treatment methods to other U.S. or global cities. Which other cities have received a Filtration Avoidance Determination and how are they protecting water quality?
- What regulations determine public health safety related to drinking water? What other regulations protect public health?

ASK THE EXPERT

Environmental Health & Safety Officer – a professional who develops and implements health and safety plans, through data capture and ongoing analysis, for the operation of water and wastewater facilities.

L6 Testing the Waters: Making it Safe

Beyond meeting the necessary federal and state water quality standards, New York City is one of only a few cities in the country that also monitors and tests its source water in order to ensure the highest water quality. DEP monitors water throughout the distribution system, as well as in upstate reservoirs and watershed streams that feed into these larger bodies of water. We test for more than 250 potential contaminants every day to protect the quality of our drinking water. These potential contaminants are monitored by scientists who conduct more than 1,200 tests daily, 37,000 monthly, and more than 450,000 annually, in our distribution system, including at nearly 1,000 sampling stations throughout the five boroughs. That's in addition to the more than 260,000 tests performed in the watershed…and they all have to pass!

To increase our ability to monitor this mostly unfiltered water source, DEP also conducts two million tests performed by a network of robotic monitoring stations that provide real-time data on the quality of the water as it moves across the reservoirs.

ESSENTIAL QUESTION

What tests are performed on our drinking water to make sure it is safe to use?

VOCABULARY

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

SUGGESTED IDEAS AND ACTIVITIES

a. Scientists conduct taste and odor tests at their central labs. Have your students conduct their own taste and odor tests using a few different samples of tap water collected from various locations. Set up a testing procedure including observation, hypothesis, prediction, experimentation, and conclusion.

b. Conduct a blind taste test for tap water versus bottled water. Label the samples by A, B, C, and so on. Allow students to taste the different samples, make observations, and then vote. Consider including multiple samples from different kinds of bottled water or tap sources.

c. Investigate the differences between tap water and bottled water. Ask students what types of bottled water have they bought in the past? Research where this water comes from and discuss the resources needed to collect, manufacture, and transport bottled water. Have students share what they learn by creating PSAs or posters to display around school, in the cafeteria, and near water fountains.

d. Using store bought water test strips and several "mystery" water samples, have students predict which sample is tap water and why. Demonstrate an experiment using four sample cups of water. For example, 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 the data collected.

e. Further investigate DEP's annual Drinking Water Supply and Quality Report with students, by reviewing the different potential contaminants or water quality concerns (pathogens, nutrients, turbidity) and where they come from. Research water supply systems for other cities to determine different water quality challenges.

CONSIDER AND DISCUSS

- Discuss the many parameters that are used (required) to determine if water is safe to drink. What are these parameters? Why do they matter?
- Discuss how technology has changed in the field and in the lab. What kind of new techniques are used to deliver accurate sampling information about water quality? (Hint: robotics)

ASK THE EXPERT

Chemist - a scientist engaged in chemical research or experiments.

L7 Water for the Future: The Big Fix

In 1990, it was discovered that a section of the Delaware Aqueduct, the longest tunnel in the world, has been leaking about 20 million gallons a day into the Hudson River. New York City and parts of four adjacent counties depend on this aqueduct for drinking water, as it delivers about 50% of our daily water. The Delaware Aqueduct Repair Project requires years of planning, design, and construction to make the necessary repairs. We are building a bypass tunnel, and connecting it to structurally sound portions of the aqueduct, to eliminate the largest leak by conveying water around it. This work will require shutting down the Delaware Aqueduct for 6-8 months in 2022. During this time, conservation will help us get through the shutdown while we rely on water from the Catskill and Croton supplies.

ESSENTIAL QUESTION

Why is it important to conserve water?

VOCABULARY

Conservation *(noun)*
The careful preservation and protection of Earth's natural resources.

Bypass *(noun)*
A secondary channel, pipe, or connection to allow a flow when the main passage is closed or blocked.

SUGGESTED IDEAS AND ACTIVITIES

a. What does it mean to conserve? Discuss some simple ways to conserve water at home and at school. Compile a list on the board. Learn how New York City is conserving water on a larger scale, including by replacing toilets in schools and adding timers to spray showers in parks. Investigate if any of these changes have occurred in your school or neighborhood.

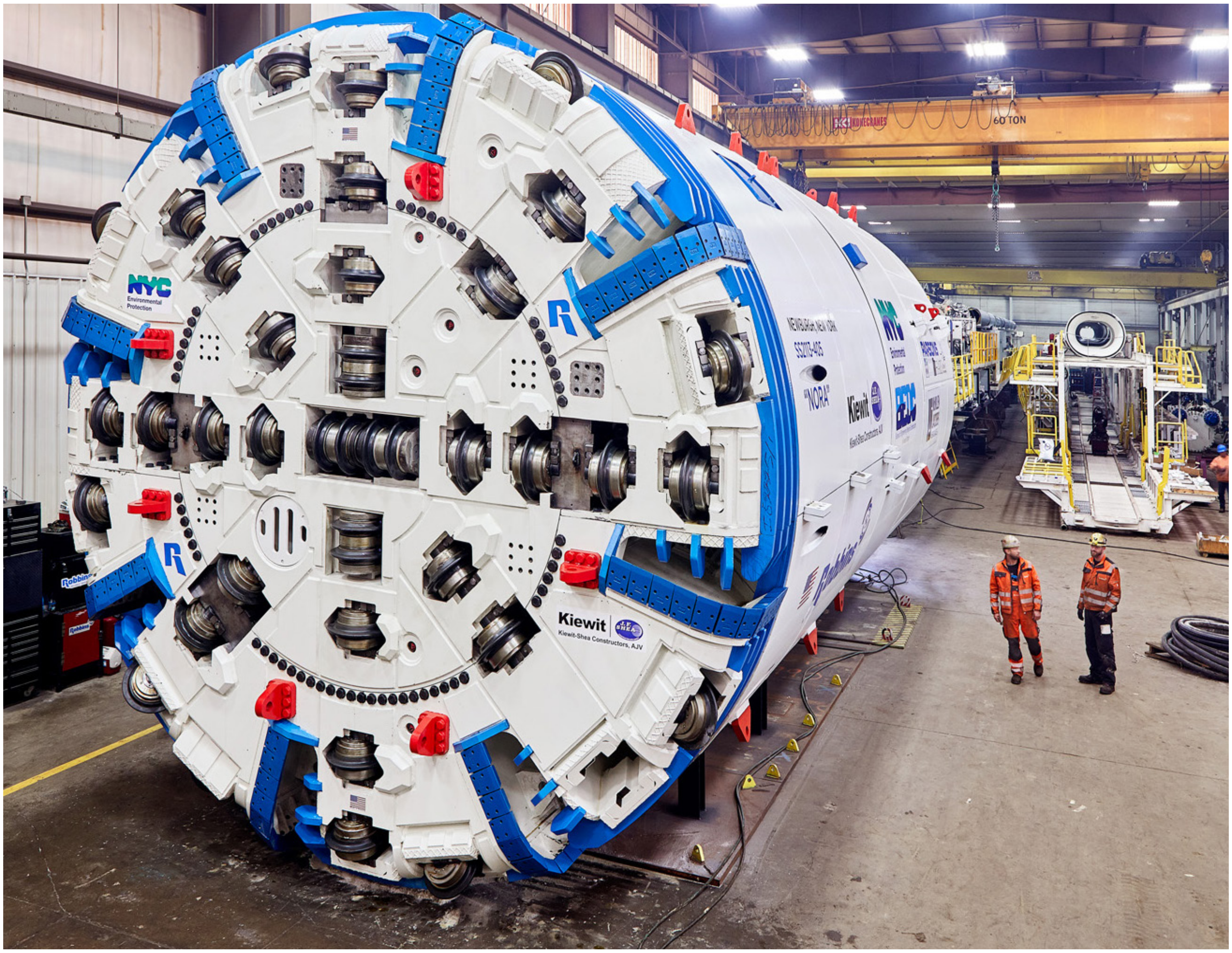
b. Using their "Water Use Logs" from the Lesson 1 activity, challenge your students to reduce their water use for a period of one week by either a number or a percentage. Make it a competition. Discuss which activities were easy to alter water use for and which were difficult.

c. Learn more about Nora Stanton Blatch DeForest Barney, the first and only woman engineer to work on the Catskill System. Look up images of the tunnel-boring machine (shown on page 42), named after Nora, used for excavating the new bypass tunnel in the Delaware Aqueduct. Research other types of cutting edge engineering technologies being used today (e.g., Autonomous Underwater Vehicles). Design and build a model for a fictional invention that replaces a difficult or unpopular chore or task.

d. Further explore the New York City Water Story: From Mountain Top to Tap map (shown on page 43) by investigating where the leaks are occurring. Locate where the Delaware Aqueduct passes underneath the Hudson River. For younger students, create an overlay and have them trace over the map. What does the picture resemble (e.g., branches of a tree)? Make a list of all the names of the aqueducts, tunnels, lakes, and reservoirs and discuss their origins. Visit DEP's website for a map teacher's guide with more suggested activities.

e. Create a watershed timeline to understand the size and sequence of the components in the water supply system. Research the history of each watershed, reservoir, and aqueduct. In a large space indoors or outdoors, use cups of water and containers to measure out the size of each reservoir (proportionally!). Map out the entire system, using rope as the aqueducts and tunnels connecting all of the pieces together.

f. Examine historical flyers and PSAs used by New York City in the past to encourage New Yorkers to conserve water. Discuss media that students could use today to share similar messages of water conservation.



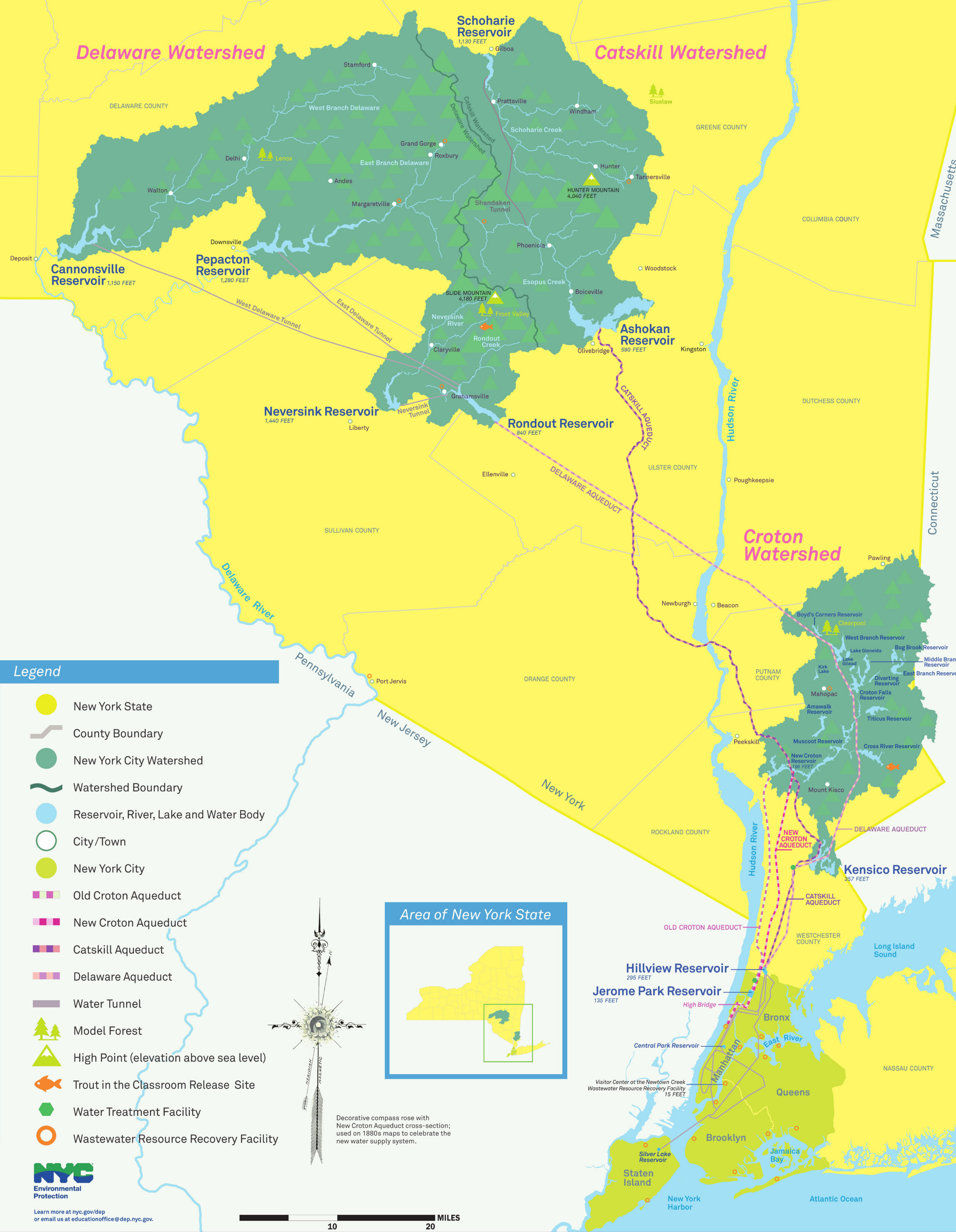
g. Facilitate a mock town hall in which students take on the different roles of stakeholders and decision-makers involved in a similar situation based on the Delaware Aqueduct repairs. How do large-scale projects like this one affect various communities? Who is involved in the repairs and how were the project plans decided on?

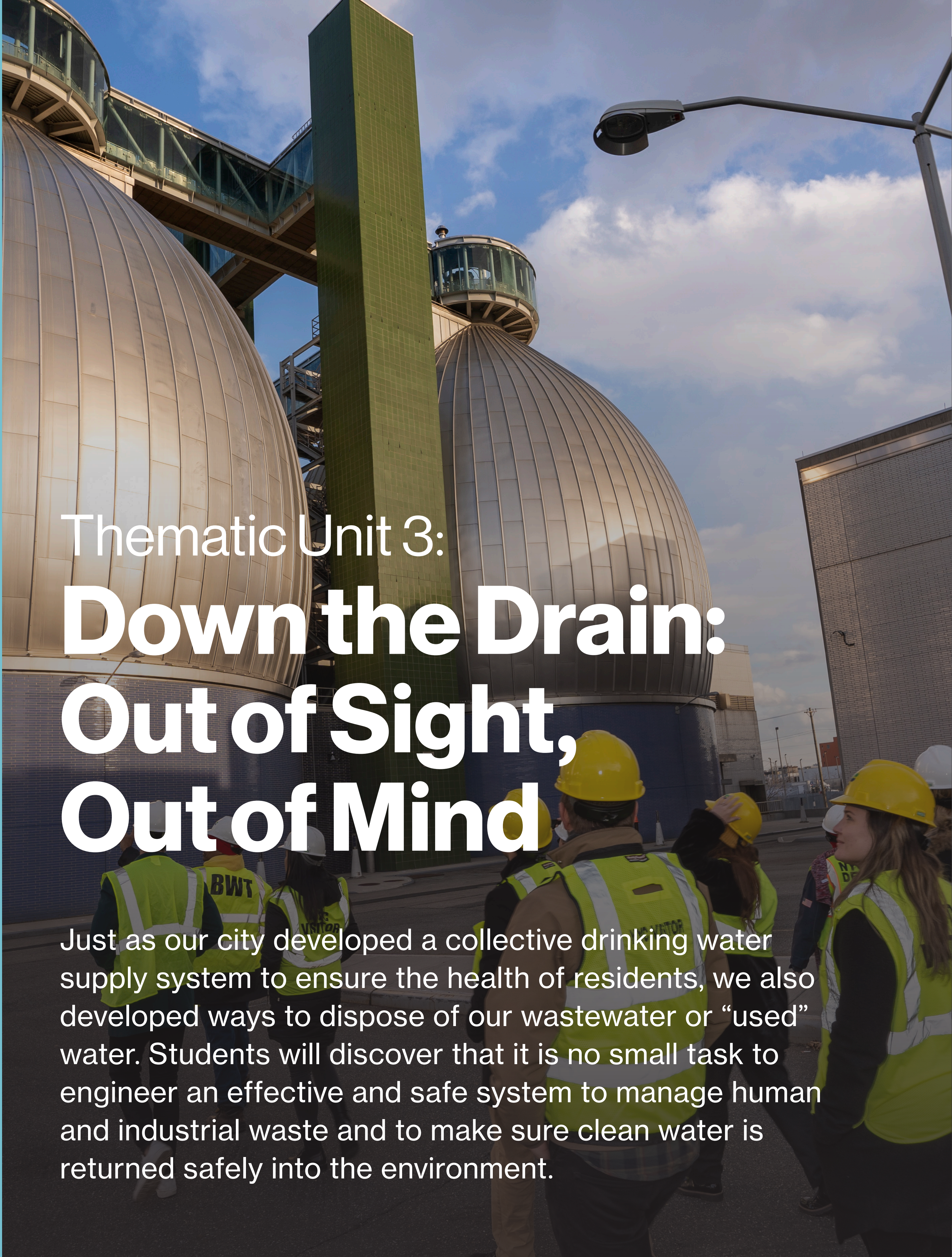
CONSIDER AND DISCUSS

- Consider what other organisms need clean water to survive. Discuss the importance of water conservation and protection for all living things.
- How has technology changed the way we manage our water supply?
- How can New York City plan and prepare for changes to its water supply system? Consider citywide sustainability initiatives. What are other cities doing to become more sustainable?

ASK THE EXPERT

Robotics Engineer – a professional who designs and maintains robots, develops software applications, and conducts research to determine how robotics can help systems function.


Delaware Watershed
Catskill Watershed
Croton Watershed
Schoharie Reservoir
1,130 FEET
Gilboa
Stamford
DELAWARE COUNTY
West Branch Delaware
Prattsville
Windham
Siuslaw
Schoharie Creek
GREENE COUNTY
Catskill Watershed
Delaware Watershed
Grand Gorge
Roxbury
Delhi
Lenox
East Branch Delaware
Hunter
Tannersville
HUNTER MOUNTAIN
4,040 FEET
Andes
Walton
Margaretville
Shandaken Tunnel
COLUMBIA COUNTY
Massachusetts
Downsville
Phoenicia
Deposit
Woodstock
Cannonsville Reservoir
1,150 FEET
Pepacton Reservoir
1,280 FEET
Esopus Creek
Boiceville
SLIDE MOUNTAIN
4,180 FEET
West Delaware Tunnel
East Delaware Tunnel
Neversink River
Frost Valley
Ashokan Reservoir
590 FEET
Rondout Creek
Claryville
Olivebridge
Kingston
Grahamsville
Neversink Reservoir
1,440 FEET
Neversink Tunnel
Liberty
Rondout Reservoir
840 FEET
CATSKILL AQUEDUCT
Hudson River
DUTCHESS COUNTY
ULSTER COUNTY
Ellenville
DELAWARE AQUEDUCT
Poughkeepsie
Connecticut
SULLIVAN COUNTY
Pawling
Delaware River
Newburgh
Beacon
Boyd's Corners Reservoir
Clearpool
West Branch Reservoir
Lake Gleneida
Bog Brook Reservoir
Lake Gilead
Middle Branch Reservoir
Kirk Lake
East Branch Reservoir
Diverting Reservoir
Mahopac
Croton Falls Reservoir
PUTNAM COUNTY
Amawalk Reservoir
Titicus Reservoir
Pennsylvania
Port Jervis
ORANGE COUNTY
New Jersey
Peekskill
Muscoot Reservoir
Cross River Reservoir
New Croton Reservoir
196 FEET
Mount Kisco
New York
ROCKLAND COUNTY
DELAWARE AQUEDUCT
NEW CROTON AQUEDUCT
Hudson River
Kensico Reservoir
357 FEET
CATSKILL AQUEDUCT
OLD CROTON AQUEDUCT
WESTCHESTER COUNTY
Long Island Sound
Hillview Reservoir
295 FEET
Jerome Park Reservoir
135 FEET
High Bridge
Bronx
East River
Central Park Reservoir
Manhattan
NASSAU COUNTY
Visitor Center at the Newtown Creek Wastewater Resource Recovery Facility
15 FEET
Queens
Brooklyn
Jamaica Bay
Silver Lake Reservoir
Staten Island
New York Harbor
Atlantic Ocean
Legend
New York State
County Boundary
New York City Watershed
Watershed Boundary
Reservoir, River, Lake and Water Body
City/Town
New York City
Old Croton Aqueduct
New Croton Aqueduct
Catskill Aqueduct
Delaware Aqueduct
Water Tunnel
Model Forest
High Point (elevation above sea level)
Trout in the Classroom Release Site
Water Treatment Facility
Wastewater Resource Recovery Facility
Area of New York State
MERIDIAN
MAGNETIC
Decorative compass rose with New Croton Aqueduct cross-section; used on 1880s maps to celebrate the new water supply system.
NYC Environmental Protection
Learn more at nyc.gov/dep
or email us at educationoffice@dep.nyc.gov.
MILES
10
20



Thematic Unit 3:

Down the Drain: Out of Sight, Out of Mind

Just as our city developed a collective drinking water supply system to ensure the health of residents, we also developed ways to dispose of our wastewater or “used” water. Students will discover that it is no small task to engineer an effective and safe system to manage human and industrial waste and to make sure clean water is returned safely into the environment.

What you should know:

In many early settlements, open channels (or sewers) were constructed to help wastewater flow away from where people lived and into larger bodies of water. Flowing water became the practical receptacle for waste of all kinds.

EARLY HISTORY

The Broad Street canal, built by the early Dutch settlers in Lower Manhattan, became New York City's first open sewer. In 1676, when the canal became too polluted and the smell became too offensive, British colonists buried it underground. That is how the story of New York's sewer system began.

By the early 1800s, the city was a crowded, bustling center of commerce and culture. Waste littered the streets from horses (a common means of transportation in those days), chamber pots (before indoor plumbing), rotting trash, and putrefying entrails from butchered animals. Wastewater and rainwater often drained into open pits and canals. To deal with this growing public health problem, we began to build a haphazard network of underground pipes to divert wastewater from homes and businesses into local waterways.

As we learned in Unit 2, by the early 1830s, New York City was experiencing outbreaks of diseases such as typhoid, cholera, and yellow fever caused by unsanitary conditions and stagnant water.. This led to the creation of the Croton water system, which began supplying clean water from about 40 miles north of the city in 1842. Although drinking water quality improved, raw sewage with disease-carrying microorganisms was still being dumped into local waterways well into the 19th century, when in 1849 the city experienced one of its worst cholera outbreaks. As the city grew, so did the underground network of sewer pipes to capture and convey waste into the nearest waterway. Building an extensive underground system was just one solution to growing public health concerns. But was the problem really out of sight, out of mind?

CONTROLLING WATER POLLUTION

By the late 19th century, the discharging of untreated **wastewater** into local waterways had caused significant impacts to fisheries and tourism. There was a new understanding that in order for New York City to reduce the public health hazards brought on by increasing water pollution, it had to clean up its waste. We began by building three rudimentary wastewater treatment facilities: Coney Island (Brooklyn) in 1886, 26th Ward (Brooklyn) in 1894, and Jamaica (Queens) in 1903. All three facilities were placed in a high priority area, close to New York City's public beaches.

The management of wastewater in a city that now boasted two million people was a daunting task. These new facilities used a basic method of treatment, known today as "primary treatment." The steps were simple: 1) wastewater went through a screening process to sift out large items, 2) a sedimentation process to allow time for heavier solids to settle and lighter materials to float, 3) a disinfection process to add chlorine before returning water to the surrounding waterways. Today, about 60% of solids can be removed from wastewater through primary treatment.

Still, with the introduction of indoor plumbing and the increasing volumes of waste from manufacturing, primary treatment could not handle the pollution entering New York's waterways every day. Pollution choked aquatic life, eradicated species, and exposed human beings to disease and odors that made life in and around the waterways inhospitable. Something had to be done. By 1906, the Metropolitan Sewerage Commission was formed to evaluate the problem. They surveyed the situation and recommended improvements desperately needed to reverse the ensuing environmental catastrophe.

IMPROVING WASTEWATER TREATMENT

A more sophisticated approach to wastewater treatment was developed. We upgraded the treatment process, installed new sewers, and built additional facilities. These more advanced facilities improved upon primary treatment by mimicking the physical and biological processes that wetlands, rivers, and streams use to eliminate waste naturally.

The new or upgraded facilities included: Coney Island (1886/1935) for the waste from south and central Brooklyn; Wards Island (1937) for the western section of the Bronx and upper east side of Manhattan; Bowery Bay (1939) for the northwest section of Queens; Tallman Island (1939) for the northeast section of Queens; Jamaica (1903/1943) to collect waste from the southern section of Queens; and 26th Ward (1894/1944) to handle the Eastern section of Brooklyn near Jamaica Bay.

Today, at these facilities, **sludge**, or the heavy solids (such as food, feces, and paper fibers), is consumed by microorganisms that like to feast naturally on a diet of organic waste matter. An added boost of oxygen to create a healthy environment for these organisms helps break down the organic matter in a hurry—in hours, instead of days or weeks. This process, called secondary treatment, routinely removes more than 85% of the solids.

Between 1945 and 1965, the population grew to nearly eight million people and five new facilities were built: Hunts Point in the Bronx (1952), Port Richmond (1953) and Oakwood Beach (1956) in Staten Island, Rockaway (1952) in Queens, and Owls Head (1952) in Brooklyn. Soon after, we built our largest capacity facility, Newtown Creek (1967/2014) in Brooklyn, to handle wastewater from downtown and the east side of Manhattan, northwest Brooklyn, and a small section of nearby Queens.

ENVIRONMENTAL POLICIES

In 1972, the monumental Clean Water Act was passed, setting required minimum standards for wastewater treatment plants throughout the country. Over the next few decades, all of New York City's facilities were upgraded to meet these federal standards and ensure the removal of at least 85% of pollutants from wastewater. This included our final two facilities, North River (1986), constructed on a platform over the Hudson River in Upper Manhattan, and Red Hook (1987) in Brooklyn, which created a system of 14 facilities in total. The Clean Water Act, which we cover more in Unit 4, was a nationwide response to decades of unchecked pollution and growing public interest in the importance of environmental protection. Subsequent regulations would also play a role in how our wastewater treatment process developed over time.

Sludge collected through the treatment process is thickened and then digested in anaerobic digesters. These oxygen-free tanks are heated to approximately 98° F to help microorganisms break down organic material and eliminate pathogens. In the past, digested sludge was transported by marine boats to a site about 12 miles off the East Coast where it was disposed of in the Atlantic Ocean. By 1987, sludge disposal was extended to a deeper location more than 100 miles off the coast, but a year later, the U.S. Congress passed the Ocean Dumping Ban Act requiring that by 1992 there would be a complete ban of ocean disposal of sludge. In its place, we constructed sludge dewatering facilities at eight of the 14 treatment facilities (six of which remain in use today), and the marine boats previously used for ocean disposal were repurposed for transporting sludge to and from the dewatering facilities. **Dewatering** is the process of pumping sludge through large rotating machines called centrifuges to remove water from the sludge (like the spin cycle of a washing machine). The resulting solids are called **biosolids.**

WASTEWATER RESOURCE RECOVERY

Today, New York City's 14 **wastewater resource recovery facilities (WRRF)** recover energy, nutrients, clean water, and other resources from the wastewater treatment process. After about 8-10 hours of treatment, we remove sludge from wastewater, the water is then disinfected, and clean water is safely returned to local waterways and back into the water cycle. During sludge digestion, we recover methane gas, or **biogas**, that can be used to produce heat and electricity for the WRRFs. Once purified, it can also be distributed as renewable natural gas for the community. After sludge is digested and dewatered, the resulting biosolids can be added to agricultural soils, composted, or used in other beneficial ways.

Currently, DEP is working with other city agencies and industrial partners to recover organic solids from our waste stream. Food scraps are collected from homes, schools, and businesses and processed off-site into a nutrient-rich mixture called **bioslurry.** This material is mixed in with the sludge at DEP's Newtown Creek WRRF to help produce more biogas during sludge digestion.

Your students can see the wastewater treatment process in real-time by visiting the Newtown Creek WRRF and viewing the massive digester eggs. These stunning structures along the Brooklyn and Queens skyline are artfully designed and expertly engineered to further digest the sludge. While visiting the facility, students learn about the innovative initiatives taking place to expand opportunities for wastewater resource recovery.

NYC'S SEWER SYSTEM

None of this would be possible without the vast network of underground sewer pipes and tunnels that collects our wastewater from homes, schools, and businesses, plus the water that drains off streets, sidewalks, and rooftops when it rains, snow melts, or we water lawns or wash our cars. As population grew over the last century to nearly nine million people, so did this network of sewers.

To carry sewage quickly and effectively to these new treatment facilities, bigger pipes, called interceptors, were built to collect water that was previously drained directly to surrounding waterways. Most wastewater flows by gravity in pipes ranging from six inches to 16 feet in diameter. Pumping stations were also built in low-lying areas to help lift the wastewater to a higher elevation and allow it to continue flowing to a WRRF by gravity. Today, on average, 1.3 billion gallons of wastewater travels through 7,500 miles of sewer pipes every day. End to end that is as far as a trip to California and back!

About 60% of New York City's sewer system is a **combined sewer system**, which carries both sanitary wastewater and stormwater off the streets in the same pipe to a nearby WRRF. **Stormwater runoff** can pick up pollutants in its path, including litter, motor oil, and pet waste. Stormwater regulators are installed to prevent WRRFs from being overwhelmed during large storm events. Regulators discharge flow, called **combined sewer overflow (CSO)**, to a surrounding waterway during heavy wet weather. CSOs include a diluted mixture of untreated wastewater and stormwater runoff. We are reducing CSOs by constructing grey and green infrastructure (covered more in Units 4 and 5), and raising awareness of the importance of water conservation.

About 40% of the city's sewer system includes separate sewers. In this system, a pipe carrying only sanitary sewage is conveyed to a WRRF, while a separate pipe carries stormwater runoff directly to a local waterway through the **Municipal Separate Storm Sewer System (MS4)**. While storm sewers do not release any sewage during wet weather, polluted stormwater runoff can still impact the health of local waterways.

WATER STEWARDSHIP

Although the New York City Department of Environmental Protection (DEP) is responsible for managing and improving New York City's water systems, we all play an important role in keeping things "flowing." Did you know that pouring leftover cooking oil or grease down the drain can clog the sewers? These clogs, called **fatbergs**, consist of cooking grease, sanitary wet wipes, and other household products that are often improperly flushed down our drains. When fatbergs develop in the sewers, wastewater can back up into your homes or onto city streets. DEP's citywide Trash It. Don't Flush It. campaign encourages individuals and businesses to properly dispose of their cooking grease, wet wipes, and other household waste.

We can also help maintain the sewer system and protect harbor water quality by disposing of trash and litter properly and conserving water during wet weather. For example, DEP's WAIT program engages residents by notifying them when wet weather may lead to a CSO event in real-time, so they remember to hold off on their usual water activities to help reduce how much water flows into the sewers.

The 21st century will have new challenges, such as those brought about by climate change (covered in Unit 5). As we work to meet these challenges, you and your students can play an important role by first understanding how the system works. The environmental health of our waterways, including the harbor, wetlands, bays, beaches, rivers and creeks, play a role in the quality of life of every New Yorker, young and old, no matter where you live, work, and play.

Sequence of Lessons

1. The Growth of the City: Population and Wastewater Systems
2. Industrial Revolution and Environmental Devolution
3. Under our Noses: Creating an Underground Infrastructure
4. Sinks, Pipes, and Systems: Making the Connection
5. Wastewater Treatment Explained
6. A Healthy Harbor: Keeping Pollution at Bay

L1 The Growth of the City: Population and Wastewater Systems

In the past, water flowing into New York Harbor could be effectively filtered and cleaned by nature because pollution existed on a small scale. However, as the city's population grew, a wastewater system was needed to keep up with the daily flushing, brushing, showering, and other healthy habits of millions of busy New Yorkers. Students will discover what drives the need for an underground drainage system and how that system meets the demands of a growing population.

ESSENTIAL QUESTION

Why is wastewater treatment important?

VOCABULARY

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

Drain *(noun, verb)*
An identified point to which liquid flows; to flow off gradually.

SUGGESTED IDEAS AND ACTIVITIES

a. Introduce a scenario based on the development of an early settlement from New York City's history. In the classroom, assume roles and determine how they contribute to their community's basic needs (e.g., clothing, shelter, food). Keep it simple. Designate an area of the classroom for your waste disposal. Use objects such as colorful blocks to symbolize waste that is disposed of in a nearby waterway. Discuss what it means for a waterbody to be polluted. Who and what are harmed by this pollution? Consider solutions for this scenario.

b. For older students, create the same type of scenario but build a smaller model of a fictional community or an early settlement based on the history of New York; include landforms to help simulate the downhill flow of water in open channels or creeks that drain to a nearby waterway. You can use beads, dried round peas, etc. to simulate water. Make the model inside a large breadbox so that you can prop up one side to mimic slope and gravity flow.

c. Find historic photographs of farms, mills, and factories that were formerly in your school's neighborhood using municipal and Public Library archives. Explore maps of streets and neighborhoods. Research other cities to see how they developed to find similar (or different) patterns of development.

d. Make a timeline of construction dates of NYC's 14 wastewater resource recovery facilities (shown on page 50) and map them using information found on DEP's website. Trace the outline of the drainage area where wastewater is captured by the facility nearest to your school and the waterway that receives clean water after treatment. How many million gallons of water does each facility process per day? How many people does each facility serve? Add it up and discuss.

e. List all the street names in your neighborhood or borough that are associated with water. Identify them on a historic map and research their origins. Find historic images to go with the names and write a story or poem about that place in time.

f. Watch the series, *Secrets of New York: The Sewers* to hear firsthand accounts from historians, community members, and DEP professionals. Each part of the series describes the history, process, and upgrades of the wastewater treatment process as the system developed in New York City. (Refer to DEP's Sewer System Education Module for the video and student worksheet).

g. After investigating where their wastewater is treated, have students create their own city or consider how to improve their own community, including how and where they would develop the necessary infrastructure, like wastewater treatment. After developing their plans on paper, introduce students to the online program, Visionmaker NYC, to further develop the layout of their city or community improvements.

New York City Wastewater Resource Recovery Facilities and Their Drainage Areas

CONSIDER AND DISCUSS

- Why was the development of a city close to the harbor so important for early settlers? Consider all of the benefits for communities close to water (transportation, energy, food, trade, waste disposal, etc.).
- What do you think New York City and the surrounding waterways were like during the early industrial age, before we began managing wastewater?
- How does building and maintaining a water or wastewater system, including underground pipes, affect communities?

ASK THE EXPERT

City Archivist – a professional who assesses, preserves, and catalogues artifacts, documents, photographs, maps, and more, from the past.

L2 Industrial Revolution and Environmental Devolution

The way we use land impacts water quality. Farms, factories, stores, homes, and transportation systems are all examples of how we change the natural landscape to meet human needs. New York City's growth in the 19th century did not happen without consequences for the natural environment—wetlands were filled in, waterways became polluted, and roadways were built. Fortunately, before we caused even more irreparable harm, we began tipping the balance the other way; but no one will deny, it continues to be a delicate balance.

ESSENTIAL QUESTION

How does human activity impact water quality?

VOCABULARY

Industrialization *(noun)*
The large-scale development of manufacturing, advanced technical enterprises, and other productive economic activity in an area, society, or country.

SUGGESTED IDEAS AND ACTIVITIES

a. Take a walking tour of your neighborhood. Take photographs, make observations, and map out places of interest in relation to where your school is located. Document such things as the different types of buildings and new construction, public transportation (subways, buses, and ferries), parks and green spaces. How might these places or activities impact water quality in nearby waterways?

b. Start a conversation about the different ways people use land to live, work, and play. Have students discuss what an ideal community might need. Plan and design your own communities. Use a large sheet of mural paper and a handful of pre-cut color-coded squares, which represent different kinds of land uses (e.g., places we live - red, places we work - purple, and places we play - green). Start with an outline of a surrounding waterway and a few roads. Discuss placement of land use and potential sources of pollution from the community that could impact the waterway.

c. Make the previous activity more complex by introducing more land use parameters such as agrarian land, industrial land, and dense city. Introduce the themes of controversy and choice. Explore different time periods in New York City's history and create a chronology of common polluters of water through time.

d. Add to the above activities by discussing zoning. Divide the class into neighborhood or community groups with connecting waterways. Discuss the impact of different actions on adjacent neighborhoods. Research famous city planners and the legacies (both good and bad) they left on city neighborhoods, including Robert Moses. Encourage some students to research the community advocates who often fought to protect their neighborhoods from large-scale changes (e.g., Jane Jacobs).

e. Visit a shoreline green space or park, such as the Newtown Creek Nature Walk (use the online scavenger hunt guide), to observe aspects of New York City's industrial history, water pollution, and present-day changes to improve community spaces.

f. Visit the Brooklyn Navy Yard and tour Building 92 to see New York City's story of industrial shipping and development come to life. How have uses of the Navy Yard evolved over time?

CONSIDER AND DISCUSS

- Discuss the balance (and imbalance) between growth and health of cities and the impacts on the natural environment. Consider the impacts due to vertical development, suburban sprawl, and expansion in search of natural resources, in New York City, throughout watershed communities, and other large cities around the world.
- What kinds of waste do different industries generate? Which industries are commonly found in New York City (past and present)?
- Define sustainability. Explore and discuss how a city can be more sustainable and what it means for our future.

ASK THE EXPERT

City Planner – a professional who designs urban spaces and plans urban land usage.

L3 Under our Noses: Creating an Underground Infrastructure

There are nearly 7,500 miles of sewer pipes below New York City streets and buildings. Not everything is hidden; from the curve of the street to the catch basins at each corner, you can watch as water drains away. In New York City, combined sewers make up about 60% of the underground system, collecting both wastewater and stormwater in one pipe and transporting it to a nearby wastewater resource recovery facility. About 40% of our sewer system is separated, and includes a sanitary sewer pipe that conveys wastewater directly to a facility, and a storm sewer that drains stormwater runoff to the nearest creek, river, or bay.

ESSENTIAL QUESTION

How does infrastructure help a city develop?

VOCABULARY

Infrastructure *(noun)*
The underlying foundation or basic framework of public works which provide services that are essential to facilitate the operations of a city, state, country, or region.

SUGGESTED IDEAS AND ACTIVITIES

a. How have you used water today? Discuss with students what goes down their drains with their wastewater and where they think it goes. Share images of the various components of the wastewater treatment system and help students begin to understand the important interconnections, including how they play a role in reducing litter on our streets and conserving water (especially when it rains!). (Refer to DEP's Navigating New York City's Wastewater Treatment System lesson).

b. Begin exploring underground systems through fictional characters in books or movies that live or travel by sewer. Have students create a character that lives in a similar setting. Write a comic strip, picture book, or narrative story about this character. The character can even be an object (such as a bag of chips) that goes down a catch basin and meets up with someone's soap bubbles from the shower drain.

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

d. Ask your students if they can identify catch basins or sewer covers along the street. Take photographs on the route to school to share. If the catch basin is clogged, what can they do to help? Do the sewer covers have a design/pattern? What information can we gather from what's engraved on top? Challenge students to redesign catch basins and sewer covers, including important messages about what happens below our feet. Consider what issues may influence a new design (litter, flooding, etc.).

e. Look at New York City sewer system maps to understand what type of drainage system is found in your neighborhood. What are the impacts of having this system? Compare what happens during wet weather and on a dry day. How can we be good stewards of this system?

f. Study historical cities and how water infrastructure was created. Build a diorama, write an essay, and/or draw a map of the different water infrastructure and management techniques (e.g., Ancient Rome, Khmer Empire).

CONSIDER AND DISCUSS

- How did ancient cities like Rome design infrastructure to deal with drainage? How did the advent of sewers help people and cities develop?
- Explore DEP's Sewer System Virtual Tour for video interviews, maps, and more activities. What do you think we would find inside the sewers? What are the sources of this waste?
- What are the advantages and disadvantages of the different types of sewer systems (combined and separate)? What other systems could be designed to collect and treat wastewater and stormwater?
- How might changes in rainfall, rising sea level, or other impacts of climate change affect New York City's wastewater system?

ASK THE EXPERT

Engineering Researcher – a professional who researches and models different engineering methods.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L4 Sinks, Pipes, and Systems: Making the Connection

There are many component parts of the underground sewers that are molded, manufactured, and engineered to create our urban system. They fit together to keep our wastewater flowing, relying mostly on gravity to keep everything moving "downhill." Sewers are built in a variety of shapes (or profiles), including rectangular, circular, and elliptical. Although at first sewers were built with brick, clay, or cement, they are now built of reinforced concrete or vitrified clay, materials that withstand corrosion.

Some materials that go down our drains can cause real damage to the system. Cooking grease, sanitary wet wipes, and other household products are the primary cause of fatbergs, or clogs that lead to back-ups in the system. Help students understand what goes down our drains is not simply *out of sight, out of mind*.

ESSENTIAL QUESTION

Where does your used water go after it flows down your drain?

VOCABULARY

Conduit (*noun*)
A closed channel or pipe used to convey water or another fluid.

SUGGESTED IDEAS AND 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), add beads to show the flow of water by gravity.

b. Make a kit of different parts using various diameter tubing, shapes, and forms to create conduits that can convey water. Test the velocity using a variety of flow and slopes.

c. Create individual homes on a street by re-using 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 (wastewater) pipe cleaners to represent the path of water coming in from a pipe underground and the waste leaving through a separate pipe. Connect the pipes from each home underground to each other. Investigate why pipes in a sewer system have names like *main, trunk, branch,* and *interceptor*.

d. Introduce the concept of fatbergs to your students. Research the proper ways to dispose of waste at home (Hint: only flush the 4 Ps -- poop, pee, puke, and toilet paper!). Have your students create and conduct a survey for their families to record the types of waste that go down their drains. List out all of the things that have clogged our pipes at home before (e.g., hair, grease, food scraps). Discuss the proper ways to dispose of waste products at home.

e. Research news articles on water and sewer operations, checking for stories of main breaks, fatbergs, or construction of new sewers in your neighborhood. What are the impacts to your neighborhood? Create public service announcements (PSAs) to share information with classmates, family members, and neighbors; for example, explain what causes sewer back-ups and what we can do to help prevent fatbergs from clogging the sewer system.

CONSIDER AND DISCUSS

- How is our sewer system constructed today? How are sewers inspected and maintained?
- Consider how the sewers co-exist with other utilities and roads, and what we can do to help such infrastructure function properly.
- How have fatbergs impacted New York City? How have other major cities prevented fatbergs and managed their sewer systems?

ASK THE EXPERT

Sewer Inspector – a professional who performs inspection work in connection with the construction, maintenance, and operation of sewer systems.

L5 Wastewater Treatment Explained

Wastewater treatment is the process of collecting wastewater, removing contaminants, and returning clean water to the environment. It is an important 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, and dishwashers in homes, schools, and businesses every day. In New York City, stormwater runoff collected from streets and sidewalks typically combines with this wastewater to travel to a nearby facility. This process ensures our own health and the protection of our waterways.

ESSENTIAL QUESTION

How does the wastewater treatment process mimic nature?

VOCABULARY

Biogas *(noun)*
The methane gas recovered from sludge digestion that can be used as renewable natural gas.

Biosolids *(noun)*
The solid by-products recovered from the wastewater treatment process that can be used beneficially.

Sludge *(noun)*
The solids, such as food, feces, and paper fibers, in wastewater that are settled out and removed during the wastewater treatment process.

WASTEWATER TREATMENT PROCESS

At New York City's 14 wastewater resource recovery facilities (WRRFs), wastewater undergoes several processes to remove pollutants before clean water is safely released to local waterways (shown on page 57). These physical, chemical, and biological steps closely mimic how wetlands, rivers, streams, and lakes naturally cleanse water (but at a much faster rate!).

- **Preliminary Treatment –** Wastewater enters a facility and passes through bar screens to remove leaves, twigs, and litter such as plastic bags, bottles, and sanitary wet wipes. Main sewage pumps then pump wastewater up from the screens to the surface level of the facility.
- **Primary Treatment –** Lighter solid material, such as grease and small plastic particles, is skimmed off the top of primary settling tanks, while gravity helps heavier solids sink to the bottom. Heavier solids, called sludge, are removed for thickening and digestion.
- **Secondary Treatment -** Wastewater then goes through aeration and final settling. During aeration, air is added to foster a healthy environment for oxygen-loving microorganisms. These helpful microorganisms consume the organic material in wastewater and, as they become "full", settle to the bottom of final settling tanks. Most of this activated sludge is removed and combined with primary sludge for thickening and digestion, while some is returned to the aeration tanks to help process incoming wastewater.
- **Disinfection -** Sodium hypochlorite (the same chemical found in household bleach) is added to remove any remaining disease-causing microorganisms. Clean water is then released to a nearby waterway.
- **Sludge Digestion -** Thickened sludge is digested by microorganisms that thrive in a low-oxygen environment heated to about 98°F. Methane gas, or biogas, released during digestion can be used to produce heat and electricity for the facility and also purified and distributed as natural gas for the community. Treated sludge is then dewatered, or spun to remove water from the solids. The resulting biosolids can be composted, added to agricultural soils, or further processed for other beneficial uses.

SUGGESTED IDEAS AND ACTIVITIES

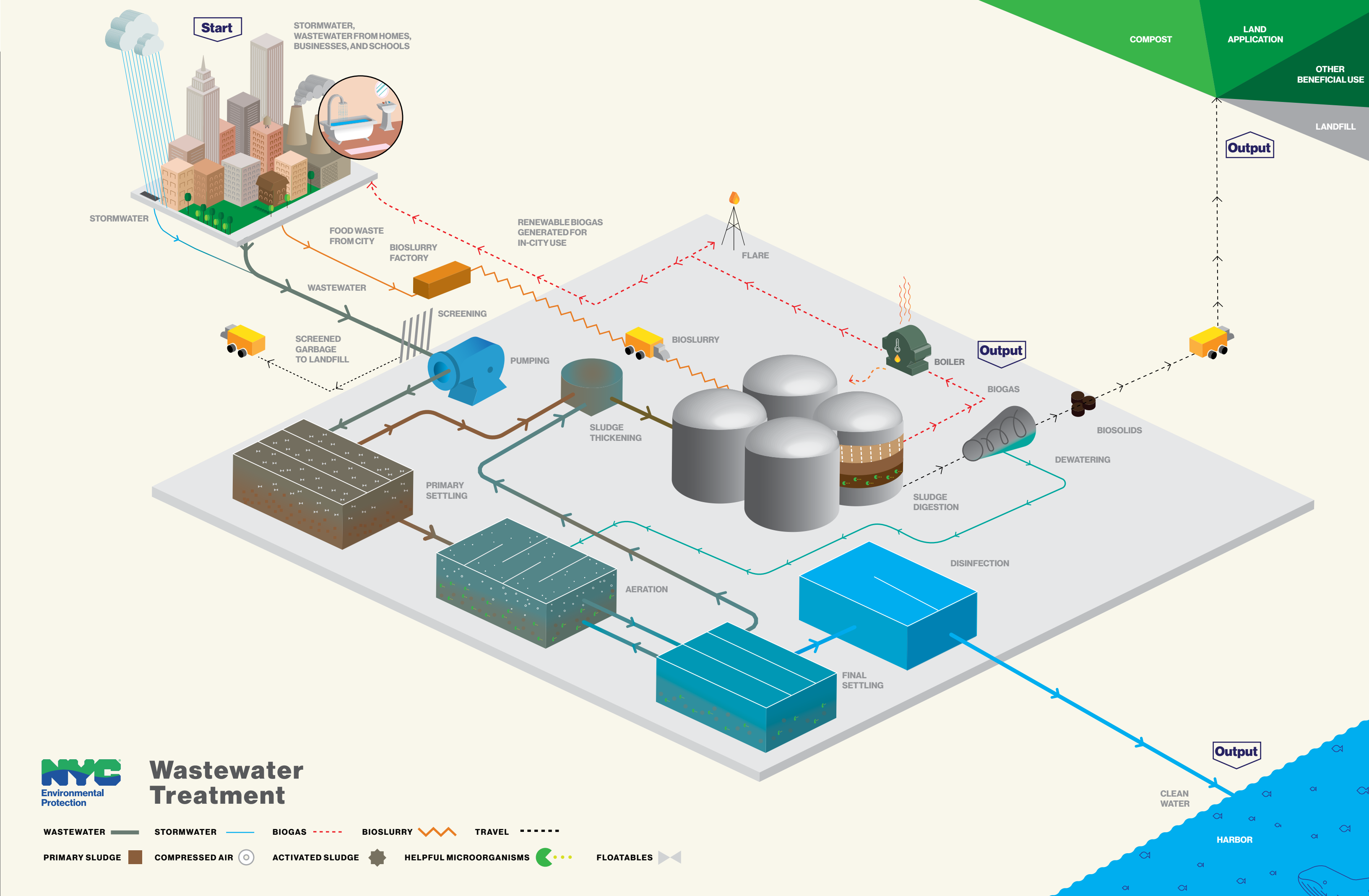
a. Discuss the idea that people make this process work! Have students learn about various jobs within our wastewater treatment system. See this process come to life at DEP's Visitor Center at Newtown Creek, located at the Newtown Creek WRRF, and learn more about the people, science, and technology behind wastewater treatment.
b. Review your previous activities related to the journey of your flush down the toilet and have 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, and what happens when you arrive at a WRRF. Next, make a storyboard book or illustration to share with classmates.
c. To help demonstrate the primary wastewater treatment process, fill up a container with water and add pieces of toilet paper, dirt, small rocks, food scraps, and cooking oil. Shake it up. Pour your mixture through a strainer into a second container. Make sure you include things that will sink, float, and stay suspended. Have your students experiment and document observations. (Refer to DEP's Wastewater Treatment lesson).
d. In small groups, act out the steps of the wastewater treatment process. What motions or gestures can you use to depict the process? Review the steps and consider the different types of science used – physical, biological, and chemical. Consider how the process mimics nature and our own bodies (sludge digestion is similar to your stomach's digestion!).
e. Research how wastewater is treated in other countries. How does the treatment process differ? Connect this research to current events related to severe weather events that may shut down or flood facilities due to storm surge, energy loss, or other issues. Compare and contrast with New York City.
f. Create a poster display of animals and plants that act as natural filters (Hint: bivalves, cattails). How much water are they able to filter in a day? How are these species an important part of our water history? Which ecosystems do they inhabit?
g. Relate this treatment process back to your school. The Newtown Creek WRRF receives food scraps from homes, schools, and businesses, which are processed into a nutrient-rich bioslurry and mixed with sludge during digestion to help produce more biogas. Discuss the importance of properly sorting food scraps in your school cafeteria. Educate classmates about this food waste-to-energy initiative with posters or videos.
h. Following a trip to the Visitor Center at Newtown Creek, consider the history of why and how New York City's facilities were upgraded. Research a specific challenge to the wastewater treatment process in current events (Hint: sanitary wet wipes, trash, or micro-plastics; or climate change and natural disasters). Discuss solutions, including the benefits of reducing waste, as well as recycling and reusing materials. What are some examples?

CONSIDER AND DISCUSS

- Discuss the history of wastewater treatment in New York City. How has the treatment process advanced over time and why was it necessary?
- Explore DEP's Wastewater Treatment Virtual Tour for video interviews, maps, and more activities on the wastewater resource recovery process. Discuss changes students can personally make to help improve the process and overall water quality (e.g., organic cleaners, picking up after their dog, not littering).
- Learn about DEP's WAIT Program for community members who voluntarily choose to wait before using water during heavy storms. How can water conservation help New York City manage wastewater and protect our harbor water quality?

ASK THE EXPERT

Sewage Treatment Worker – a professional who operates and maintains machinery, equipment and structures for the wastewater treatment process at wastewater resource recovery facilities.


Start
STORMWATER, WASTEWATER FROM HOMES, BUSINESSES, AND SCHOOLS
STORMWATER
FOOD WASTE FROM CITY
BIOSLURRY FACTORY
RENEWABLE BIOGAS GENERATED FOR IN-CITY USE
FLARE
WASTEWATER
SCREENING
SCREENED GARBAGE TO LANDFILL
PUMPING
BIOSLURRY
BOILER
Output
BIOGAS
SLUDGE THICKENING
BIOSOLIDS
DEWATERING
PRIMARY SETTLING
SLUDGE DIGESTION
DISINFECTION
AERATION
FINAL SETTLING
COMPOST
LAND APPLICATION
OTHER BENEFICIAL USE
LANDFILL
Output
Output
CLEAN WATER
HARBOR
Environmental Protection
Wastewater Treatment
WASTEWATER
STORMWATER
BIOGAS
BIOSLURRY
TRAVEL
PRIMARY SLUDGE
COMPRESSED AIR
ACTIVATED SLUDGE
HELPFUL MICROORGANISMS
FLOATABLES


VISITOR
NYC VISITOR
NYC VISITOR

L6 A Healthy Harbor: Keeping Pollution at Bay

For nearly a century, human and industrial waste was discharged untreated into our once-pristine waters. The odors, the filth, the bacteria festering in the creeks, streams, and bays posed a threat to our public health and also to the health of the ecosystem. The construction of wastewater resource recovery facilities along with significant policy changes, have contributed to the water quality improvements that have seen an increase in recreational boating and resurgence of marine life, including increasingly frequent sightings of whales and dolphins. Treated water from all 14 wastewater resource recovery facilities is tested before it is discharged into local waterways. We began monitoring the health of New York Harbor more than 100 years ago, and today, DEP continues to sample and test water quality from more than 70 locations citywide.

ASK THE QUESTION

How do we determine the health of the harbor?

VOCABULARY

Water Quality *(noun)*
The biological, chemical, and physical conditions of a body of water; a measure of a waterway's ability to support aquatic life and beneficial uses.

SUGGESTED IDEAS AND ACTIVITIES

a. Collect historical postcards from Coney Island and other beaches in and around New York City and create an exhibit in the classroom. Add photographs from present day. Create and compare works of art of the same theme.

b. Make a model, diorama, or classroom size drawing of a busy harbor filled with various types of boats (e.g., cruise ships, tug boats, sailboats, ferries, freighters). Add piers and landings, buoys, boardwalks, and warehouses. Discuss what a harbor is, what role these boats play in the life of New Yorkers, and how pollution could impact these activities.

c. Take a field trip by boat! Travel to Ellis Island and the Statue of Liberty to celebrate New York Harbor as a symbol of liberty and freedom in America. Plan a trip with a local organization that showcases the history of boating and the harbor, such as South Street Seaport Museum or Hudson River Sloop Clearwater. Or visit another location (like Brooklyn Bridge Park) and travel by New York City Ferry, New York Water Taxi, or Staten Island Ferry. Make observations from the water about different land uses seen along shorelines.

d. Visit the Jamaica Bay Wildlife Refuge at Gateway National Park in Queens. Take a walk with a park ranger to explore the many species of plant life, waterfowl, and other wildlife inhabiting the historic area. Keep observations and illustrations in a field journal. Refer to the Jamaica Bay Education Resource Directory for additional ideas.

e. Introduce students to harbor water quality testing. Over the course of the year, collect water samples from a nearby waterway to measure water temperature, pH, dissolved oxygen, salinity, turbidity, and more. Compare results to data from DEP's Harbor Survey Program, plot and graph results, and analyze data trends and fluctuations throughout the year.

f. Research and present a report about the life of various notable leaders in New York City's sewage history like Dr. George Soper, who led the Metropolitan Sewerage Commission in the early 1900s, or Richard H. Gould, a sanitary engineer who evaluated survey data in the early 20th century. Find other sanitary, chemical, or civil engineers of note.

g. As a class, participate in the annual, "A Day in the Life of the Hudson River & Harbor" event, hosted by New York State Department of Environmental Conservation and Lamont-Doherty Earth Observatory. Collect water samples and compile data on the conditions of the river ecosystem as citizen scientists.

h. Explore and explain the history of the shellfish industry and current efforts to restore them to the waterways. Team up with educators from Billion Oyster Project to hear how the organization is working with citizen scientists (like you!) to restore healthy oyster habitat and populations around New York Harbor.

CONSIDER AND DISCUSS

- Consider how important the scientific data from water quality monitoring was, and continues to be, for informing the decisions engineers make about maintaining and improving the wastewater treatment system.
- Discuss what changes students can personally make to help improve water quality in New York's waterways and why protecting waterways is important.
- Explore DEP's Harbor Water Quality Virtual Tour for video interviews, maps, and more activities on water quality monitoring and stewardship. Connect the concepts of harbor water quality with previous topics, including combined and separate sewer systems, and Combined Sewer Overflow (CSO).

ASK THE EXPERT

Marine Biologist – a scientist that studies organisms that live in saltwater.

Thematic Unit 4:

Land and Water: A Delicate Balance

Homes, schools, businesses, parks, and roadways are all part of the essential fabric of our urban life. When our built environment grows, development can overwhelm the natural environment and impact surrounding waterways. Students will learn how this relationship between land and water is a delicate balancing act for humans and nature. Periodically, throughout the last two centuries, human activities have tipped the balance leading to a loss in equilibrium. Finding and maintaining this balance in order to protect public health and sustain ecological well-being is a commitment we must make for our future.

What you should know:

NEW YORK HARBOR

New York City is shaped by water. The waters of New York Harbor set boundaries for the City's boroughs and define our history. Hundreds of years ago, freshwater wetlands, salt marshes, streams, and rivers supported communities, commerce, and wildlife. In earlier times, we depended exclusively on our waterways to transport vital (and luxury) goods. New York's proximity to major waterways in the industrial age propelled it to become America's primary hub for manufacturing and trade, most notably in the garment, sugar refining, publishing, and boat building industries. Eventually, wetlands and marshes were filled in and the resulting tributaries became some of the nation's busiest commercial waterways.

As one of the world's great waterfront cities, the development and rapid urbanization of New York City is intrinsically linked to the waters around it. This growth eventually adversely impacted the environment and our quality of life. Since its settlement, New York's waterways also became the "drain" for our untreated waste, and dumping ground for industrial chemicals with the intent to convey it away from homes and hope that the tides would carry it out to sea. As we learned in the previous unit, the industrial age tipped the balance, as nature could not keep pace with the waste produced by a population in the millions. "Out of sight, out of mind" eventually caught up to us.

More than a century of effort has been dedicated to creating and implementing innovative ways to restore ecological equilibrium. In 1909, the Metropolitan Sewerage Commission was established in an effort to assess and improve water quality in the rivers, bays, and estuaries-- collectively known as the **New York Harbor**. New York Harbor includes the inner harbor of the Hudson River up to Westchester County, the lower New York and Raritan Bay, Jamaica Bay, the East River, western Long Island Sound, and dozens of tributaries. We continue to monitor harbor water quality today through the Harbor Survey Program, by which scientists have collected more than a century of data on the health of our harbor and helped to identify the need for innovative infrastructure projects. The introduction of wastewater treatment facilities (the first in 1886) to treat our wastewater and the advancements in technology to enhance these processes have had a tremendous impact on improving water quality and restoring the healthy marine ecosystems we experience today.

CHALLENGES TO WATER QUALITY

New York City continues to protect the health of our harbor today by identifying and addressing stormwater pollution. As described in earlier units, New York City's sewer system is comprised of both combined and separate sewer systems. A **combined sewer system** carries sanitary waste (or sewage) from homes, schools, and businesses, plus stormwater runoff from streets, sidewalks, and rooftops, to a wastewater resource recovery facility where it is treated before clean water is released to a nearby waterway. During wet weather, our 14 wastewater resource recovery facilities can treat up to twice as much incoming wastewater as on a typical dry day. However, in times of moderate to heavy rainfall, these facilities may reach capacity. When the system reaches capacity, **combined sewer overflows (CSOs)** can occur, discharging a diluted mixture of untreated wastewater and stormwater runoff directly to the nearest waterway. In New York City, there are over 400 of these permitted combined sewer outfalls, or locations where this overflow can be released. Approximately 60% of the city is part of the combined sewer system, while the remaining areas, including most of Staten Island, south Queens, and south Brooklyn, rely on separate sewers.

These areas of New York City's land are drained by the **municipal separate storm sewer system (MS4)**. This kind of system collects stormwater runoff and wastewater separately into two discrete pipes. Wastewater is collected in a sanitary pipe and sent to a wastewater resource recovery facility for treatment. Stormwater runoff is conveyed through a storm sewer pipe and discharged directly to the nearest waterway. While this discharge is cleaner than a CSO, it can still result in water pollution due to trash or bacteria that gets swept up with stormwater and flows untreated to waterways.

CHANGES TO POLICIES AND INFRASTRUCTURE

Still, the waters surrounding New York City today are cleaner and healthier than they have been since the Civil War. The federal Clean Water Act of 1972, the State Pollutant Discharge Elimination System (SPDES), and other important environmental regulations for industries and public water and sewer departments have been a driving force for setting the standards that help protect the health of our waterways. By the time the United States Congress passed the Clean Water Act in 1972, New York City was well on its way to reversing the effects of neglect.

Over the past several decades, we have invested more than $45 billion in the construction and upgrade of critical infrastructure to improve the health of our vital ecosystems. These essential investments included upgrading wastewater treatment facilities to handle twice as much flow during wet weather, building new storm sewers in low-lying areas, upgrading pumping stations to keep flow moving throughout the system, building out sewers where more capacity was needed, and implementing a wide range of best management practices to reduce potential pollutants in stormwater. These improvements can be seen throughout the five boroughs: seals exploring the Bronx River, whales splashing in the Upper New York Bay, and millions of New Yorkers and tourists flocking to waterways for recreation.

Despite these regulations and investments, our work is not done. We continue to invest billions of dollars to reduce CSOs, coordinate with state and federal regulators, work with legislators to pass regulations for property owners, and develop innovative solutions to complex challenges. Today we have taken a more green approach to improve this land-water imbalance by investing in green infrastructure to improve our urban landscape's ability to absorb stormwater where it falls (covered more in Unit 5). We recognize that our actions on land affect the health of our waterbodies, and with continued sustainable urban planning, stewardship and education, we, and future generations, can enjoy the benefits of a clean and healthy environment.

Sequence of 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 Movement

New York City Waterways

L1 The Rain Drain: Stop Trash in its Tracks

One of the threats to water quality today is pollution from stormwater runoff. This happens when rain and snowmelt washes away trash, oil, pet waste, and other pollutants from our streets and sidewalks into local waterways. There are more than 144,000 catch basins capturing and draining stormwater runoff from streets and sidewalks in New York City. Stormwater pollution is an ongoing issue in our communities that continues to challenge the health of our rivers and ocean. Learning about this issue through real-world observations, data collection, and action are the best ways to engage your students in helping to protect our waterways.

ESSENTIAL QUESTION

What is the relationship between trash on my street and the waterways that surround the city?

VOCABULARY

Pollution *(noun)*
The introduction of harmful substances, such as oils, chemicals, sediments, and trash that can contaminate or dirty water, air, and land.

Stormwater Runoff *(noun)*
Water from precipitation that lands on rooftops, parking lots, streets, sidewalks, and other impervious surfaces, and flows over the land instead of seeping into the ground.

Catch Basin *(noun)*
A type of drain structure located next to the curb that collects stormwater runoff into the sewer system in order to decrease street flooding.

SUGGESTED IDEAS AND ACTIVITIES

a. Take a walk around your school community to identify nearby catch basins. Create a simple checklist for students to gather their observations, including the condition of the catch basin and the different kinds of litter and pollutants they observe near the catch basin. Discuss next steps for helping to maintain catch basins (e.g., report issues to 311, request another trash bin from New York City's Department of Sanitation, reduce litter and help clean up).

b. Have students observe the condition of catch basins in dry weather versus in wet weather. Can you find the message "Dump No Waste, Leads to Waterways"? Do you notice any symbols or other messages on this particular catch basin? What do you think this means? In the classroom, have each student select one item of trash or debris they saw and write a story about it. Consider where it may have come from and what will happen to it after a storm. Research who and what stormwater pollutants can affect (e.g., sea turtles and plastic bags).

c. Create a litter survey with students to study the most common types of trash and debris around your school community, as well as their locations. Hypothesize on the sources of these different items. Organize a clean-up and spread awareness to community members and local businesses on how to reduce street litter and protect water quality.

d. Have students create an art piece featuring commonly-littered items. Students can use discarded items (upcycling) to create materials or artwork for display. Share students' artwork and related stewardship projects using the interactive Zero Waste Schools website.

e. Discuss and develop a school wide plan to reduce trash, increase recycling, and raise awareness. Conduct a waste audit using examples from GrowNYC and the Zero Waste Schools program. Using this information, have students make posters, write slogans, and create public service announcements for the school community about reducing litter waste and advocating for solutions.

f. Visit the Recycling Education Center at Sims Municipal Recycling in Brooklyn to learn about how the recycling system in New York City works. Where do different types of litter originate? Recall that many items that are littered could have been recycled. What happens to the items we recycle?

g. Research citywide regulations that ban or restrict the use of some disposable (often littered) items such as plastic bags and Styrofoam. How are other U.S. cities addressing similar issues? Discuss reusable alternatives to use at school and home. Allow students to get creative and design their own reusable canvas bag using compostable or recyclable material (e.g., an old t-shirt). Check out Materials for the Arts for some inspiring materials or activity ideas ahead of time.

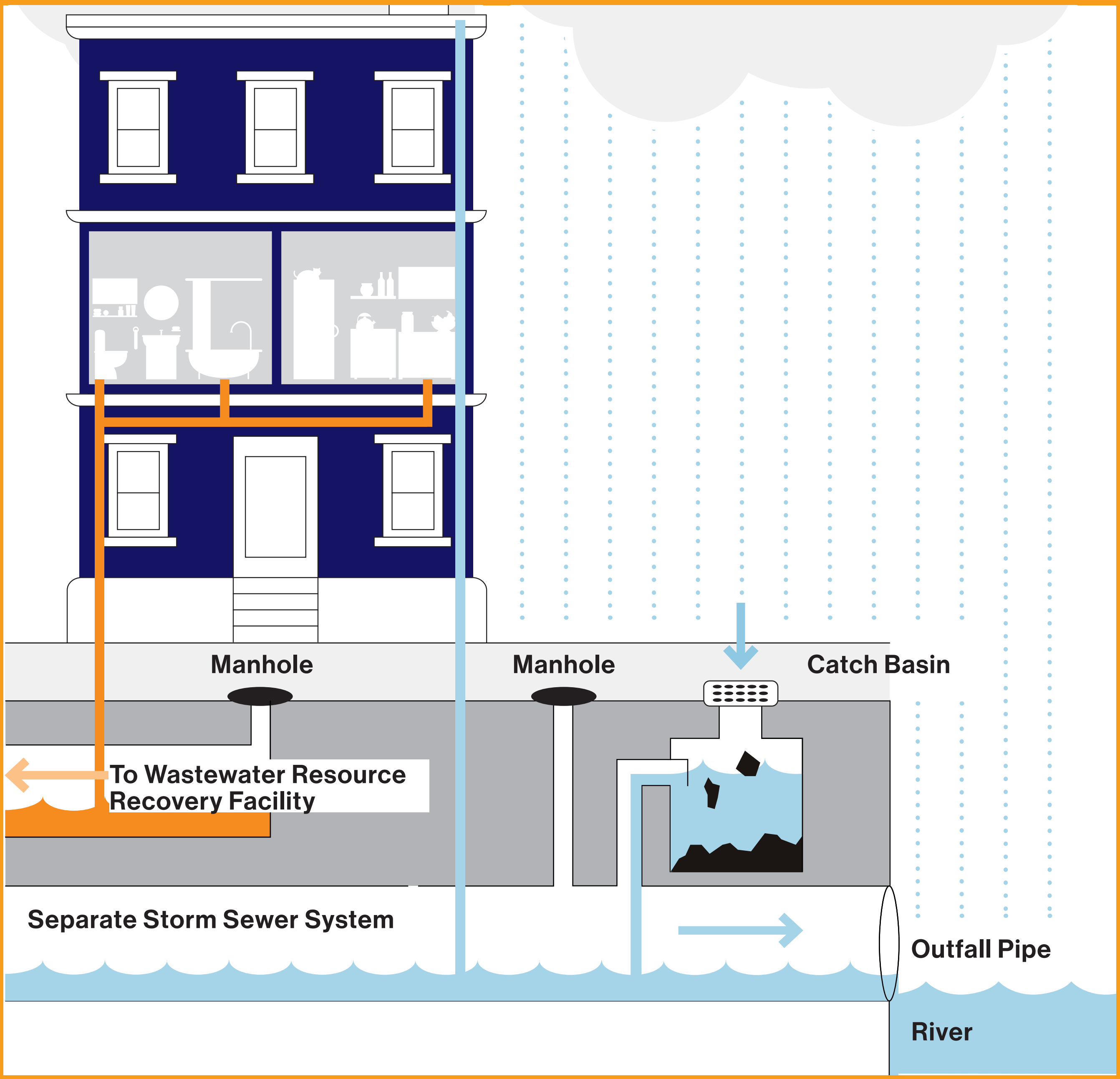
CONSIDER AND DISCUSS

- Do we all live *in* a watershed? Revisit what a watershed is. Consider how many watersheds exist in New York State (about 70,000!); in New York City? (Hint: Water draining off the land into pipes is still part of a watershed)
- Explore DEP's Sewer System Virtual Tour for video interviews, maps, and more activities on stormwater and the sewers. What happens to stormwater runoff that drains into catch basins?
- How does trash move through your local watershed? Where are the different places it can end up?

ASK THE EXPERT

Now students are becoming the experts! Students should ask friends and family what they think happens to street litter. Remind them why it's so important to dispose of waste and recycling properly.

Separate Sewer System



While most areas of New York City rely on a combined sewer system, nearly 40% of the sewer system is separated. A separate sewer system consists of two pipes: a sanitary sewer pipe that carries wastewater to a wastewater resource recovery facility for treatment and a storm sewer that conveys stormwater runoff directly to a nearby waterway. During wet weather, stormwater runs off city sidewalks and streets, picking up pollutants, such as litter, car oil, and pet waste, and flows directly out to waterways untreated. This runoff is harmful to water quality and can negatively impact the local ecology or limit recreational uses of waterways. The City of New York received its first Municipal Separate Storm Sewer System (MS4) Permit, issued by the New York State Department of Environmental Conservation in 2015, to further manage urban sources of stormwater runoff and reduce pollution to our vital rivers, creeks, and bays. What individual and collective actions can we take to help reduce stormwater pollution from entering our waterways?

L2 What's the Point: Exploring Point Source and Non-point Source Pollution

Before we can work on reducing pollution in our waterways, we need to identify its source. When something harmful is dumped directly into the water, this is considered point source pollution. When waste from numerous sources is deposited on the land and makes its way into the water indirectly, that is considered non-point source pollution. Both sources of pollution are quite common in an urban environment like New York City.

ESSENTIAL QUESTION

What is the difference between point and non-point sources of pollution?

VOCABULARY

Point Source Pollution *(noun)*
Any single source of pollutants dumped or discharged directly into a waterway from a pipe or outfall.

Non-point Source Pollution *(noun)*
Pollutants that originate from multiple sources over a relatively large area, rather from a single source.

SUGGESTED IDEAS AND ACTIVITIES

a. Brainstorm a list of activities and things that can cause pollution in our waterways. Ask students to separate this list into point source and non-point source pollutants. Ask them to describe the difference. Illustrate a comic strip about a specific pollutant's travels. Is it point or non-point source pollution?

b. Create an I-Spy game for students to conduct neighborhood observations of all the different types of non-point source pollution they notice. Make a display of drawings or photographs collected from their observations. Record by type and create a graph to display results.

c. Research a nearby waterway, its history in the community and to New York City, types of local industry and development, and its current water quality conditions and uses (e.g., boating, fishing, swimming). Using their observations and litter surveys from activities in Lesson 1, create an inventory of any potential (or proven) point and non-point source pollutants they can identify from their neighborhood research. Discuss the issues and plan strategies for solutions.

d. Build off of your school wide campaign activity in Lesson 1 by developing a community wide campaign. Research ongoing citywide litter campaigns; for example, the Bring It. campaign to remind New Yorkers to use reusable bags, water bottles, and more. In small groups, come up with a catchy slogan and actions everyone can do to reduce pollution in New York City. Discuss different types of media for reaching a wider audience and local community leaders (e.g., video, PSA, artwork, poetry). Have students write a letter (to family, school administrators, or local council members) to accompany their announcement.

e. Refer back to watershed modeling activities in Unit 1, this time create a watershed model of our urban environment (e.g., more low-lying, less forested, more developed) to investigate the relationship between the local landscape and surrounding waterways. Compare potential pollutant sources in an urban environment versus a suburban or rural environment like New York City's upstate watersheds. Summarize how land use management and water protection impact each other.

CONSIDER AND DISCUSS

- Research New York City's Green Infrastructure Program to understand what the city is doing to reduce stormwater runoff and manage potential pollutants from runoff. What are other cities doing to reduce pollution and protect water quality?
- Research the history of your community or borough and its relationship to environmental pollution in New York City. What types of pollutants affected your community in the past (and presently)?

ASK THE EXPERT

Environmental Engineer – an engineer who designs, plans, and implements measures to prevent, control, or remediate environmental pollution.

L3 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, rain gardens, and porous pavement (or permeable surfaces) requires some understanding of the key components of success: soil and plants.

ESSENTIAL QUESTION

How does our urban landscape affect water quality?

VOCABULARY

Pervious/Permeable (*adjective*)
Allowing water to pass through.

Impervious/Impermeable (*adjective*)
Preventing or slowing water from passing through.

SUGGESTED IDEAS AND ACTIVITIES

a. 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. Learn about the parts of the plant and the purpose of each. Have students sketch plant growth each week, and compile their sketches in a field journal.

b. Have students observe their growing plants once a week and write poetry from their observations. Connect with your school or local library, or Poets House to find sample poems to share with students that capture the richness and value of nature.

c. Build a terrarium in the classroom (or small individual terrariums), make daily observations, and measure temperature. Observe and discuss the cycle of water throughout this ecosystem.

d. 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 (an empty liter bottle cut in half with the top inverted works well). Add compost or grow grass in your soil and compare what happens.

e. Have students conduct a survey of your schoolyard or surrounding community to measure surface area and percent land coverage that is impervious versus permeable. Compare results to annual rainfall data and hypothesize trends for stormwater runoff. (Refer to DEP's Green Infrastructure Education Module).

f. Take a walk around your school community or to a nearby park. Bring field journals for writing and sketching observations, along with tree and bird identification guides for determining common street trees and bird species. Connect with the Urban Park Rangers for a guided program. What do your findings tell you about our urban ecosystem? Why are parks important?

g. Sign your class up to care for a local street tree. Determine ways to monitor the tree pit daily or weekly for infiltration, growth, and pollutant control. Contact Trees New York to learn about a tree care and maintenance program for your students.

h. Visit the botanical garden in your borough to learn about local and native plant species that make up New York City's landscape. Connect with garden educators for a guided program. Learn how some botanical gardens have redesigned their spaces to be more sustainable (and LEED-certified!) with a focus on stormwater management and conservation.

i. Research the Wildlife Conservation Society's Mannahatta and Welikia projects, which depict the original natural landscapes of New York City. Consider how the landscape naturally handled stormwater in the past. Further explore Visionmaker NYC's online data and mapping tools to experiment with land use management practices (past, present, and future) by creating climate-resilient and sustainable designs.

CONSIDER AND DISCUSS

- What are our perceptions of nature in the urban environment?
- In addition to protecting water quality, what other community benefits are there to increasing green space and building green infrastructure?

ASK THE EXPERT

City Park Landscape Architect – an architect who designs attractive and functional public parks, including the gardens, playgrounds, athletic fields, as well as roads, walkways, plants and trees.

L4 What is Combined Sewer Overflow?

In Thematic Unit 3, students learned about the New York City sewer system engineered to convey waste, both stormwater and wastewater, away from where we live, work, and play. During dry weather, the city's combined sewer system and wastewater resource recovery facilities have the capacity to transport and treat all the wastewater from homes, schools, and businesses. However, when flow increases as a result of heavy rainfall or snowmelt, the facilities can reach their capacity. When system capacity is reached, a diluted mix of untreated wastewater and stormwater runoff can be released to nearby waterways from combined sewer outfalls to prevent neighborhoods and the facilities from flooding. This discharge is called a Combined Sewer Overflow (CSO).

ESSENTIAL QUESTION

How can I play a part in reducing water pollution in and around my neighborhood?

VOCABULARY

Outfall *(noun)*
The outlet of a pipe that discharges into a body of water.

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

SUGGESTED IDEAS AND ACTIVITIES

a. Ask students to share examples of something overflowing (e.g., the bathtub, the sink, a glass of milk or juice). Demonstrate an example in the classroom. What were the consequences? How did they deal with the clean up? Relate this to combined sewers and waterways during a heavy rainstorm.

b. Set up a demonstration (or have students work in teams to create models) of a combined sewer overflow. Start with two separate plastic tubes each outfitted with a funnel on top. These two tubes are connected to another larger tube. Pour water dyed with food coloring–blue for rainwater and red for wastewater—into the separate tubes and see the water turn purple and spill out the bottom. Then divert some of the water from the larger tube (simulating the journey to the wastewater resource recovery facility). Next, pour larger quantities of water down the stormwater tube and simulate overflow.

c. Learn more about CSOs using the Center for Urban Pedagogy's (CUP) Sewer in a Suitcase model. Watch as stormwater runoff picks up debris and contaminants from streets and get diverted into a nearby waterway when a CSO occurs. Try out different scenarios using the model and discuss water quality concerns.

d. Research when CSOs occur using New York City's Waterbody Advisory System. Look up the weather forecast for the upcoming week and ask students to hypothesize on which days CSOs may occur. Track, monitor, and graph data. What could be in a CSO that can affect water quality and the species living in and around the waterway?

e. Refer back to activities in Unit 2 that had students calculate how much water they use on a daily or weekly basis. Consider how their water use habits can impact the sewer system on a rainy day. Ask students to create a weekly water use schedule while studying the weather forecast for the upcoming week. Read more about DEP's WAIT program, and study how water conservation during wet weather can play a role in reducing CSOs.

f. Consider what types of waste go down our drains from our water use activities at home (e.g., feces, toilet paper, toothpaste, food scraps, oil) that could pollute waterways during a CSO. Create a list and ask students to determine which items can be flushed and which should be thrown out (remember, only flush the 4 Ps -- pee, poop, puke, and toilet paper!). Refer back to Lesson 3 to learn more about DEP's Trash It. Don't Flush It. campaign and the importance of properly disposing of household waste to reduce fatbergs from forming in the sewers.

g. Research local waterways using DEP's Long Term Control Plans (LTCPs). Choose a waterway of interest, and refer to DEP's simplified fact sheets and the graphs and data found in the City's recommended plan summary to learn more. Discuss the different Best Management Practices (BMPs) that we can use to improve local waterways and reduce CSOs. What plans would you suggest including to improve water quality? Write a proposal and create design sketches.

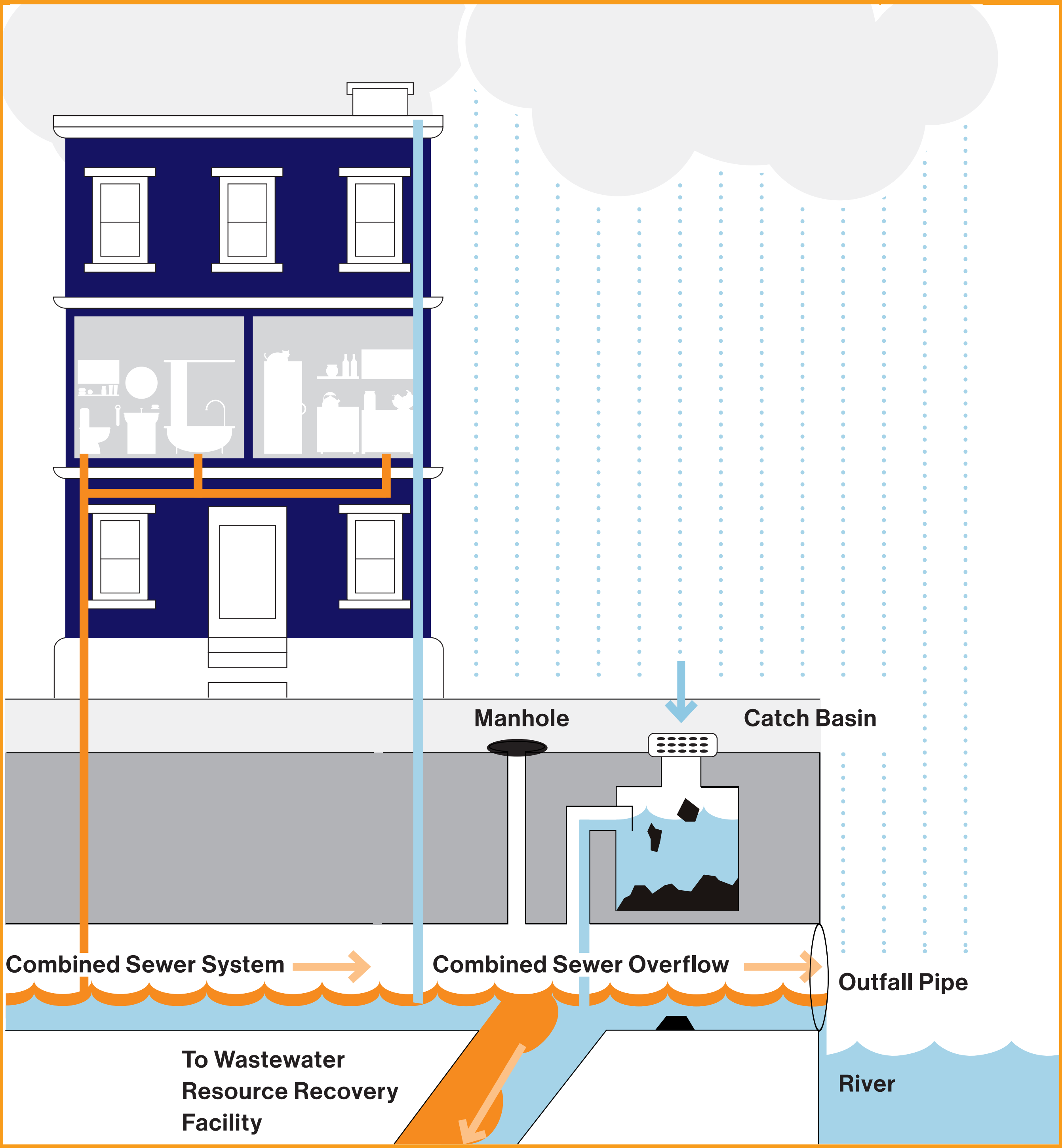
CONSIDER AND DISCUSS

- Speculate as to why the combined sewer infrastructure exists in older neighborhoods. What was the initial objective of New York City's early sewers?
- Explore DEP's Harbor Water Quality Virtual Tour for video interviews, maps, and more activities on water protection and stewardship. How do you think we can play a role in reducing overflow events? What can individuals do? What can we do as a community?
- Connect stormwater management to climate change. Research and consider climate change trends for New York City. Why is stormwater management important? Refer to DEP's Climate Change Education Module for more information.

ASK THE EXPERT

Environmental Planner – a professional that plans and designs land use in an environmentally, socially, and economically responsible way.

Combined Sewer System



Similar to many older cities around the United States, New York City relies primarily on a combined sewer system. A combined sewer system is a single sewer system that carries both sewage and stormwater in one pipe, to a wastewater resource recovery facility for treatment before being released to a waterway. During moderate to heavy rainfall events, the system will reach capacity, leading to an overflow of a diluted mixture of wastewater and stormwater runoff directly to our waterways from more than 400 permitted Combined Sewer Overflow outfalls around New York City. Approximately 60% of New York City's sewers make up the combined sewer system.

L5 The Clean Water Act: A Policy Movement

Enacted in 1972, the federal Clean Water Act began a movement for monumental environmental change in the U.S. The Clean Water Act and numerous subsequent regulations set standards for controlling pollution and maintaining water quality in America's waterways. The U.S. Environmental Protection Agency has put into place federal 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. Within New York, the State Department of Environmental Conservation enforces all environmental regulations, and is a critical partner involved in our efforts to reduce water pollution and introduce a new generation of New Yorkers to the Harbor.

ESSENTIAL QUESTION

How are significant environmental laws established?

VOCABULARY

Regulation *(noun)*

A rule, order, or code issued by an executive authority or regulatory agency of a government.

SUGGESTED IDEAS AND 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.

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, "I'm Just a Bill" from Disney's Schoolhouse Rock.

c. Why was the Clean Water Act so successful? What else was happening during the 1970s that impacted positive change for the environment? Research the first Earth Day and plan an Earth Day event for your school. What topics would you like to educate classmates and community members on?

d. Make a timeline of important changes and regulations enacted throughout the environmental movement. Who were the leaders of this movement? Introduce the topic of environmental justice and discuss the importance of grassroots community activism. Discuss the movement today; who are the leaders now?

e. Research the U.S. Environmental Protection Agency and other regulatory agencies that oversee and protect public health and the environment. What else do they protect besides water? Research Superfund sites in New York City, such as the Newtown Creek and Gowanus Canal. Meet with a community-based organization like the Newtown Creek Alliance or Gowanus Canal Conservancy for a guided walking tour to learn about the history and natural landscape of these waterways.

f. Connect the role of the Clean Water Act to the advancement of wastewater resource recovery facilities and decisions on how to manage byproducts like sludge. Use DEP archival images and maps to document the system upgrades that took place. Refer back to the wastewater timeline activity in Unit 3.

g. Research regulations that were influenced by and implemented following the Clean Water Act of 1972. Have students play the role of environmental lawyers and draft an environmental bill (either original or one that was previously introduced) for which to argue in a mock Congress.

CONSIDER AND DISCUSS

- What other laws help protect public health? How are these laws enforced? Are there any rules in your school or classroom that are made to help protect all students?
- Research other environmental protection policies, including for our drinking water supply. Looking at our history, what occurred that influenced significant policies and who influenced these decisions? (e.g., Three Mile Island, Rachel Carson's Silent Spring, New York City's Watershed Memorandum of Agreement)
- Consider how our city life would be different if these policies were never passed. Consider how the results might have been different if there were not important laws to support our stance or decisions today.

ASK THE EXPERT

Environmental Law Attorney – a lawyer with an intimate knowledge of environmental laws, regulations, and policies.

Thematic Unit 5:

Plan for the Future: Playing a Part

Some of the most challenging threats to water quality in the 21st century are created by stormwater runoff and exacerbated by climate change. As students have learned, solutions and innovations to monitor and improve the environment have helped move our water story forward. Now, your students will explore how individuals, communities, and public agencies continue to play key roles in shaping the future health and well-being of water for New York City. Words like sustainability, resiliency and stewardship will become actions as we plan for the future of our shared water resources.

What you should know:

STORMWATER RUNOFF

The Earth has a very efficient method of cycling water through the atmosphere and the land. As precipitation falls from the sky, it infiltrates and replenishes the groundwater, gets absorbed by plants, and runs into waterways refreshing surface water. The heat from the sun warms the water and turns it into a gas that rises back into the atmosphere through the process of evaporation. Transpiration also releases water from plants as a gas into the atmosphere. Unfortunately, in an urban environment, many of these natural processes can be thwarted by our developed landscape.

Modern towns and cities are full of **impervious** surfaces, like roads, sidewalks, and parking lots, which cannot absorb rainwater. New York City's ultra urban landscape is approximately 72% impervious. Because infiltration is not possible, this stormwater will flow downhill until it reaches a waterway or a catch basin where it will enter the sewer system. The water that does not infiltrate but instead runs off the land is called **stormwater runoff.** As it flows over impervious surfaces, stormwater runoff picks up pollutants like litter, pesticides, fertilizers, animal waste, and motor oil.

When polluted stormwater runoff reaches our waterways the ecological balance suffers. Trash creates a risk for wildlife when it is mistaken 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 deplete the oxygen levels in the water. Too much animal waste can introduce unhealthy levels of bacteria into the waterways. Stormwater runoff, and the pollutants it carries, remains a challenge for New York City's combined and separate sewer systems, and ultimately, harbor water quality. With 520 miles of waterfront, most New Yorkers are connected in one way or another with New York Harbor and its rivers, creeks, and bays. Remedying the problems caused by stormwater runoff will improve the quality of life for all New Yorkers, visitors, and marine ecosystems.

GREY AND GREEN INFRASTRUCTURE

One way to improve water quality is to upgrade existing infrastructure to help reduce discharges and pollutants from contaminating our waterways. **Grey infrastructure** includes system improvements that manage stormwater, such as the installation of underground stormwater retention tanks or large-scale tunnels, and construction of new separate sewers where none existed. While grey infrastructure can be effective at diverting or retaining large amounts of water during wet weather, these techniques tend to be costly and are only "working" when it's raining.

Another approach to improve water quality includes more natural, land-based solutions to manage stormwater runoff. Since 2010, New York City has invested in **green infrastructure** that uses innovative and sustainable tools engineered and constructed to absorb or hold water in place during a rainstorm, which reduces flow into catch basins. Green infrastructure techniques increase green space in our urban environment, mimicking the water cycle to reduce the impact of stormwater pollution. Trees, flowers, and grasses planted in special engineered soil maximize the capture and slow release of water as it infiltrates into the ground and promote evapotranspiration. **Rain gardens, green roofs, blue roofs, permeable pavement,** and **rain barrels** are all common types of green infrastructure found throughout New York City.

Such projects also provide many community benefits, including improving air quality, creating habitats for pollinators and animals, offering shade and cooler air temperatures from planted trees, and beautifying neighborhoods.

Staten Island's **Bluebelt** system is another unique stormwater management program. Bluebelts provide an engineered solution to stormwater that relies on streams, ponds, and wetlands to convey, store, and filter water in an environmentally responsible manner. Wetlands and waterways naturally help control street flooding, something that has become increasingly critical as we experience more intense rain events. While these projects are aesthetically pleasing, engineered weirs, and rocks and riffle ponds also naturally promote aeration and maintain flow to prevent stream bank erosion and sedimentation.

WATER SYSTEMS AND CLIMATE CHANGE

The most recent and pressing challenge to water management is our changing climate. Protecting New York City's water systems means developing a clear understanding of the impact of sea level rise and creating tools to adapt to new weather and climate conditions. The average annual rainfall in New York City has increased by nearly 20% or more than 8" over the last century. This may not seem like much, but it manifests in rainstorms of increased intensity and frequency that lead to flooding.

Improved stormwater management practices are part of New York City's long-term resiliency plan. The City's OneNYC 2050 plan is a strategy to secure our future against the challenges of today and tomorrow by taking bold actions to confront our climate crisis, achieve equity, and strengthen our democracy. Within the plan, DEP's goals include building green infrastructure on City-owned property like sidewalks, parks, and schools as well as creating incentives to encourage private property to build green infrastructure on their own. Data proves that as more green infrastructure projects are constructed on land, the healthier our waterways become. Investing in these sustainable solutions is essential to protecting New York City's water quality and marine ecosystems.

Systemic and collective understanding along with action will help us meet these new challenges together. Encouraging your students to understand the problems as well as the solutions will inspire them to act as responsible citizens *for the love of water*.

Sequence of Lessons

1. Green Infrastructure: Following Nature's Lead
2. Calculating Rainwater
3. Restoring Urban Waterways
4. A "Model" Schoolyard
5. Climate Change: Engaging in Action


NYS
RAIN GARDEN

L1 Green Infrastructure: Following Nature's Lead

New York City is helping transform its urban environment into a greener, healthier place to live, work, and play. By understanding and adapting to water quality challenges, together we can sustain not only the ecological health of our waterways, but also the public health, economy, and quality of life for all New Yorkers.

ESSENTIAL QUESTION

What are the benefits of constructing green infrastructure in our community?

VOCABULARY

Rain Garden *(noun)*
A planted area with engineered soils designed to collect and manage stormwater runoff from streets and sidewalks.

Mitigate *(verb)*
To cause a situation to become less harsh or severe.

SUGGESTED IDEAS AND ACTIVITIES

a. Working in small groups, have students look at different materials and consider how each item interacts with water (e.g., tin tray, cardboard, paper towel, coffee filter, sponges, rocks, straws, plastic sheet). Ask students to share out their observations and then define terms like absorb, convey, infiltrate, filter, and runoff. Look at images of New York City's rain gardens and consider how the different design components interact with water in similar ways. (Refer to DEP's Green Infrastructure Education Module).

b. Walk outside along the block directly across from your school entrance. Take a series of photos (or make individual drawings) to capture a panoramic of the entire block when "stitched" together. In the classroom, create a streetscape mural using the photos and drawings of the block. Highlight any green practices on the street (e.g., street trees, window boxes, rain barrels) and include additional practices that you think could benefit the area.

c. Use the DEP Green Infrastructure Program Map to find an existing project (or one under construction) in your neighborhood. Organize a tour (when accessible) to a green roof or community garden. Plan a self-guided tour to a rain garden in your neighborhood. Observe plants and wildlife, and sketch the project including how stormwater might flow through it. Find out how you and your students can help maintain these sites through DEP's Harbor Protectors program.

d. Compare historic maps of your neighborhood or borough to the DEP's Green Infrastructure Program Map. Research historic maps online using the Public Library or Historical Society digital collections. Investigate the natural landscape of your neighborhood through these maps; how has it changed over time? Identify the nearby waterway(s) where water drains. Then compare to DEP's map; discuss the placement of green infrastructure and its role in our city's landscape today.

e. Define and identify native (and common non-native) plants and trees in parks or on the streets around your school, and catalogue these using photographs or drawings. Discuss the environmental benefits of green infrastructure, including how rain gardens and green roofs provide habitat for native and migratory animal species. Study the wildlife that these plants attract, including monarch butterflies.

f. Visit Brooklyn Grange Rooftop Farms to explore a large-scale rooftop farm and green infrastructure project. Meet with educators from City Growers to learn about the many benefits of urban farming and to find out how the farm was constructed as a green infrastructure project. Research other large-scale green infrastructure projects that are open for visits in your neighborhood or borough, such as Kingsland Wildflowers.

g. In groups, build small-scale cityscapes using Lego blocks in paint trays. Create a rainstorm, spraying water on top. Monitor stormwater runoff and measure how much is collected after watering 1-cup of "rainwater" atop the city. Add in different size and color sponges to represent types of green infrastructure; measure stormwater runoff collected after a second rainstorm. (Refer to CUSP's Extreme Events activity kit).

CONSIDER AND DISCUSS

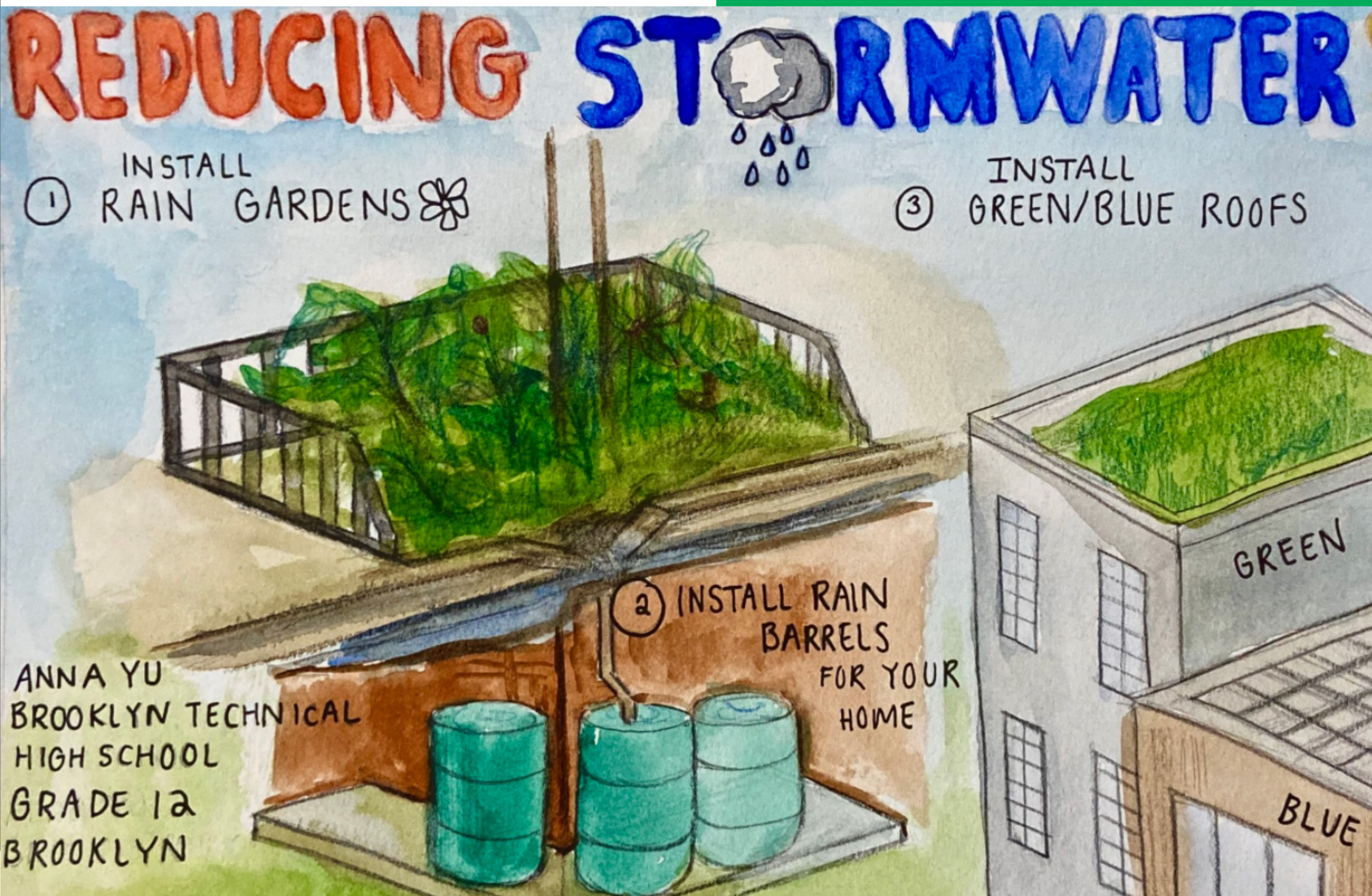
- Explore DEP's Harbor Water Quality Virtual Tour for video interviews, maps, and more activities on green infrastructure. What are the different types of green infrastructure? Where have you seen these techniques in your community?
- What are the benefits that green infrastructure can have in my community? Consider how green infrastructure can help mitigate the local impacts of climate change, including increases in stormwater and air temperature.

ASK THE EXPERT

Horticulturist – a specialized agriculturist who manages the art, science, technology, and business of plants.

GREEN INFRASTRUCTURE

Green infrastructure collects rainfall which would normally flow along street gutters and into catch basins, entering the sewer system. These vegetated features (e.g., engineered soils, rocks, plants, and trees) manage rain where it hits the ground similar to the way a natural system such as a forest or a meadow would handle runoff. DEP works with other city agencies to design, construct, and maintain all types of green infrastructure across New York City. More than 10,000 curbside rain gardens have been constructed and more are on the way. These rain gardens help prevent flooding and reduce Combined Sewer Overflows into surrounding waterways.



L2 Calculating Rainwater

Rainwater landing on city streets and rooftops is often measured in volume. Help students visualize just how much water falls on the roof of a single home or apartment building by calculating gallons of rain. There are different categories of storms, some which will precipitate more than others. Students will be able to understand that if this water is not being absorbed by the land, many gallons of water may end up as stormwater runoff, flowing into our waterways.

ESSENTIAL QUESTION

Why is capturing rainfall where it lands important for water quality?

VOCABULARY

Absorb *(verb)*
To soak up or take up a liquid or another substance (such as in plants).

Infiltration *(noun)*
The action of passing into or through a substance by filtering or permeating its pores (such as in soil).

Transpiration *(noun)*
The passage of water vapor from a living body (as of a plant) through its membrane or pores.

SUGGESTED IDEAS AND ACTIVITIES

a. Use the chart below to help students understand how to calculate the volume of stormwater. Explain that storms of different intensities can generate large quantities of runoff on impervious surfaces. Discuss how this would increase per building, block, or neighborhood.

b. Go outside and select various sites around the schoolyard that feature different slopes. In small groups, have students measure the slope and learn about different rates of stormwater runoff at each site. What types of land surfaces can be found at each of these sites? (Refer to DEP's Green Infrastructure Education Module).

c. Working in small groups, have students play the part of city planners tasked with managing stormwater runoff. Map out and investigate your school community to determine where constructing green infrastructure could improve stormwater conditions. Explain why you chose these sites, and the types of green infrastructure you would like to use. Explore the Gowanus Canal Conservancy's Blue Schools curriculum for activity ideas on site analysis and design development.

d. Install a rain gauge at your school to collect data on rainfall levels. Students can take turns each week recording data for the class. Compare and analyze seasonally and/or annually.

e. Collect and graph rainfall data with students using available online data from the National Oceanic and Atmospheric Administration (NOAA). Discuss trends in the data, including seasons, locations, and large wet weather events. Look at yearly rainfall data over the last decade or more and have students discuss what trends they can infer. Have students share their hypotheses.

f. Explore the Climate and Urban Systems Partnership (CUSP) NYC interactive map; add map layers to display city infrastructure and flooding. Discuss how climate change plays a role, and relate back to your activities on calculating rainfall. Zoom in on your borough and then your school neighborhood. Research or take a walk to nearby sites to see "What's being done?" and record what you see. Follow up in your classroom by adding to the "Impacts & Observations" map layer.

Volume of Rain Calculations:

Rain Event (in)	Square Footage (ft2)	Rain (ft)	Cubic Feet (ft3)	Conversion (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?
- Consider the impacts of climate change on New York City. How are these changes affecting different communities and the surrounding waterways?

ASK THE EXPERT

Geographic Information Service (GIS) Mapping Specialist – a professional who uses computer-based methods to collect, manage, analyze, model, and present geographic or spatial data.

L3 Restoring Urban Waterways

Urbanization is responsible for many of the sources that contribute to ecological degradation in our waterways. Increases in impervious surface area and stormwater runoff have negative effects on stream flow. If the health 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.

One example of an innovative and cost-effective stormwater management approach is the Bluebelt system on Staten Island. The Bluebelts are an engineered solution that take advantage of the natural drainage properties of waterways. These designed streams, ponds, and wetlands effectively prevent street flooding by slowing the flow of stormwater runoff. Wetlands provide native habitats for local wildlife and plant species which help filter stormwater and absorb nitrogen and phosphorous.

ESSENTIAL QUESTION

What are the long-term benefits of restoring urban streams, for people and wildlife?

VOCABULARY

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

Flood *(noun)*
An overflow of water, caused by either a large body of water or heavy rainfall, onto normally dry land.

SUGGESTED IDEAS AND ACTIVITIES

a. Create a very simple stream by filling a plastic storage container with sand or potting soil and creating a light rain shower; students can "make it rain" using a spray bottle or other gentle methods. At first, they will see how channels naturally form. Next, 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 (e.g., add rocks and plants to simulate a real riparian buffer); adapt your models and try again.

b. Take a field trip to the nearest waterfront, observe and record conditions of the waterway and surrounding area before and after a rain event. Hypothesize on what changes they expect to notice; what would cause these changes? Consider and discuss student observations of the flow, water temperature, available habitat, evidence of erosion, and types of pollution.

c. Refer back to lessons in Unit 1 to discuss the benefits of maintaining the riparian buffer around waterways. While visiting a nearby waterway, have students fold their paper in half and sketch what they see above on the surface of the riparian buffer and then illustrate what they think it looks like below the surface (e.g., layers of soil, roots, rocks, animals). Discuss important terms, such as erosion, filter, intercept, and infiltrate. Ask students to identify the different parts of their image that are working to help protect water quality.

d. Meet with a community organization in your borough to conduct water sampling and monitoring along the Bronx River, Gowanus Canal, Newtown Creek, or other accessible waterbody. Plan an education program with Solar One at Stuyvesant Cove Park along the East River or Hudson River Park Trust on the Hudson River.

e. Connect with DEP to visit the Staten Island Bluebelts. Identify native plants and wildlife that you observe (e.g., pickerelweed and its properties). Organize volunteer efforts to clean up a Bluebelt and develop a plan for long-term stewardship.

f. Create a story, a photographic essay, or a documentary video about life in and around a local waterway. Consider the outside impacts that have shaped or altered the waterway's history and landscape, such as pollution, development, industry, or climate change. Have students share and present their projects to classmates, the entire school, or their families and the school community.

CONSIDER AND DISCUSS

- Review the riparian buffer activity and discuss the function as well as the beauty of the bank of a river. Do most of New York City's waterways have riparian buffers? Examine different waterways as examples. How has New York City's waterfront changed over time?
- Review again why these green tools are considered "infrastructure." Bluebelts are constructed in areas with separate sewer systems, and are considered an ecological extension of the city's infrastructure.

ASK THE EXPERT

Ecologist – a scientist who surveys ecosystems to study the relationship between plants, animals, and the environment.

L4 A "Model" Schoolyard

Using your own building, schoolyard, and surrounding community, you can begin connecting all that your students have learned to becoming active environmental stewards. The goal of this lesson is to engage students with opportunities to be creative, get involved in their school community, and make sustainable decisions. The next Thematic Unit will share additional activities and resources for moving these ideas forward to create a real project, fund it, monitor its benefits, and ensure its long-term care.

ESSENTIAL QUESTION

How would you like to change your schoolyard or school community?

VOCABULARY

Stewardship (*adjective)*
Taking personal responsibility to help protect your environment.

SUGGESTED IDEAS AND ACTIVITIES

a. Form a green team in your school to get students more involved in stewardship and sustainability projects. Connect with the New York City Department of Education's Office of Sustainability to hear about resources and programs to help you get started. Have a Sustainability Specialist visit your school and meet with your green team.

b. Measure and draw a plan of your schoolyard. Use your own body or the entire class as units of measure. Use your own feet and relative units of measure and proportion. Find a scale drawing of the school and have students duplicate it. Transfer measurements to a base, like cardboard or poster paper. First with a pencil, label the base with all prominent features, including the school building, the play area, surrounding sidewalks and streets. Make this three-dimensional using different building materials (e.g. shoeboxes, foam board, cardboard, blocks). Use crumpled tissue paper, straws, pipe cleaners, sponges, to make your green areas. Consider where students would want to add new green features.

c. Research schoolyards in your borough that have been redesigned to manage stormwater by the Trust for Public Land and DEP. Plan a visit to one of these schoolyards, which open up to the community during after-school hours and on weekends. Explore, make observations, and discuss some initial smaller-scale changes that can be implemented in your own schoolyard. Present and propose student plans to school administrators.

d. Connect with DEP to receive a free rain barrel for your schoolyard. Work with your custodial engineer to determine the best location for connecting the rain barrel to the gutter system. If your school does not have gutters, consider building a small lean-to to demonstrate where water collects. What can you do with this water (e.g., watering plants, starting a garden)?

e. If you were to build a school, or community, garden, where would it be located? What would you need to get started? What types of plants would you include? Have students plan their ideal school garden, then work with your school administration to make your garden a reality. Begin growing plants in the classroom, and then move them to raised plant beds in the schoolyard. Connect with GrowNYC educators to learn more about how to get started.

f. Survey your school community to create a sustainable plan that addresses the needs of school stakeholders. Research the City's OneNYC 2050 plan to learn how community input was incorporated into the goals to create a stronger and more fair city. Have students identify the stakeholders in your school community and strategize methods for disseminating their survey. (Refer to DEP's Breaking Down OneNYC lesson).

CONSIDER AND DISCUSS

- How will changes to the schoolyard change your feelings toward the outside space of your school?
- Consider how much of New York City's landscape is made up of school properties. How will greening your schoolyard help water quality and our local environment?

ASK THE EXPERT

Environmental Educator – a professional who teaches students, adults, and the general public about nature, and how to be a good steward of our environment.

L5 Climate Change: Engaging in Action

Concentrations of greenhouse gases trapped in our planet's atmosphere are causing an overall change in the Earth's temperature at an ever-increasing rate. As a coastal city, New York is experiencing higher ocean and atmospheric temperatures, which lead to more intense and frequent rainfalls, flooding, and sea level rise that affects our harbor and surrounding waterways. A changing climate will also impact New York City's water supply and wastewater treatment system. In an effort to strengthen climate resiliency, New York City is taking action to mitigate the effects and adapt to these changes. Young people are already engaging in action in their schools and communities, both independently and in partnership with community leaders, city agencies, and environmental advocacy organizations, to create the change needed to prepare our city for the impacts of climate change.

ESSENTIAL QUESTION

How is climate change affecting New York City?

VOCABULARY

Weather *(noun)*
The state of the atmosphere with respect to temperature, wind, humidity, precipitation, and cloudiness.

Climate *(noun)*
The long-term average of conditions of weather at a place as exhibited by temperature, wind velocity and precipitation.

Adaptation *(noun)*
The actions taken to modify or remodel a situation to fit new conditions.

Resiliency *(noun)*
The ability to withstand or swiftly recover from changing conditions as a result of preparation and adaptation measures.

SUGGESTED IDEAS AND ACTIVITIES

a. Look at photographs of different weather and discuss what characterizes weather. Add in images that depict climate, and discuss the differences between weather and climate. Group students in teams for a game of weather versus climate trivia. Discuss how weather and climate are forecasted differently. (Refer to DEP's Distinguishing between Weather and Climate lesson).

b. Record daily weather reports for a given period (a few weeks or months); set up your own temperature station outside the classroom to collect and compare local data if possible. Discuss patterns and compare the results from different sources (e.g., NOAA's National Weather Service or The Weather Channel). Consider how this weather data could be used as a snapshot of our current climate in the future. (Refer to DEP's Recording Weather and Climate lesson).

c. Introduce the greenhouse effect by modeling the Earth's atmosphere using shoe boxes. Add a layer of soil to the bottom and place a thermometer in the center of the soil. Cover each box with a different material (e.g., plastic wrap, tin foil, cardboard, Plexiglas). Place boxes in a sunny area and measure the temperature twice a day for a week. Discuss which covers trapped more heat and how these warmer boxes represent our changing atmosphere. (Refer to DEP's Modeling the Earth's Atmosphere lesson).

d. Ask students to think about whether they have ever been affected by climate change. Explain how New York City has already seen shifts in temperature, precipitation, and local sea level. Introduce each of these climate impacts. In their journals, ask students to reflect on their own experiences related to extreme heat, increased wet weather, and flooding. (Refer to DEP's Placing Climate Change in New York City lesson).

e. Introduce the term "resiliency" and ask students to brainstorm what they think it means for New York City to be a resilient city. Research major climate-related events that have challenged New York City's resiliency (e.g., Hurricane Sandy). Survey classmates, friends, and family members about their experience with the event.

f. Explore what New York City has done to build more resiliency using the NYC Mitigation Actions Map. Refer back to students' experiences with the impacts of climate change. Discuss other ideas for building resiliency in your neighborhood; allow students to get creative by illustrating and designing their own strategies.

g. Refer back to lessons in Units 2 and 3 that introduce the different components of the New York City water supply and wastewater treatment systems. Define the term "system." Discuss how climate change can impact these interconnected systems. In groups, brainstorm some strategies for helping protect our water resources and how it relates back to climate change (e.g., water conservation helps during wet weather and during a drought).

CONSIDER AND DISCUSS

- How do overall rising atmospheric and ocean temperatures impact our water supply, wastewater treatment, and stormwater management systems?
- Review the water cycle and discuss how temperature rise and sea level rise may alter this cycle.
- Research OneNYC 2050. Discuss what New York City is doing to increase climate resiliency and sustainable practices.

ASK THE EXPERT

Climate Scientist – a scientist who studies weather and climate data over long periods of time, using computerized climate models and projections based on Earth's systems.

Thematic Unit 6: **Environmental Stewardship**

We all have the power to affect positive environmental change! Through education, we can help students realize their potential for conserving and protecting New York City's shared water resources and the environment. By understanding that both the small individual actions we take at home and school and the larger service projects we initiate in our communities have an impact, students can become empowered as agents for change in their own neighborhood, city, and beyond.

What you should know:

This thematic unit is about motivating active student participation in stewardship projects. To culminate their study of New York's water resources, students can think critically and creatively about how to engineer their own solutions to challenges and share what they have learned with their community. Students have discovered New York City's water story, from where our drinking water comes from to where our wastewater goes. They understand how water cycles through our environment, influenced by both the natural and built features of our landscape. They have acquired an awareness of the harmful impacts of stormwater pollution, and the even greater challenge of sea level rise on our waterways.

Youth, as well as adults, can participate in environmental **stewardship** through a broad range of activities, projects, and disciplines, including science, social studies, and the arts. There are many opportunities in the performing, visual, and language arts for students to express their appreciation for, and new understanding of, water. Students can also share their new knowledge by making what they are studying available to their school and community.

Engagement in real-world projects helps students become environmental stewards now and for the future. Through interactive project-based learning, students can research, plan, engineer, and assess solutions to individual and collective problems. By presenting their projects in creative ways, such as public service announcements (PSA), flyers, social media, video interviews, and blogs, students can educate their peers, families, and community members. Further, through place-based learning, students can engage in local learning experiences and explore the many unique environments and waterways, as well as historical and cultural institutions in their own neighborhood. For example, **citizen science** projects, such as ongoing testing and monitoring of water quality, are direct ways to involve students in local data collection related to decision-making, regulations, and community planning.

By focusing projects on topics that students have become experts in, they will also be able to make deeper connections to larger environmental issues. Students will not only understand how changing what we put down our drains helps the sewer system function now, but they will also recognize how their actions help optimize our system for the future as the frequency and intensity of wet weather increases due to climate change. Or that educating others on the importance of water conservation now as we embark on major repairs of the Delaware Aqueduct will also help our city maintain a sustainable water supply over time.

A variety of opportunities for stewardship, citizen science, and community engagement can be found in the suggested activities in earlier units. What follows are additional ideas and resources for what we think are the best projects and programs to get you started. Keep in mind, the impact of your project along with the work of others can and will "move the needle." Students and citizen partners, along with public and private agencies and organizations, can impact the future quality of the environment for all New Yorkers, young and old, from New York City's watersheds to New York Harbor.

ESSENTIAL QUESTION

Can my actions make a difference in protecting the environment?

VOCABULARY

Citizen Science *(noun)*
Opportunities for citizen volunteers to support scientists on science research and data collection projects in their community.

Service Learning *(noun)*
Activities that both support student learning goals and service or improve the community.

Environmental Literacy *(noun)*
An understanding of and consideration for environmental issues and the actions needed to help protect and improve the environment.

SUGGESTED IDEAS AND ACTIVITIES

Drinking Water and Conservation

Consider any or all of these as suggested actions to engage your students in the long-term protection of water quality in our upstate watersheds and the conservation of our drinking water supply.

a. Create a program to monitor and conserve water at home and school. Sharing what they have learned, have students develop a school-wide or community-wide campaign to engage a wider audience in water conservation. Relate your water conservation campaign to an ongoing or pressing issue, such as minimizing our water footprint, preparing for the Delaware Aqueduct Repair Project, or reducing CSOs and harbor water pollution during wet weather.
b. Apply for a DOE Office of Sustainability grant to install a water filter fountain in your school. Work with Sustainability Specialists to display accompanying signage featuring the New York City's Water Story: From Mountain Top to Tap map and information about where our drinking water comes from. Calculate how many plastic water bottles are not wasted by refilling reusable bottles.
c. Participate in the Trout in the Classroom program to help raise awareness about New York City's watershed ecosystem. Raising trout provides students opportunities to learn about the role of indicator species and the importance of protecting water quality in watershed streams and reservoirs.
d. Visit the watershed on a day or overnight trip with funding support from the Watershed Agricultural Council or the Catskill Watershed Corporation. While planning your trip, work with students and educators to include a service-learning component, such as planting trees, removing invasive plant species, studying and identifying local species, monitoring tree growth and healthy forests, or working to improve stream and riparian habitats.
e. Plan a trip to the watershed around an annual event, such as DEP's Reservoir Clean-up Day each fall. Connect with students and teachers from other participating schools.
f. Participate in the Watershed Agricultural Council's Green Connections program and develop an upstate - downstate partnership with another school. Share letters, connect virtually, and then plan your trips to meet in-person. Discuss shared interests and concerns, such as climate change, and plan stewardship activities to conduct both upstate and downstate.
g. Participate in DEP's annual Water Resources Art and Poetry Contest. Students can express their new knowledge through various kinds of artwork and poetry. Contest themes cover the importance of water, drinking water supply, wastewater treatment, harbor water quality, and climate change. Create your own exhibit at school to raise awareness and showcase the student entries for your school community.

Wastewater, Stormwater, and Harbor Water Quality

Consider any or all of these suggested actions to give students the opportunities to collect important data to help monitor the health of our waterways, play a role in preventing pollution from entering the harbor, and raise awareness in their community.

a. After learning about stormwater management and green infrastructure, identify and plan locations for planting new trees and plants around your school neighborhood. Develop a plan for maintaining these new green spaces over time. Connect with organizations like Trees New York or NYC Parks.

b. Start small and scale up with possibilities to re-design your schoolyard to help manage stormwater, reduce flooding, and provide new outdoor learning environments. Work with organizations like DEP, DOE Office of Sustainability, GrowNYC, New York City Soil & Water Conservation District, and local botanical gardens to cultivate plants, plan and construct planters or a larger school garden, incorporate rain barrels, and install outdoor classrooms.
c. Based on a water topic of interest, have students help plan, coordinate, and promote a neighborhood clean-up. Become a Harbor Protector with DEP or connect with the New York City Parks Department to organize clean-ups and campaigns for neighborhood catch basins, parks, waterfronts or beaches. Organize a litter-free campaign to go along with your community clean-up efforts. Connect with local City Council Members to strategize ways to reduce litter and stormwater pollution in your community.
d. Plan, promote, and coordinate a school and community campaign on the importance of keeping cooking grease, wet wipes, and other household products out of our drains. Use DEP's Trash It. Don't Flush It. campaign for inspiration.
e. Identify and maintain a rain garden near your school through DEP's Harbor Protectors program. Participate in training and involve students in weekly monitoring to remove litter and maintain plants and soil. Determine ways to track the success of the rain garden and collect data, while conducting routine stewardship.
f. Conduct ongoing water quality monitoring in the harbor, creeks, and streams around New York City. Focus on the waterway closest to your school or participate in a larger study of a unique ecosystem, such as Jamaica Bay, the Bronx River, or the Staten Island Bluebelts. Connect with DEP, New York State Department of Environmental Conservation, Hudson River Park Trust, Bronx River Alliance, or another organization focused on improving water quality in New York Harbor.
g. Monitor marine animal habitats, such as the American eel, or oysters. Participate in ongoing monitoring programs with the Billion Oyster Project or the New York State Department of Environmental Conservation. Partner with DEP to participate in the New York State Department of Environmental Conservation's annual eel count on Staten Island.
h. Study weather and climate using a rain gauge and other weather monitoring equipment. Connect with local universities and agencies that collect climate data and offer citizen science opportunities. Explore DEP's Climate Change Education Module for more lessons and activities related to climate resiliency.
i. Apply for the Department of Sanitation's Zero Waste Schools mini-grant to help kickstart your green team. Explore topics your team is interested in spreading awareness about, including proper trash, recycling, and food waste disposal in your school cafeteria.
j. Using what you have learned, identify opportunities to fund larger projects for your school. Propose plans to your school administrator. Explore funding opportunities and submit ideas through the New York City Council Participatory Budgeting, or work with your City Council Member to identify community needs and propose plans.

CONSIDER AND DISCUSS

- It all adds up! Consider the impact of our actions on our water resources and the environment, student-by-student, block-by-block, school-by-school, within the watersheds, and in the city.
- What are the current and long-term benefits of forest land conservation and high quality drinking water for New York City and watershed consumers?
- What are the current and long-term benefits of green infrastructure, restored wetlands, and improved harbor water quality for New York City?
- Discuss the different ways you can measure success (both quantitative and qualitative measures).
- What will students remember most from their water studies?

ASK THE EXPERT

Your students! Find out what they are most interested in learning more about, and what kinds of actions or projects they are interested in putting their new expertise to.

Find more New York City and watershed resources and organizations in the appendix of this guide.

Glossary

Absorb *(verb)* – to soak up or take up a liquid or another substance *(such as in plants)*.

Adaptation *(noun)* - the actions taken to modify or remodel a situation to fit new conditions.

Aeration *(noun)* – the process of adding air. In wastewater treatment, air is needed to provide oxygen to microorganisms that help consume the solid organic material.

Aerobic *(adjective)* – life or natural processes that require the presence of oxygen.

Anaerobic *(adjective)* – life or natural processes that require an environment with low to no oxygen.

Aqueduct *(noun)* – a conduit or structure designed to carry water over a long distance, usually by gravity.

Bacteria *(noun)* – single-celled microscopic organisms that may be used in a variety of biological treatment processes.

Biodiversity *(noun)* – the variation of life in the world or in a specific habitat or ecosystem.

Biogas *(noun)* – the methane gas recovered from sludge digestion that can be used as renewable natural gas.

Bioslurry *(noun)* - a nutrient rich mixture of processed food scraps from stores, restaurants, schools, and businesses.

Biosolids *(noun)* – the solid by-products recovered from the wastewater treatment process that can be used beneficially.

Blue Roof *(noun)* – a rooftop designed without vegetation for the purpose of detaining stormwater, creating temporary ponding, and gradually releasing stormwater.

Bluebelt *(noun)* – a stormwater management program that preserves natural streams, ponds, and wetlands, and enhances them to help drain, store, and filter stormwater runoff.

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

Built Environment *(noun)* – all of the human-made structures that provide people with living, working, and recreational spaces.

Bypass *(noun)* – a secondary channel, pipe, or connection to allow a flow when the main passage is closed or blocked.

Carbon Dioxide *(noun)* – a heavy, colorless greenhouse gas *(CO2)* produced naturally from animal respiration and absorbed by plants during photosynthesis. It can be emitted during human activities such as burning fossil fuels.

Catch Basin *(noun)* – a type of drain structure located next to the curb that collects stormwater runoff into the sewer system in order to decrease street flooding.

Catskill Mountains *(noun)* – a mountainous region in New York State occupying almost 6,000 square miles. It is the location of New York City's Catskill Water Supply System.

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

Chlorine *(noun)* – a common chemical used to disinfect water and remove harmful bacteria.

Citizen Science *(noun)* – Opportunities for citizen volunteers to support scientists on science research and data collection projects in their community.

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

Climate *(noun)* – the long-term average of conditions of weather at a place as exhibited by temperature, wind velocity, and precipitation.

Climate Change *(noun)* - a significant and persistent change in the average state of the climate. Climate change occurs in response to shifts in the Earth's environment, including regular changes in Earth's orbit about the sun, re-arrangement of continents through plate tectonic motions, or anthropogenic *(human caused)* changes to the atmosphere.

Collect *(verb)* – to bring together into one body or place.

Combined Sewer Overflow *(CSO) (noun)* – a mix of excess stormwater runoff and untreated wastewater that discharges from combined sewers to waterways. CSOs can occur during heavy rain or snowmelt when wastewater resource recovery facilities reach capacity.

Combined Sewer System *(noun)* – A sewer system designed to collect and carry wastewater and stormwater runoff together to wastewater resource recovery facilities.

Community *(noun)* – an interacting population of various kinds of individuals *(as species)* in a common location.

Condensation *(noun)* – water that collects as droplets on a cold surface when humid air is in contact with it. It is the conversion of a vapor or gas to a liquid.

Conduit *(noun)* – a closed channel or pipe used to convey water or another fluid.

Conservation *(noun)* – the careful preservation and protection of Earth's natural resources.

Convey *(verb)* – to move or transport in a continuous stream or mass.

Decomposition *(noun)* – the biological breakdown of organic wastes.

Dewater *(verb)* – to remove water from treated sludge in order to reduce the volume and create biosolids.

Digestion *(noun)* – the biological decomposition of organic matter; during the wastewater treatment process, sludge is digested by anaerobic microorganisms in a digestion tank.

Disinfection *(noun)* – the process of introducing a chemical or other added product to remove or inactivate disease-causing organisms.

Dissolved Oxygen *(noun)* – Oxygen, from the air, that dissolves into water which is essential for respiration for most aquatic life.

Drain *(noun, verb)* – an identified point to which liquid flows; to flow off gradually.

Drought *(noun)* – a prolonged period of dryness when there is very little or no precipitation.

Ecology *(noun)* – a branch of science concerned with the interrelationship of organisms and their environments.

Ecosystem *(noun)* – the interactions between all living and non-living things in a particular environment.

Eminent Domain *(noun)* – a right of a government to take private property for public use.

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.

Environmental Literacy *(noun)* – an understanding of and consideration for environmental issues and the actions needed to help protect and improve the environment.

Erode *(verb)* – to wear away by the actions of water, wind, or glacial ice.

Evaporation *(noun)* – the process of liquid water becoming water vapor *(gas)*.

Fatberg *(noun)* - A combination of the words "fat" and "iceberg" to describe the masses of congealed grease and personal hygiene products that can clog sewer pipes and damage wastewater treatment equipment.

Filter *(verb)* – to pass or move through in order to separate out or hold back elements.

Filtration *(noun)* – the act of capturing impurities from the water as it passes through a medium like sand and/or charcoal.

Flood *(noun)* – an overflow of water, caused by either a large body of water or heavy rainfall, onto normally dry land.

Forest *(noun)* – a dense growth of trees and underbrush covering a large area.

Freshwater *(noun)* – water containing less than 1,000 milligrams per liter of dissolved salt.

Gravity *(noun)* – an invisible force that pulls objects towards the center of the Earth.

Green Infrastructure *(noun)* – practices designed and constructed to manage stormwater runoff; the use of soils, stones, and plants to mimic the natural movement of water and absorb runoff before it can enter the sewer system or waterbodies.

Green Roof *(noun)* – a rooftop designed with a vegetative layer in specially designed soil which captures the precipitation that falls on the roof.

Grey Infrastructure *(noun)* – conventional drainage systems designed to manage and detain stormwater and reduce combined sewer overflow.

Groundwater *(noun)* – water located underground in porous spaces in soil and openings in rock.

H2O *(noun)* – the chemical formula for water; each water molecule consists of two hydrogen atoms attached to one oxygen atom.

Hydrologic Cycle *(noun)* – the cycle of water that evaporates from water bodies into the atmosphere, rises further into the atmosphere to form clouds through condensation, falls onto land as precipitation, and then returns to streams, rivers, and eventually the ocean as runoff *(also called the Water Cycle)*.

Hydrology *(noun)* – a science dealing with the properties, distribution, and circulation of water on and below the Earth's surface and in the atmosphere.

Hygiene *(noun)* – the conditions or practices *(as of cleanliness)* conducive to health.

Impervious/Impermeable *(adjective)* – preventing or slowing water from passing through.

Impervious Surface *(noun)* – a surface, or an area, which water cannot seep in or pass through.

Industrialization *(noun)* – the large-scale development of manufacturing, advanced technical enterprises, and other productive economic activity in an area, society, or country.

Infiltrate *(verb)* – to soak into; in the case of stormwater, to gradually soak into soil or a porous surface.

Infiltration *(noun)* – the action of passing into or through a substance by filtering or permeating its pore *(such as in soil)*.

Infrastructure *(noun)* - the underlying foundation or basic framework of public works which provide essential services for the operations of a city, state, country, or region.

Macroinvertebrate *(noun)* – an animal without a backbone that can be seen with the naked eye; mostly aquatic insects.

Methane Gas *(noun)* – a colorless, odorless gas that occurs in nature and as a product of certain human activities, such as wastewater treatment. It has the chemical formula CH4 and is a potent greenhouse gas.

Microorganism *(noun)* – an extremely small living thing that can only be seen with a microscope.

Mitigate *(verb)* – to cause a situation to become less harsh or severe.

Municipal Separate Storm Sewer System *(MS4) (noun)* – a sewer system that collects stormwater runoff from properties and streets, and discharges it directly to surrounding waterways.

Non-point Source Pollution *(noun)* – pollutants that originate from multiple sources over a relatively large area, rather than a single source.

Nutrients *(noun)* – substances such as carbon, hydrogen, oxygen, nitrogen, phosphorus, and sulfur, which are required to support living things.

Outfall *(noun)* – the outlet of a pipe that discharges into a body of water.

Permeable Pavement *(noun)* – pavement materials and techniques that allow stormwater to infiltrate and be absorbed into the ground.

Pervious/Permeable *(adjective)* – allowing water to pass through.

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

Pipe *(noun)* – a tube used to distribute and convey liquids such as water.

Point Source Pollution *(noun)* – any single source of pollutants dumped or discharged directly into a waterway from a pipe or outfall.

Pollutants/Pollution *(noun)* – harmful substances such as oils, chemicals, sediments, and trash that can contaminate or dirty water, air, and land.

Pollute *(verb)* – to contaminate water, air, or land with harmful substances *(pollutants)*.

Potable *(adjective)* – safe or suitable for drinking.

Precipitation *(noun)* – any water that falls from the sky as part of the water cycle, whether it be rain, snow, hail, or sleet.

Rain Barrel *(noun)* – a rainwater harvesting tool that catches stormwater and connects to the existing downspout of a roof.

Rain Garden *(noun)* – a planted area with engineered soil designed to collect and manage stormwater runoff from streets and sidewalks.

Regulation *(noun)* – a rule, order, or code issued by an executive authority or regulatory agency of a government.

Reservoir *(noun)* – a pond, lake, or basin, either natural or artificial, used to store water.

Resiliency *(noun)* – the ability to withstand or swiftly recover from changing conditions as a result of preparation and adaptation measures.

Riparian *(adjective)* – relating to, living or located on the bank of a natural waterway.

Saltwater *(noun)* - water naturally containing a significant amount of salt, more than 1,000 milligrams per liter of dissolved salt.

Sanitary Sewer *(noun)* – a sewer pipe intended to carry wastewater from homes, businesses, schools, and other facilities.

Separate Sewer System *(noun)* – a system consisting of sanitary sewers that carry wastewater to wastewater resource recovery facilities and storm sewers that convey stormwater runoff directly to nearby waterways.

Service Learning *(noun)* – activities that both support student learning goals and service or improve the community.

Sewage *(noun)* – used water mixed with solid waste that flows down the drains from homes, schools, and businesses. Also referred to as "wastewater."

Sewers *(noun)* – a system of underground pipes that collect and deliver wastewater to treatment facilities or receiving waterways.

Slope *(noun, verb)* – A surface of which one end is at a higher level than another; to slant up or down.

Sludge *(noun)* – the solids, such as food, feces, and paper fibers, in wastewater that are settled out and removed during the wastewater treatment process.

Stewardship *(noun)* – taking personal responsibility to help protect your environment.

Storm Sewer *(noun)* – a sewer pipe that carries only surface runoff, street wash, and snow melt from the land.

Stormwater Runoff *(noun)* – water from precipitation that lands on rooftops, parking lots, streets, sidewalks, and other impervious surfaces, and flows over the land instead of seeping into the ground.

Suspended Solids *(noun)* – solids that either float on the surface of, or are suspended in, wastewater.

Technology *(noun)* – a manner of accomplishing a task especially using technical processes, methods or knowledge.

Topography *(noun)* – the art or science of making maps that show the height, shape, or other features of the land in a particular area; the arrangement of the natural and artificial physical features of an area of land.

Transpiration *(noun)* – the passage of water vapor from a living body *(as of a plant)* through its membrane or pores.

Tributary *(noun)* – smaller waterway, such as a stream or canal that feeds into a larger body of water.

Turbidity *(noun)* – the measure of cloudiness in a liquid due to the suspension of solid particles.

Urbanization *(noun)* – the rapid growth of, and migration to, large cities.

Vegetation *(noun)* – plant life or total plant cover of an area.

Weather *(noun)* – the state of the atmosphere with respect to temperature, wind, humidity, precipitation, and cloudiness.

Wastewater *(noun)* - used water mixed with solid waste that flows down the drains from homes, schools, and businesses. Also referred to as "sewage."

Wastewater Resource Recovery Facility (WRRF) *(noun)* – a facility designed to treat wastewater and stormwater runoff before releasing clean water into a nearby waterway. These facilities recover energy, nutrients, clean water, and other resources from the treatment process.

Water *(noun)* – the liquid that descends from the clouds as rain or snow, forms streams, lakes, and seas. Water is a major component of all living matter. When pure it is odorless and tasteless; freezes at 32o F *(0o C)* and boils at 212o F *(100o C)*. It is the only substance that can naturally occur as a solid, liquid, and gas.

Water Cycle *(noun)* – the stages of water as it travels from the ocean to the atmosphere to the land and back again, through processes such as precipitation, evaporation, and condensation.

Water Quality *(noun)* – the biological, chemical, and physical conditions of a body of water; a measure of a waterway's ability to support aquatic life and beneficial uses.

Water Vapor *(noun)* – water in its gaseous state that leads to the formation of clouds and precipitation.

Watershed *(noun)* – an area of land that drains and collects water, by gravity, in rivers, lakes, streams, and underground.

Well *(noun)* – a hole that is dug in the ground to access freshwater, or groundwater.

Additional Resources

DEP EDUCATION PROGRAMS AND RESOURCES

Education Modules
These comprehensive modules feature lessons, activities, and resources to help students and educators explore topics related to New York City water, including Climate Change, Green Infrastructure, and the Sewer System. Each module is interdisciplinary and provides a wide range of educational opportunities. Many of the hands-on lessons and activities highlighted throughout this guide can be found in the modules.

NYC Water Virtual Tours
Continue exploring New York City's incredible water resources by using virtual tours of the NYC Watershed, Sewer System, Wastewater Treatment, and Harbor Water Quality. Featuring staff interviews, in the field footage, interactive maps, and historical images, these virtual tours will help you discover where our drinking water comes from, what happens after it's flushed down the drain, and how we can all help protect our waterways. A student worksheet accompanies each tour.

NYC's Water Story: From Mountain Top to Tap Map
Students can explore the map to discover the natural and human-made landscapes within upstate watersheds and New York City that relate to their study of water. They can learn more about the physical, cultural, and historical features of our water and wastewater systems, and examine how these components are all interconnected. This map comes with accompanying slides and a teacher's resource guide full of activity ideas.

Wastewater Treatment in NYC Education Brochure
This brochure is designed to help students understand the essential process that takes place at our facilities everyday, removing pollutants from wastewater, releasing clean water to local waterways, and recovering valuable resources from our waste.

Visitor Center at the Newtown Creek Wastewater Resource Recovery Facility
The Newtown Creek Wastewater Resource Recovery Facility in Greenpoint, Brooklyn, is the largest in New York City and the only facility that offers students an inside look at our water infrastructure! DEP offers free education programs (in-person or virtual) to learn more about New York City's water story, from drinking water supply and consumption to wastewater treatment and harbor water protection.

Trout in the Classroom
Students participate in a year-long study about trout, an important indicator species in freshwater ecosystems. By raising trout from eggs to fingerlings in a classroom aquarium, students learn about the trout life cycle, water quality monitoring, watershed streams and forests, and our water supply system. In the spring, students release their trout into streams within the New York City watersheds and explore their natural habitat by taking a hike, analyzing macroinvertebrates, and testing water quality.

Water Resources Art and Poetry Contest
This annual program for 2nd – 12th grade students in New York City and the East and West of Hudson Watersheds provides a fun opportunity to learn more about our shared water resources and express appreciation through paintings, collages, animation, performances, public service announcements, poetry, and more. The contest runs from January – March and concludes with an event in May to celebrate the contest winners, called Water Champions.

City that Drinks the Mountain Sky
Hosted by DEP and presented by the Arm-of-the-Sea Theater, City that Drinks the Mountain Sky is a show about the New York City water supply system told through mask and puppet theater. Audiences will see how forests act like kidneys, "meet" some of the engineers and laborers who built the reservoirs and aqueducts, and discover how our water supply system brought great changes to watershed communities and New York City. An accompanying study guide for educators is available.

Additional Locations and Organizations for Educational Excursions

The following are only some of the many water-related locations and organizations to connect with for educational excursions with your students. As highlighted throughout this guide, many of the organizations listed here provide classroom curricula, digital and print resources, field trips, and grant opportunities.

NEW YORK CITY:

American Museum of Natural History
Billion Oyster Project
Botanical Gardens (citywide)
Bronx Children's Museum
Bronx River Alliance
Brooklyn Bridge Park Conservancy
Brooklyn Grange Rooftop Farms, City Growers
Brooklyn Navy Yard Building 92
Cafeteria Culture
Center for Urban Pedagogy
Central Park Reservoir
Children's Museum of Manhattan
The Climate Museum
Climate & Urban Systems Partnership NYC
Collect Pond Park
Genovesi Environmental Study Center
Gowanus Canal Conservancy
GrowNYC
The High Bridge
Hudson River Park Trust
Jamaica Bay Wildlife Refuge
Museum of the City of New York
National Wildlife Federation
Newtown Creek Alliance, Kingsland Wildflowers
Newtown Creek Nature Walk
New York City Department of Education, Offices of Sustainability and STEM
New York City Department of Parks & Recreation, Urban Park Rangers
New York City Soil & Water Conservation District
New York Hall of Science
New-York Historical Society
New York Horticultural Society
New York State Department of Environmental Conservation
New York State Office of Parks, Recreation and Historic Preservation
NYC H2O
Poets House
Public Libraries (central branches)
Randall's Island Park Alliance
Queens Museum
Sim's Recycling Education Center
Solar One
South Street Seaport Museum
Staten Island Bluebelts
Trees NY
Trust for Public Land
Visitor Center at Newtown Creek

NEW YORK CITY WATERSHED:

Ashokan Center
Catskill Center for Conservation & Development
Catskill Fly Fishing Center and Museum
Catskill Interpretive Center
Catskill Water Discovery Center
Catskill Watershed Corporation
Center for the Urban River
Clearpool Model Forest and Education Center
Commemorative Reservoir Kiosks
Cross River Reservoir
Croton Gorge Park
Delaware County Historical Society
Friends of the Old Croton Aqueduct
Frost Valley Model Forest and YMCA Education Center
Gilboa Museum
Hilltop Hanover Farm & Environmental Center
Kensico Dam Plaza
Lennox Model Forest
Muscoot Farm
Old Croton Aqueduct State Historic Park
Ossining Visitor Center & Heritage Area
Siuslaw Model Forest
Taconic Outdoor Education Center
Teatown Lake Reservation
The Keeper's House
Time and the Valleys Museum
Ward Pound Ridge Reservation
Watershed Agricultural Council

New York State K-8 Science Learning Standards

DEP Lesson(s)	Standard*	Amplify Related Lesson**
Unit 1: Water in Our World		
Lesson 1: Water for Life	• K-LS1-1: Use observations to describe patterns of what plants and animals (including humans) need to survive • 5-ESS2-2: Describe and graph the amounts of salt water and fresh water in various reservoirs to provide evidence about the distribution of water on Earth • 5-LS1-1: Support an argument that plants get the materials they need for growth chiefly from air and water. • MS-LS2-3: Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem	• The Earth System 5.2.1: Investigating Water Drop Formation • Matter and Energy in Ecosystems 6.1.2: Investigating a Biodome • Earth's Changing Climate 6.1.3: Exploring Energy in the Earth System
Lesson 2: The Water Cycle	• 2-ESS2-3: Obtain information to identify where water is found on Earth and that it can be solid or liquid • MS-ESS2-4: Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity	• The Earth System 5.2.2: From Water Vapor to Liquid Water • The Earth System 5.2.6: Explaining How Raindrops Form • Weather Patterns 6.1.3: Investigating Condensation • Weather Patterns 6.1.4 Reading "What Are Clouds?" • Weather Patterns 6.1.5: Investigating Why Clouds Produce Rain • Weather Patterns 6.2.1: Air Parcels in the Troposphere • Weather Patterns 6.2.3: Simulating a Large Storm
Lesson 3: Landforms and Watersheds	• 2-ESS2-1: Compare multiple solutions designed to slow or prevent wind or water from changing the shape of the land • 2-ESS2-2: Develop a model to represent the shapes and kinds of land and bodies of water in an area • 4-ESS2-2: Analyze and interpret data from maps to describe patterns of Earth's features • MS-LS2-3: Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem	• Changing Landforms 2.3.4: Landform Change Over Time • Geology on Mars 8.1.2: Observing the Surfaces of Mars and Earth • Geology on Maris 8.2.2: Modeling a Geologic Process
Lesson 4: Trees, Plants, and Other Buffers	• K-ESS3-1: Use a model to represent the relationship between the needs of different plants or animals (including humans) and the places they live • 5-ESS2-1: Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact • MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect population	• Plant and Animal Relationships 2.3.5: Plant and Animal Interdependence • Matter and Energy in Ecosystems 6.1.2: Investigating a Biodome • Matter and Energy in Ecosystems 6.1.6: Examining Data from the Biodome
Lesson 5: Ecology of Waterways: Diverse and Abundant Communities	• 5-ESS2-1: Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact • MS-ESS2-4: Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity	• Ecosystem Restoration 5.1.2: Introducing Ecosystems • Matter and Energy in Ecosystems 6.1.6: Examining Data from the Biodome
Lesson 6: Life Aquatic: Microscopic Organisms and Macroscopic Invertebrates	• 3-LS4-3: Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all • 3-LS4-4: Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change • MS-LS2-5: Evaluate competing design solutions for maintaining biodiversity and ecosystem services	• Plant and Animal Relationships 2.3.4: Diagramming a System • Changing Landforms 2.3.3: Accumulation of Small Changes • Microbiome 7.1.3: Observing Microorganisms

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** Aligned with the Amplify Curriculum.

DEP Lesson(s)	Standard*	Amplify Related Lesson**
Unit 2: Drinking Water and You		
Lesson 1: My Daily Water Use Log	• K-LS1-1: Use observations to describe patterns of what plants and animals (including humans) need to survive • MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment	• The Earth System 5.2.5: Drinking Cleopatra's Tears • Matter and Energy in Ecosystems 6.1.2: Investigating a Biodome
Lesson 2: Water for New York City: Creating a Public Water Supply System	• 2-ESS2-3: Obtain information to identify where water is found on Earth and that it can be solid or liquid • 3-5-ETS1-1: Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost • MS-ESS2-4: Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity	• The Earth System 5.4.2: Investigating Rainfall Distribution • Earth's Changing Climate 6.2.6: Investigating Paths of Energy
Lesson 3: Technology and Innovation: Engineering New York City's Water Supply	• 3-5-ETS1-2: Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem • MS-ESS3-4: Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems • MS-ETS1-2: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem	• The Earth System 5.1.3: Explaining the East Ferris Water Shortage • Earth's Changing Climate 6.2.2: Reading "Past Climate Changes on Earth" • Earth's Changing Climate 6.2.3: Learning More About Past Climate Changes
Lesson 4: Clean Water and Public Health: Consider the Source	• K-ESS3-3: Communicate solutions that will reduce the impact of humans on the land, water, air, and/or other living things in the local environment • MS-ESS3-1: Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes	• The Earth System 5.2.7: Designing Freshwater Collection Systems • Earth's Changing Climate 6.2.6: Investigating Paths of Energy
Lesson 5: Drinking Water Treatment Explained	• K-ESS2-2: Construct an argument supported by evidence for how plants and animals (including humans) can change the environment to meet their needs • MS-ETS1-1: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions	• The Earth System 5.3.4: Iterating on Freshwater Collection Systems • Earth's Changing Climate 6.3.3: Explaining Possible Solutions
Lesson 6: Testing the Waters: Making it Safe	• 5-ESS3-1: Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment • MS-ETS1-3: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. • MS-ETS1-4: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved	• The Earth System 5.2.8: Engineering Clean Water • Phase Change 7.1.3: Investigating the Molecular Scale • Phase Change 7.1.6: Modeling the Molecular Scale
Lesson 7: Water for the Future: The Big Fix	• 4-ESS3-2: Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans • 5-ESS3-1: Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment • MS-LS2-5: Evaluate competing design solutions for maintaining biodiversity and ecosystem services	• The Earth System 5.5.6: Reflecting on Water Availability • The Earth System 5.1.2: Water Shortages, Water Solutions • Earth's Changing Climate 6.3.3: Explaining Possible Solutions

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DEP Lesson(s)	Standard*	Amplify Related Lesson**
Unit 3: Down the Drain: Out of Sight, Out of Mind		
Lesson 1: The Growth of the City: Population and Wastewater Systems	• K-ESS3-1: Use a model to represent the relationship between the needs of different plants or animals (including humans) and the places they live • MS-ESS3-4: Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems • MS-ETS1-4: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved	• Inheritance and Traits 3.3.4: The Role of The Environment • Matter and Energy in Ecosystems 6.1.2: Investigating a Biodome
Lesson 2: Industrial Revolution and Environmental Devolution	• 4-ESS3-2: Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans • MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment	• Ecosystem Restoration 5.3.2: Walk in the Woods • Matter and Energy in Ecosystems 6.1.6: Examining Data from the Biodome
Lesson 3: Under our Noses: Creating an Underground Infrastructure	• 3-5-ETS1-1: Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost • MS-ESS2-1: Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process • MS-ESS2-4: Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity	• The Earth System 5.2.7: Designing Freshwater Collection Systems • Harnessing Human Energy 6.1.4: "Energy Inventions" • Earth's Changing Climate Engineering Internship 7.1.5: Considering Feedback and Redesign
Lesson 4: Sinks, Pipes, and Systems: Making the Connection	• 3-5-ETS1-1: Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost • MS-ETS1-1: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions	• The Earth System 5.4.1: Investigating the Movement of Water • Earth's Changing Climate Engineering Internship 7.1.6: Choosing an Optimal Design
Lesson 5: Wastewater Treatment Explained	• K-ESS3-3: Communicate solutions that will reduce the impact of humans on the land, water, air, and/or other living things in the local environment • MS-LS2-3: Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem	• The Earth System 5.5.1: Investigating Wastewater Treatment • Earth's Changing Climate Engineering Internship 7.1.10: Applying Engineering Skills
Lesson 6: A Healthy Harbor: Keeping Pollution at Bay	• 5-ESS3-1: Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment • MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect population • MS-LS2-5: Evaluate competing design solutions for maintaining biodiversity and ecosystem services	• The Earth System 5.2.8: Engineering Clean Water • Earth's Changing Climate Engineering Internship 7.1.5: Considering Feedback and Redesign

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DEP Lesson(s)	Standard*	Amplify Related Lesson**
Unit 4: Land and Water: A Delicate Balance		
Lesson 1: The Rain Drain: Stop Trash in its Tracks	• K-ESS3-3: Communicate solutions that will reduce the impact of humans on the land, water, air, and/or other living things in the local environment • MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment • MS-ESS3-4: Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems	• The Earth System 5.2.8: Engineering Clean Water • The Earth System 5.1.3: Explaining the East Ferris Water Shortage • Earth's Changing Climate 6.3.2: Reading "Climate Change Solutions"
Lesson 2: What's the Point: Exploring Point Source and Non-point Source Pollution	• 5-LS2-1: Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment. • MS-LS2-3: Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem	• The Earth System 5.4.1: Investigating the Movement of Water Vapor • Earth's Changing Climate 6.2.6: Investigating Paths of Energy
Lesson 3: Plants and Pavement: Pervious and Impervious Surfaces	• 5-ESS2-1: Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact • MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect population • MS-LS2-5: Evaluate competing design solutions for maintaining biodiversity and ecosystem services	• Inheritance and Traits 3.3.4: The Role of The Environment • Geology on Maris 8.1.2: Observing the Surfaces of Mars and Earth
Lesson 4: What is Combined Sewer Overflow?	• 3-ESS3-1: Make a claim about the merit of a design solution that reduces the impacts of a weather-related hazard • MS-ESS2-4: Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity	• Weather and Climate 3.4.3: Preparing for Natural Hazards • Phase Change 7.1.4: Weird Water Events
Lesson 5: The Clean Water Act: A Policy Movement	• 4-ESS3-2: Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans • 5-ESS3-1: Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment • MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment • MS-ETS1-2: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem	• The Earth System 5.3.4: Iterating on Freshwater Collection Systems • Earth's Changing Climate Engineering Internship 7.1.1: Introducing the Engineering Internship • Earth's Changing Climate Engineering Internship 7.1.7: Composing Proposal Outlines • Earth's Changing Climate Engineering Internship 7.1.8: Writing Design Decisions

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DEP Lesson(s)	Standard*	Amplify Related Lesson**
Unit 5: Plan for the Future: Playing a Part		
Lesson 1: Green Infrastructure: Following Nature's Lead	• K-ESS3-3: Communicate solutions that will reduce the impact of humans on the land, water, air, and/or other living things in the local environment • 5-ESS2-1: Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact • MS-LS2-3: Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem • MS-ESS3-2: Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects	• Energy Conversions 4.1.2: Introducing Systems • Energy Conversions 4.1.3: Exploring Systems • Harnessing Human Energy 6.1.4: "Energy Inventions"
Lesson 2: Calculating Rainwater	• 3-ESS3-1: Make a claim about the merit of a design solution that reduces the impacts of a weather-related hazard • 4-ESS3-2: Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans • MS-ESS2-4: Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity • MS-ESS3-4: Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems	• Sunlight and Weather K.5.4: Investigating Flooding Solutions • Environments and Survival 3.3.1: Changing Environment • Weather Patterns 6.1.6: Explaining Surface Water and Rain in Galetown
Lesson 3: Restoring Urban Waterways	• 2-ESS1-1: Use information from several sources to provide evidence that Earth events can occur quickly or slowly • 5-ESS3-1: Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment • MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect population • MS-LS2-5: Evaluate competing design solutions for maintaining biodiversity and protecting ecosystem stability	• Plant and Animal Relationships 2.3.5: Plant and Animal Interdependence • Matter and Energy in Ecosystems 6.1.6: Examining Data from the Biodome
Lesson 4: A "Model" Schoolyard	• K-2-ETS1-1: Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool • 3-5-ETS1-2: Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem • MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment • MS-ETS1-2: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem	• Environments and Survival 3.2.8: Sharing and Revising Designs • Environments and Survival 3.4.5: Presenting Design Arguments • Earth's Changing Climate Engineering Internship 7.1.6: Choosing an Optimal Design • Earth's Changing Climate Engineering Internship 7.1.7: Composing Proposal Outlines
Lesson 5: Climate Change: Engaging in Action	• K-ESS2-1: Use and share observations of local weather conditions to describe patterns over time • 3-ESS2-1: Represent data in tables and graphical displays to describe typical weather conditions expected during a particular season • MS-ESS2-6: Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climate • MS-ESS3-5: Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century	• Sunlight and Weather K.1.1: What is the Weather Like Today • Weather and Climate 3.3.2: Discovering Climate Through Data • Weather and Climate 3.4.1: Regional Climate Patterns • Weather and Climate 3.3.5: Comparing Climates • Weather and Climate 3.3.6: Evaluating Evidence About Climate • Earth's Changing Climate Engineering Internship 7.1.1: Introducing the Engineering Internship • Earth's Changing Climate Engineering Internship 7.1.10: Applying Engineering Skills

* Aligned with the [New York State P-12 Science Learning Standards.]

** Aligned with the [Amplify Curriculum.]

DEP Lesson(s)	Standard*	Amplify Related Lesson**
Unit 6: Environmental Stewardship		
Stewardship Project Ideas	• K-2-ETS1-1: Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool • K-2-ETS1-2: Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem • K-2-ETS1-3: Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs • 3-5-ETS1-1: Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost • 3-5-ETS1-2: Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem • MS-ETS1-1: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions • MS-ETS1-2: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem • MS-ETS1-3: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. • MS-ETS1-4: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved	• Environments and Survival 3.3.2: Environment News • Weather and Climate 3.1.1: Pre-Unit Assessment • Earth's Changing Climate Engineering Internship 7.1.9: Completing the Proposal • Earth's Changing Climate Engineering Internship 7.1.10: Applying Engineering Skills

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** Aligned with the Amplify Curriculum.

NYC Environmental Protection

FAIRMOUNT WATER WORKS

PHILADELPHIA WATER