Localized Hydrologic Cycle: Human-Water Cycle Interaction in the Appoquinimink River Watershed

Victoria L. Deschere

Water. It sustains us physiologically, affects us psychologically, drives us sociologically, and defined us anthropologically. It is life. "Water is one of the few cultural universals, inspiring a profound mingling of ritual and day-to-day use."[i] With its importance, one would think that it would be the most protected and revered resource on the planet. Sadly, water is taken for granted. Most people don't think twice when they turn on the faucet. Where did the water come from? How can I preserve it? What is my impact on water and how does it affect me? The connection between what is commercially available and what is in the environment is lost to too many. For example five years ago, a local teacher tasted milk straight out of a cow and exclaimed, "It tastes like real milk." In this teacher's mind there is little or no connection between what is bought in jugs at the supermarket and what an animal produces. Similarly students are ignorant of the connection between the tap/bottled water and the water in the atmosphere. Being ignorant of this integral part of our lives is a big mistake. Very little of the water on the earth is available for our use. It is a precious commodity.

Ninety seven and a half percent of the Earth's water is too salty for consumption (1,351,000,000 km^3), while the remaining two and a half percent of the Earth's water is fresh (35,000,000 km^3). Of that, two-thirds of the fresh water is not available for use because it is frozen (24,500,000 km^3) or may be inaccessible in the ground (10,600,000 km^3). Only eighty three hundredths of a percent is on the surface (135,000 km^3).[ii] In the year 2000, humans used 642 m^3/yr/person on average worldwide. This average totals 3,973 km^3/yr worldwide and is projected to increase to 5,235 km^3/yr by the year 2025.[iii] Water will set the Carring Capacity (K-factor or limiting factor) for the human population on Earth if we do not begin to use it more responsibly. We must learn to live within our hydrological means, or it will limit us.

Location, location, location

The Appoquinimink School District is located, for the most part, in the Appoquinimink River Watershed and the C & D Canal East Watershed. Redding Middle School and its students are in the former. The majority of the students live in a suburban to urban setting with little exposure to public parks and public lands. Not much is left of the forest that once dominated the landscape 300 years ago. Instead, students play on well-manicured lawns, parking lots, the street or in their homes. Other than a rainstorm interrupting play or flooding a field or basement, students notice very little of the hydrologic cycle. They are insulated from the natural world and a crucial part of all life and society.

"A watershed is all of the land that water moves across and under while flowing to a specific body of water."[iv] This includes the water and organisms in that area. The Appoquinimink River Watershed drains 47 mi^2 of land (approximately 25,167 football fields[v]) on the coastal plains of Delaware into the Appoquinimink River and ultimately the Delaware Bay.[vi] Before colonization it was forest and marsh. After colonization, the area was used to transport goods from the Delaware River to other parts of the Delmarva Penninsula and the Chesapeake Bay. Middletown and the surrounding communities of Odessa and Townsend were founded as stops for traveling merchants. The land was then developed for agriculture, and the majority of it is still used for the growing of corn, soybeans and small grains[vii] but is rapidly being urbanized.[viii]

There are small, discontinuous forests of oak, hickory, pine, and other southern tree varieties dotting the stream sides and valleys.[ix] Very few uninterrupted tracts of forest remain. These forests and the wetlands support communities typically comprised of herons, egrets, kingfishers, osprey, swallows, otters, mink, beavers, deer, flying squirrels, meadow jumping mice, bats and opossum. They are also home to bald eagles, bog turtles and different species of hawk – all endangered.[x] The Appoquinimink River Watershed contains the last undisturbed marsh system left in Delaware.[xi] It is highly valued as a spawning and nursery area for aquatic life and water fowl.[xii] Through Delaware Natural Resources and Environmental Control (DNREC), the water currently is designated for primary recreational contact, secondary recreational contact, industrial water supply and agriculture,[xiii] though the Appoquinimink River is on the impaired water list. The EPA found the river contains sufficient amounts of PCBs and dioxins to restrict consumption of fish caught in this waterway.[xiv]

Topography and Tributaries

Middle and southern Delaware is relatively flat. The highest point in the Appoquinimink River Watershed is 88 feet above sea level, located half a mile north of the southwest tip of the watershed boundary. Its lowest point is the west side of Silver Lake, 3 feet below sea level. It drains into Delaware Bay at sea level.[xv] The steepest slopes in the watershed are along the streambeds.[xvi] Shaped like a piece of pizza or an arrow pointing east, the headwaters start in the west and drain eastward into four man-made ponds or impoundments maintained by dams[xvii]: Shallcross Lake, Silver Lake, Noxontown Pond and Wiggins Mill Pond (from north to south). The tributaries include Deep Creek, Dove Nest, Hangman's Run, Drawyer Creek and the main stem of the Appoquinimink River.[xviii] The water is tidal, salt or brackish water from the mouth of the Appoquinimink River to the confluence of Drawyer Creek, the dam at the head of Silver Lake and the dam at the head of Noxontown Pond. Waters above these barriers are nontidal freshwater.[xix] The watershed is divided into seven subwatersheds: Appoquinimink One and Two, Dove Nest Branch (Redding Middle School's location), Hangman's Run, Deep Creek, Noxontown and Drawyer Creek.[xx]

Changing Use

The Middletown-Odessa-Townsend area (MOT) is one of two of the fastest growing areas in Delaware.[xxi] The Appoquinimink River Watershed lost 30% of the forested land to agriculture and urbanization,[xxii] but the expansion of land used for agriculture has not continued. Between 1992 and 2007, the percent of land cultivated for agriculture dropped from 62% to 44% and the forested land dropped to a low of 8% of the land in the watershed. Land for residential and urban use increased from 11% to 28%. The amount of wetland increased a percent (from 13% to 14%), as well as land submerged (4% to 5%).[xxiii] Another distressing change is that of the impervious surfaces (surfaces through which precipitation and snowmelt cannot infiltrate, but instead runs off as storm water). They have increased from covering 4% to covering 9% of the land in 2007. "Hydrologic changes resulting from the urbanization of agricultural lands may result in increased flooding, channel erosion and water quality impacts in the watershed."[xxiv] The most affected areas, in Middletown and Odessa city limits, are the Dove Nest Branch subwatershed with 19% impervious surfaces, Deep Creek subwatershed with 16% impervious surfaces and Appoquinimink One with 14% impervious surfaces. These have seen an increase of 33%, 38% and 25% prospectively.[xxv]

Less than 10% of the land is protected from development and only one parcel of forest remains, in the Drawyer Creek subwatershed. 60% of the land in the Appoquinimink River Watershed is able to be developed for medium to low density residential use.[xxvi]

> One common characteristic of urbanized areas is the high percent of impervious surface. Much of the impervious surface directly connect to nearby surface waters through storm drainage systems. As a result, runoff is rapid following rain events and flow in urban streams is typically dominated by stormwater runoff during these periods.[xxvii]

Of the 50 miles of the Appoquinimink River and its tributaries, all are considered nutrient impaired due to runoff issues from the agricultural, residential and urban use of the land, though all the ponds still support life and 84% of them can still support recreational use.[xxviii] Nutrient impairment is high nutrient levels in the watershed.

Impairment

Appoquinimink River Watershed is on the impaired water list for high nutrient levels, low dissolved oxygen[xxix], the presence of DDT, dieldrin, PCBs and dioxins in the water.[xxx] High nitrates and phosphate levels (nutrients) promote algal growth. When the algae die, bacteria populations grow with the added food source. They consume the oxygen in the water through cellular respiration and the fish suffocate.[xxxi] The nutrients are coming from point and nonpoint sources in the watershed: residential fertilizers, agricultural fertilizers, animal waste deposits and the MOT Wastewater Treatment Plant.[xxxii] The EPA ordered a reduction in the Total Maximum Daily Load (TMDL) by 83.5 lb/day for nitrates and 4.5 lb/day for phosphates in 2003. To assess further damage of the increased storm water runoff, twenty miles of waterways were walked and assessed for their eroded banks, impacted riparian buffers, dumped trash, utility crossings, stream crossings and channel modifications. Recommendations were made and local residence and DNREC worked to remediate the watershed. By the spring of 2006 the nitrate contamination had dropped 446 lbs and the phosphate contamination was down 33 lbs.[xxxiii]

Additionally, *Enterococcus* bacteria impairs the local waterways. When humans come in contact with freshwater with over 100CFU[xxxiv]/100ml and marine water with 35CFU/100ml, they are likely to become sick: urinary tract, wound, blood, brain and heart infections. The only point source polluter in the area is the MOT Wastewater Treatment Plant.[xxxv] The nonpoint source is the storm water runoff. DNREC ordered the level be reduced between 69 and 73% in marine water and 9 and 15% in freshwater in the Appoquinimink River Watershed.[xxxvi] Best Management Practices were recommended to limit the amount of runoff flowing into storm water drains and directly into streams. Riparian buffers, vegetative cover and precipitation management measures were proposed and implemented.[xxxvii]

Curricular Matters

The seventh grade science standards include the hydrologic cycle, the Clean Water Act of 1972, water testing, and the interaction between humans and the environment. In the past, my teammates and I have taught the water cycle (evaporation, transpiration, condensation, precipitation, surface and underground runoff and infiltration) as a purely theoretical exploration. The students label various models of the cycle and pretend they are water molecules to see the random nature of the cycle. They document the state of matter of H_2O in all parts of the process. The eighth grade teachers share that the students are very confident on the state test about the facts and terms, but they should be more than knowledgeable and more than prepared for a test. The hydrologic cycle is part of the students' lives. There should be some application, a direct connection between the cycle and the world around them. This unit is designed to do just that.

Background

The sun fuels the hydrologic cycle starting the movement of water through evaporation and transpiration. The water then condenses and forms water droplets and clouds which drop precipitation. Then the cycle is fueled through gravity. The water moves downhill on the surface of the land or into the ground through infiltration. The water can return to an open surface water source and evaporate, be absorbed by an organism and transpire or join an aquifer in the groundwater. Underground the water can travel deeper into the soil until it hits an impermeable layer and stay or begin to move in a horizontal downward trajectory until the surface drops lower than the water table and the water becomes surface water again. Some water can be trapped in aquifers underground. The hydrologic cycle is random in flow and duration.

Evapotranspiration

Thermal energy changes liquid H_2O on the surface or in organisms into a gas. This is evaporation and evapotranspiration, respectively. Fifty-five times more water evaporates from the ocean than from freshwater sources (502,800 km^3/yr: 9,000 km^3/yr)[xxxviii]. The water evaporating from the Earth's oceans can fall back into the ocean or fall on land and replenish the freshwater on the surface or in the ground since the evaporation process leaves the salt in the ocean. The ocean only replenishes approximately 38% of the fresh water; 50% of freshwater replenishment on Earth comes from transpiration (water from plants).[xxxix] Areas with poor soil permeability or large areas of impervious surfaces can see large amounts of their rainfall return to the sky through evaporation and transpiration. For example, 12% of precipitation recharges the groundwater in arid Southwest Australia: 88% of it re-evaporates or transpires.[xl]

The east coast of the United States is surrounded by multiple sources of evaporation and transpiration causing it to be very humid during the summer months.[xli] The jet stream and prevailing westerlies also direct moisture from the Gulf of Mexico along the Appalachian Mountains to our region. Though deforestation has an impact on transpiration, in our watershed it has more of an impact on the infiltration and surface runoff rates.

Precipitation

Precipitation is water in a liquid or solid state falling from the sky (rain, sleet, hail, freezing rain or snow). It is four times more likely to fall in the ocean than on land (458,000 km^3/yr:119,000km^3/yr).[xliii] Precipitation remains fairly constant on the planet.[xliii] The temperate climates have short term or seasonal fluctuation, while tropical and polar climates have long term atmospheric/oceanic fluctuations (El Nino/La Nina).[xliv] Currently humans only use one-third of the precipitation on Earth. The location of the population in relation to the precipitation (location and time) causes water shortages. The greatest disparity between population and water sources is in North Africa and East China. China has 19% of the world's population and only 6% of the world's freshwater. India has 16% of the world's population and only receives 3% of the world's freshwater. Their seasonal precipitation causes long periods of drought and shortage during the dry season. Regions in India were involved in violent conflicts over the allocation of this precious commodity.[xlv]

In the United States, only Utah, North Dakota, Iowa, Illinois, Mississippi, Vermont, Connecticut, Maryland and Delaware do not expect water shortages.[xlvi] Though Delaware has a growing population and is located between many high population areas, the ratio between population and precipitation is not of concern. There is a sufficient precipitation rate (between 30in and 60in/yr) from the surrounding bodies of water mentioned in the previous section. Climate change is predicted to have an effect on rain patterns and the freshwater supply.[xlvii] Thus, students must be trained to become advocates of the environment and be able to apply their knowledge of the hydrologic cycle so that they may respond to these changes appropriately.

Condensation

Condensation is the changing of water from a gaseous state to liquid through the loss of thermal energy. The collection of these liquid droplets can be seen as clouds. The Appoquinimink Watershed is particularly prone to fog, being surrounded by so many sources of water. They usually 'burn off' or re-evaporate as the temperature increases and the sun rises. In the coastal deserts between the Pacific Ocean and the Andes Mountains in Peru and Chile, whole biomes survive on moisture collected from condensation because the precipitation rate is so low.[xlviii] This is not necessary in our watershed. Instead, the high moisture content in the area causes issues for mold and mildew allergy sufferers.

Infiltration

Infiltration is the recharge of groundwater by surface water percolating through the soil. In 2005, the United States withdrew 482.2 km^3/yr of the 10,600,000 km^3 of groundwater available on Earth (1,518 m^3/person/yr). The majority of this was for industrial and agricultural use; only 13% was for domestic use.[xlix] If water continues to be taken from the ground and not replenished, salt water will begin to seep into the freshwater supply or the supply will run out. Plants, wetlands and certain soil types help the water stay in one location on the surface to percolate and recharge the groundwater supply.

Unlike the Midwest and western portion of the United States, Delaware (and most of the east coast) have high aquifer recharge rates.[l] The Appoquinimink River Watershed has a particular advantage because of the extent of its wetlands which hold water and increase infiltration rates like a sponge into its three aquifers: the Columbia, the Englishtown and the Mt. Laurel.[li] Unfortunately between 1992 and 2007, our watershed has lost 414 acres of wetland and only 66.5% of the remaining 171,045 acres perform well to moderately well in retaining surface water for infiltration.[lii] During times of drought, the wetlands are particularly helpful for storing surface water and aiding in recharge.[liii] The increase in impervious surfaces in the watershed has also changed infiltration rates. "During dry conditions, urban streams contain little stormwater since urban watersheds drain quickly and base flows are reduced due to lower infiltration rates and reduced recharge of groundwater."[liv]

Deforestation also changes the makeup of the surface of the watershed. Though the land is still used by plants, agricultural use is only on the uppermost layers of the soil. The agricultural organisms grow seasonally with shallow roots. Large permanent plants, such as trees, help percolation of water through the soil with their deep roots increasing the permeability of the soil. The shallow layer of permeability created in deforested areas creates greater issues. Japanese scientists found that the surface moisture level increased when a temperate coniferous forest was removed which led to more flooding and less infiltration.[lv] Deforestation changes the soil's permeability and the hydrologic cycle.

The recharge rates for the aquifers in the Appoquinimink River Watershed are not all the same. The Columbia is an unconfined aquifer at a fairly shallow depth. Water in this watershed can easily infiltrate through the highly permeable soil into the Columbia. This is good for recharge rates but nutrients, undesirable, can also easily infiltrate into the unconfined aquifer. The ground water was last tested in 1995 and the nutrient levels were below the EPA's maximum recommended load of 10mg/L, but since then the Appoquinimink River Watershed has been cited for nutrient impairment.[lvi] Measures have been taken to remediate the nutrient overload, but further testing should be conducted to ensure safe drinking water. The Englishtown and Mt. Laurel aquifers are confined aquifers. Confined aquifers have impervious surfaces above the aquifer in certain areas restricting access of infiltrating water into the aquifer. These aquifers can only be recharged in limited areas where the ground above is penetrable. Nutrient contamination cannot infiltrate into the Englishtown and Mt. Laurel aquifers from this watershed because there is impervious surfaces above them in the Appoquinimink Watershed.[lvii]

Surface Runoff

Water flowing downhill on the surface is surface runoff. Fueled by gravity, surface runoff draws all water toward sea level or infiltration into the soil. Steeper slopes increase the speed of the water. Consequently the faster the water moves, the less likely the water will infiltrate. Surface runoff has the greatest potential in the hydrologic cycle to cause destruction and to become contaminated because it is sharing the same space with many organisms on the planet.

Surface runoff is measured in runoff curve numbers: an approximation of the amount of runoff from a rain event in a specific location. Soil type, land use and hydrology of the area are utilized to calculate this value. The numbers range from 30 to 100, with low rates meaning lower runoff resulting in higher infiltration and high rates indicating higher runoff resulting in less infiltration.[lviii] Higher numbers indicate a higher likelihood of localized flooding. In the past decade, flooding has increased 200% worldwide. The United States has suffered from more than 50 floods in this same time period, one of only three countries on the highest end of the scale. Climate change, drainage of wetlands, dam/embankment construction, and deforestation increase the chances of flooding.[lix] Locally, the majority of the Appoquinimink River Watershed has a runoff curve number in the seventies with a low of sixty-nine and a high of ninety-nine, which increases the likelihood of flooding in our area.[lx]

The loss of wetlands in our watershed has greatly impacted these numbers. Wetlands act like a sponge, holding water during rain events, then slowly releasing the water. One acre of wetland can hold 330,000 gallons of water. The vegetation in the wetlands take in sediment, minerals and nutrients in the runoff as well as blocking and holding the water from upstream and from wave/tidal action downstream.[lxi] FEMA noted that the expanse of Delaware's wetlands spared Delaware Beaches much of the destruction during Superstorm Sandy from the high level of precipitation and storm surge. Up to 25% of Delaware's land is wetlands (320,076 acres), 42% of these in the Delaware Bay Basin of which Appoquinimink River Watershed is a part. This regulates 40% of the surface runoff flow.

Since 1780, however, Delaware has lost 54% of its wetlands – over 4,000 acres in just the last twenty years. This land has been converted to other uses: agriculture, residential and urban development, transportation and pond creation. Delaware's wetlands are mostly made up of two types: estuarine downstream[lxii] and palustrine upstream[lxiii]. Much of the estuarine wetlands loss in Delaware is due to submergence[lxiv] (238 acres). The remaining and majority of the wetland loss is palustrine. The loss is due to construction and agricultural development. Wetlands are frequently damaged by real estate development, agricultural conversion, pine plantations, damning for water supply, pond construction, channeling or draining, pollutants, invasive species, landfills and navigational dredging. [lxv] The Appoquinimink River Watershed is currently affected by the first eight of these ten factors.

Of these factors, real estate development and agricultural conversion are having the greatest impact. Sixty percent of the land in the Appoquinimink Watershed is designated as developable.[lxvi] This continued change from permeable surfaces to impervious surfaces such as roads, parking lots and buildings changes the hydrologic cycle in the area. Impervious services stop infiltration of precipitation or snowmelt causing it to runoff instead, becoming storm water which picks up and carries surface contaminants into the waterways: oil, gasoline, dirt, litter, debris, pesticides, and nutrients from human activity. DNREC has cited the Appoquinimink River Watershed for nutrient impairment and other pollution contamination from increased storm water runoff, improper draining and inadequate treatment from the MOT Wastewater Treatment Plant before release to the environment.[lxvii] Among the recommended Best Management Practices from DNREC, it is noted that New Castle County has a 100ft minimum riparian buffer ordinance, but Middletown does not.[lxviii] Riparian buffers are vegetated areas surrounding open bodies of water that act as filtration or sponge to stop nutrients and other contaminants from reaching the water and to slow surface runoff to increase infiltration. This lack of ordinance is not the only cause of contamination in our watershed; the storm drains empty directly into the local waterways. The storm water is not filtered or cleaned and takes the remains from human activity directly into our local water supply. I hope this curriculum alleviates this problem through education of the students and through them, their families and our local community.

Watershed Unit

Currently, the Appoquinimink School District gets resources from the Delaware Science Coalition. The students have already studied a unit on basic chemistry: density, phase change and solubility. Some of these support the concepts in this unit. The state-provided watershed unit contains lessons about the water cycle in general: a lab about transpiration through collection of water from leaves, a lab on permeability in which students test the porosity of clay, gravel and sand and a lab about the random nature of the movement of water particles through the water cycle. After the water cycle instruction, the students learn how to delineate watershed bounders using topographic maps and test water for dissolved oxygen, turbidity, nutrient levels and acidity. The students also learn about water treatment plants. The lessons purposed in this paper are in addition to those in the unit, to localize and connect the unit to our immediate community. They will be incorporated into the water cycle concept of the learning map.

Strategies

Students will be using multiple strategies to aid their learning: writing, movement, song, and experimentation. Students will journal, write logs and document their observations through stream walk analyses. Writing makes students organize their thoughts and rehearse information as they document. It increases their understanding through analysis, repetition and movement.

Additionally, students will use song and movement to understand and remember the multiple –ation vocabulary of the water cycle. They will sing a modified version of a well-known children's song: *It's raining, it's pouring, the water cycle's restoring: evaporation, transpiration, condensation, precipitation, infiltration. It's restoring!* [Sung to the tune of "It's Raining, It's Pouring"]. For each of the vocabulary terms the students will perform movements. For evaporation they will wiggle their fingers as they move them from waist level to arm pit level. This will help them remember that water changes from liquid on the ground to gas in the air. Then the students will use their hands at armpit level to wave at their arm pits, as if cooling off sweat. They will use this to remember that transpiration is the evaporation of water from living things. While chanting condensation, their hands will form bubbly clouds in the air, tying condensation to the formation of clouds: water in a gaseous state returning to a liquid state. Next their hands will flatten and move straight down toward waist level again, mirroring the movement of rain toward the earth. Lastly, the students will angle their flat hands at a 45 degree angle toward the earth at waist level and push down and outward to indicate the water entering the earth's surface while they chant infiltration. I will allow my students to play with the movements and tune to personalize as long as they have a rational for their movement. Mnemonics are best when they are created (or in this case modified) by the individual trying to use them for memory aids.

Finally students will be doing multiple labs in which they will be observing the world around them or documenting results and then analyzing. Experimentation is active learning. Passive learners retain much less information. Learning from lectures or readings alone are less effective tools of instruction.

Organization of the Unit

Students will begin the unit with vocabulary instruction. They will learn the song described above, use Frayer Model graphic organizers and label general illustrations of the water cycle. Students learn concepts at higher rates if they are familiar with the vocabulary before starting the lesson. They will learn the words hydrologic cycle, evaporation, transpiration, condensation, precipitation, surface/underground runoff and infiltration. Percolation, permeable/impermeable and porosity will be added later. The lessons will then be organized by the components of the hydrologic cycle.

Evaporation

Students will examine evaporation through analysis of water bodies in our area and documenting the sources of water for our watershed. They will compare the amount of water sources available for our highly populated area with similarly highly populated areas, such as Chicago, Phoenix and Seattle. They will determine which areas might have greater issues with insufficient water resources and describe why our area currently does not have issues with population to water issues though we have a high population density.

Deforestation Evaporation Lab

To study the consequence of deforestation in the Appoquinimink Watershed, students will examine the difference vegetation makes on evaporation rates. The lesson essential question is "How does the loss of vegetation affect evaporation?" The activating strategy will be looking at aerial maps of the Appoquinimink Watershed for the last fifty years. They will write about the changes they see. We will discuss the changes in forested and agricultural coverage of the land in the last three hundred years. The students will hypothesize how the change affects the evaporation of the water that falls on this area.

The materials for this lab are three pie pans per group, electronic scale, sunny day, 500ml of water for each pie pan, top soil to cover the bottom of 2 pie pans 1in deep and moss or sod to cover one pie pan. Students will fill one pie pan with 500ml of water and record the mass. Second students will fill the second pie pan with 1in of top soil and 500ml of water and record the mass. Third students will fill the last pie pan with 1in of top soil, cover that with a layer of moss or sod and add 500 ml of water. They will record the mass. The students will place the three pans in a sunny location (one that gets sun for most, if not all the day). After twenty-four hours, students will collect their pie pans, measure and record the masses and analyze their data. Why did the empty pie pan lose the most mass? Why did the pie pan with the vegetation retain the most? How does this apply to our watershed? The students will draw conclusions about the consequences of deforestation on the hydrologic cycle in our watershed as an exit ticket. Note: this lab must be done when there is no precipitation forecasted if the pie pans are place outside.

Transpiration and Condensation

The next lesson is from the Science Coalition kit. The students will collect water transpired from trees to see the process that is usually invisible to the naked eye. Through the evaporation and transpiration lessons, students will be keeping a fog journal. They will document how many mornings they awaken to fog and the density of fog on a scale of one to ten, developed by the class. The data will be collected and analyzed after our evaporation lessons. We will discuss the consequences of high condensation and humidity levels through the use of weather.com warnings concerning high mold/mildew ratings for allergy suffers.

Runoff and Infiltration

After this the students will study infiltration and surface runoff at the same time since the two are so closely linked. The group of lessons will start with a vocabulary opener for students to learn permeability, porosity, permeable and impermeable. They will draw illustrations and compare the words permeability and porosity. The next lesson will be the kit lesson testing the permeability and porosity of sand, gravel and clay. We will discuss the makeup of the soil in different areas of Delaware and the consequences to the hydrologic cycle in the various watersheds.

Next we will continue the discussion started during the evaporation lab, how does the land use changes affect the hydrological cycle in the Appoquinimink Watershed? We will re-examine the aerial maps of the watershed and document the increase of impervious surfaces. The students will be instructed to collect data that evening of the impervious surfaces covering the earth in their neighborhood and storm drains. Students will be encouraged to use their electronic devices with digital photographing ability to document their findings. I will upload these images and use Google maps to plot our findings. At this time I will invite a paving company to come in and discuss the different paving surfaces currently available on the market, including the permeable pavement.

Permeability of pavement lab

To study the consequence of impervious surfaces, students will examine the runoff rate of different pavements. The lesson essential question is “How does the paving material affect infiltration?” The activating strategy will be discussing their prior knowledge of what happens around their homes when it rains. Where does the rain go? Where do they see puddles afterward? Why? We will discuss the differences and compare the surfaces upon which these differences occurred. The students will hypothesize how pavement affects runoff rates.

The materials for this lab are a camera, tin turkey baking dishes, flat dry sponges, a camera, 1000ml of water, a level, graph paper, sections of impervious pavement, cinderblock, permeable pavement and other paving materials such as brick pavers or gravel. Each lab group will test one of the paving materials. In the baking dish, the students will line the bottom with dry, flat sponges. On top of the sponges, they will place their paving material (solid). They must try to make it as level as possible. The students will then pour the water slowly onto the pavement. The photography will take picture of the movement of the water on or through the surface. Once the water has fully been poured and is off the source of the pavement, the students will carefully lift the pavement and take a picture of the sponges. They will diagram where the water has gone on a graph paper, like coordinate mapping. The students will then compare where the water went with the different surfaces. They will analyze their results. What paving materials stopped water from infiltrating? What material had the greatest infiltration? What consequences would this have on the hydrologic cycle? Why is the paving material the allows for the least infiltration used most often? Why is gravel not used as often? Brick pavers? Permeable asphalt? How could you convince the local government on their next repaving job to use more ecologically friendly materials? The last question is their exit ticket. They students will be reminded to use evidence from their lab and knowledge from class to support their answer.

Stream Survey

The last activity the students will do before learning about topographic mapping and watershed boundary delineation is a stream survey. Students will examine the consequences of the increased impervious surfaces on the surface runoff and streams in the Appoquinimink Watershed. The lesson essential question is "How does increase of impervious surfaces affect surface runoff?" The activating strategy will be reading the data chart DNREC published about the urbanization increase and loss of agricultural and forested land in the watershed. The students will color code maps of Middletown where impervious surfaces have increased in the last 30 years. These maps will have the streams and waterways on them as well.

The materials for this lab are maps of the Appoquinimink Watershed with streets, developments, major buildings and waterways documented, colored pencils, rulers or tape measures and a survey sheet. After shading the areas they believe are most affective, we will share as a class and talk about the reasons for these changes, the possible ramifications of these changes on water and where the water flows in our watershed. I will then distribute the stream survey. The students will pick a stream that they will walk that week (walk along the stream's banks) and document what they see. I will encourage them to take pictures to support their findings.

The stream survey will ask the students to document location and number of storm drains, human channeling under roads or other obstructions, construction of reinforced embankments or dams, or ramps for human access to the waterway. The students will also note the amount of tree coverage and depths of unmowed border on the stream banks (riparian buffer) at a number of locations. They will measure the lowest and highest stream banks and their location on the stream. They will mark areas of litter collection and size of pebbles, rocks or silt on the stream bottom for 100 yds (length of a football field) of a stream.

The students will use this collected data to analyze the effects of storm water runoff. How badly eroded is the bank of the stream? Why? Where is there evidence of human interference? What, if any, are the consequences to the water? Why have humans done these things to the water?

To help their analysis, the students will read a copy of the Appoquinimink Tributary Action Team's report on improving the water quality in the Appoquinimink Watershed. They will discuss the possible consequences to these actions and their exit ticket will be how they can help. They will make a plan about how they can improve the surface runoff problems in the Appoquinimink Watershed.

The unit will continue after the topographic mapping to investigate an ecomystery in the Appoquinimink Watershed, a fish kill. The mystery is a fake one but will involve the problem areas we discussed in the hydrologic cycle concept: nutrient contamination from high surface runoff, high pH from urbanization, high turbidity from construction and surface runoff and oil and other pollutants from storm water drainage. We have used this ecomystery for many years, but this will be the first year we support the mystery with background knowledge of the Appoquinimink Watershed to this depth. The culmination of the unit is to give the students the real water from various locations in the watershed and have them test the water, analyze the health of the streams through pictures and report back their findings and suggestions to keep the MOT area the most undisturbed wetland in Delaware.

Annotated Bibliography

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Localized Hydrologic Cycle: Human-Water Cycle interaction in the Appoquinimink River Watershed   Victoria Deschere

Key Learning

Water is a precious commodity that must be treated with respect, locally and globally, for life to continue on Earth.

Unit Essential Question

How do we become conservers and preservers of the water on Earth?

Concept 1	Concept 2	Concept 3
Water Movement	**Watershed Outlines**	**Human Impact**

How much water is accessible for human use?
How does water move through the hydrologic cycle?
How does the loss of vegetation affect evaporation?
Why does water puddle in northern Delaware more than southern Delaware?
How does the paving material affect infiltration?
How does increase of impervious surfaces affect surface runoff?

How do you determine what is downhill?
Why are estuaries, marshes and wetlands important?
How do you define a watershed?
Why are we called the Appoquinimink Watershed and Delaware Estuary?

How do humans impact water?
How does air pollution impact water?
How does fertilizer impact water?
How does land development impact water?
How can we lesson our impact on local watershed?

Hydrologic cycle, evaporation, transpiration, condensation, surface runoff, underground runoff, precipitation, infiltration, percolation

Topographic map, contour lines, slope, gradual, steep, marsh, estuary, wetland

pH, turbidity, nitrates, phosphates macro-invertebrates, biodiversity, riparian buffer, conservation, fertilizer, land development, acid rain

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