The New York City Envirothon

Science Stations Resource Packet

Third Edition
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New York City Soil and Water Conservation District

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NYC Envirothon

Aquatics, Current Issue, Forestry, Soil Science & Wildlife

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Introduction

Welcome to the *Envirothon Resource Book*. This book was designed to provide a starting point for student teams, by bringing together Envirothon information in a cohesive form.

Inside you will find sections containing information on all four science stations. At the beginning of each section there is a list of National Envirothon objectives, which were set forth by the current National Envirothon Committee. Basic information on a career in each particular field of study is also listed at the beginning of each section. Career information will not be tested and is purely for student enrichment. What follows is the main body of information. The resource information contained within each section is relatively basic and students are encouraged to further explore the suggested resources in order to become more familiar with the material.

The appendices contain information on select vocabulary terms, sample dichotomous keys, as well as sample questions. These additional resources will aid in preparation.

The 2006 New York City Envirothon will be held on Friday, April 7th at Inwood Hill Park in north Manhattan. The NYSWCD will also offer Envirothon training sessions in late February and early March of 2006. Look for announcements over email and within the mail. If you require more copies of the *Envirothon Resource Book*, please print them from the NYC Envirothon website: www.nycswcd.net/envirothon.cfm.

If you have any comments or questions about this booklet, please feel free to contact me by phone 212-431-9676 x391 or by email at anne@nycswcd.net. Thank you and good luck!

Sincerely,

Anne Carpenter
Education & Policy Coordinator, NYCSWCD

What is the Envirothon?

The Envirothon is a national environmental science competition for high school students (Grades 9-12). Winning teams, each representing a single high school, progressing from the county or regional level to state and national levels. Envirothons are organized by local Soil and Water Conservation Districts in partnership with school teachers. Teams include 5 students and one alternate.

The Envirothon began in Pennsylvania in 1979. New York State held its first Envirothon in 1990 and New York City held its first Envirothon in 1996. The State Envirothon is sponsored by the NYS Conservation Districts Employees' Association.

The New York City Soil and Water Conservation District sponsors the New York City Envirothon in partnership with a host institution, universities, government and non-profit partners, and high schools. Funding for the past several years has been provided by Con Edison. The NYC Envirothon 2005 was held in partnership with the Alley Pond Environmental Center in Queens, NY with assistance from the Metro Forest Council, New York City Department of Environmental Protection, New York City Department of Parks and Recreation and the USDA–Natural Resources Conservation Service.

The Envirothon competition involves five subject categories on which teams are tested: Aquatics, Forestry, Soils, Wildlife, and a Current Event category that is linked to the National Current Issue for the competing year. For each category, the test includes 25 multiple choice questions worth four points each (plus a tie breaking question). At least half the questions involve the use of equipment, maps or audio/visual identification. Students also participate in the Current Issue Role Play station and the Take Action station which was introduced in 2004. While participating in the Take Action station, students have the opportunity to explore ways in which they can take action on current environmental issues (or natural resource issues) that might concern them with the help of an expert Stationmaster. This station is intended as an information station and students will not be scored.

Aquatic Ecology

NATIONAL ENVIROTHON OBJECTIVES:

- Identify the processes and phases for each part of the water cycle.
- Describe the chemical and physical properties of water and their relation to fresh and saltwater systems.
- Analyze the interaction of competing uses of water for water supply, hydropower, navigation, wildlife, recreation, waste assimilation, irrigation, industry, and others.
- Discuss the methods of conserving water and reducing point and non-point source pollution.
- Identify common aquatic organisms through the use of a key.
- Delineate the watershed boundary for a small water body.
- Explain the different types of aquifers and how each type relates to water quantity and quality.
- Briefly describe the benefits of wetlands, including both function and value.
- Describe the benefits of riparian areas, including both function and value.
- Describe the changes to the aquatic ecosystem based on alteration to the aquatic habitat.
- Know methods used to assess and manage aquatic environments and be able to utilize water quality information to assess the general water quality of a specific body of water. This includes sampling techniques and water quality parameters used to measure point and non-point source pollution.
- Be familiar with major methods and laws used to protect water quality and utilize the information to make management decisions to improve the quality of water in a given situation.

BUT WHAT DO AQUATIC ECOLOGISTS DO?

Water nourishes life. It is the single most important resource on the earth, and without it humans could not survive. Aquatic Ecologists study the earth's water systems; they monitor, research and analyze the relationship of aquatic organisms to one another and to their watery habitat. Aquatic Ecologists also observe microscopic life, chemical reactions, human impact, geologic activity and native as well as non-native species within a specific aquatic environment. Through these observations they hope to garner an understanding of how aquatic ecosystems interact as a whole. They use the information gained from monitoring programs to determine future conservation and management strategies for aquatic ecosystems.

To become an Aquatic Ecologist one must first attend a four year bachelor's degree program at an accredited university. Graduates with majors in Environmental Science are the most prevalent in the field of Aquatic Ecology, but Aquatic Ecologists can also come from a varied scientific background including chemistry, geology, biology, climatology, statistics and even economics. In today's economy, a postgraduate degree in ecology or science is becoming a requirement for work in Aquatic Ecology research.

Aquatic Ecologists work many hours out doors gathering data and just as many hours in the lab or behind a computer analyzing that field data. They often work with mathematical models analyzing and interpreting human actions and their effects on aquatic ecosystems. An Aquatic Ecologist must have strong verbal and writing skills in order to accomplish intensive research and present their findings in simple, concise and well-written oral reports and journal articles.

An Aquatic Ecologist may work with the government, a non-profit, or even in the corporate sector. They often work for government agencies such as the US Environmental Protection Agency, US Fish and Wildlife Service, and state environmental agencies. Aquatic Ecologists can also become teachers, professors or researchers for private companies. A recent graduate can expect to make between $30,000 and $40,000 per year, or more depending on experience and the extent of their education.

Water is arguably the most valuable substance on the planet, and is the common name applied to the liquid state of the hydrogen oxygen compound H_2O.

- Water covers 70% of the surface of the Earth forming swamps, lakes, rivers, and oceans.
- Pure water has a blue tint, which may be detected only in layers of considerable depth.
- It has no taste or odor.
- Water molecules are strongly attracted to one another through their two hydrogen atoms. At the surface this attraction produces a tight film over the water (surface tension). A number of organisms live both on the upper and lower sides of this film.
- Density of water is greatest at 39.2° Fahrenheit (4° Celsius). It becomes less important as water warms and, more important, as it cools to freezing at 32° Fahrenheit (0° Celsius), and becomes ice.
- Ice is a poor heat conductor. Therefore, ice sheets on ponds, lakes and rivers trap heat in the water below. For this reason, only very shallow water bodies ever freeze solid.

The Hudson River rarely freezes as it flows by the New York City area because of its constant movement, tidal changes, and varying levels of salinity.

Water is the only substance that occurs in all three states of matter at ordinary temperatures : solid, liquid, and gas. In its solid state, water is ice, and can be found as glaciers, snow, hail, and frost, as well as ice crystals in clouds and across liquid water surfaces. It occurs in the liquid state as rain, clouds formed of water droplets, and on vegetation as dew. In addition, some liquid water occurs as moisture in the upper soil profile. Under the influence of gravity, water may accumulate in the openings of hard rock beneath the surface of the earth. This groundwater sustains wells, springs and some streams. As a gas, or water vapor, it occurs as fog, steam, clouds, and humidity.
The transparency of water permits enough light to penetrate for plants to carry on photosynthesis. The depths to which light can penetrate decreases as water contains more suspended materials and becomes turbid (or less clear). Less light means fewer plants can grow, thus attracting less wildlife.

The Universal Solvent:

What Water Contains

Water in an aquatic environment is essentially a solution. It will dissolve more substances than any other liquid, and for this reason it is called "the universal solvent". Oxygen, carbon dioxide, and nitrogen from the atmosphere are all dissolved in water. Oxygen is also present as a product of photosynthesis, and both plants and animals release carbon dioxide through respiration .

Oxygen and carbon dioxide are passed back and forth between plants, other living organisms and their environment. The proportion of these gases in the atmosphere is generally constant: oxygen, 21%; carbon dioxide, 0.03%. In rivers and coastal waters, the proportion may vary greatly, even from night to day.

Oxygen

Oxygen, which is necessary for the survival of all plants and animals, is quite soluble in water. The amount dissolved in fresh water however, is much lower than the atmosphere. Oxygen from the air is slowly absorbed by waterbodies and the process is accelerated when wind and waves disturb the water surface (creating a higher level of dissolved oxygen, or DO readings, during water testing).

The cooler the water, the more dissolved oxygen it will hold. During the day, when sunlight penetrates the water, plants give off oxygen as a byproduct of photosynthesis. This oxygen is produced more rapidly than it is used in respiration by aquatic organisms, thus a reserve of oxygen builds up. In darkness, when photosynthesis stops, aquatic organisms use this oxygen. For this reason the oxygen content in ponds and shallow water varies greatly in a 24-hour period.

Carbon Dioxide

Carbon dioxide, which is more soluble in water than oxygen, comes both from the decay of organic material and from the respiration of aquatic organisms. It also comes from the atmosphere, either directly or with rain. Near the bottom of deep water the amount of dissolved carbon dioxide (which plants use in photosynthesis) may be quite high. However, the lack of light at great depths inhibits the growth of plants and therefore many other living organisms.

Carbon dioxide is also important in determining the water's pH—its degree of acidity or alkalinity. It combines with water to form weak carbonic acid, which can react with limestone or dissolved lime (if present) to form carbonates and bicarbonates. These compounds are indirect sources of carbon and serve also as "buffers" that regulate pH. The pH of water often determines what animals and plants live there. For example, mollusks with limy shells cannot live in acidic waters.

Fifty to ninety percent of the weight of living organisms is water. The basic material of living cells, known as protoplasm, consists of a solution of water, fats, carbohydrates, proteins, salts and similar chemicals. Water acts as a solvent, transporting, combining, and chemically breaking down substances. Both blood in animals and sap in plants consist largely of water and serve to transport food and remove waste material. Water also plays a key role in the metabolic breakdown of essential molecules such as proteins and carbohydrates. This process, called hydrolysis, goes on continually in living cells.

The Water Cycle

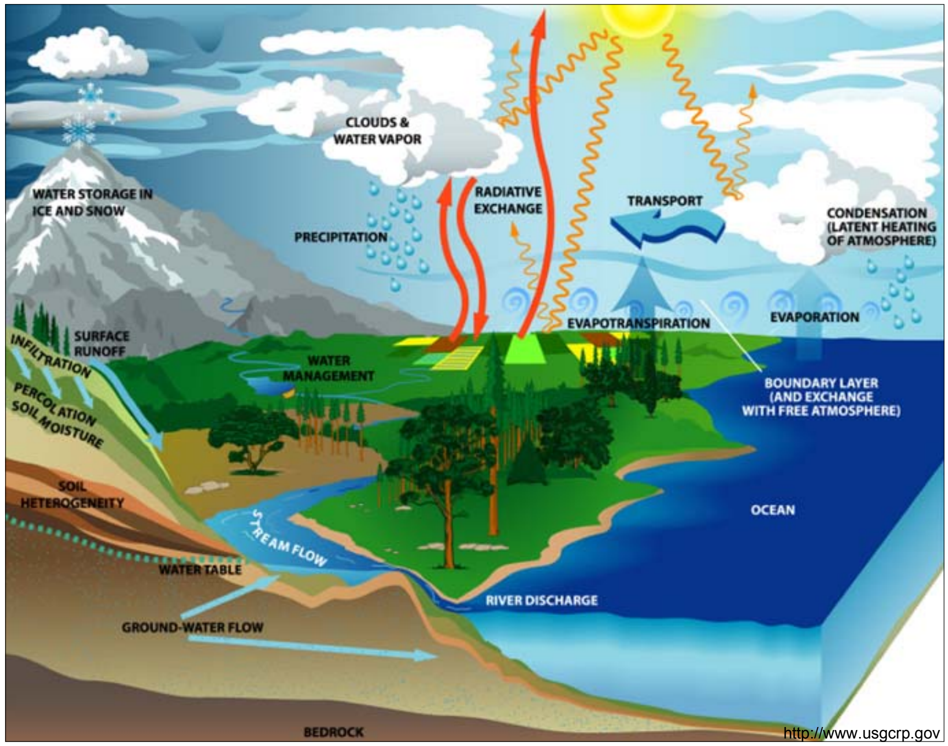
Water has cycled and will continue to cycle through the natural processes of plants, living organisms and the earth itself. This continuous movement of water between the Earth and the atmosphere is known as the hydrological cycle. Under several influences, predominantly heat, water evaporates from the surface of the earth and transpires from living organisms. This water vapor circulates through the atmosphere and is precipitated in the form of rain or snow.

During cycling water can get trapped for long periods in glaciers, clouds or aquifers (underground waterbodies). Because of its capacity to dissolve numerous substances in large amounts, pure water rarely occurs in nature. During condensation and precipitation rain or snow absorbs varying amounts of carbon dioxide and other gases as well as traces of organic and/or inorganic material from the atmosphere. Precipitation may also carry sulfur dioxide (SO^2), a product of fossil fuel combustion, which is better known as acid rain.

Upon striking the land, water follows two paths. It may flow directly into streams and rivers (and eventually into oceans or landlocked waterbodies) while the remainder filters into the soil. A part of the filtered water becomes soil moisture. This may be evaporated directly or may be taken up by the roots of vegetation and later transpired from the leaves. The portion of water that overcomes these forces percolates downward, accumulating as ground water. The surface of groundwater is known as the water table. Under natural conditions, the water table rises intermittently in response to replenishment and lowers as a result of drainage to natural outlets such as springs. In urban areas the process is drastically interrupted by streets, sidewalks, buildings and sewer systems. These can divert, delay and even pollute rain run off, creating special problems for local waterbodies.

Water is a precious, limited resource and only a small percentage of the earth's drinkable (potable) water available for people. The water that we drink has cycled through the systems of the earth many times. Natural filtering processes have traditionally keep water clean and safe to drink. Unfortunately, urban sprawl and the human industrial footprint have tampered with these natural processes by paving over watersheds, increasing urban runoff, and releasing chemicals and other pollutants into our groundwater. Today, most water that runs through our urban taps has been manually treated and is constantly monitored for pathogens and other pollutants, to ensure that it is safe for human consumption.

The Water Cycle



The majority of water currently on the planet was present long ago and will continue to be here for many years to come, long after all of us are gone. The earth has a limited amount of water, which goes through a number of steps to move through the water cycle.

There are six main processes of the water cycle:

Evaporation happens when the water is heated up (usually by solar energy) to form water vapor or steam. The vapor or steam then rises into the atmosphere.

Transpiration happens when plants loose water through their leaves. This turns into vapor, then rises into the atmosphere.

Condensation happens when water vapor is cooled and then forms into droplets. Clouds are condensed water.

Precipitation is the consequence of condensation. When clouds become too condensed and too heavy, the water falls to earth as rain, sleet or snow.

Collection is a loose term referring to water in streams, rivers, ice caps and run off. It is the consequence of precipitation.

Infiltration is the percolation of water down to the groundwater.

In the natural water cycle, precipitation occurs in the form of rain, snow, sleet, etc. When rain hits the ground or when snow melts, the water runs downhill to streams (runoff) or is absorbed into the ground (infiltration). Streams then run into rivers and the rivers into oceans. Water from the surface of these waterbodies evaporates back into the atmosphere. Some of the water in soil is taken up by plants while some of that water transpires back into the atmosphere. Water which transpires or evaporates forms clouds from which precipitation falls.

The structure of the urban environment can significantly change the water cycle. All water cycle processes still take place but in different proportions. In the urban environment, there are not many permeable surfaces and thus infiltration is severely reduced. Much of the water that would normally percolate into the ground instead runs off into storm drains. When rain events are too large, the combined sewers of our city overflow into receiving waterbodies.

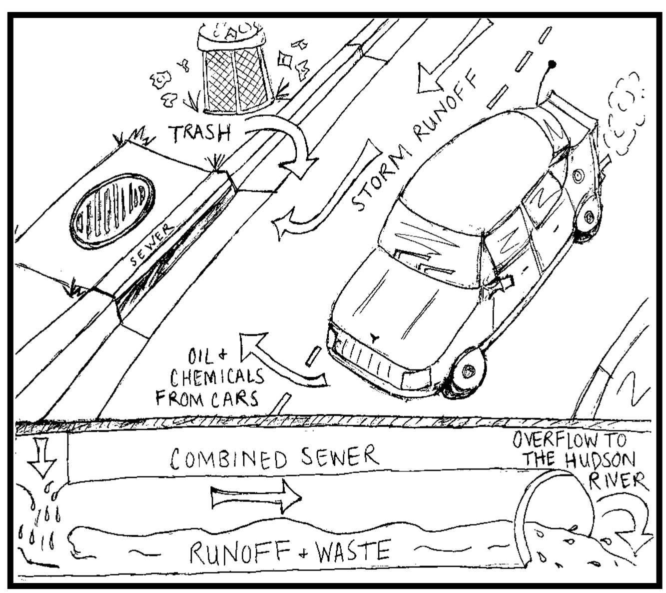


Figure 1.2: The Urban Water Cycle ©Anne Carpenter

New York City's Water Supply
In the 1600's when the Dutch founded New York drinking water came from ponds, springs and private wells within the city. The main water source was the Kalch-Hook or Collect Pond, a spring-fed pond near Franklin and Pearl Streets in lower Manhattan. As population in the city began to increase, the available supply of clean water decreased.

In 1800 the Manhattan Company (now known as the Chase Manhattan Bank) was given full rights to supply all water to New York City. The Company sank wells into the Collect pond and pumped water into a reservoir on Chambers street. The water was distributed to the city through wooden pipes. In 1830 the wooden pipes were changed to 12-inch iron cast pipes to protect them from destruction by fire. As population continued to increase the water supply became polluted and insufficient to meet the City's demands.

By the late 1820's the City decided to impound water from the Croton River (Westchester County) and build a an aqueduct to carry water from the subsequent reservoir to the City. The system known as the Old Croton Aqueduct began service in 1842 and had a capacity of 90 million gallons of water a day. The water traveled from the Croton River reservoir to reservoirs in Central Park (now the Great Lawn) and 42nd street (now the New York Public Library) which were both discontinued in 1925 and 1890 respectively. In 1873 and 1878, new reservoirs were constructed to increase supply and in 1883 a second aqueduct, the New Croton Aqueduct, was built from the Croton River.

As the city continued to grow, the installation of sewers, flush toilet and household faucets led to more water use and in turn more waste. At the turn of the 19th Century the city decided to develop the Catskill region as a site for an additional reservoir. In 1905 the Board of Water Supply was created by the state and the new entity facilitated the impounded of water from the Esopus Creek, one of four Catskill watersheds, and constructed the Ashokan Reservoir, Catskill Aqueduct, and Schoharie Reservoir.

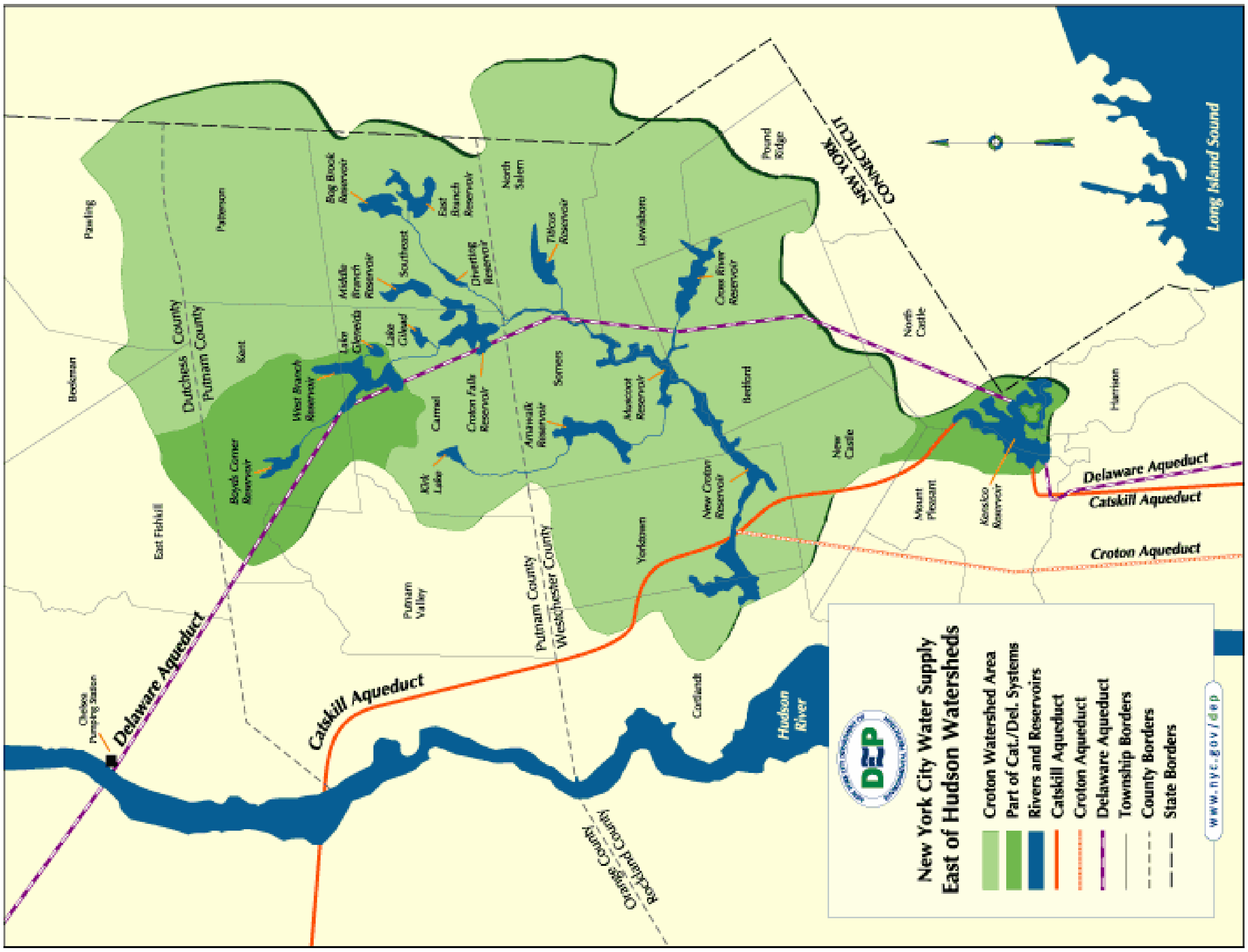
In 1927, the Board of Water introduced plans to develop the upper portion of the Delaware River and the Rondout watershed for the City's water supply. Construction was by legal action brought on by New Jersey in the Supreme Court of the United States, which aimed to stop New York from using the waters of any part of the Delaware River. In 1931, the Supreme Court upheld the City's right to augment its water supply from the Delaware River and to continue its development of the Delaware water system. The Delaware water system began service in stages: the Rondout Reservoir, 1950; the Neversink Reservoir, 1954; the Pepacton Reservoir, 1950; and the Cannonsville Reservoir, 1964.

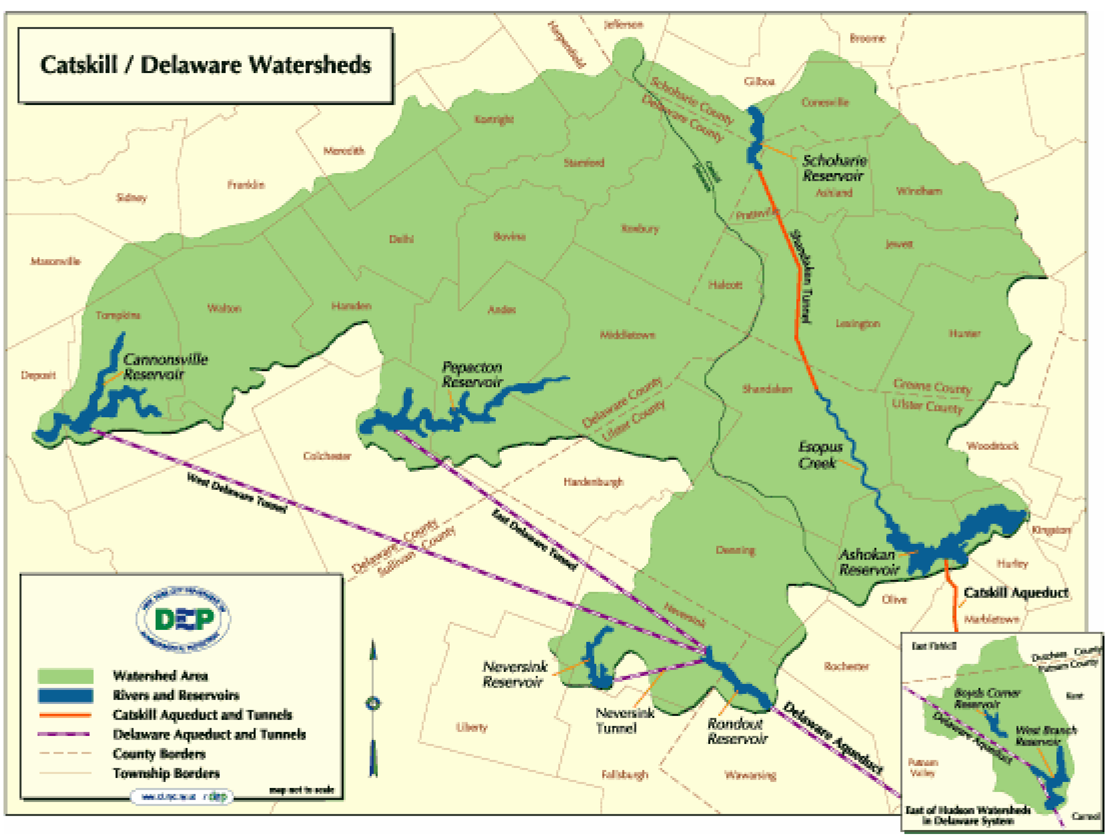
New York City's water supply system (Croton, Catskill, and Delaware) covers an area of about 2,000 square miles. The reservoirs combined have a holding capacity of 587 billion gallons of water. The Croton System has 12 reservoirs and 3 controlled lakes, the Catskill system has 2 reservoirs and the Delaware system has 4 reservoirs. The Croton, Catskill, and Delaware systems supply, respectively 10, 40, and 50 percent of the city's water. The system was built with several interconnections which allow for increased flexibility through the exchange of water from one reservoir/aqueduct to another. This is especially important in localized droughts when one watershed can take advantage of water in another.

Approximately 97% of New York City's water supply reaches homes through gravity and only 3% is regularly pumped. The system provides approximately 1.2 billion gallons of safe drinking water daily to over 8 million residents of New York City and approximately one million people in Westchester, Putnam, Ulster, and Orange counties.

The NYC Water Supply & Open Space Preservation
Open spaces such as parks, farmlands, and forest lands provide natural water filtration to which ensure the supply of clean drinking water. Unplanned development and urban sprawl reduces the percentage of open space in our region and replaces swathes of permeable surfaces with

New York City's Watersheds

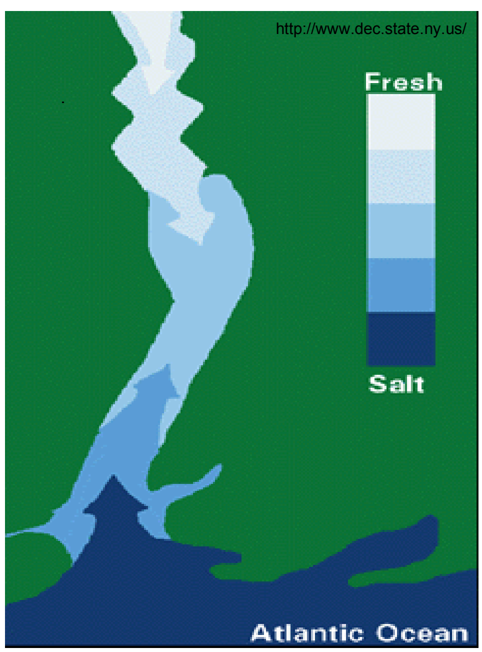




impermeable roads, sidewalks and other types of pavement. These impermeable surfaces prevent water from filtering naturally into the soil and create runoff, which often contains toxic chemicals and excess nutrients (such as phosphorus and nitrogen) picked up as it flows along streets and through suburban yards. This runoff, known as nonpoint source pollution is the second most common source of water pollution for lakes and estuaries nationwide and the third most common source for rivers. In order to preserve the quality of our water supply and water resources, our open spaces must be protected to prevent the proliferation of nonpoint source pollution and to insure that our water supply can be naturally filtered. Open space protection is especially important in the Croton, Catskill and Delaware watersheds. Once the areas of open space are gone in these areas, the integrity of the water supply becomes compromised, thus introducing the need for costly industrial water filtration.

The quality of the water supply in the Croton watershed has become a major issue among city officials and environmentalists over the past few decades as the area has increasingly developed. Currently, the Croton water supply meets all health standards but with continued development in the region it is questionable whether standards will be met in the future.

Construction of a filtration plant for the watershed is currently underway and will be built primarily underground at Mosholu Golf Course in the Bronx's Van Cortlandt Park. Many environmentalists fear that once the plant is built public concern for open space protection in the watershed will decrease because it will be perceived as no longer necessary. In order to reduce the need for the construction of another filtration plant, open spaces must be preserved for to ensure a safe, reliable and sufficient water supply for our region.



Salinity Variations in an Estuary

The Hudson River Estuary

The Hudson River is an estuary, a unique and extremely productive aquatic environment. Estuaries are shoreline ecosystems located where rivers empty into the sea and are characterized by a mixture of freshwater and saltwater. Estuarine environments include marshes, bays, inlets, sounds, mudflats and other smaller environments found in areas where fresh and salt water mix. They support a high density and diversity of both terrestrial and aquatic plants and organisms. Estuaries create more organic matter than other ecosystems of equivalent sizes and are critical habitat for marine mammals, reptiles, fish, crustaceans and migratory birds.

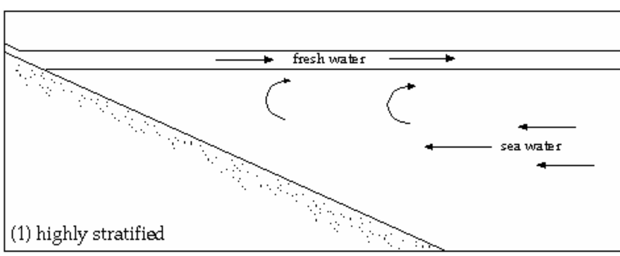
Tidal forces are necessary to maintain a dynamic relationship between the salt and fresh waters. Estuaries are typically found at the tidal mouth of rivers and estuaries are often characterized by sedimentation of silt which usually comes mainly from the sea. Estuaries are more likely to occur on submerged coasts, where the sea level has risen in relation to the land. Generally these only become estuarine environments if there is a significant river flowing into the sea. The Hudson (also known as a drowned river) was formed in this way when rising sea levels caused by the retreat of the Wisconsin glacier (during the most recent ice age) resulted in a marine incursion which drowned the coastal plain and brought salt water well above the river's mouth.

At times of low tide (twice a day) in the river, fresh water currents flow south to the New York/New Jersey Harbor while during high tide water flows in from the New York Bight (the large gulf between the coasts of New Jersey and Long Island) forcing currents north towards Troy. The Hudson's estuarine environment stretches 153 miles and its original name Muh-he-kun-ne-tuk, the Mahican name for the river meaning "the river that flows that both ways" describes its strong tidal influences.

The official source of the Hudson is *Lake Tear of the Clouds* in the Adirondack Mountains. The fresh water in the estuary derives from this upriver source and additional land drainage and tends to float over the denser sea water, but tidal mixing can reduce or sometimes even obliterate this stratification.

Generally the stratification in an estuary can be categorized as highly stratified, moderately stratified, or vertically homogeneous depending on the extent of fresh water flow, friction and tidal mixing.

In a highly stratified estuary, fresh water flows over a deeper layer of dense sea level and only occurs in estuary where river flow is stronger than tidal forces.



(1) highly stratified

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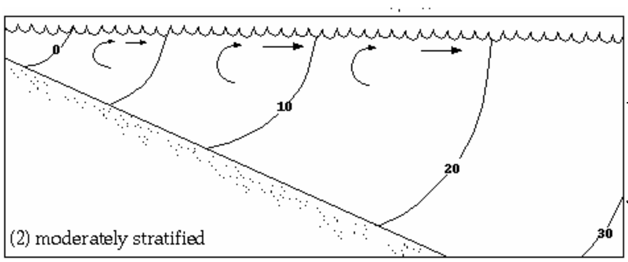
In a moderately stratified estuary moderate tidal motion causes mixing occurs at all depths. Vertical mixing causes the salinity of both upper and lower layers to increase seaward, but at any point the salinity of the deeper layer is greater than the surface salinity.



(2) moderately stratified

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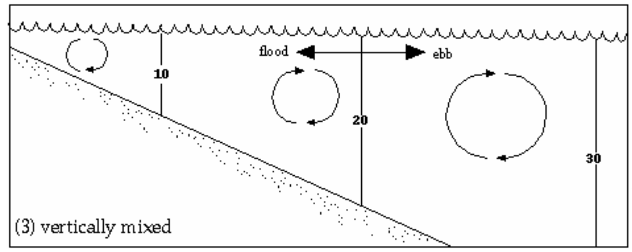
In a vertically homogenous estuary, vigorous tidal mixing homogenizes the vertical salinity gradient. The salinity in the estuary, however, can change rapidly with the state of the tide. At low tide, the salinity is dominated by the fresh downstream river flow, whereas at high tide the inflow of sea water dominates.



(3) vertically mixed

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Moderately stratified and vertically mixed estuaries create brackish water conditions (water which is a mix of salty and fresh).

Salinity itself, is measured in grams of dissolved salts per 1000 g of sea water. It is expressed as parts per thousand (ppt) and in the open ocean can be as high as 33 to 40 ppt.

The Hudson River estuary can be divided into 4 salinity zones: polyhaline (18.5-30 ppt), mesohaline (5-18 ppt), oligohaline (0.3-5 ppt), and limnetic (<0.3 ppt). Location of these zones can vary seasonally as well as daily depending on tidal and fresh water inputs. During average fresh water flow, salt water intrusion reaches West Point which is about 50 miles upstream from the Battery. During conditions of high fresh water runoff (usually in the spring), salt water intrusion can be pushed as far south as 15 miles off the Battery.

The Hudson River estuary is generally well mixed during low fresh water flow conditions. Only a 10% increase in salinity is usually found from the top to the bottom (during high fresh water input, vertical salinity differences of 20% are observed). A sharp salinity gradient occurs 25 miles north (upstream) of the Battery indicating distinct fresh and saline layers, but this gradient disappears approximately 41 miles upriver as the channel deepens (these channel irregularities create water turbulence and promote vertical mixing). Average temperatures within the estuary generally follow mean air temperature and temperatures range from 0°C in January to a maximum of 27°C in July.

The National Estuary Program
Section 320 of the Clean Water Act directs the Environmental Protection Agency to develop plans which facilitate attainment or the maintenance of water quality in the nation's estuaries and the National Estuary Program (administered by EPA) was established by Congress in 1987 to perform this function. Estuaries deemed an "Estuary of National Significance" are managed for protection of public water supplies, the protection and propagation of a balanced, indigenous population of shellfish, fish and wildlife, the quality and availability of recreational activities in and on water and the control of point and nonpoint sources of pollution. In several cases, more than one State is participating in a single National Estuary Program. Each program must create a Comprehensive Conservation and Management Plan (CCMP) to meet the goals of Section 320 of the CWA.

Over the past few decades, the Hudson River Estuary has become the focus of many local environmental, governmental and educational organizations both for its unique productivity as well as its level of pollution from the surrounding density of population. In 1988, the National Estuary Program deemed the New York/New Jersey Harbor an "Estuary of National Significance" and identified it as an area in need of water quality improvement and maintenance. Currently, the Hudson River has programs targeted at improving the estuary working exists side by side. The NY/NJ Harbor Estuary Program (HEP) was initiated by the National Estuary Program and the Harbor River Estuary Program (HRE) run by the New York State Department of Environmental Conservation.

Each of the programs focus on their respective estuarine environments but deal with many of the same local issues such as invasive species and toxicity levels (mainly from sewage and non-point source pollution). Contaminants and changes in water quality upstream affect all organisms downstream including the area in the New York Bight. The bight is an area of ocean that extends about 100 miles offshore south from Cape May, NJ and north to Montauk, Long Island.

The goals of HEP are to "protect, conserve, and restore the estuary" and the program has produced a CCMP to guide efforts in meeting these goals. HEP has working groups which focus on different aspects of estuary's conservation including toxics, nutrients, local habitat, citizen involvement and policy. The groups publish reports, fact sheets and informational resources on the condition of the estuary and the work being done on it. In addition, the program supports teachers, educators and stewards with grants for programs which benefit the estuary and its surrounding communities.

The goals of HRE are similar to HEP and the program works (further upriver) to "conserve and restore the Hudson's extraordinary natural heritage, scenery, and mystique." Means of achieving these objectives are outlined in the goals and targets of the Estuary Program's Action Agenda, which was first released in May 1996 by Governor George Pataki and is updated approximately every four years.

Combined Sewer Overflows (CSOs)
Combined Sewers were created to transport sewage and storm water in the same pipe to a sewage treatment plant. After heavy rainfall or snowmelt events, the volume of wastewater is often more than the sewer system or treatment plant can withstand. During these periods of high flow the combined sewers overflow directly into rivers, lakes and coastal areas. The wastewater which is discharged from the combined sewers is not only storm water but also untreated sewage. In addition to the fecal coliform, enterococus bacteria and other disease-causing pathogens found in human and animal waste, the sewage and stormwater can contain industrial waste, toxic materials and floating debris (known as floatables).

About half the time it rains in New York City, which is once a week on average, raw sewage and polluted runoff combine in the sewer pipes and overflow into the waterbodies surrounding the City. In an average rain year almost 27 billion gallons of untreated wastewater pours out of the City's sewer system to nearby waters. Eliminating these discharges is often an enormous financial challenge.

The New York City Department of Environmental Protection (NYC DEP) has instituted many collection management practices which can capture as much as 40% of the rainfall which enters the City's combined sewer systems. In addition, there are plans for the construction of combined sewer overflow retention tanks throughout the City. These underground tanks are designed to hold combined sewer overflow after storms and provide preliminary treatment until the capacity in the sewer system returns to a normal level and the water is discharged to the nearest treatment plant to complete the treatment process. In March 2001, Flushing Meadow Park was the first site to be outfitted with a retention tank which subsequently ended combined sewer overflows into Flushing Bay.

A CSO warning sign

The DEP also conducts a floatables collection program to both prevent and capture debris in the water. In order to trap the debris before it reaches the water, floating containment barriers have been installed across major combined sewer outfalls in the tributaries which surround New York City. The debris is removed from the traps by four "skimmer" vessels created to maneuver in small bodies of water. Unfortunately, these barriers are not installed at every outfall around the city and thus the remaining debris must be collected from the surface of the water. A fifth and larger vessel, referred to as the *SV Cormorant*, retrieves floatables from the Harbor's open waters which have traveled from outfalls unequipped with the containment barriers.

In addition, the DEP oversees many programs specifically geared towards reducing the introduction of toxic substances into the local system and wastewater treatment plants. The Industrial Pretreatment Program works to control commercial discharges by requiring certain industries to treat and remove specific toxics from their wastewater before it is released into the City's sewer system. The Pollution Prevention Program relies on outreach to educated the public on ways to reduce the use of toxic materials, thus reducing the sources of residential and commercial pollution.

Low Impact Development
Low impact development comprises a relatively new group of techniques used to reduce the amount of nonpoint source pollution which enters local waterbodies. It is a comprehensive land planning and engineering design approach which aims to maintain and enhance the maintaining pre-development hydrologic character (the water cycle) of both urban and developing watersheds. LID techniques infiltrate, filter, store, evaporate, and detain stormwater runoff close to its source. Some LID practices have been in place in Europe for over a century and have proven to be effective and affordable.

Low Impact Development utilizes several methods of filtration and retention including bioretention basins, green roofs, rain barrels, rain gardens, green swales, rain gutter disconnects, and permeable pavements.

Bioretention basins
Bioretention basins design depends on local soil type, site conditions and land use. The basins incorporate six different components, each of which performs different function. The components are:

- *Grass buffer strips*– Areas of grass used to reduce runoff velocity and filter particulate matter.
- *Sand bed*– Areas of sand which provide aeration and drainage for the planting soil and also assists in the filtration of runoff-pollutants caught in the soil materials.
- *Ponding area*– Areas where excess stormwater runoff can be detained and stored. These

facilitate the settling of particulate matter and the evaporation of excess water.

- *Organic layer*– An area set aside for the decomposition of organic material. It provides a medium for biological growth (i.e. microorganisms) which can degrade petroleum based pollutants. It also aides in the prevention of soil erosion.
- *Planting soil*– Provides an area for stormwater storage and nutrient uptake by plants. It contains clays which absorb pollutants such as hydrocarbons, heavy metals and nutrients.
- *Vegetation (plants)* - Facilitates the removal of water through natural evapotranspiration and pollutant removal through natural nutrient cycling.

Greenroofs
Greenroofs are vegetated roof systems which decrease the amount of stormwater runoff by reducing impervious cover in urban areas. They consist of four layers: vegetation, media, geotextile, and a synthetic drain layer. Greenroofs capture and evaporate up to 100% of the precipitation that falls on it, reducing the volume and speed of stormwater runoff. This system offers a place for rainwater to percolate into to the soil during storm events. Greenroofs protects our waters, prevents sewer overflows, and act as air filters by removing airborne dust particles.

http://www.gaia-

Green Roof at Saint Simon Stock School in the Bronx

Rain barrels
Rain barrels are barrels that collect and store rain that falls on rooftops. This reduces the costs associated with off site treatment systems and decreases the amount of sewage released by combined sewer overflows.

http://www.sprucecreekrainsaver.com

A Rain Barrel connected to a Downspout

Rain Gardens
Rain gardens are depressed "bowl-shaped" landscaped areas, typically planted with wild flowers or native vegetation, which function as mini wetlands. These gardens provide a place for stormwater to infiltrate allowing approximately 30% more water to soak into the ground. The rain garden helps to filter rain water by allowing it to collect, once there the water is filtered by the plants and soil rather than running off into the storm drain. This method improves water quality by increasing absorption of runoff near its source.

Grass swales
Grass swales or channels function as a mechanism to reduce runoff velocity and as filtration devices. They are areas or stretches of grass that are primarily used along residential streets and highways. This method is adaptable to a variety of site conditions, is flexible in layout and design and affordable. Sedimentation is the primary pollutant removal function with infiltration and adsorption being secondary functions.

Rain gutter disconnects
Rain gutter disconnects redirects runoff from rooftops conveyed in rain gutters out of storm sewers and into grass swales, bioretention systems and other LID landscape devices. This can significantly reduce the amount of runoff flow to surface waters and reduce the number of combined sewer overflow events in urban areas.

Permeable pavements
Constructing and implementing the use of

permeable pavements is an effective means of reducing the percent of imperviousness in a drainage basin. Permeable pavements are best suited for areas with low traffic such as parking lots and sideways, and in coastal areas with sandy soils and flatter slopes. This allows stormwater to infiltrate into the underlying soils promoting pollutant removal and recharge groundwater, rather than producing large volumes of rainfall runoff requiring conveyance and treatment.

The Gaia Institute in NYC

The Gaia Institute is a local organization which works "to couple ecological engineering and restoration with the integration of human communities with natural systems through research and development, education, design and construction." The institute works to restore and ecologically re-engineer our local natural systems to maintain, enhance and protect environmental quality.

Through research and the development of new techniques the Gaia Institute explores how human activity and the local waste stream can be changed and treated to increase "environmental quality, biodiversity, ecological productivity, and economic well being. "

Lead by Dr. Paul Mankiewicz, the institute has created and fostered innovative green building and low impact development projects throughout the City. Recent projects include:

El Jardin del Paraiso, the Lower East, Manhattan
El Jardin del Paraiso is a community garden which was built on top of the rubble and fill of an old tenement site. In collaboration with the NYC Department of Parks and Recreation and with the help of NYC Department of Environmental Protection, Gaia lead the development and construction of what is believed to be the first biogeochemical cap and stormwater capture parkland in the New York City region. The rich soils and native plant communities were restored in the garden to capture storm water and re-establish natural cycles. Compost from New York City's waste stream was used to create soil buffers and wetlands which both re-established habitat and mitigated the historic lead contamination on the site.

Green Roof: Saint Simon Stock School, the Bronx
Twenty years ago, the Gaia Institute developed, from the City's waste stream, a very lightweight soil which could be used establish ecological and agricultural systems on rooftops. Utilizing a grant from the Bronx Initiative in Energy and the Environment and the Bronx Overall Development Corporation in the Bronx Borough President's Office made it possible to build a stormwater capture and educational green roof facility in partnership with St. Simon Stock.

The Gaia Institute, with NYC Parks Department's Green Apple Corps as well as St. Simon Stock faculty and students, constructed a native plant community and urban vegetable garden on top of the grammar school. After a roof membrane was installed and fully tested for its water holding capacity, our lightweight soil was installed and planted with a native meadow in June 2005. The finished green roof was outfitted with a weather station, including rain gauge, heat sensors, temperature, and humidity meters to supplement St. Simon Stock's educational programs and to document the behavior of the first green roof in the Bronx.

Green Corridor: Lafayette Ave/Edgewater Rd
This 1,200 ft. green corridor, located in the Bronx, is a stormwater capture system which helps to address stormwater problems in the City. Soil buffers and street-side plantings are directly connected to the standard storm drains on city streets. This direct connection allows road and sidewalk drainage stormwater to flow directly into natural biological and geochemical filters which hold stormwater for plantings and keep it of the combined sewer system. The project was funded by Congressman José E. Serrano's Wildlife Conservation Society-National Oceanic & Atmospheric Administration's Lower Bronx River Partnership .

Aquatic Habitat Restoration

The tidal strait of the East River was historically bordered on the north and west by extensive eel grass and shellfish reefs and beds. The oysters were harvested by colonists and, in the eastern Bronx, remained productive well into the 19th Century. Eelgrass supported thousands of brant (small saltwater geese) and other water fowl fed on the eelgrass which provided habitat in the western Long Island Sound's extensive fishery.

In the 1930s, eelgrass was ravaged by disease and by the 1950s had all but disappeared. A combination of high nitrogen and increased turbidity acted to eliminate near-shore habitat for eel grass. In addition, increasing sewage discharge removed oxygen and destroyed habitat from the waterways surrounding New York City, which decimated remaining oyster beds from the early 20th Century onward.

Improvements in local water quality and clarity have made some habitat again suitable for oyster reefs and eel grass ecosystems. In partnership with the Hudson-Raritan Bay Keeper and with the New York City Department of Parks and Recreation, the Gaia Institute is currently surveying nutrient inputs, sediment quality and water flow which are favorable to oyster reefs and eel grass beds and hopes to begin the restoration of oyster reefs and eelgrass in the future.

Water Treatment in the City

The New York State Department of Health monitors the delivery of drinking water to ensure that it is safe for human consumption. The NYS Department of Health in cooperation with local county health departments oversees the operation, design and quality of public water supply operations and commercial bottled water suppliers; assures water sources are adequately protected; provides monetary assistance to public water suppliers; reviews and approves plans for proposed subdivisions; and sets the standards for building individual water as well as wastewater systems (septic systems).

The New York City Department of Environmental Protection (DEP) works to guarantee a safe drinking water supply for the citizens of the greater Metropolitan area. In 1997, DEP installed water quality sampling stations around the city to facilitate improved water quality monitoring, ensuring that the city's water supply meets federal and state drinking water regulations.

The DEP gathers more than 1,300 water samples each month from 488 sites. Water samples are analyzed for bacteria, chlorine levels, pH, inorganic and organic pollutants, turbidity, odor and numerous other water quality indicators. These stations are located throughout the five boroughs, in order to a collect representative distribution of samples throughout the city.

The sampling stations rise about 4 ½ feet above the ground and are constructed of heavy cast iron. Inside a ¾ inch copper tube feeds water from a nearby water main into the station. Each station is equipped with a spigot from which water samples are taken. The total cost of the construction and installation of the new stations was approximately 11 million dollars.

Federal Drinking Water Standards

The National Primary Drinking Water Regulations (known as NPDWR's or the Primary Standards) are legal standards which limit the levels of contaminants in the public water supply. Pollutants in the drinking water are monitored according to allowable MCLs or maximum contaminant levels, usually measured in mg/l. Many microorganisms (including viruses) are monitored including *giardia lamblia*, which can cause vomiting and cramps and is found in human and animal fecal waste. Harmful inorganic and organic chemicals such as are also monitored and restricted. Measured inorganic chemicals include arsenic, lead and mercury and organic chemicals include dioxins and PCBs, which are believed to be carcinogenic and may cause neurological damage. Radionuclides such as uranium and alpha or beta particles, which also increase the risk of cancer, are monitored closely and restricted. In addition, water disinfectants, such as chlorine (which can cause eye irritation and stomach pain) are required to remain below certain levels.

The National Secondary Drinking Water Regulations are an additional set of standards which are recommended but not enforced by the EPA. States may choose to adopt these regulations into state law if they deem it necessary. The regulations deal with cosmetic issues such as contaminants which may affect skin or tooth color and contaminants which may affect taste, odor or water color. Listed contaminants include foaming agents, aluminum, sulfate, copper and fluoride.

Water Quality Regulation

The Clean Water Act (CWA) of 1972, established basic regulations to deal with contaminated discharges into the waters of the United States. With the advent of this new law, the Environmental Protection Agency was given a new degree of authority which enabled the agency to set standards for industry waste effluent. In additions, it extended earlier regulations which created standards for contaminants in national waters. The Act created a grants program which funded the construction of sewage treatment plants nationwide. Eventually the grants program was revised in 1987, to become the Clean Water State Revolving Fund.

The CWA deems it unlawful of any individual to release a contaminated substance from any point source into any national waterway without a permit from the National Pollutant Discharge Elimination System (NPDES). More recently the law has been expanded to help create programs in partnership with state and municipal authorities to control non-point source pollution.

The Clean Water Act approaches non-point source pollution (stormwater runoff) through a system of phased regulations. In 1990, Phase I Amendments to the CWA initiated stormwater management across the nation. The Amendments require NPDES permits for municipal separate storm sewer systems (MS4s) which serve medium or large populations (100,000 or more), plus permits for construction activity on 5 or more acres and other similar industrial activity. In December 1999, the EPA announced its Phase II regulations which targeted smaller, less obvious culprits. Small MS4s (serving 1,000 or less people) located in urban areas and some located outside of urban areas are now covered. MS4 operators (usually municipal public works) are required to create and manage plans to protect water quality and reduce discharges. The new regulations also cover construction activity on areas less than 5 acres.

Phase II requires those seeking NPSDES permits to participate in six activities which will aid in pollution reduction including public education and outreach; public involvement and participation; eliminating illegal discharges into water systems; stormwater runoff control for construction sites; stormwater management for new development and redeveloped areas after construction; and creation of municipal pollution prevention programs.

The Competing Uses of Water

Water scarcity is an increasingly significant global issue. As the world's population continues to increase at exponential rates, humans are placing enormous pressure on local natural resources, including water. Due to this scarcity competing interests are vying for use of a very limited amount of water. As scarcity increases, water is becoming a marketable commodity with many different investors attempting to purchase exclusive water rights.

Biological and Economic Survival

It is difficult to maintain the delicate balance in water distribution among various local, national and natural needs. Water serves as both a drinking source and as an important ecosystem for plants and animals. The human population depends on clean drinkable water not only for its basic survival but also for economic prosperity. In addition it serves an integral part in navigation, electrical production, recreation and industry.

Industry utilizes water within production methods as a coolant or a cleanser and relies upon access to the resource in order to meet business demands. Agriculture also depends upon water for irrigation and is often piped in from other regions, especially in places that are relatively arid. Often the water used in both industry and agriculture returns to the water cycle via runoff laden with toxic chemicals and excessive nutrients.

Navigation

Both the New York Harbor and the Hudson River provide systems of navigation which connect agricultural and industrial products to markets across the nation. Such waterways also offer citizens with local recreation. Waterways and water bodies provide areas for sailing, fishing, and swimming. Keeping these waterways pristine and safe for recreation requires that they remain free of garbage and other pollution.

Hydropower

Water is also used in the hydropower industry. Hydropower utilizes moving water's kinetic energy to create electricity. Hydropower facilities use dams to store water. Water stored in a dam is released across turbines. The turbines, pushed by the falling water, rotate generators which produce electricity. Hydropower produces emissions-free electricity, but it is not without its environmental problems.

Hydropower facilities can cause damage to the natural balance of riparian ecosystems. Turbines hinder the passage of fish up and down the river. They interrupt spawning runs and also kill many fish which attempt to pass through them. Water quality is often compromised downstream from the facility, which releases dissolved gases into the river. Currently, the U.S. Department of Energy (DOE) is developing technology to minimize fish mortality as well as to contain gas releases. Many environmental and engineering groups have developed fish ladders which allow fish to swim safely over hydropower turbines and continue along the river.

Wastewater

The earth's water cycle can naturally assimilate and filter small amounts of contaminated water. However, due to the extreme pressure which competing water interests place on the resource, including pollution these interests create, the water cycle is unable to assimilate the subsequently large volume of waste. Water treatment plants are needed to treat and clean used water, including household wastewater, before it is released back into the water cycle.

Water Conservation, Point Source Pollution, and Non-point Source Pollution

The problem of water scarcity creates the need for focused water conservation. According to the United States Subcommittee on Water Resources and the Environment, "The population of many metropolitan areas is growing so fast that the available supplies cannot keep up with the skyrocketing demands for water. For example, the Southeast has seen tremendous growth [in population] over the past 20 years, and is projected to grow an additional 50% by 2040". As the national and global populations increase rapidly and the need for water follows, individual citizens, municipalities and industry must participate in water-saving activities in order to preserve this precious and finite resource.

Conservation approaches, which can be practiced by individual citizens include,

- Making sure that one's home or office is free of leaks by reporting or fixing leaking faucets, broken pipes, or leaking hydrants.
- Reading home water meters before and after a two-hour period when water is not in use to check for variation and thus evidence of hidden leaks.
- Not disposing of water down the drain when it can be used for other uses such as plant watering or cleaning.

Industry can also aid in water conservation by reusing water previously used in cooling or manufacturing processes and preventing the release of chemical or organic waste into neighboring water bodies or groundwater. New York City can help conserve water through metering, which requires customers to pay for what they use as well as public outreach programs which help educate the community on easy and efficient ways to save water. The city is currently working toward the establishment of permanent local runoff control programs which catch and direct storm water runoff into catch basins or permeable areas. These runoff control programs can help to reduce non-point source pollution (To learn about the programs in greater detail, refer to the previous section, *Water in New York*).

The differences between point source and non-point source pollution are important in identifying the cause of water pollution and thus maintaining and improving the quality of our water. Point source pollution refers to pollution which can be traced to a specific source, like industrial dumping, large oil spills, or any unauthorized toxic release which is discharged from a pipe into a water body. The National Pollutant Discharge Elimination System (NPDES), a portion of the federal Clean Water Act, regulates point source pollution by granting permits to point source dischargers and municipal wastewater treatment plants. These permits regulate what certain industries or business can discharge into local waterways and in what amounts.

National and state regulations target and successfully control most industrial point source pollution. Currently, one of the most difficult problems in water pollution control is non-point source pollution.

Non-point source pollution primarily consists of runoff from urban areas as well as from agricultural lands. Rapid expansion of urban areas has caused a drastic increase in impermeable surfaces. Construction of malls, new homes, offices and especially miles of urban sidewalks, streets and parking lots covers permeable soils with new impermeable surfaces. Storm water flows off these surfaces collecting refuse, oil, chemicals, animal excretion and other substances which cover the city streets and sidewalks. This polluted runoff (non-point source pollution) is unable to percolate into the soil and recharge ground water. It runs off the land and our rivers and harbors, often causing erosion on the riverbanks and within the surrounding vegetated area. During heavy rainstorms, the city's combined sewers catch the excess water flow and eventually release into local waterways like the Hudson river, the East river, or the NY/NJ Harbor. The untreated water of Combined Sewer Overflows can contain excess nutrients, chemicals from household drains, street runoff and untreated sewage (To learn more about CSOs refer to previous section, *Water in New York*).

The federal government took the first step toward regulating non-point source pollution with the Non-point Source Management Program, created during the 1987 Clean Water Act Amendments. It also revised the National Pollutant Discharge Elimination System (NPDES) to target runoff issues in local and state municipalities. In 1990, the Coastal Non-point Pollution Program was created through the Coastal Zone Act Reauthorization Amendments.

Delineating a Watershed

According to the Environmental Protection Agency, a watershed is "simply the land that water flows across or through on its way to a common stream, river, or lake". These watersheds can be large, or small with smaller watersheds lying within larger ones.

On a U.S. Geological Survey (USGS) topographic map, one can delineate a watershed using the blue hydrographic lines which symbolize water and the brown elevation contour lines which represent areas of equal elevation above sea level. Water always flows downhill, from high elevation to low. To delineate the watershed, one first needs to draw a line connecting the highest points of elevation along the ridge tops which surround the designated body of water. The watershed is the area within the line which has been created on the map.

To see how a watershed is delineated, visit EPA's *Watershed Academy Web, Core Principle 1, Delineating a Watershed (*http://www.epa.gov/watertrain/watershedmgt/principle1.html) and also visit the *Center for Watershed Protection* (www.cwp.org/).

Dichotomous Keys

Dichotomous keys are important tools which allow both ecologists and naturalists to identify unknown organisms. The keys are similar to a *Choose Your Own Adventure* book. They first offer two general descriptions of organism characteristics to choose between and then each description offers two more specific descriptions to choose between. The choices made will eventually lead to a final description which will identify the specific organism. A sample guide to dichotomous keys, which can be found online at (www.ekcsk12.org/science/lelab/dichotomouskeys.html) is shown in Appendix A..

Alteration to Aquatic Habitats and Changes to Aquatic Ecosystems

As the human population increases, we continue to develop more land at extremely fast rates. Land which was traditionally considered wild is disappearing and urban developments are taking its place. This increased, and often haphazard, development of land is altering natural ecosystem cycles as hard, impermeable, paved surfaces take the place of natural soils and vegetated land cover.

This rise in the nation's amount impermeable land cover has drastically increased the amount of urban runoff. The decrease in ground water recharge caused by this increase means that most of the flow is directed straight into local water bodies. Most riparian zones are unable to absorb the increased volume of runoff from urban areas and the stream beds fill to flood capacity, eroding banks and destroying the vegetation. This increased flow and erosion eventually straightens and widens stream beds, eroding them from within the channel.

Once the riparian vegetation is gone, wiped out by erosion, so is the food source for many aquatic organisms. Without the riparian canopy, water temperatures fluctuate affecting the amount of dissolved oxygen in the water (warm water holds less oxygen).

According to many national studies, when the surrounding watershed has just 30% impervious cover, local streams become degraded and biologically deficient. As the impervious surface cover increases beyond 30%, streams and other local water bodies can become sterile.

Eutrophication is another result of increased urban and agricultural runoff. Runoff (urban and agricultural) as well as wastewater discharges from water treatment plants often contain large amounts of nitrogen and phosphorous. The accumulation of these nutrients in a waterbody can spur excessive algal growth (known as algal blooms or red tides in some waterbodies). When these blooms decay, the process removes oxygen from the water. The subsequent low dissolved oxygen levels cause large fish kills and the death of other aquatic organisms.

Aquifers

Aquifers are underground reservoirs of water, consisting of permeable rock, often sandstone, which feed springs and groundwater flow, and are sufficiently large enough to be used as a water source for pumping and wells. Aquifers are divided into two distinct types; confined and unconfined. An unconfined aquifer is a underground body of water which is not overlain by an impermeable layer of rock inhibiting vertical water movement. A confined aquifer is both underlain and overlain by an impermeable rock layer. These layers restrict vertical flow and place the waterbody under pressure. A confined aquifer can range from minimally confined to completely confined depending upon the composition of the restricting rock layer. Some rock types will permeable, allowing water to seep through slowly while other rock types may be completely impermeable.

A "pressure head" is what distinguishes confined from unconfined aquifers. The pressure head is the elevation (height) to which water in a confined aquifer would rise if the top layer of impermeable rock were absent. Sometimes this elevation is above the height of the ground's surface (which is often the case, due to the enormous pressure the water is under). If a well is drilled into the top layer of the rock, water will flow up from the aquifer to its natural water level. No pumping is needed. This flow of water up from a unconfined aquifer through a well is known as an artesian flow and the well is known as an artesian well.

Wetlands and their Benefits

Wetlands in the U.S. fall into four categories: swamps, marshes, bogs and fens. These areas are transitional zones between aquatic and terrestrial environments. Depending on location, wetlands can be either freshwater or saltwater and are fed by surface water or ground water. Swamps consist of predominately woody plants and marshes are dominated by soft-stemmed vegetation. Bogs are freshwater wetlands (sometimes formed in old glacial lakes) which consist of spongy peat deposits covered by evergreens, shrubs and a thick layer of moss. Fens are also peat forming but are covered with grasses, reeds and wildflowers. Wetlands are water saturated meaning they are covered in shallow water for most of the year or at least during some part of the yearly growing season.

Wetlands are a precious national and international resource. They provide habitat for many species of aquatic and terrestrial plants and animals. In addition, wetlands offer benefits to humans in many areas such as water quality, waste assimilation, storm and flood protection and recreation.

Wetlands are extremely important resources in the fight to protect our water quality from pollution and unwise use. When water enters a wetland it seeps deep into underground aquifers or joins the ground water flow, eventually recharging neighboring streams or rivers. Runoff and waste from agricultural, urban and other industrial sites can be caught and naturally filtered if wetlands are present, thus removing and containing the dangerous waste. Contaminants are either bound to the organic (carbon) rich soil-particles or taken up by plants. Water leaving a wetland is always cleaner than water entering a wetland. This offers a clear economic advantage to citizens and municipalities as wetlands filter and assimilate waste naturally, with no cost for processing local drinking water. These areas are naturally occurring, cheap detoxification devices which help keep our nation's water bodies and groundwater clean and healthy.

Wetlands also offer both flood and storm protection. Floods are natural and beneficial events but due to an increased human presence in flood prone areas, they pose a severe economic threat. Wetlands can act as buffers against high flood waters which have the potential to destroy property and agricultural areas in developed regions. Wetlands are a natural counterpart to floods and offer easy protection to property because they can absorb extreme volumes of water during flood events and then distribute this water slowly back into the underground system. They offer a better alternative to dams and floodwalls since wetlands can redistribute water back into the system, rather than simply restraining it from a coastal community.

Wetlands also act as a refuge and habitat for many diverse forms of wildlife. They help maintain genetic diversity, which fosters the survival of species worldwide. Species which exhibit a wide range of genetic diversity are better equipped to handle the stresses which events like natural disasters, climate change, habitat contamination or famine might bring.

Wetlands also provide recreational and aesthetic benefits. These areas offer a wide variety of opportunities to fish, hunt, canoe, and merely observe or photograph the diverse wildlife. Wetlands can also serve as outdoor labs for students and researchers in the field of Natural Sciences, aiding in education and science.

Tidal Wetlands

Tidal wetlands are situated along large portions of the salt water shores, bays, inlets, canals and estuaries of New York City, Long Island and Westchester County. They also border the Hudson River and its upstream counties up to the farthest reaches of tidal influence. Tidal wetlands, like all wetlands, are valuable areas which provide habitat for wildlife; flood, hurricane and storm protections; recreational activities; educational and research benefits; and aesthetic values.

New York State has created a policy known as the Tidal Wetlands Act in order to help preserve and protect these wetlands. The New York State Department of Environmental Conservation administers the Tidal Wetlands Regulatory Program which was implemented to prevent the destruction of tidal wetlands by creating and enforcing regulations that: preserve, protect and enhance the present and potential values of tidal wetlands; protect the public health and welfare; and also give due consideration to the reasonable economic and social development of the state.

Wetlands as Habitats

Wetland ecosystems house a vast array of species including microbes, plants, insects, amphibians, reptiles, birds, fish and mammals. Wetlands can be thought of as "biological supermarkets". They produce large volumes of food which are appealing to many animal species. Within a wetland decaying organic material breaks down in the water to form small particles of organic matter known as detritus. Detritus is a source of food for small aquatic insects, shellfish and fish. These species are food for larger predatory fish, reptiles, amphibians, birds and mammals.

More than one third of the United States' threatened and endangered species reside only in wetlands and approximately half utilize wetlands during some point in their life span. Often estuarine, marine and terrestrial species require coastal wetlands to complete their life cycles. Many commercial and game fish breed and raise their young in coastal marshes and estuaries. The life cycles of some plants and animals such as wood ducks, muskrat, cattails and swamp rose have become adapted specifically to wetland environments. U.S. bird populations such as ducks, geese, woodpeckers and raptors feed, nest, and raise their young in wetlands. Other migratory waterfowl use coastal and inland wetlands as resting, feeding, breeding, or nesting grounds for at least part of the year.

Riparian Areas and their Benefits

Riparian areas are the vegetated and forested regions that lie along rivers, lakes, streams and even wetlands. These areas provide environmental, social and economic benefits. Riparian forest zones send complex root systems into the soil, stabilizing the banks of these water bodies. The trees and vegetation litter the ground with a thick layer of organic debris (leaves and tree branches) which slows the velocity of runoff and allows it to slowly seep into the soil. This prevents the banks from eroding and sediment from building up in the waterbody. Such sediment buildup destroys wildlife habitat and, if the waterway is used as an economic thoroughfare, requires the implementation of costly dredging operations.

The thick organic layer of debris and complex root systems found in riparian areas also aid in maintaining local water quality. The organic soil allows runoff to percolate slowly into the ground and filters out many pollutants. Excess phosphorous and nitrogen which runoff agricultural areas can degrade water quality through a process known as *Eutrophication* (a process in which excessive algae production results in decreased dissolved oxygen levels in the water, causing fish kills). The thick organic soil can catch this runoff which is absorbed by vegetation and used to promote growth.

Plants and trees which borders streams, lakes and rivers drop leaves and other debris into the water, providing food for small aquatic organisms. The overhang of leaves and branches across the surfaces also helps maintain a relatively cool water temperature. Water at cooler temperatures is able to hold higher levels of dissolved oxygen thus promoting more aquatic diversity and health.

These riparian zones also aid in flood control, absorbing the energy of high flood waters and slowing their velocity, allowing the water to disperse back into the system. This reduces the possibility of erosion and property damage. In addition, these areas provide beautiful regions to camp, fish, exercise and observe wildlife and can also function as natural borders or screens for private property.

One of the most significant contributions of riparian areas is clean drinking water. Just as riparian zones improve the quality of the waterbodies they border, they also improve the quality of ground water as a whole. Organic soils (like those in wetlands) and vegetated areas catch and filter out toxins and contaminants, preventing them from seeping into the groundwater flow.

Local Aquatic Plants

The largest population of plants in the ecosystems comprising the Hudson River and its surrounding communities, can be found floating within the river. Phytoplankton (microscopic plants) float in the water and provide the foundation for the area's countless food chains. The planktonic community consists of both tiny plants (the phytoplankton) and also animals (zooplankton) which are weak swimmers or unable to move on their own.

Submerged aquatic vegetation (SAV) are rooted plants which grow submerged in the subtidal zone. These plants are limp and often buoyant and their stems float upward toward the sunlight. They are an important habitat for many invertebrates including insect larvae, crustaceans and snails. Young and small fish spend time amongst these plants using them as shelter from predators and as feeding grounds. SAV species include wild celery, curlyleaf pondweed, horned pondweed and water chestnut, an invasive.

Salt marshes are local ecosystems (which is becoming increasingly threatened) composed of many unique plants and can be found in City parks like Alley Pond and Idlewild. When the glaciers melted 7,000 years ago, the oceans rose to their present levels. Sediments washed from the land were deposited offshore in narrow sandy strips, forming long islands parallel to the shoreline. These barrier beaches received the pounding surf on their ocean side, but had calm, protected bays behind their landward shores. While the waters were calm enough for vegetation to take root, the presence of saltwater made survival difficult.

One species, saltmarsh cordgrass (*Spartina alterniflora*), was able to colonize the flat expanses of sand and silt. It adapted to this low oxygen environment, which was covered twice a day by the ocean's tides. This grass comprises the dominant vegetation in the lowest, near shore zones of marshes along the Atlantic. As the grass spreads, its stems trap floating debris. Debris and detritus slowly build up forming nutrient-rich mud, which supports life on the marsh. The fiddler crab (*Uca*) and ribbed mussel (*Geukensia demissa*) have developed a mutually beneficial relationship with the saltmarsh cordgrass. The crabs and mussels benefit from feeding on the decaying matter trapped within cordgrass roots and the cordgrass benefits from the fiddler crab's burrowing, which aerates the soil, and the mussel's excretion, which provides nitrogen for growth. At the end of each season, the cordgrass dies, and creates a spongy peat. Each year the new peat layer raises the surface level of the marsh, expanding the marsh away from the tide line. A variety of plants with less salt tolerance can colonize the peat, as it is out of the range of most of the high tides. This causes the formation of two separate plant communities.

Saltwater cordgrass grows within the intertidal zone, both above and below the mean tide level. In the intertidal zone, the area below the mean tide level is known as the low marsh and the area above the mean tide level is known as the high marsh. Plants which grow below the mean tide level and which are always submerged at high tide are known as emergent species. Local species include spatterdock (*nuphar luteum*) and pickerelweed (*pontederia cordata*). These species push their leaves and stems above the water's surface and are fertilized by the nutrients brought in with tidal currents. During the spring and summer, emergent plants store the nutrients in their roots, stems and leaves. During the winter, much of the nutrients are released back into the river as the plants die back and their stems and leaves fall off into the water. Very few species are able to survive in the low marsh and the environment tends to favor freshwater varieties. Therefore, in the lower regions of the estuary, where the water is saltiest, most of the low marsh is lacking vegetation except for stands of cordgrass.

The high marsh (sometimes known as a salt meadow) is dominated by reed and grass-like plants. These plants have a strong and complex underground networks of stems (rhizomes) which stabilize the soil against erosion caused by storms or waves. These stable areas act as breeding, wintering and nesting grounds for many avian and terrestrial species. Saltmeadow cordgrass (*Spartina* *patens*), which is shorter than saltwater cordgrass, grows in dense mats in the high marsh. Narrow-leaved cattails are also a common high marsh plant. They grow up to six feet in height and their rhizomes are a prime food source for muskrats. Other plants of the high marsh include saltwater cordgrass, swamp rose-mallow and two common invasives; purple loosestrife and common reeds (phragmites).

Local Diadromous Fish Species

The term diadromous refers to species of fish which migrate between fresh and salt waters, often to spawn, mature or find food. Only one percent of all fish species in the world are diadromous. Many of those make the Hudson River their home.

There are two groupings of diadromous fish in the Hudson: anadromous and catadromous. Striped bass, american shad and the shortnose sturgeon (endangered) are all anadromous. This means they mature to adulthood in sea water and then migrate upstream to fresh water to spawn. American shad, which are large herring fish, spend most of their life at sea and only return to fresh water to spawn 4-6 years after birth. Striped bass spend less time in saltwater and follow a yearly migration/ spawning pattern. Female shortnose sturgeon return to freshwater every third year to spawn and male shortnose sturgeon spawn every other year.

The American eel is a local catadromous species. It is spawned in seawater and migrates to freshwater to mature and live out its life. The American eel is the only catadromous species found in or around the United States. The eels begin their lives in the Sargasso Sea (north of the Bahamas) and live out their lives in the fresh and brackish waters of the coastal lands along the Atlantic. After 5 to 20 years, the eels return to the Sargasso Sea to spawn and then die.

Invasive Species

Invasive species are non-native species which have been introduced to new environments which contain no native predators to check the population's growth. These species often crowd out and out-compete the area's native species. The following four local invasive species have few native predators and competitors, which allows them to grow unchecked in local environments.

The zebra mussel is a small mussel which arrived in the ballast water of ships traveling from Eurasia to the Great Lakes. A ship is built to float with a large cargo, whose weight pushes the ship down into the water. When a ship is emptied of its cargo, this missing weight needs to be replicated in order for the ship to maintain its balance. Ballast water serves this purpose and is held in the bottom of large ships. This water is taken in at the place of departure and upon arrival, once the cargo has been loaded, it is released into the bay or port waters of the destination city. This release is a common way in which invasive species are imported.

Zebra mussels are harmful because they proliferate rapidly to form mat-like structures in areas of free-flowing freshwater where they can filter out large quantities of plankton. They accumulate on boat hulls and clog the water-intake pipes and screens of water filtration plants, power plants and industrial facilities. They grow very rapidly to the size of a thumbnail and one female can produce 30,000-100,000 eggs/year. The mussels consume most of the available planktonic food supply, pushing out native shellfish and they may also pose a health hazard to humans and wildlife by increasing their exposure to toxins like PCBs and PAHs. Zebra mussels can accumulate these pollutants in concentrations 300,000 times ambient levels and deposit the contaminants in loose pieces of mucus mixed with the particulates they filter from the water. Animals which consume these excretions will pass these high contaminant concentrations up the food chain.

The water chestnut is an emergent plant species originally from Eurasia and has become the second most abundant aquatic plant in the Hudson River estuary. It prefers slow moving, nutrient rich water, both of which characterize the Hudson. In contrast to its native competitor, the water celery, the water chestnut reduces the dissolved oxygen (DO) content of waters in which it grows, therefore creating environments of *Hypoxia* (low DO) or even *Anoxia* (no DO). These conditions seriously alter and disrupt conditions for other species.

Purple loosestrife is a marsh plant that has spread across the United States. The species was introduced in the early 1800's by American settlers, who wanted them for their flower gardens. Purple loosestrife is a hardly perennial and colonizes tidal marshes as well as other wetlands, riverbanks, pond edges and even ditches. It fares well in both natural and disturbed areas. The plant forms dense thick beds which crowd out native species and reduce viable habitat for waterfowl and other animals.

The common reed or *Phragmites australis* is a tall perennial grass which grows in wet areas and is an aggressive colonizer of disturbed soils. The plants grow in dense stands along marsh edges, crowding out cattails and reducing habitat for nesting waterfowl. These impacts decrease native biodiversity and the quality of wetland habitat.

All four of these invasive species can be found in wetlands and shallow areas along the Hudson River estuary are found along with other aquatic invasives, such as the green crab and the mitten crab.

Image 1: Water Celery (in the Water)

www.aquaticbiologists.com

Image 2: Water Celery (out of the Water)

www.aquaticbiologists.com

Image 3: Curlyleaf Pondweed

Image 4: Male Fiddler Crab

Image 5: Ribbed Mussels

www.jaxshells.org

Aquatic Species: Images

Image 6: Saltmarsh Cordgrass

http://images.enature.com

Image 7: Saltmeadow Cordgrass

www.assateague.com

Image 8: Spatterdock

users.nac.net/imele/GSNWR.html

Image 9: Pickerel Weed

www.wildflowersofontario.ca

Image 10: Cattails

www.gaygardener.com

Image 11: Zebra Mussel Mat

http://students.uwsp.edu

Image 12: Purple Loosestrife

http://web.fastermac.net/~destowe/gallery_2004.html

Image 13: Water Chestnut

http://www.nps.gov/plants/alien/midatlantic/tma.htm

Image 14: Water Chestnut Seed

©Michael R. Martin

Image 15: Phragmites

www.kulak.ac.be/facult/wet/biologie/

There are a number of different tests and surveys which can be performed to assess the health and quality of a waterbody. These can be divided into roughly two categories: chemical and biological. Chemical testing uses certain chemical indicators to give the tester a snapshot of the current health of the waterbody. Over a period of time, chemical testing can help testers determine what type of pollution may be in the water. Changes can be tracked seasonally and by rain event. Biological testing samples the flora and fauna of the waterbody and is usually an indicator of long term health rather than the conditions on a particular day.

Chemical testing

Water Collection Techniques

How you collect your water sample is just as important as what you are testing for and can have a significant impact on the data you collect. Samples should be collected at a site which is typical of the waterbody. If the majority of the waterbody is a fast flowing stream, then data should be collected in the fast flow rather than a slow pool. Safety is always the first concern, so data should not be collected in a location which would endanger those testing the waterbody.

One should be careful not to introduce more of what is being tested into the sample. For example, when testing for dissolved oxygen one must make sure that additional oxygen is not introduced into the sample. All collection bottles should be rinsed with deionized water no matter what you are collecting.

Tests other than Dissolved Oxygen

Use an HDPE (milk jug) or polypropylene (soda bottle) bottle or bucket to obtain a water sample. Collect from the main current (if there is a current). If possible, collect your sample from the middle of the water column.

Tests for Dissolved Oxygen

When testing for dissolved oxygen, use the bottle provided in the test kit. This bottle is designed to collect the proper amount of water and to keep extra air out of the sample.

It is easiest to collect a sample of water for DO testing by actually standing in the water or at least crouching down at water level. After the cap of the sample bottle is removed, the bottle should be slowly lowered into the water with the top of the bottle pointing downstream. The lower lip of the bottle to be just submerged. Allow the water to fill the bottle gradually. When the water level has stabilized, slowly tilt the bottle to fill it all the way. Keep the bottle underwater and cap it while still submerged.

Examine your sample for air bubbles. If air bubbles are present, the sample must be dumped and a new sample collected.

What is pH?

pH is the measure of how acidic or basic (alkaline) a solution is. pH measures the hydrogen activity in a solution, which is expressed as a negative logarithm. Acids produce free floating hydrogen ions (H+), while bases produce hydroxide ions (OH-). Distilled water (water that has been highly purified) has an equal number of hydrogen and hydroxide ions. pH measurements are recorded on a scale from 0.0 to 14.0. When distilled water is tested for pH, the results are perfectly neutral (7.0) because the there are no free floating hydroxide or hydrogen ions, all are paired in molecules of H_2O. Water measuring under 7.0 is acidic and water measuring above 7.0 is basic. If a compound such as baking soda (a base) is added to distilled water, there will be an excess of hydroxide ions which will raise the pH of the solution.

Why is pH important?

pH is important in the lifestyles of aquatic organisms. Many species of fish cannot lay eggs except in a certain pH range. Fish gills can become clogged with protective mucus (secreted to protect the fragile gills) at a low pH. A low pH can also soften fish bones. Most estuarine organisms prefer a pH ranging from about 6.5 to 8.5.

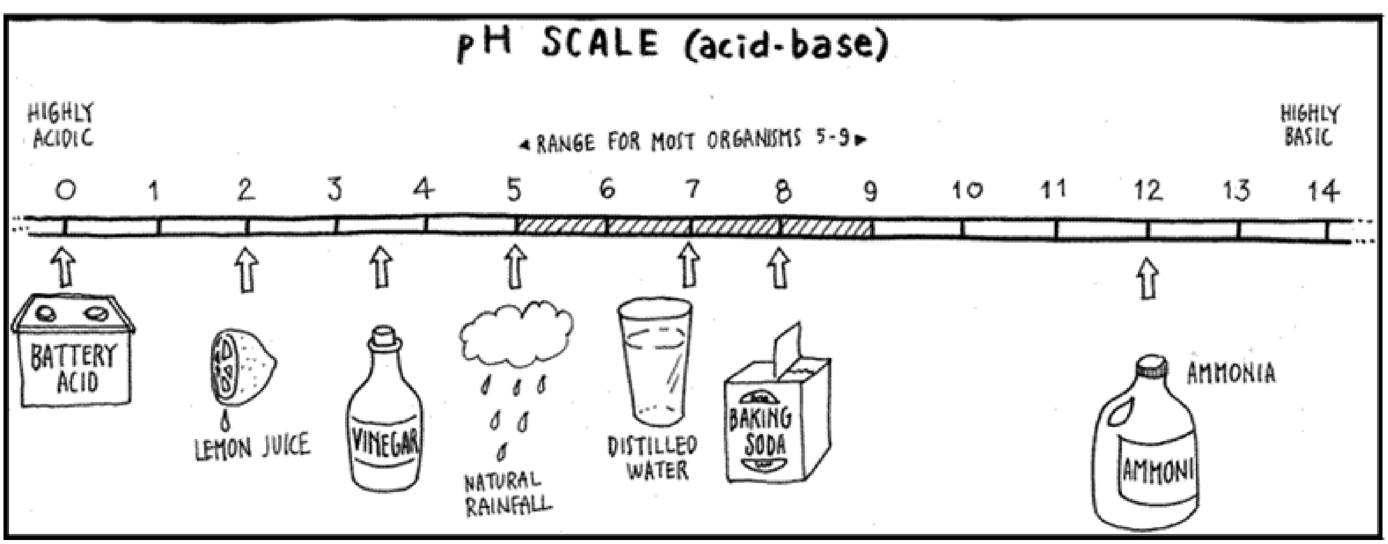
Natural rainfall is slightly acidic with an approximate pH of 5.6. However, certain factors can change the pH of water as it moves through the water cycle. This includes the type of substrate holding the groundwater or the waterbody. Substrates like limestone rock will raise the pH, even if the groundwater or rain is acidic.

What is acid rain?

Acid rain is the result of contamination from sulfides (SO_2) and nitrous oxides (NO_x). When released into the atmosphere sulfur oxides and nitrous oxides spread from their point of release and mix with other particles in the atmosphere. These acidic particles can dissolve in atmospheric water and then precipitate. This is known as acid rain. The EPA has determined that acid rain in the United States is a byproduct of electric power generation. Cars and other combustible engines also produce nitrous oxides contributing to the problem.

Measuring pH

There are a number of different ways to measure pH. The simplest way to measure pH is with litmus paper. Wetting the paper with the water sample will change the color of the paper and indicate whether it is acidic or basic. The second way to measure a water sample's pH is to use a chemical test. These use a color indicator solution which is added to the sample and changes its color to indicate pH. The last way to measure pH is to use a pH probe. The ends of these probes are held in the water and will measure the amount of available hydrogen or hydroxide ions in the sample.



Turbidity

What is turbidity?

Turbidity is the measure of water clarity. It measures how much the suspended solids in the water restrict the passage of light and is not exclusively associated with the color of the water. Suspended solids can include soil particles (clay, silt and sand), organic matter, inorganic matter and micro-organisms (such as algae). The more turbid a waterbody, the less light reaches the bottom. Some natural waters can be slightly brownish due to the movement of sediment in the water column and the activity of aquatic organisms. At other times turbidity can signal pollution, such as water polluted by runoff from a construction site. Some sites have a naturally high turbidity.

http://www.rockhillridge.com

The water of the Hudson River, as seen in this picture, is naturally somewhat turbid.

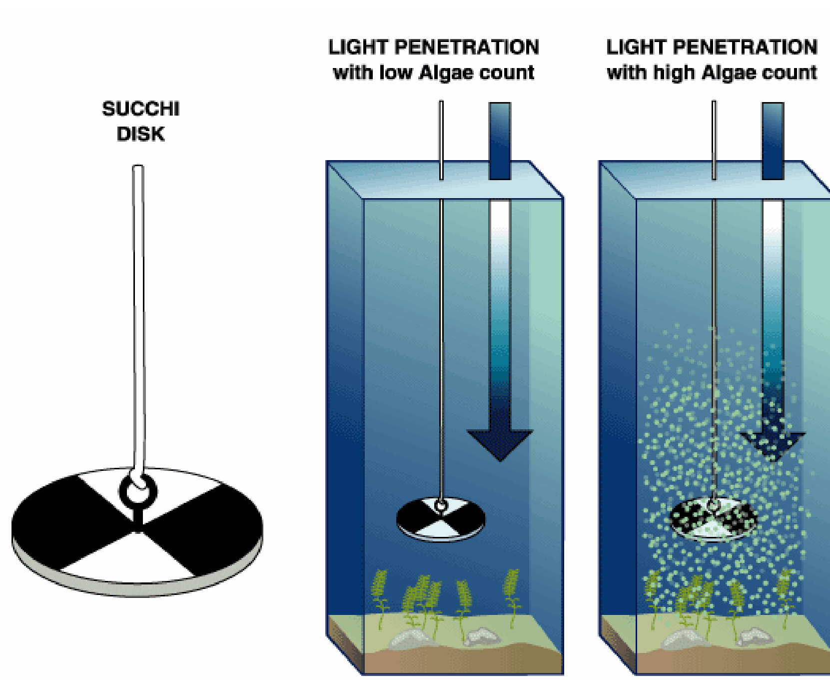
Why look at turbidity?

Organisms such as plants and animals need a certain level of turbidity which is optimal for their growth. If sunlight is unable to reach areas of the water column in which aquatic plants grow, those plants will die. This in turn can effect the level of dissolved oxygen in the waterbody, as fewer aquatic plants are producing oxygen. Suspended particles also absorb heat, causing water temperature to increase. Warm water holds less dissolved oxygen than cooler water, thus reducing oxygen readings.

Fish and invertebrates are also affected by turbidity. The gills of these organisms can be clogged with sediment if waters are polluted by runoff full of suspended solids. Increased sediment loads can also foul the filter feeding systems of some species.

How to use a Secchi disk

The Secchi disk provides a very simple means of making transparency determinations in a waterbody. The Secchi disk is a black and white circular plastic plate, 20cm in diameter. A measured line is attached to the center of the disk which stabilizes it parallel to the water surface. Water that is clear has a high transparency or low turbidity. Transparency usually decreases in the summer when plankton, silt and organic matter are more prevalent. Measurements are taken by lowering the disk into the water until it completely disappears and noting the marked distances on the rope. The deeper the measurement, the clearer the water (low turbidity). Conversely, more shallow measurements indicate higher turbidity. Secchi disk measurements give a general indication of problems with algae, zooplankton, water color and silt.

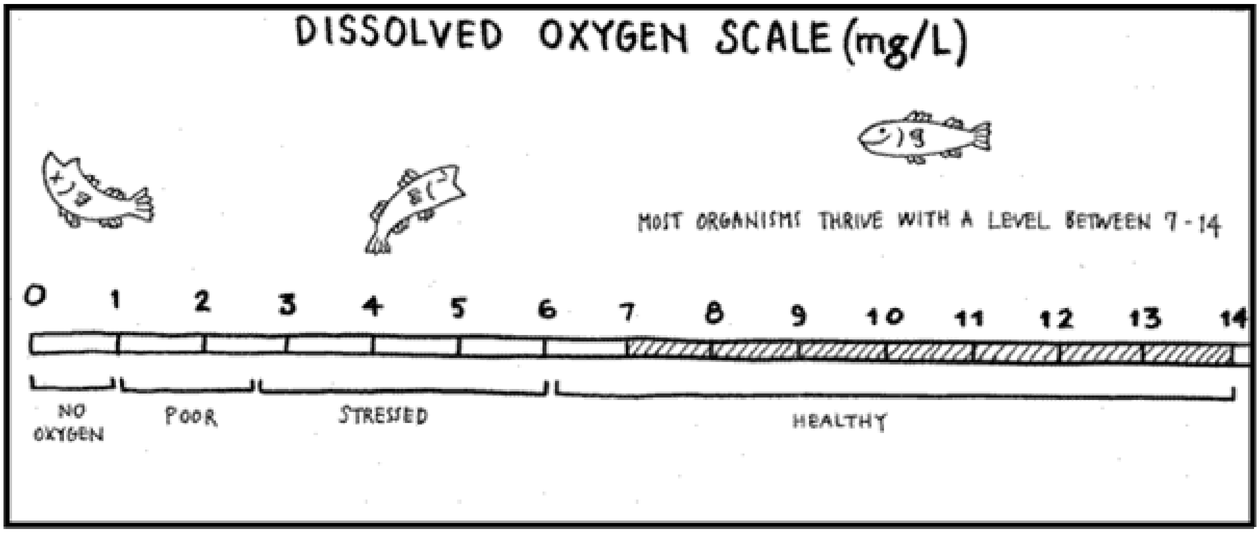


http://www.ngdir.ir/

Dissolved Oxygen

What is Dissolved Oxygen?

Dissolved oxygen or DO, is the concentration of oxygen gas dissolved water. Both water turbulence and plant photosynthesis contribute to the amount of oxygen in the water. DO varies with temperature, as warmer waters cannot hold as much oxygen as cooler waters.



Why measure DO?

Oxygen is essential for most living organisms. In water with little dissolved oxygen, fish and invertebrates cannot survive. In streams with a lot of siltation, dissolved oxygen will be less because higher turbidity levels inhibit the growth of plants and the production of oxygen.

What causes changes in Dissolved Oxygen?

Changes in dissolved oxygen are caused by many factors including: turbidity; salinity; presence of excess nutrients; amount of sediment; the velocity and turbulence of the water; and plant growth and coverage. Excess nutrients, such as nitrogen (nitrates) and phosphorous (phosphates) in the form of fertilizers or human waste, are one of the largest causes of dissolved oxygen reduction in this area via eutrophication.

Nitrates and Phosphates:

What are nitrates and phosphates?

Nitrates and phosphates are naturally occurring plant nutrients. Nitrates are used by plants and animals as the building blocks of proteins. Phosphates are used in plant growth.

Even though both nitrate and phosphate are necessary for plant growth, they are considered limiting nutrients. They are depleted before other nutrients and only need to be present in small amounts. Problems with algal blooms and the overgrowth of aquatic plants can occur when nitrate and phosphate nutrients are added to the aquatic system.

Why measure nitrates and phosphates?

Excess nitrates and phosphates can produce uncontrolled growth of phytoplankton (microscopic floating plants) and algae, which are known as blooms. Water covered thick blooms may not receive sufficient light to support aquatic plant growth. When the algae and plankton die, they are decomposed by oxygen-consuming bacteria. This may cause the water body to become hypoxic (low in oxygen) and sometimes under very bad conditions the bottom waters will become anoxic (without oxygen). This entire process is known as eutrophication.

Sources of nitrates and phosphates?

Nitrates and phosphates are deposited into waterbodies through runoff, combined sewer overflows and atmospheric deposition. Fertilizers and animal waste wash into our regions storm drains and off the land during rain events. During large rain events, when combined sewers overflow, human waste is also dumped into receiving waterbodies.

Salinity

What is salinity?

Salinity is the amount of dissolved salts in water. Water can be fresh, brackish or salt/seawater. Freshwater has little to no salt while brackish and seawater have varying amounts. In the Hudson River Estuary the salinity of the water undergoes a gradual change across the estuary's length as freshwater from tributaries and upriver mixes with seawater coming in from the ocean. Salinity is expressed in parts per thousand (ppt).

Why measure salinity?

Certain organisms have more or less tolerance to salt in their environments. In the estuary, there are a number of different types of organisms which tolerate a wide range of salt concentrations. Freshwater species will be restricted to the upper regions of the estuary while marine species will inhabit the mouth of the estuary. Some species can only tolerate an intermediate range of salinity while others can acclimate to any salinity from fresh to salt. Salinity also affects the amount of dissolved oxygen that water can hold by crowding out oxygen molecules.

The Estuarine Salinity Regime

Estuaries are divided into portions distinguished by the amount of tidal influence and salinity of the water. The major salinity regimes are, from least saline to most saline:

- *Tidal Fresh*– waters at the extreme reach of tidal influence.
- *Oligohaline*- waters in the upper portion of the estuary.
- *Mesohaline*– waters in the mid-portion of the estuary.
- *Polyhaline*– waters in the lower portion of the estuary where the ocean and the estuary meet.

Measuring Salinity

Salt water is denser than fresh water and thus has a greater specific gravity (which is the ratio of the density of something to the density of water). One can determine salinity by measuring a water sample's specific gravity with a hydrometer.

Using a hydrometer

1. Put the water sample in a hydrometer jar (a large clear plastic jar).
2. Take the temperature of the water sample and record.
3. Carefully lower the hydrometer into the jar. Make sure the top of the hydrometer stem (which is above the water) is free of water drops.
4. Allow the hydrometer to stabilize and then record the specific gravity. Read the specific gravity (to the fourth decimal place) at the point where the water level and the hydrometer scale meet in the middle of the jar. Make sure not to record the level of the meniscus (the upward curvature of the water along the side of the glass).
5. Using the recorded specific gravity and temperature, consult a hydrometer conversion table (which generally comes with the hydrometer or can be found easily on the web) to determine the salinity.

https://fscimage.fishersci.com

Hydrometers and a Hydrometer Jar holding both a sample liquid and a hydrometer

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