Unit VI:

Effects of Land Use On the Watershed

Unit VI Land Use
Introduction

Land use has a major impact on the water quality of both surface and ground water. Land use refers to the human use of the land. What are the historical uses as well as the current uses of land in the watershed? How was the land used by indigenous people before European settlers? How did the early settlers use it? Did the industrial revolution affect the watershed with dams, mills and concentrated village areas? What has the population movement been like over the last 100 years? Where are the cities and large towns in the watershed? Is there agriculture or industry in the watershed? Are there any wastewater treatment plants?

Certain kinds of land use can change the hydrology of the Watershed, altering the way water and pollutants move through the drainage basin. For example, as an area of land is converted from open space (e.g., woodland) to residential, the amount of runoff for that area of land will increase as the amount of impervious surface increases. Rain, which would have once seeped into the soils beneath the forest floor and been absorbed by tree roots, instead flows off impervious surfaces (roofs, driveways, streets, parking lots, etc.) into the nearest stream, pond, or lowland area. As rainwater runs off these surfaces, it will also carry off any existing pollutants. Thus, not only has the rate of runoff increased for that area, but the amount of pollution that enters nearby waterbodies may also increase. In addition to hydrologic changes, some land uses may not be appropriate for certain types of soils (See previous chapter). It would not be advisable, for example, to install a septic system in an area characterized by wet soils as this may cause the system to fail, releasing untreated waste into the surrounding environment. These are just some examples of how land use can determine the health of a watershed. Other examples will be provided in the following activities and units.

Humans have lived in the Pettaquamscutt Watershed for at least 3,000 years, perhaps as long as 10,000, using the land as needed. Prior to European arrival most of the Watershed, like all of Rhode Island, was forested. The Narragansett and Niantic Tribes, who originally inhabited this area, cleared small portions of the Watershed for sustenance crops of beans, corn, and squash. Early settlers, however, soon displaced the Native Americans from this bountiful land, and cleared much of the area for pasture and large agricultural fields. Numerous stone walls still mark the efforts of the area's early European farmers and their slaves. By the early 1700's, significant parts of the Watershed were included in "Narragansett Country," a fertile agricultural area that supported large plantations and exported horses, cattle, cheese, and tobacco. Agriculture remained a significant activity in Narragansett Country well into the nineteenth century. However, much of the Watershed reverted to forest during 1800s when first the canals and later the railroads opened up the American Midwest and West. This drew people away from the Watershed in droves, leaving it relatively unpopulated until the mid twentieth century.

Land use today is devoted primarily to residential use, with over 35% of the land area in the Watershed already developed. Development has been increasing steadily over the *past fifty years within the Watershed towns, with the most accelerated growth rate occurring in Narragansett. This development has occurred in a piecemeal fashion, particularly in the lower portions of the Watershed, and has resulted in the creation of high-density neighborhoods close to the Narrow River. The proximity of housing close to the River has contributed significant negative impacts to this already fragile ecosystem. Most of the remaining undeveloped land is located in the northern and northwestern regions of the Watershed. Natural features such as steep slopes, high water tables, and wetlands have prevented much of this area from being developed. However, due to recent technological advances and the installation of public utilities in these areas, there is a potential for a 36% increase in residential development (over 1000 more houses).*

References:

Applied Science Associates, Rhode Island Watershed Watch, SAIC Engineering, Inc., Urish, Wright, and Runge. 1995. *Narrow River Stormwater Management Study Problem Assessment and Design Feasibility*, prepared for the Towns of Narragansett, South Kingstown, and North Kingstown.

Ernest, L. M., L. K. Miguel, and J. Willis. 1999. *The Narrow River Special Area Management Plan.* Coastal Resources Management Council, South Kingstown, RI.

Gibbs, E., T. Corey, M. Schwartz, D. Grossman-Garber, C. Jaworski, and M. Bucheit. 1995. *A Guide to Rhode Island's Natural Places.* Rhode Island Sea Grant, University of Rhode Island, Narragansett, RI.

Narrow River Preservation Association. 2002. *The Narrow River Handbook – A Guide to Living in the Watershed*, second edition. Narrow River Preservation Association, Narragansett, RI.

Town of Narragansett. 1994. *Narragansett Comprehensive Plan.*

Town of South Kingstown. 1992. *Town of South Kingstown Comprehensive Plan.*

<u>NOTE:</u> This Introductory Discussion should describe the historical and current land uses and hydrology in your watershed. This whole page is an example.

INTRODUCTORY DISCUSSION:

Land use in the Flat River Reservoir Watershed has changed over the last 500 years. These changes have altered the hydrology of the watershed. Hydrology refers to the movement of water through the watershed, both through infiltration to ground water and surface water runoff. Land use changes have altered the hydrology because different land uses have different effects on the way water moves through a watershed.

1. How has land use changed over time?
    a. <u>What was the original land use?</u>
        The vegetation following the last glacier was an evergreen hardwood mixed forest.
    b. <u>What happened when the Indians settled here?</u>
        They used very small clearings in the forests for some crops and their villages.
    c. <u>What happened when the Europeans settled in the New World?</u>
        They began clearing large areas for homesteads, pastures, crops, and, in the case of Coventry, mills along the waterways, in addition to roads, similar to the “urban” areas they had experienced in Europe. Eventually all of the original forests in Rhode Island were cleared. Therefore, all of the forests you see in the state now are second and third growth forests.

2. What are some of the many different current land uses in Rhode Island?
    Land uses include: forest, agriculture, industry (factories), residential (homes), commercial (stores and businesses), recreational (parks and preserves), roads and streets, etc.

ACTIVITY I: HOW DOES LAND USE AFFECT INFILTRATION AND RUNOFF?

OBJECTIVE: Students will demonstrate to each other how various land uses affect rates of runoff and infiltration.

METHOD: Students will pour equal amounts of water onto a model simulating pavement, bare earth, and sod. A comparison of the volume of water collected in runoff from each treatment will be made.

MATERIALS: water, quart jar, watering can, soil, sod, runoff model*, bucket

BACKGROUND INFORMATION:

1. Infiltration is water that seeps into the soil and recharges the aquifer. An aquifer, or ground water reservoir, is the saturated water-bearing portion of the Earth's crust. Runoff is water that does not infiltrate into the aquifer, but instead runs over the surface of the land.

2. Runoff water, or overland flow, eventually collects in surface water bodies such as rivers, streams, or wetland swamps.

3. Forests have less runoff because the leaves and trees slow the rainfall that hits the ground, plant roots absorb water, and water is able to infiltrate into the earth. Pavement has greater runoff because nothing slows the rainfall, and water is not able to soak into the ground.

4. Rates of infiltration for various land uses are as follows (from greatest infiltration to smallest):

forest > pasture > row crops > bare earth > pavement > surface water

Thus rates of runoff are the opposite (from greatest runoff to smallest):

surface water > pavement > bare earth > row crops > pasture > forest

PROCEDURE:

1. Discuss the terms infiltration, runoff, and review aquifer and surface water. Draw the relationships in #4 above to illustrate how the rates of infiltration and runoff compare for different land uses.

2. Place the runoff model on a table in such a manner that the tubing will drain all runoff water to the bucket. Sprinkle a measured volume of water, (1/2 full quart jar) over the

bare surface and record the amount collected in the bucket. What does the bare surface represent? (pavement)

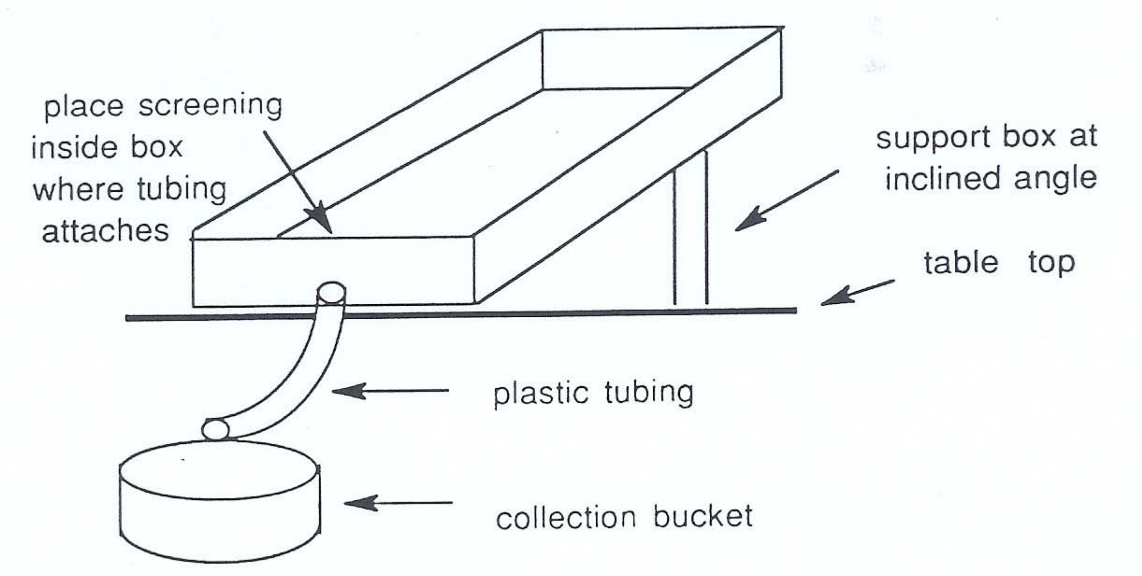
3. Place a mesh screen over the inlet to the tubing and cover the surface with soil. Sprinkle the same volume of water over the soil-covered surface and record the amount collected in the bucket. Now what does the model represent? (bare soil, e.g., from agriculture or construction sites)

4. Place turf grass over the surface and sprinkle the same volume of water over it. Record the amount of water collected.

5. Discuss differences in the amounts of water collected. Almost all of the water should be collected from the bare surface, as would runoff from a rainstorm over pavement. A moderate amount of murky water should be collected from the bare soil. This also demonstrates the effect of erosion on surface water quality, but this concept will be covered later in the “Non-point Sources of Pollution” section. Hardly any water should be collected from the turf, illustrating how plants covering the bare earth greatly increase infiltration.

6. How have the changes in land use over time affected the hydrology of the watershed? Is there more runoff now than there was 200 years ago? Does the runoff water reach the mouth of the (**river(s) your watershed flows into** [*Hunt River and Potowomut River*]) faster now than it did back then?

* You can make your own **Runoff Model** by constructing a shallow wooden box, drilling a hole at one end, and attaching plastic tubing. Old window screening fastened to the inside of where the tubing drains runoff from the box is necessary to keep the tubing from becoming clogged with “eroded” soil.



ACTIVITY II: HOW DOES DEVELOPMENT AFFECT RUNOFF?

OBJECTIVE: Students will understand how a very small change in land use can greatly affect the volume of runoff that occurs.

METHOD: Students will use math skills to calculate cubic feet of runoff on a 100 acre parcel of land. They will compare runoff for pre- and post-development scenarios.

MATERIALS: paper, calculators, runoff graph

BACKGROUND INFORMATION:

1. Runoff increases as developed land increases. Hydrologists use curve numbers to calculate the expected amount of runoff that will result from various land uses. Curve numbers are values assigned to sites based on their soil type and inherent ability to absorb water. The lower the number, the more water will infiltrate, and the less water will run off. Thus pavement has a much higher curve number than forest.

2. In this sample problem, curve numbers are assigned to different land uses. Note that in reality curve numbers will vary with soil type, cropping practices, zoning acreage, etc. For example, farms that use cover cropping (planting a winter grass to hold the soil in the winter) will have lower curve numbers than farms that do not use cover cropping. Two acre zoning areas will have lower curve numbers than ½ acre zoning areas, because the proportion of vegetated land (lawns, trees) to pavement will be higher in the two acre zoning areas.

3. Civil engineers design retention basins which catch runoff from highways, parking lots, and other developed areas. These basins help store and slow down overland flow and thus help to reduce flooding. Retention basins also help to control pollution that may be carried in runoff; thus they will be cover in more detail in the "Non-point Sources of Pollution" section.

PROCEDURE:

1. For this activity, use the following data:

pre-development land use	curve #	area (acres)
woodland	55	30
pasture	79	40
potato farm	81	30

post-development land use	curve #	area (acres)
roads	98	3
homes	75	27

pasture	79	40
potatoes	81	30

Put the data on the board and ask students to identify what area of land was developed, and what it was developed into (30 acres of woodland were developed into 3 areas of roads and 27 acres of homes).

2. The first step is to calculate an average curve number for the whole area of land, properly weighted such that it takes the varying acreage of the different land uses into account. To do this, expand the table of data on the board, adding another column entitled "curve # x area". Have students multiply the curve number x area for each land use in the pre-development scenario and list the products in this new column. A weighted average curve number is obtained by summing these products and dividing the sum by the total acreage. The weighted average curve number for the pre-development scenario is 72.4 (see chart below).

land use	curve #	area	curve# x area
woodland	55	30	1650
pasture	79	40	3160
potatoes	81	30	2430
sums		100	7240

to calculate weighted average curve number: 7240/100 acres = 72.4

2. The next step is to find the amount of runoff, using the curve number graph provided. Rainfall is on the x-axis, runoff is on the y-axis. Assume the rainfall is (**amount of rain you receive in a typical 10 year, 24 hour storm** [*5*]) inches, which is the amount of rain that falls in a typical 10 year, 24 hour storm in (**your state** [*Rhode Island*]) (A (**amount of rain you receive in a typical 10 year, 24 hour storm** [*5*]) inch rainfall occurs about every 10 years). Find (**amount of rain you receive in a typical 10 year, 24 hour storm** [*5*]) inches on the x-axis and follow up the graph until you intersect the curve number 72.4 (halfway between the curves for 70 and 75). From this point, follow horizontally across to the y-axis to find the inches of runoff. In this case, the answer is 2.2 inches.

3. To find the total runoff for the 100 acre parcel, multiply the inches of runoff by the total area. You will need to convert inches to feet and acres to square feet to get a cubic foot value:

$$2.2 \text{ inches} \times \frac{1 \text{ foot}}{12 \text{ inches}} = 0.183 \text{ feet of runoff}$$

$$100 \text{ acres} \times \frac{43560 \text{ square feet}}{1 \text{ acre}} = 4{,}356{,}000 \text{ square feet of area}$$

0.183 feet x 4,356,000 square feet = 798,000 cubic feet of runoff

To convert this figure to gallons:

$$798{,}000 \text{ cubic feet} \times \frac{7.48 \text{ gallons}}{1 \text{ cubic foot}} = 5{,}969{,}040 \text{ gallons of runoff}$$

4. Discuss the fact that a lot of water runs off a 100 acre parcel of land!

5. To find the runoff for the post-development scenario, repeat procedures 2 – 4, using the post-development data:

land use	curve #	area	curve# x area
roads	98	3	294
homes	75	27	2025
pasture	79	40	3160
potatoes	81	30	2430
sums		100	7909

to calculate weighted average curve number: 7909/100 acres = 79

Using the graph, (**amount of rain you receive in a typical 10 year, 24 hour storm** [*5*]) inches of rainfall with a curve number of 79 corresponds to 2.8 inches of runoff.

To calculate total runoff:

$$2.8 \text{ inches} \times \frac{1 \text{ foot}}{12 \text{ inches}} = 0.233 \text{ feet of runoff}$$

$$100 \text{ acres} \times \frac{43560 \text{ square feet}}{1 \text{ acre}} = 4{,}356{,}000 \text{ square feet of area}$$

0.233 feet x 4,356,000 square feet = 1,016,400 cubic feet of runoff

To convert this figure to gallons:

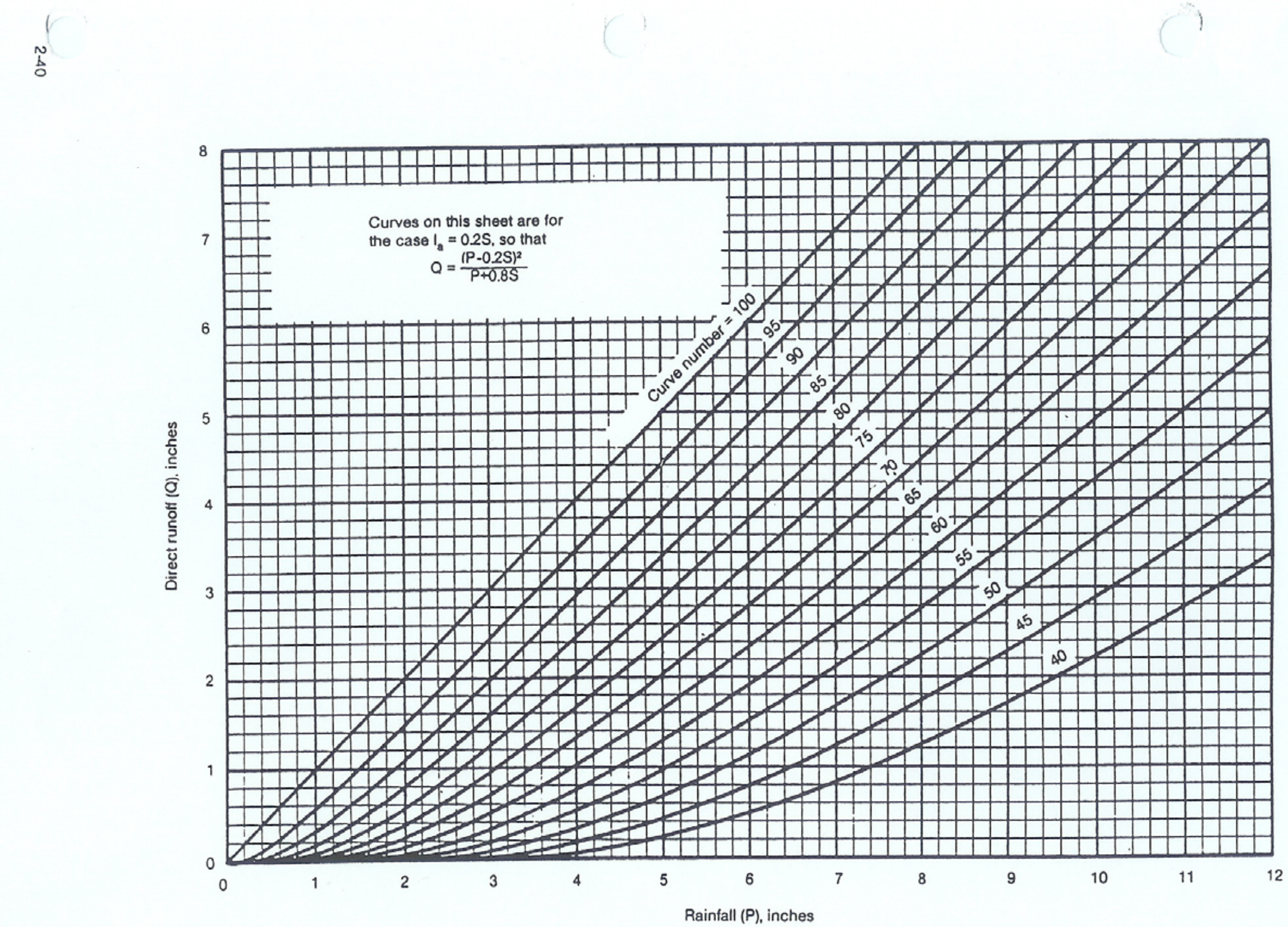
$$1{,}016{,}400 \text{ cubic feet} \times \frac{7.48 \text{ gallons}}{1 \text{ cubic foot}} = 7{,}602{,}672 \text{ gallons of runoff}$$

6. Note the difference in volume of runoff between the pre- and post-development scenarios. There was an increase of 1,633,632 gallons, a 27% increase in runoff when just 30 acres were developed. Remind students that this amount would only result from a (**amount of rain you receive in a typical 10 year, 24 hour storm** [*5*]) inch rainstorm, which occurs about every 10 years in (**your state** [*Rhode Island*]).

7. Is runoff bad? Not necessarily. It depends on what is downstream and if structures are built to prevent flooding.

8. How could this development be designed to reduce the amount of runoff that would result?

9. What structures can be built to control runoff once it occurs?



Runoff Graph

ACTIVITY III: **LAND USE PLANNING**

OBJECTIVE: Students will be able to evaluate an area's suitability for development, based on soil limitations.

METHOD: Students will use soil survey sheets and tables from the Soil Survey of (**your state** [*Rhode Island*]) to determine if an area is suitable for a certain type of development.

MATERIALS: Soil Survey of (**your state** [*Rhode Island*])*, loose soil survey sheets of an area near your school*, GIS maps*, soil survey activity sheets

BACKGROUND INFORMATION:

1. Soils have certain characteristics that make them more or less suitable for certain development projects. A few of these characteristics are wetness, stoniness, depth to ground water, excessive slope, and erodibility. It is important to understand the limitations of the soil to determine if the development is feasible.

2. Look through the Soil Survey of (**your state** [*Rhode Island*]) until you feel comfortable with its contents. You will need to help your students find the proper tables to look up the soil suitabilities for all the given development projects.

PROCEDURE:

1. Divide the students into 4 working groups. Assign each group one of the development projects given in the soil survey activity sheets. Each activity sheet tells the students which tables they will need to use from the Soil Survey of (**your state** [*Rhode Island*]). You may want to Xerox the proper tables for each group if you only have one copy of the Soil Survey.

2. Pass out the loose soil survey sheets. Students can then follow the directions on the activity sheets.

* Copies of your state's Soil Survey, loose soil survey sheets, and GIS maps are all available from your local office of the USDA Natural Resources Conservation Service.

SOIL SURVEY ACTIVITY SHEET

Task: Find an area on your map with about 25 acres to make into a wildlife refuge with a pond.

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1. Pick an area that will be good for woodland and wetland wildlife.
2. Decide which type of trees will work best in this area, conifers or hardwoods. What will grow well that the animals can eat?
3. Look at the table on water management and see if the soil is suitable for a pond reservoir.
4. Look for soils that paths can be put on so that people can hike through the wildlife area.

You will need to use tables 21, 22, and 23.

1. Look up the soils and check if they are suitable for all of the requirements.
2. For a site to be acceptable, all limitations should be "slight" or "good".
3. Draw a circle around all of the areas that have soils that meet all of the requirements.

Follow-up activity:

Find a wildlife refuge on the GIS maps. Use the Soil Survey to determine if the soils are suitable for wildlife habitat development. If not, why do you think they were located there? (HINT: Is the land not suitable for any other use?)

SOIL SURVEY ACTIVITY SHEET

Task: Find an area on your map with about 25 acres that you can make into a recreational area with playgrounds, soccer fields, and baseball fields. You also want a pond and a walking and biking path.

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1. This area will need to have bathroom facilities on it so the soil has to be acceptable for a septic tank absorption field.
2. You need to see if the ground is acceptable for large grassy areas with no rocks and if the area is dry enough to use most of the year. Check if the soil is good for paths.
3. Look at the table on water management and see if the soil is suitable for a pond reservoir.

You will need to use tables 19, 21, and 22.

1. Look up the soils and check if they are suitable for all of the requirements.
2. For a site to be acceptable, all limitations should be “slight” or “good”.
3. Draw a circle around all of the areas that have soils that meet all of the requirements.

Follow-up activity:

Find a park or open space recreation area on the GIS maps. Use the Soil Survey to determine if it is located on suitable soils. If not, why do you think they were located there? (HINT: Was the land donated to the state or town?)

SOIL SURVEY ACTIVITY SHEET

Task: Find an area on your map with about 25 acres to build into a subdivision with 20 houses.

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1. To pick an area for your subdivision, you will have to be able to build roads to the site.

2. The contractor wants to use fill material from the site, so good road base material should be available.

3. The soil will have to be acceptable for basements, since the contractor wants one half of the houses to have basements.

4. You will need to be careful of any wetlands on your property. You can not build near them, nor put roads through them.

5. The last thing to look for is if the soil is acceptable for septic tank absorption fields, since there will be no sewer lines in the area.

You will need to use tables 18, 19, and 20.

1. Look up the soils and check if they are suitable for all of the requirements.

2. For a site to be acceptable, all limitations should be “slight” or “good”.

3. Draw a circle around all of the areas that have soils that meet all of the requirements.

Follow-up activity:

Look at the GIS maps of urban areas. Use the Soil Survey to determine if the urban areas are generally found in areas where the soils are suitable for urban development. If not, why do you think these urban areas were first settled in these locations? (HINT: Are they near water?)

SOIL SURVEY ACTIVITY SHEET

Task: Find an area on your map with about 25 acres that you can grow crops on.

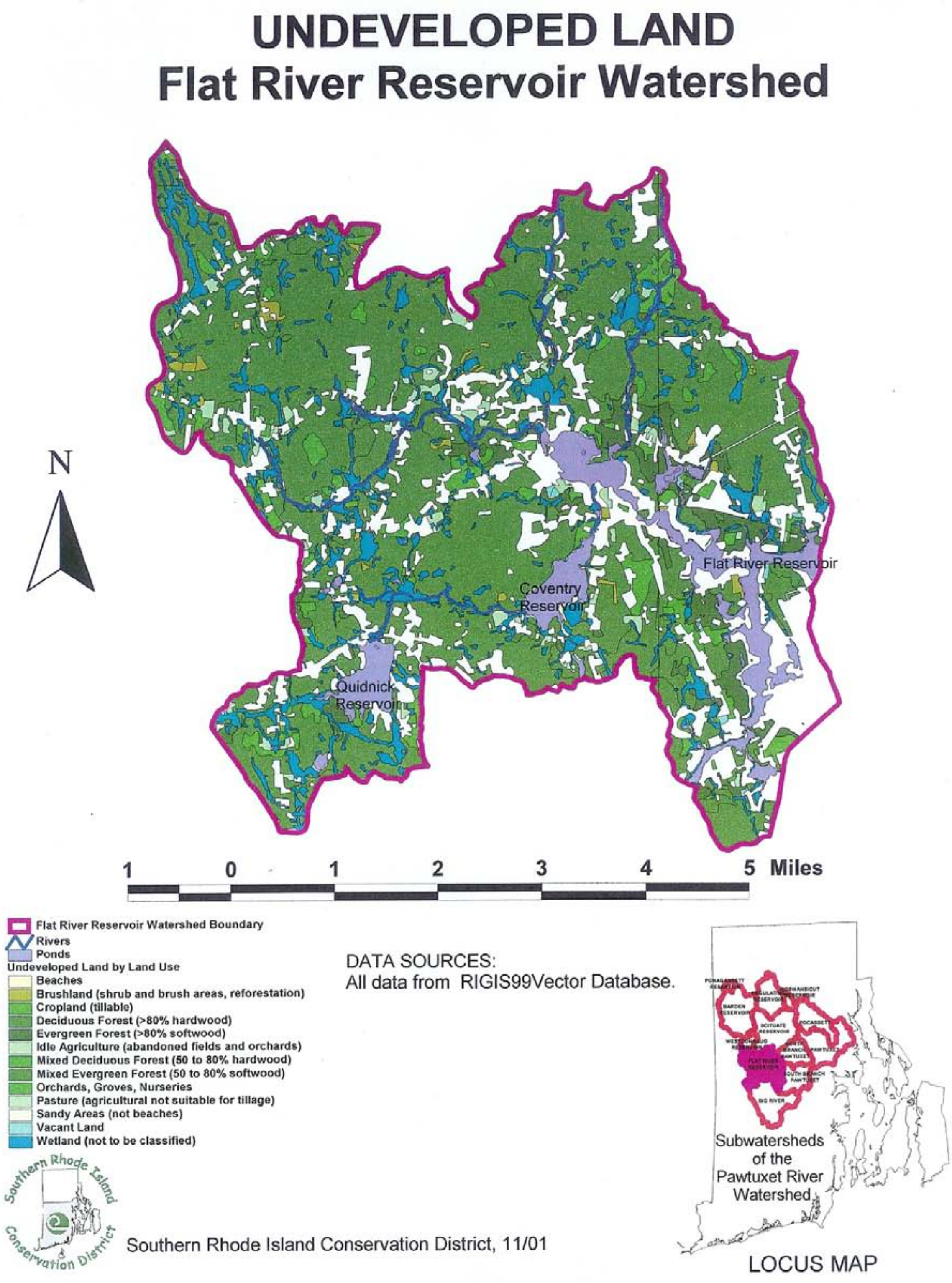
1. You want to grow the crop that has the highest yields.
2. Make sure that the soil is not going to flood.
3. Make sure that the soil is not too steep or too stony.

You will need to use the soil legend and tables 15 and 26.

1. Look up the soils and check if they are suitable for all of the requirements.
2. For a site to be acceptable, all limitations should be “slight” or “good”.
3. Draw a circle around all of the areas that have soils that meet all of the requirements.

Follow-up activity:

Look at the GIS map of agricultural areas in the watershed. Use the Soil Survey to determine if they are generally located in areas with soils suitable for growing crops.


UNDEVELOPED LAND
Flat River Reservoir Watershed
N
Flat River Reservoir
Coventry Reservoir
Quidnick Reservoir
1 0 1 2 3 4 5 Miles
Flat River Reservoir Watershed Boundary
Rivers
Ponds
Undeveloped Land by Land Use
Beaches
Brushland (shrub and brush areas, reforestation)
Cropland (tillable)
Deciduous Forest (>80% hardwood)
Evergreen Forest (>80% softwood)
Idle Agriculture (abandoned fields and orchards)
Mixed Deciduous Forest (50 to 80% hardwood)
Mixed Evergreen Forest (50 to 80% softwood)
Orchards, Groves, Nurseries
Pasture (agricultural not suitable for tillage)
Sandy Areas (not beaches)
Vacant Land
Wetland (not to be classified)
DATA SOURCES:
All data from RIGIS99Vector Database.
Southern Rhode Island Conservation District
Southern Rhode Island Conservation District, 11/01
Subwatersheds of the Pawtuxet River Watershed
LOCUS MAP

Watershed Model: Understanding Nonpoint Pollution and What You Can Do

Teacher Resource Page

<u>Grade Level:</u> 3-6
<u>Time</u>: 1 - 2 class periods
<u>Adapted From</u>: BTNEP/LSU Ag Center: *Nonpoint Source Water Pollution* and from *Save The Bay's San Francisco Bay Watershed Curriculum*

<u>Learning Objectives:</u>

- Make a model watershed using simple inexpensive materials.
- Use the model watershed to investigate runoff and nonpoint source pollution.

<u>Rhode Island Grade Span Expectations Addressed:</u>

Science	**ESS1 - The earth and earth materials as we know them today have developed over long periods of time, through continual change processes.**	
	ESS1 (K-4) - 2	*Use results from an experiment to draw conclusions about how water interacts with earth materials*
	ESS1 (5-6) - 2a	*Diagramming, labeling and explaining the processes of the water cycle including evaporation, precipitation, and run-off, condensation, transpiration, and groundwater.*
	ESS1 (K-4) - 4	*Explain how wind, water, or ice shape and reshape the earth.*
Written and Oral Communication	***W – 11 Demonstrates the habit of writing extensively***	
	W – 9 Writing Conventions: Applying Rules of Grammar, Usage, and Mechanics	
	OC – 1 Oral Communication Strategies: Interactive Listening	
Civics and Government	***C&G 3: In a democratic society all people have certain rights and responsibilities.***	
	C&G 4: People engage in political processes in a variety of ways.	
	C&G 4 (3-4) –3	*Students participate in a civil society by identifying problems, planning and implementing solutions, and evaluating the outcomes in the classroom, school, community, state, nation, or world and explaining how individuals can take responsibility for their actions and how their actions impact the community*
	C&G 5: As members of an interconnected world community, the choices we make impact others locally, nationally, and globally.	
	C&G 5 (3-4) - 3	*Students demonstrate an understanding of how the choices we make impact, and are impacted by an interconnected world*

Materials:

- large piece of plastic sheet
- powdered cocoa mix
- colored drink mix powder (red and green)
- torn paper and cut up plastic
- Coarse salt
- Vegetable oil (optional)
- Sprinkles (optional)
- watering can with sprinkler on spout or large water spray bottle
- water supply
- sponges or cloths for cleanup
- a variety of objects to place beneath plastic cloth to create contours
- toy tractors, trees, animals, cars, buildings
- map or aerial photograph of local watershed
- Permanent markers to draw in land types

Advance Preparation:

1. Spread plastic cloth on a large, flat surface, either inside or outside. Have materials for mopping up water on hand and containers for holding water.

2. Fill spray bottle and/or watering can

3. Prepare the "pollutants."
    a. Cocoa powder can be soil
    b. Vegetable oil or Cocoa/water mixture in a spray bottle - can be used for oil
    c. Cocoa paste or sprinkles can be dog waste and cow manure
    d. Red drink mix powder can be pesticides; green drink mix powder can be fertilizers.
    e. Torn paper and plastic can be litter
    f. Coarse salt can be road salts in the winter time

4. Collect props for the watershed, including:
    a. Toy cars, trucks, tractors, trees, animals, buildings

5. Access an aerial picture of your school and closest water way.

6. Understand nonpoint source pollution comes from many widely scattered sources. These include our own lawns, streets, as well as farms, forests, construction sites, parking lots, and oil and gas extraction facilities. The sources of nonpoint source pollution are difficult to identify, making it much harder to control nonpoint source than point source pollution. The table outlines the causes and effects of nonpoint pollutants.

Nonpoint Source Pollutants		
Source location	**Pollutant**	**Potential Effects**
Farms, residential lawns and gardens, parks, golf courses, school grounds	soil/sediment	turbidity in water, affecting aquatic life, clogging culverts and drainage ditches and carrying pollutants attached to soil particles.
	fertilizers	nutrient overload, which can cause excessive growth of aquatic vegetation (such as algae)
	pesticides	toxicity
	livestock, wildlife and pet wastes	nutrient overload, pathogens
Forestry operations, construction sites, roads, parking lots, driveways, gas stations, airports, industrial sites	soil/sediment	turbidity
	soil, grease, antifreeze, spilled fuel, solvents	accumulation of organic chemicals in water bodies, oil slicks on water surface, toxicity

Procedure:

1. Assist student in answering the "Questions to think about before you begin." Discuss the definition of a watershed (the area of land where all the water drains to one place), how humans may alter their watershed (buildings, roads, dams, drains, etc) and brainstorm how humans might pollute local water bodies.

Download a map of your area from RIGIS website or from Google and put it on overhead or projector. Have students locate their school and identify a close river or stream.

2. Explain that the large piece of plastic laid out on the floor (or ground) represent a watershed. The students need to make some topography, or changes in ground elevation. Ask them how they can use some of the objects to change the elevation in the watershed? (Students suggest ways to create topography and put the objects under the plastic sheet.)

3. Before adding water to this watershed, ask students where they think the water will go? (If the water will run off the plastic, then assign students cleanup duty to take care of the spills.) Using the water cans or spray bottles, rain on the watershed and have students notice whether their predictions of where the water would travel were correct.

4. Have students add other features to the landscape. Have a collection of cars, tractors, animals, trees and buildings, and have students add them in appropriate places to complete the landscape. Have students brainstorm and delineate land-use types such as roads, parking lots, farms, lawns, forests and construction sites by using permanent markers and coloring them in. (Try to keep this simple, so the watershed effect will still work when you add water.)

5. Talk about sources of pollution that might exist on the areas they drew. Have students place the pretend pollutants where they might exist:
    a. Loose Soil = cocoa powder (place on plowed fields, construction site, stream bank, etc.)
    b. Pesticides = red drink mix (place on golf course, farm fields, etc.)
    c. Fertilizers = green drink mix (place on yards, farm fields, golf course, etc)
    d. Oils and grease = vegetable oil or cocoa/water mix (place on parking lots, driveways, streets)
    e. Road salts = Coarse salt (place on roads)
    f. Dog and animal waste = cocoa paste or sprinkles (place on yards and farm fields)
    g. Litter = torn paper and plastic (place on roadsides, parking lots, beaches, parks, etc.)

6. Have students take turns making it “rain” by spraying the watershed with water from a spray bottle or watering can.

7. Students should note where the water takes all of the pollutants left on the landscape. Much of the pollution ended up in the local water body and it looks very polluted, but some remained on the ground or in the ditches.

8. Ask students what pollutants might be picked up by rain water on their school yard and where they would go.

Extension:

- Students should use what they learned in this activity to write answers to the extension questions.

Watershed Model: Understanding Nonpoint Pollution and What You Can Do

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Name: ____ Date: ______________

Questions to think about before you begin

1. What is a watershed?

   ____

   ____

2. What are some ways in which humans have changed watersheds?

   ____

   ____

   ____

3. List some ways humans have polluted their local water bodies.

   ____

   ____

   ____

Illustration thanks to Rivers of Alabama

Procedure and Activity Questions:

9. As a class, use some of the objects to change the topography in the watershed.
   a. What is topography and how did you change it?

      ____

      ____

10. Now that we have hills and valleys, where do you think water will go when it rains?

    ____

11. Using the water cans or spray bottles, rain on the watershed.
    a. Did the water go where you predicted? If not, where did it go?

       ____

12. Knowing where streams and rivers are located in your watershed, add other features to the landscape. List at least six different ways we use the land in our community:

a. ______________________________ d. ______________________________

b. ______________________________ e. ______________________________

c. ______________________________ f. ______________________________

13. What are some pollution sources that might exist on the areas you drew?

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

14. Take turns placing the pretend pollutants on the watershed.

15. Take turns making it "rain" by spraying the watershed with water from a spray bottle or watering can.
    a. What happened to all the pollutants you added to the landscape after it rained?

       ____

       ____

    b. What do the rivers look like now?

       ____

       ____

    c. Would you want to swim, fish, or play in that water? Why or why not?

       ____

       ____

16. What kind of pollutants do you think rain water picks up on your school yard?

    ____

17. Where do those pollutants go?

    ____

18. Help your teacher clean up all of the water and materials.

Extension:

1. Write a letter to a friend or parent telling him/her how their actions impact the environment and how they can help to reduce the amount of pollutants that get washed into local water bodies.

Using the EnviroScape® Model to Understand Stormwater

www.ristormwatersolutions.org

Teacher Resource Page

Grade Level: 3-6 (Adaptable for all grade levels)

Time: 1 class period

Lesson Plan to Accompany: EnviroScape model available on loan through the URI Outreach Center

Learning Objectives:

- Explain the parts of the water cycle and understand the importance of water.
- Use the model to illustrate a watershed.
- Investigate sources of stormwater pollution
- Brainstorm ways to reduce water pollution.

Rhode Island Grade Span Expectations Addressed:

Science	**ESS1 - The earth and earth materials as we know them today have developed over long periods of time, through continual change processes.**	
	ESS1 (K-4) - 2	*Use results from an experiment to draw conclusions about how water interacts with earth materials*
	ESS1 (5-6) - 2a	*Diagramming, labeling and explaining the processes of the water cycle including evaporation, precipitation, and run-off, condensation, transpiration, and groundwater.*
	ESS1 (K-4) - 4	*Explain how wind, water, or ice shape and reshape the earth.*
Civics and Government	***C&G 3: In a democratic society all people have certain rights and responsibilities.***	
	C&G 4: People engage in political processes in a variety of ways.	
	C&G 4 (3-4) –3	*Students participate in a civil society by identifying problems, planning and implementing solutions, and evaluating the outcomes in the classroom, school, community, state, nation, or world and explaining how individuals can take responsibility for their actions and how their actions impact the community*
	C&G 5: As members of an interconnected world community, the choices	

	we make impact others locally, nationally, and globally.	
	C&G 5 (3-4) -3	*Students demonstrate an understanding of how the choices we make impact, and are impacted by an interconnected world*

Materials

- EnviroScape model, carrying case and associated pieces
- Water
- Water pitcher
- 3 spray bottles for rainmakers
- Pollution sources
    - Chocolate sprinkles – dog poop, cow waste
    - Colored sprinkles or kool aid and water – fertilizers
    - Grass clippings (from lawn)
    - Food coloring and water – pesticides
    - Paper towel – litter
    - Hand soap – car wash soap
    - Instant coffee – motor oil and sewage sludge
    - Sand and kosher salt– road salt and sand
    - Cocoa powder- dirt from erosion
- Water cycle diagram (optional)
- Laminated story board depicting the path of storm drains and consequences of pollution (optional)

Troubleshooting and Care of Model

- Slide the open container under the drainage hole in the bottom of the "bay." ***Important* Make sure that hole in cover of model does not line up with hole in base.** Put the plug in the bay's drainage hole. Do not press too hard on the plug.
- Rinse off all pieces, cover and base of model after use.
- Please replace all materials that have been used (i.e. sprinkles, soap, etc.).
- Please return the model no later than a week after it was borrowed.
- Be careful washing the trees. Rinse them delicately.
- If necessary, houses, cars, bridges, etc. can be soaked in a mild bleach solution.
- Dry all pieces before returning to plastic carrying case.

Advance Preparation

- See the "Additional Resources folder" and *Enviroscape: User's Guide* for additional activities, handouts and worksheets.
- **Bolded** words have definition and more information in following pages.

- Inform your town's stormwater manager about your program, which helps the town meet stormwater requirements. A list of R.I. stormwater managers is available at: http://www.ristormwatersolutions.org/docs/LocalCommitteeList07-15-08.pdf

Procedure:

- Water Cycle Activity
  1. Importance of the water cycle:
     - Ask students "What did you eat for breakfast?" Connect what they ate for breakfast to the need for water to grow plants, and for animals and people to drink.
     - Brainstorm about how we depend on water; plants need water to grow, animals eat the plants, and people eat the animals and plants.
     - Ask student "What is one way you use water?"
  2. Water Cycle (Diagram)
     - "Does anyone know how old this water is?" (Hold up water pitcher.) The water from the shower you took this morning may have fallen as rain in the Amazon rainforest last year or could have been a drink for a dinosaur 100 million years ago.
     - Show students the water cycle diagram.
     - There is no "new" water. The water on Earth moves constantly through a process called the **water cycle.**
  3. EnviroScape Model Water Cycle
     - If we pretend this model (EnviroScape) is Rhode Island, we can demonstrate how the water cycle works.
     - Water falls to the earth as **precipitation**. This comes down from the clouds as rain, snow or sleet.
       - Have 3 students demonstrate rainfall by spraying the model. Involve the other students by having them pat their knees to make a sound like a thunderstorm.
     - Observe the water **collecting** on the model. The water collects in rivers, lakes, ponds, Narragansett Bay and the ocean.
     - There are also a few parts of the water cycle that are not so easy to see. Water turns from liquid to gas in a process called **evaporation**. The water that is in the air is called water vapor. Think about a humid day in the middle of the summer, when you feel sticky. Those are days when there is a lot of water in the air.

        - There is a special word to use when plants release water vapor into the air, called **transpiration**.
        - When water vapor is then transformed into water droplets in the air (usually in the form of clouds and fog), this is called **condensation**. The mirror getting fogged up in the bathroom after a shower is an example of condensation in action.
        - When the precipitation hits the ground, it can follow a few paths:
            - The rain can **infiltrate** into the ground. Once the water infiltrates into the ground, through the soil, it follows different paths, but generally becomes groundwater. This water then flows underground and eventually reaches the rivers and streams.
            - If the rain does not infiltrate, it runs off. Water runs off for a lot of reasons. First, the water can't get into the ground because whatever is on the surface is impermeable. Second, the ground has become saturated and all the puddles and lakes, etc. are full.
            - Ask students if they have seen runoff. Mention water running down roads during a rainstorm.

- Human Alterations to the Water Cycle Activity
    1. Humans have altered the water cycle by building houses and paving roads; creating hard surfaces that make it impossible for the water to soak into the ground.
        - In a natural setting, rain will typically fall in a field or forest. Have a student demonstrate this by pouring some of the water from the pitcher onto the soil or grass. Ask them to observe where the water goes. It **infiltrates** into the ground and forms groundwater, replenishing our drinking water sources and streams. The rain water could also be taken up by plants or simply evaporate.
    2. When people built houses, driveways and streets, they created many more hard (impervious) surfaces than were here naturally. Have a student demonstrate by pouring water onto a paved surface. Where does the water go? It runs off in sheets, flowing over the pavement. Have the students point out all of the impervious surfaces represented on the model.
        - Note: If indoors, have the students imagine rain falling in a forest and ask where it goes. Use a sponge to represent pervious surfaces like the ground and the roads on the model to represent impervious surfaces.
    3. As this water travels over the roof tops, streets and driveways it mixes with what's there and picks up all sorts of pollution (oil from cars, fertilizer and lawn

clippings, bacteria from animal waste) on its way to the storm drain. We call this **stormwater runoff**.

4. List all types of stormwater pollution:
   - Nutrients
   - Pesticides and fertilizers
   - Suspended sediments
   - Metals and other chemicals
   - Thermal stress
5. In addition to adding pollution, the addition of impervious surfaces to the landscape also causes the water to reach waterways much more quickly, resulting in erosion of stream banks, etc.
6. Ask students if there are any other ways that people have changed the water cycle. (Wells, sewers, ice caps melting due to global climate change are a few suggestions.)

- Know Where it Goes Activity (Storm Drain Laminated Story Board)
  1. Have you ever looked down into the storm drains (gutter) in the street and wondered where the water goes? While many people think that it enters a sewer system, that's almost never the case. Once water enters a storm drain it empties directly into the nearest pond, river or bay without being cleaned.
  2. This stormwater pollution can create a lot of problems for the environment, and also for people who want to use the water bodies. Have you ever wanted to go to the beach and it was closed? Have you ever wanted to fish in an area that had a fishing ban in place? Sometimes stormwater pollution can even lead to a loss of biodiversity, like the fish kill in Greenwich Bay in 2003.
     - Additional Activity: Pass out articles about recent stormwater-related news events such as beach and shell fishing closures.
  3. The Clean Water Act was established in 1972 by the federal government to protect water quality. More specifically, section 319 of the CWA attempts to reduce stormwater (or nonpoint source) pollution. State agencies like the Department of Environmental Management and the Department of Transportation work to reduce stormwater pollution, as well as local city and town government. Despite these efforts, stormwater remains the #1 source of water pollution in the United States. So what can we do to make sure our water stays clean enough to enjoy?

- What is a Watershed? (EnviroScape Model)

1. Before we look at the sources of water pollution in Rhode Island, we must first look at the way that water travels.
2. This model represents a **watershed**, or all of the surrounding land area and waterways (like rivers and streams) that empty into a particular body of water. Our model, specifically, represents the Narragansett Bay watershed.
   - Note: Customize this section for your target watershed area.
3. What types of things can you see in our watershed? (Houses, golf course, roads, rivers, etc.)

- Stormwater Pollution Sources Activity (EnviroScape Model)
  1. We can demonstrate the sources of stormwater pollution that result from our everyday activities, and how that pollution travels through the watershed to the Bay.
  2. Who here has a dog? Benny (any name) next door has a dog too and when he takes his dog for a walk he never cleans up his poop. Have a student sprinkle the *animal waste* near the dog. There are lots of dogs in this neighborhood (which is why the dog is not to scale) so make sure to sprinkle a lot.
     - Farmer Rob lets his cows wade right into the river near the farm. What do you think they do there? Make sure to add some *animal waste* to the farm area and the river.
     - Benny likes to walk down to the Bay to feed the ducks and geese. With so many geese concentrated in one area, comes more animal waste. Add some *animal waste* to the Bay.
  3. Can anyone guess why we shouldn't litter? Benny always throws his candy wrappers and soda bottles on the ground. Have a student rip small pieces of *paper towel* and place them on the street.
     - The people driving by in their cars throw their trash right out the window. Have the student throw the *paper towel* in the ditch near the road.
  4. Who has a lawn at home? Mrs. Pots has a lawn too and she thinks the more fertilizer she uses the, greener her grass will be. But really, when you use too much fertilizer you can damage your plants and the extra fertilizer washes into our water sources. Have a student sprinkle the *fertilizer* on the lawns near the houses.
     - The golf course and the Farmer Rob also use too much fertilizer to grow the grass and crops. Make sure to sprinkle your *fertilizers* on the golf course and farm.
  5. When Benny mows the lawn, he leaves all of the grass clippings on the street and in the driveway. When it rains these get washed into the storm drain.

6. Have a student grab a small handful of *grass* from the lawns to put on the lawns near the houses.
    - Note: With older students, this may be a good time to explain that when grass clippings, leaves and yard fertilizers are added to the Bay, they act as fertilizer and cause algae to bloom. This macroalgae, which looks like large sheets of green seaweed that you sometimes see washed up on the shoreline, then decomposes. As it breaks down, it robs the water of dissolved oxygen, causing marine organisms to leave the area or die. Examples of this are the Fish Kill in 2003 (pictured in the storyboard).
7. Who has a garden at home? Mrs. Pots has a flower garden and she uses too many pesticides to get rid of the insects that eat her flowers.
    - Squirt some of the *pesticides* on the lawns near the houses. Note: food coloring stains, so you may want to demonstrate this yourself.
    - The golf course and the farmer also use too many pesticides too. Make sure to sprinkle *pesticides* there as well.
8. Does anyone help their family wash their car? Mrs. Pots washes her car in the street and all the suds from the car wash soap and dirt from the car go right into the storm drain.
    - Have a student pump the *car wash soap* onto the car.
9. Mrs. Pots also changes her own oil in her car. She is not very environmentally friendly and she dumps the extra oil directly down the storm drain.
    - Have a student squirt some *oil* into the storm drain and observe that it leads directly to the water body.
    - Wally World has lots of cars in their parking lot with leaking oil and automotive fluid. Have a student squirt some *oil* onto the parking lot near the "factory."
    - These cars are also leaking oil while they drive, so squirt some oil onto the roads as well.
10. Do you have a septic system? Some houses are connected to sewers, and others have septic systems buried in their yards. Mrs. Potts' forgot to pump out her septic system and it overflowed.
    - Have a student squirt some *motor oil* on the lawn of a house.
11. Have you ever noticed all of the road salt and sand that ends up on the roads after the winter? That is left over from when it was put down to help cars drive on icy roads. This is another source of stormwater pollution.
    - Have a student sprinkle *sand* on all of the roads.
12. In order to make all the new houses in town, the builders needed wood. They cut down the forest. When the forest is cut down, the trees are gone, leaving the

ground bare. If you have ever walked in a forest, you probably noticed there was very little grass under the trees. Once the trees are gone, the bare soil is open to the rain.

- Sprinkle *sand* on the deforested site.
- What about the construction site? There is no vegetation or silt fencing on the construction site to hold soil in place, and therefore it erodes, or wears away, and is carried by runoff into the water body. Sprinkle *sand* around the construction site.
- The farm area also exhibits erosion near the Bay. Sprinkle *sand* there.

13. A big storm is coming! Have three students use the squirt bottles to simulate a rain storm on the model. You may pour additional water onto the model with the pitcher to pick up remaining pollutants. Observe with the students as all of the stormwater pollutants travel through the **watershed**, eventually into Narragansett Bay. Ask them where the pollution has travelled.
    - Emphasize that the things we use in this activity are colored for greater visibility. In real life, however, most of these pollutants are invisible as they are added into the water.
14. Ask the students: Would you want to swim or fish in that water? If that was a reservoir would you want to drink it?

- Optional: Point Source Pollution Activity
    1. Explain that in addition to stormwater, there are also point sources that contribute to water pollution. These are sources of pollution that flow from pipes; sources that you can point to.
    2. One example would be if an industrial plant were discharging waste and the water it uses to heat and cool its machines. To demonstrate: squirt sludge mixture in the top of the industrial plant and watch it run from the plant to the river.
        - Mention that since point source pollution is much easier to monitor, there are very strict regulations on this type of discharge.
    3. Another example is the sewage treatment plant. Squirt sludge mixture into each clarifier tank (the two round indentations in front of the treatment plant). Spray water into clarifier tanks to make them overflow. Sometimes, when there is excessive rainfall, tanks will overflow directly into the nearest water body.
        - Note: The Combined Sewer Overflow Abatement project in Providence, launched in 2008 by the Narragansett Bay Commission is one solution to this issue. Instead of wastewater discharging directly into the Bay during a storm, a large underground pipe will collect the overflow and then

return the water to the plant to be treated. It is projected that areas previously closed to shell fishing will be closed 50% less in the upper Bay and 78% less in the lower Bay.

- What's the Solution? Activity
  1. What are some ways that we could have prevented our water from becoming polluted? These are all examples of steps that can be taken around the home by the students and/or their parents. Remind the students of specific examples:
     - **Never dump anything in the storm drain!**
     - Scoop your dog's poop, seal it in a bag and throw it in the trash.
     - Don't be a litter bug! Throw you waste in the recycling bin, compost bin or trash can.
     - Famer Rob could put a fence around his cows so they can't get in the river. Place the fence in front of the river on the farm. He could also compost his manure.
     - Tell your parents to reduce the amount of fertilizers and pesticides used on the lawn and garden. Sweep up any spills.
     - Sweep grass clippings back onto the lawn. They'll act as a natural fertilizer! Compost yard waste to keep it out of our waterways and the landfill.
     - Tell your parents to wash your car at a commercial car wash (where they must dispose of soapy water properly) or on the lawn.
     - Tell your parents to make sure your car isn't leaking oil. If they change their own oil, recycle the used oil.
     - Conserve as much water as possible. Don't waste water and use less water in our daily activities like watering the lawn.
     - There are also things that are done in your town and by the government to help reduce stormwater pollution, such as using different salt blends on the road that are environmentally friendly and educating people and kids about what they can do to help!

- Optional: Best Management Practices Activity
  1. Refer to p. 36 of the *EnviroScape User's Guide* for a demonstration of the best management practices (i.e. restore a wetland, plant vegetation, etc.) that can be implemented to control stormwater pollution.

2. Visit the R.I. Low Impact Development Atlas for examples of stormwater reduction practices. http://www.ristormwatersolutions.org/SW_ri_lidtour.html

- Conclusion
  1. Now that we've learned about water pollution we can all do our part to make sure we have clean water to swim in, fish in and drink.

BACKGROUND INFORMATION: Water Cycle and Stormwater Pollution Prevention

The Water Cycle (http://ga.water.usgs.gov/edu/watercyclesummary.html):
The water cycle has no starting point. But, we'll begin in the oceans, since that is where most of Earth's water exists. The sun, which drives the water cycle, heats water in the oceans. Some of it evaporates as vapor into the air. Ice and snow can sublimate directly into water vapor. Rising air currents take the vapor up into the atmosphere, along with water from evapotranspiration, which is water transpired from plants and evaporated from the soil. The vapor rises into the air where cooler temperatures cause it to condense into clouds. Air currents move clouds around the globe; cloud particles collide, grow, and fall out of the sky as precipitation. Some precipitation falls as snow and can accumulate as ice caps and glaciers, which can store frozen water for thousands of years. Snowpacks in warmer climates often thaw and melt when spring arrives, and the melted water flows overland as snowmelt. Most precipitation falls back into the oceans or onto land, where, due to gravity, the precipitation flows over the ground as surface runoff. A portion of runoff enters rivers in valleys in the landscape, with streamflow moving water towards the oceans. Runoff, and ground-water seepage, accumulate and are stored as freshwater in lakes. Not all runoff flows into rivers, though. Much of it soaks into the ground as infiltration. Some water infiltrates deep into the ground and replenishes aquifers (saturated subsurface rock), which store huge amounts of freshwater for long periods of time. Some infiltration stays close to the land surface and can seep back into surface-water bodies (and the ocean) as ground-water discharge, and some ground water finds openings in the land surface and emerges as freshwater springs. Over time, though, all of this water keeps moving, some to reenter the ocean, where the water cycle "ends" ... oops - I mean, where it "begins."

Processes of the Water Cycle (www.usgs.gov)**:**

Precipitation is water released from clouds in the form of rain, freezing rain, sleet, snow, or hail. It is the primary connection in the water cycle that provides for the delivery of atmospheric water to the Earth. Most precipitation falls as rain.

Collection (storage): The water cycle sounds like it is describing how water moves above, on, and through the Earth ... and it does. But, in fact, much more water is "in storage" for long periods of time than is actually moving through the cycle. The storehouses for the vast majority of all water on Earth are the oceans.

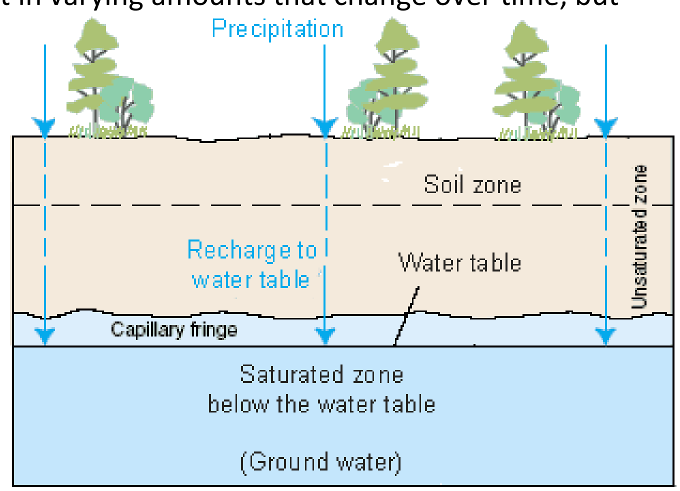
Infiltration: The downward movement of water from the land surface into soil or porous rock

Evaporation is the process by which water changes from a liquid to a gas or vapor. Evaporation is the primary pathway that water moves from the liquid state back into the water cycle as atmospheric water vapor. Studies have shown that the oceans, seas, lakes, and rivers provide nearly 90 percent of the moisture in our atmosphere via evaporation, with the remaining 10 percent being contributed by plant transpiration.

Transpiration: The release of water from plant leaves Transpiration is the process by which moisture is carried through plants from roots to small pores on the underside of leaves, where it changes to vapor and is released to the atmosphere. Transpiration is essentially evaporation of water from plant leaves. It is estimated that about 10 percent of the moisture found in the atmosphere is released by plants through transpiration.

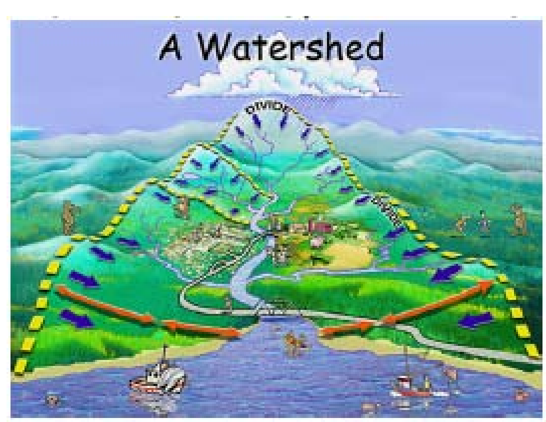
Condensation is the process in which water vapor in the air is changed into liquid water. Condensation is crucial to the water cycle because it is responsible for the formation of clouds. These clouds may produce precipitation, which is the primary route for water to return to the Earth's surface within the water cycle. Condensation is the opposite of evaporation.

Groundwater: Large amounts of water are stored in the ground. The water is still moving, possibly very slowly, and it is a part of the water cycle. Most of the water in the ground comes from precipitation that infiltrates downward from the land surface. The upper layer of the soil is the unsaturated zone, where water is present in varying amounts that change over time, but does not saturate the soil. Below this layer is the saturated zone, where all of the pores, cracks, and spaces between rock particles are saturated with water. The term ground water is used to describe this area. Another term for ground water is "aquifer," although this term is usually used to describe water-bearing formations capable of yielding enough water to supply peoples' uses. Aquifers are a huge storehouse of Earth's water and people all over the world depend on ground water in their daily lives.



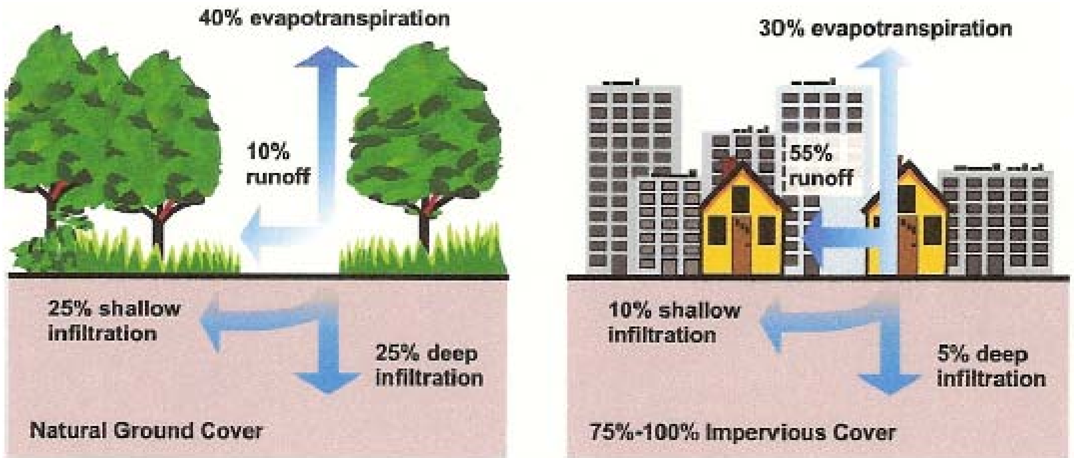
What is a Watershed?

A watershed, or drainage basin, is the area of land and all waterways that drain into a particular body of water. A water body is any river, lake, stream, ocean, pond or basin; water bodies receive stormwater runoff from a watershed. Watersheds come in all shapes and sizes. They can be as small



as a footprint or large enough to encompass multiple states. Everyone lives in a watershed, and most are interconnected, eventually draining to the ultimate water bodies – the bays or oceans. There are about 14 different watersheds in Rhode Island, each named for the body of water that they drain into (i.e. Narragansett Bay watershed).

Human Alterations to the Water Cycle (Northern RI Conservation District)
Stormwater is a problem because of 2 things: Increased runoff (due to increased development) and increased pollution loading (also due to increased development). Below are graphics that display how urbanization alters the natural water cycle.

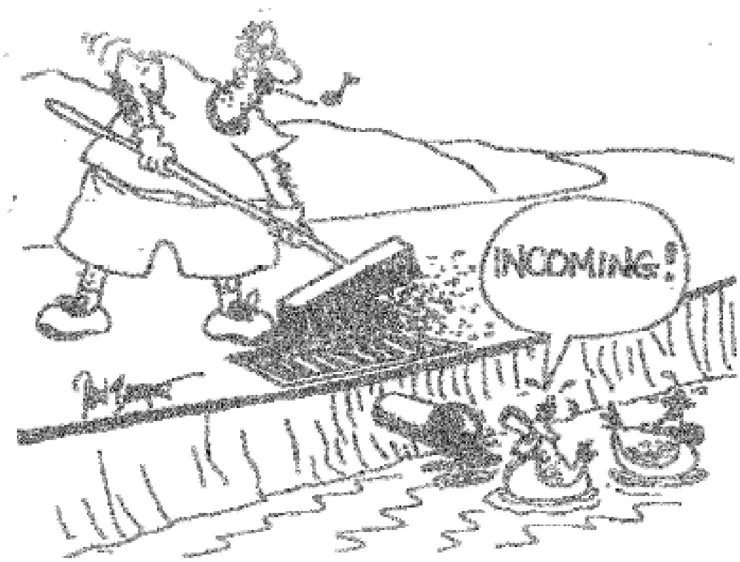


The Problem with Increased Runoff
In a natural environment, like a forest or wetland, the ground is very porous. The topography varies with high and low areas. Precipitation falls and either infiltrates into the soil quickly, or becomes trapped in low areas. The portion of precipitation that is trapped in the low spots is then allowed time to soak into the ground slowly. In this setting, runoff moves slowly, which allows further infiltration, as well as a cleaning process. Although soil is also called dirt, the dirt has chemical compositions that pull various pollutants out of the water as it moves down through the soil. So, the dirt ends up significantly cleaning the water before it reaches the groundwater; which is why infiltration is so important.
In developed areas, where there are substantial amounts of impervious areas, the precipitation remains above the surface. The graphic above shows a city scene, where
75%-100% of the land area is impenetrable. You can see that there is much more runoff in this setting than with natural ground cover. Although this may be extreme and not exactly how most areas in Rhode Island look, as the second most densely populated state, our towns do have developed areas—village centers, roads, parking lots, roofs. In these areas, rain is not allowed to soak into the ground. As the precipitation remains on top of surfaces, it begins to move rapidly and in unnaturally large amounts—creating increased runoff. In addition to increased amounts of runoff, stormwater from developed areas gains so much speed as it runs off surfaces through storm drains that it carries a severe erosion power. Groundwater recharge does not fully occur. Increased water temperature from this runoff is detrimental to the health and reproduction of fish. And the lack of infiltration causes increased pollution in water bodies

Stormwater Pollution (www.ristormwatersolutions.org):
Have you ever noticed water flowing down the street when it rains? Have you ever wondered where the water flows to? Have you thought about what's in the water? When it rains onto a forest or a field, some of that rain is absorbed by the ground, replenishing groundwater that is used by many for drinking water. Some of the rain is taken up by plants, and some of it simply evaporates. Very little of the rain flows over the ground. In a more developed setting, such as our cities and towns, rain falls onto pavement or other surfaces such as roofs, sidewalks, parking lots, and driveways that don't allow the water to be absorbed by the ground. The water that you see flowing down the street is called stormwater runoff

It's Not Just Rain? Why Is It A Problem?
When stormwater hits the pavement, it picks up and mixes with what's there. That might include:

- oil, grease, and automotive fluids;
- fertilizer and pesticides from gardens and homes;
- bacteria from pet waste and improperly maintained septic systems;
- soil from poor construction site management;
- sand from wintertime snow removal;
- soap from car washing;
- debris and litter.



Storm drains lead directly to local waters. No filters. No treatment. Pollutants that enter storm drains wind up in the water we drink, fish, and swim. Many people assume that stormwater flows down storm drains and then to a treatment facility. Unfortunately, that is almost never the case. Stormwater either flows directly into local waters or down storm drains, which channel it into local water bodies. **The polluted runoff closes swimming beaches and fishing grounds, threatens water resources, harms natural areas, and contributes to flooding.**

How Water Pollution Occurs (*EnviroScape User's Guide*)
The invisible components of runoff may be damaging such as:

Nutrients, toxic substances and bacteria.

Let's take Nutrients first
Though nutrients are essential to life, excessive nutrients can adversely affect the fish and plant life in the water. Nutrients that are found in some fertilizers, for example, nitrogen and phosphorous, can speed up the aging process of a lake (eutrophication) by causing sudden and excessive growth of algae and aquatic plants. Excessive growth of algae and plants can crowd

the water body, suffocating plant life**.** When these plants die and decay, they deplete the oxygen needed by the fish and other aquatic life. This lack of oxygen can kill the fish. So, excess nutrients are potential pollutants; not the nutrients themselves.

**Note: In salt water like Narragansett Bay excess nutrients cause the growth of macroalgae, the large sheets of green seaweed that sometimes washes up on the shoreline. As it decomposes, the algae rob the water of dissolved oxygen, resulting in loss of biodiversity like the 2003 Greenwich Bay Fish Kill.

Then there are Bacteria
Some bacteria are helpful, but certain species can cause diseases in humans who come in contact with them. Bacteria can also infect shellfish, making them inedible. Therefore, when a person eats raw oysters or fish that are infected with this bacteria, he or she could become ill. Salmonella is one example of fish poisoning. Bacteria can also harm other aquatic organisms. Health risks in water can close or restrict the use of shellfish beds and beach areas.

And Toxic Substances are also found in the runoff
Toxins are poisonous substances including metal compounds and chemicals. They are found in substances such as household cleaners and pesticides. Other sources of toxic substances are chemicals such as sulfuric acid, nitric acid and carbonic acid emitted from burning fossil fuels such as coal. These chemicals fall to the earth as acid rain. Too many toxic substances in the water can cause allergic reactions and illness in humans who contact the water. Fish can also ingest these toxics, which can ultimately affect the food chain by affecting what other animals and humans eat.

Let's visit the cows for a moment
When cows walk in the streams and lakes they stir up sediment, which is called turbidity. Turbidity creates a cloudy effect that decreases the light so plants can't get enough sunlight for growth; they die, depleting the oxygen level needed for fish to survive. Cows and other domestic animals can also enter the stream and deposit their waste in the water body. The action raises the nutrient and bacteria levels in the water. The animals can also cause erosion of the bank by trampling the vegetation.

Here are some examples of how we pollute at home

- **Improper or careless use and disposal of household chemicals, oils, cleaning solutions.** Many of us unknowingly use toxic chemicals on yards, cars boats, lawn furniture and houses. One rainstorm can carry chemicals directly to a river, lake or bay where they can be harmful to all forms of wildlife.
- **Excessive use of water**. The water you use washing your car or watering your lawn adds to the runoff of water off the land.
- **Failure to maintain septic systems and overuse of systems.** Too often, homeowners with septic tanks forget that whatever goes down the drain or toilet ultimately finds its

way into the soil (and groundwater) or remains in the septic tank until it is pumped out. A malfunctioning septic system may not be effective in removing disease-causing bacteria, some toxic chemicals or nutrients. What happens? The drinking water can become contaminated. Nutrients can fuel the growth of plant life and algae in lakes, rivers and estuaries, limiting recreation and affecting aquatic life.

- **Even pet wastes must be disposed of properly**. Pet wastes left on lawns, sidewalks or in street gutters can be washed into surface waters, causing significant bacterial contamination and boosting the nutrient level. It’s not one, two or even three dogs that pose the greatest threat – it’s the total number of pets, the accumulation of all pet waste, that we’re concerned about.

Stormwater: How Does it Flow And Where Does It Go?

www.ristormwatersolutions.org

Teacher Resource Page

<u>Grade Level</u>: 4-6
<u>Time</u>: 1 class period
<u>Adapted From</u>: Save the Bay's San Francisco Bay Watershed Curriculum
<u>Objectives</u>:

- Identify which land surfaces cause runoff and which cause water to soak into the ground
- Locate rain gutters and storm drains in the schoolyard and determine the flow of rain water into or over the land.

<u>Rhode Island Grade Span Expectations Addressed</u>:

<table>
<tr><td rowspan="6">Science</td><td colspan="2">ESS1 - The earth and earth materials as we know them today have developed over long periods of time, through continual change processes.</td></tr>
<tr><td>ESS1 (K-4) - 2</td><td>Use results from an experiment to draw conclusions about how water interacts with earth materials</td></tr>
<tr><td>ESS1 (5-6) - 2a</td><td>Diagramming, labeling and explaining the processes of the water cycle including evaporation, precipitation, and run-off, condensation, transpiration, and groundwater.</td></tr>
<tr><td>ESS1 (K-4) - 4</td><td>Explain how wind, water, or ice shape and reshape the earth.</td></tr>
<tr><td>ESS1 (K-4) -6</td><td>Given information about earth materials explain how their characteristics lend themselves to specific uses</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td rowspan="3">Written and Oral Communication</td><td colspan="2">W – 11 Demonstrates the habit of writing extensively</td></tr>
<tr><td colspan="2">W – 9 Writing Conventions: Applying Rules of Grammar, Usage, and Mechanics</td></tr>
<tr><td colspan="2">OC – 1 Oral Communication Strategies: Interactive Listening</td></tr>
<tr><td rowspan="5">Civics and Government</td><td colspan="2">C&G 3: In a democratic society all people have certain rights and responsibilities.</td></tr>
<tr><td colspan="2">C&G 4: People engage in political processes in a variety of ways.</td></tr>
<tr><td>C&G 4 (3-4) –3</td><td>Students participate in a civil society by identifying problems, planning and implementing solutions, and evaluating the outcomes in the classroom, school, community, state, nation, or world and explaining how individuals can take responsibility for their actions and how their actions impact the community</td></tr>
<tr><td colspan="2">C&G 5: As members of an interconnected world community, the choices we make impact others locally, nationally, and globally.</td></tr>
<tr><td>C&G 5 (3-4) - 3</td><td>Students demonstrate an understanding of how the choices we make impact, and are impacted by an interconnected world</td></tr>
</table>

Materials:

- Metal can (or other cylinder) with two open ends
- Beaker or measuring cup
- Pitcher or empty jug for pouring water
- Stop watch
- Student worksheet

Preparation:

- Prepare the materials
- Determine how much water the students will pour into the can, when the students will start timing.
- Walk around the school and make note of where gutters, stormdrains, impervious materials, and potential sources of stormwater contamination (i.e. litter, exposed dirt/sediment, any soapy water from cafeteria, oil stains in parking lots, etc).

Part I: Percolation Test – How does it Flow?

1. Find various land surfaces around your schoolyard: grass, gravel, packed dirt, loose dirt, pavement, etc. Students should record these in data chart.
2. Either as a class or in separate groups, have students place the cylinder on a land surface. If possible, twist the percolation cylinder into the ground slightly so that water will not flow out the edges.
3. Measure an amount of water and pour it into the cylinder. Students record amount of water in data chart.
4. With a stopwatch, have students time how long it takes for all the water to soak into the ground. Students record this in data chart.
5. Students should record any other observations made at the site, if water leaked out from under the can, etc.
6. Repeat steps 2-5 for each land surface.

Part II: Where does it go?

1. Have students locate the rain gutters attached to the school building and answer the questions on the student sheet for each (or some) of the school's gutters.
2. Have students locate the storm drains nearby and answer the questions on the student sheet for each (or some) of the school's gutters.

Extension:

- Students should use what they learned in this activity as well as the "Model Watershed" activity to write answers to the extension questions.

Stormwater: How Does it Flow And Where Does It Go?

Name: ____ Date: ______________

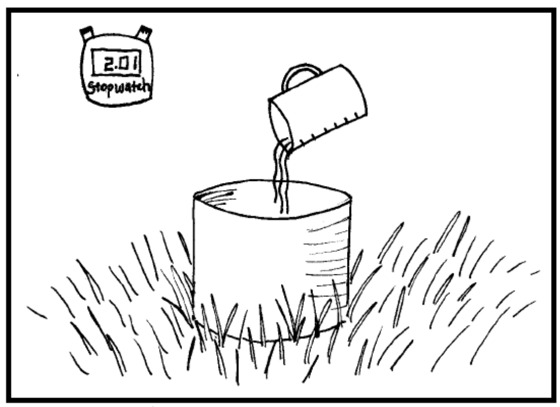
Introduction:

What happens to the water as it falls to the ground? Imagine a rainstorm in a wooded area. Grass, leaves, soil, and vegetation act like a sponge, soaking the water into the floor of the forest to become groundwater. Now imagine the same rainstorm on a road, or in a parking lot. These surfaces are solid, and water has nowhere to go. As it flows along, it gains speed and is able to pick up and carry pollutants that might be on the land.

In this activity, your group will do a percolation test on various land surfaces around your school. A percolation test measures how long it takes for water to soak into the ground. This test will help you determine whether water that falls on your schoolyard becomes groundwater, runoff, or both.

Materials:

- Metal can (or other cylinder) with two open ends
- Pitcher or empty jug for pouring water
- Beaker or measuring cup
- Stop watch
- Data chart



Sharón Friedner

Questions to think about before you begin

1. Read the introduction. Explain how a stream might be affected by a rainstorm in a paved area. How is this different from what you expect would happen in a forest?
   ____
   ____
   ____

2. Before you go outside, decide who will be responsible for each task. Be sure to switch jobs so everyone gets a chance to do everything. You will need:
   a. Timer____
   b. Recorder____
   c. Can Twister_______________________________________
   d. Water Pourer______________________________________
   e. Observer ____

<u>Part I: Percolation Tests – How does it Flow</u>

Procedure:

1. Find various land surfaces around your schoolyard: grass, gravel, packed dirt, loose dirt,
   pavement, etc. Record these in your data chart.
2. Place the cylinder on a land surface. If possible, twist the percolation cylinder into the ground slightly so that water will not flow out the edges.
3. Measure an amount of water and pour it into the cylinder. Record amount of water in your data chart.
4. With a stopwatch, time how long it takes for all the water to soak into the ground. Record this in your data chart.
5. Record any other observations made at the site.
6. Repeat steps 2-5 for each land surface.

Percolation Data Chart

Land Surface/ Location	Amount of Water Poured	Time for water to soak in	Observations

Part II: Where does it go?

Locate the rain gutters attached to your school and answer these questions for each gutter:

7. What kind of land surface is under the bottom of the gutter?
   ____

8. Using your observations from your data sheet, do you think rain water would soak into the ground or run off over the land?
   ____

9. Predict where the rain would go after it leaves the gutter?
   ____

10. If you were a rain drop predict what would happen to you after you fell from the clouds and hit the roof of the building.

    ____
    ____

Locate storm drains nearby and answer these questions for each storm drain:

11. Describe the storm drain you have found near your school. What does it look like? Can you see water in it? Can you see objects other than water in it?

    ____
    ____
    ____
    ____

12. Where does the water in the drain come from?

    ____

13. What kind of materials might the water be able to pick up and carry to the storm drain during a storm?

    ____
    ____

14. Where is the water in the storm drain going?

    ____

15. Would you like to swim or play in that water? Why or why not?

    ____
    ____

Extension:

1. Imagine that your entire school yard had been paved with concrete. Write a paragraph describing what would happen when it rained.
2. Imagine that the whole state of Rhode Island, except for the streams, creeks, and rivers had been paved with concrete. Write a paragraph describing what would happen to these waterways when it rained.

3.0 RIPARIAN BUFFER STANDARDS

Current Practice

A riparian buffer is the area of land along streams and rivers and other open water bodies. Riparian buffers are essential to the ecology of aquatic systems. Riparian buffer zones, due to their location between surface waters and adjacent land areas, provide a range of important functions such as:

- Trapping/removing sediment, phosphorus, nitrogen, and other nutrients from runoff, as these pollutants lead to eutrophication of aquatic ecosystems;
- Trapping/removing other contaminants, such as pesticides;
- Providing habitat and contiguous travel corridors for wildlife;
- Stabilizing stream banks and reducing channel erosion;
- Storing flood waters, thereby decreasing damage to property;
- Maintaining habitat for fish and other aquatic organisms by moderating water temperatures and providing woody debris;
- Improving the aesthetics of stream corridors (which can increase property values); and
- Offering recreational and educational opportunities.

Because they maintain all of these services, riparian buffers can be thought of as a "**conservation bargain**." Preserving a relatively narrow strip of land along streams and rivers, which is frequently unsuitable for other uses can help maintain good water quality, provide habitat for wildlife, protect people and buildings against flood waters, and extend the life of reservoirs. The preservation and restoration of natural riparian buffers is considered to be the single most important management practice to protect water resources.

Figure 3-1 Healthy Riparian Buffers.

The Clean Water Act goal that all waters should be fishable and swimmable is not achievable in Rhode Island's waters without the careful protection of riparian buffers (RI Rivers Council 2005 Establishment of Riparian and Shoreline Buffers: A Report to the Governor). (HW photo)

In Rhode Island, most freshwater wetlands, and the buffer areas protecting them, are regulated by the Freshwater Wetlands Act[5], administered by the RI DEM. In addition, the RI CRMC regulates both fresh and tidal water resources and their buffers within the coastal zone of Rhode Island. The RI DEM Wetlands Program framework does not protect riparian buffers around all wetlands.[6] Both programs protect the minimum buffers as defined by the Act. Some weaknesses in the current regulatory program are as follows:

- RI DEM is not able to protect riparian buffers around all wetland systems. Special aquatic sites (vernal pools), small ponds less than one-quarter acre in size, and small forested/shrub wetlands less than three acres in size do not have regulated buffer zones;
- Authors of the Wetland Act had the foresight to protect adjacent buffer areas for other wetlands; however, the science regarding the importance of buffers has grown in the last 30 years, and we know that current buffer zones regulated by law are often not large enough (e.g., the buffer zone width should consider sensitivity of wetland type and the land use that is proposed in both urban and suburban settings, as well as other factors); and
- State regulatory programs can be limited where substandard lots of record have been created and property use is grandfathered.

Most communities rely on RI DEM or RI CRMC to regulate buffers instead of exercising their zoning authority to help guide new development away from these sensitive areas. Eighteen RI municipalities have their own setbacks from wetland edges. Of these, seven communities regulate all disturbances within the setback; three communities regulate all buildings, structures and onsite wastewater treatment systems (OWTS), and the remaining eight regulate only OWTS location. In most cases the setbacks apply community-wide. A few communities either apply the setback only within a critical resource area or establish more stringent setbacks and/or performance standards for the critical area. R.I. General Law 45-24-30, the RI Zoning Enabling Act, enables communities to regulate development through a municipal zoning ordinance that has the ability to protect environmental resources while providing for the orderly growth and development which recognizes:

3(ii) The natural characteristics of the land, including its suitability for use based on soil characteristics, topography, and susceptibility to surface or groundwater pollution.
3(iii) The values and dynamic nature of coastal and freshwater ponds, the shoreline and freshwater and coastal wetlands.

Objective

Communities should use their land use regulatory power to require the preservation or restoration of a naturally vegetated buffer along all jurisdictional wetland resources to the maximum extent practicable[7] in both new development and redevelopment. The

[5] Rhode Island General Law 2-1-18 et seq.

[6] Refer to Perimeter Riverbank and Floodplain Wetlands Fact Sheet No.9 (RI DEM, 2007)

[7] For all references to "maximum extent practicable" in this guide, an applicant must demonstrate the following: (1) all reasonable efforts have been made to meet the standard in accordance with current local, State, and Federal regulations, (2) a complete evaluation of all possible management measures has been performed, and (3) if full compliance cannot be achieved, the highest practicable level of management is being implemented.

determination of buffer widths may require extra consideration in different locations depending on site specific characteristics, such as the presence of hydric soils and steep slopes.

Figure 3-2 Example of Vegetated Riparian Buffers.

The green area in the figure above represents the vegetated riparian buffer and the shaded blue area indicates a buffer zone of 100 feet on either side of the stream as a reference. (HW graphic)

Recommended Practice

A community buffer program should be created to establish a naturally vegetated buffer system along all streams and wetlands to supplement and expand upon the minimum requirements of the RI DEM and RI CRMC programs where applicable. Other important environmental features important to water quality preservation and enhancement should be included within the buffer, such as the 100-year floodplain and steep slopes. Communities implementing buffer programs should consider issues such as minimum width, target vegetation, allowable uses, and performance standards to avoid and minimize impact, as discussed below.

Minimum Buffer Width

The effectiveness of various buffer widths has received much attention from the scientific and regulatory community, particularly in relation to water quality and local land use policy. A summary of over 150 scientific studies of effective buffer widths for a variety of biological, hydrologic, and physical functions is summarized by the Environmental Law Institute (2003). The Army Corps of Engineers (Corps) released national recommendations for riparian buffer design in 2000 (Fischer and Fischneich, 2000). Desbonnet, et al. (1994) published material specific to Rhode Island that can also be used to shed light on site specific buffer issues. Table 3-1 summarizes a wide range of buffer widths reported by these studies and provides a recommended minimum width to support a variety of buffer functions. A minimum buffer of 100 feet seems to be the most widely recommended width for protection of most buffer functions. Critical resources, such as public drinking water supplies may have larger buffer requirements for enhanced protection and should be clearly identified in the buffer regulations. The values recommended represent the distance from the edge of a resource (e.g., stream bank, not the centerline).

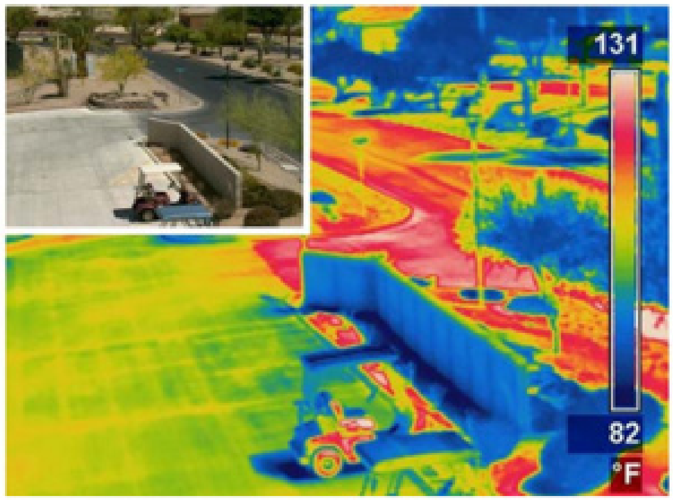
Table 3-1 Recommended Minimum Buffer Widths (adapted from Environmental Law Institute, 2003).

Function	Range of Riparian Buffer Widths		Minimum Recommended Buffer Width
	Environmental Law Institute (2003)	*Fischer and Fischneich (2000)*	
Stream Stabilization	30-170 ft	30-65 ft	50 ft[1]
Water Quality Protection	15-300 ft (remove nutrients)[2] 10-400 ft (remove sediment)	15-100 ft	100 ft[3]
Flood Attenuation	65-500 ft	65-500 ft	FEMA 100-year floodplain plus an additional 25 ft[4]
Riparian/Wildlife Habitat	10 ft-1 mile	100 ft-0.3 mile	300 ft[5]
Protection of Cold Water Fisheries	>100 ft (5 studies) 50-200 ft (1 study)	--	150 ft[6]

1. Larger buffers may be necessary based on steep slopes and highly erodible soils.
2. Different buffer designs should be considered for protection of different resources (coastal vs. inland).
3. Larger buffers may be necessary based on land use, resource goals, slope, and soils.
4. Additional buffer recommended to compensate for variability in flood model results at a site level and due to a changing climate.
5. Larger buffers may be necessary based on species and vegetation.
6. Larger buffers are necessary as the impervious cover in the watershed exceeds 8%.

In developed areas, as stormwater runoff flows over impervious surfaces such as asphalt and concrete, it increases in temperature before reaching a stream or other water body. Water temperatures are also increased due to shallow ponds and impoundments along a watercourse as well as fewer trees along streams to shade the water. Since warm water can hold less dissolved oxygen than cold water, this "thermal pollution" further reduces oxygen levels in suburban and urban streams. As described in the RI Stormwater Manual, temperature changes can severely disrupt certain aquatic species, such as trout and stoneflies, which can survive only within a narrow temperature range.

Figure 3-3 Thermal Imaging of Pavement.



(Kaloush, Kamil; Pavements and the Urban Heat island Effect)

For the specific protection of trout habitat, a number of researchers have demonstrated that a larger protective buffer is needed. A 150-foot minimum "no touch" buffer zone seems to be the most widely recognized width for protection of cold water streams. Effective riparian buffer widths reported for protecting trout stream habitat range from 50 to 200 feet. Meyer et al. (2005) studied the correlation between forested buffers, in stream temperature, and benthic substrate conditions in over 8,000 trout streams to evaluate the impact of a State policy to reduce required buffer widths from 100 to 50 feet. They found that the reduction of forested riparian buffers widths from 100 to 50 feet resulted in a 3-4 degree increase in stream temperatures and 11% increase in sediment in riffle habitats. While this change seems insignificant, this shift is expected to reduce the young trout populations by 81-88%.

Vegetative Target

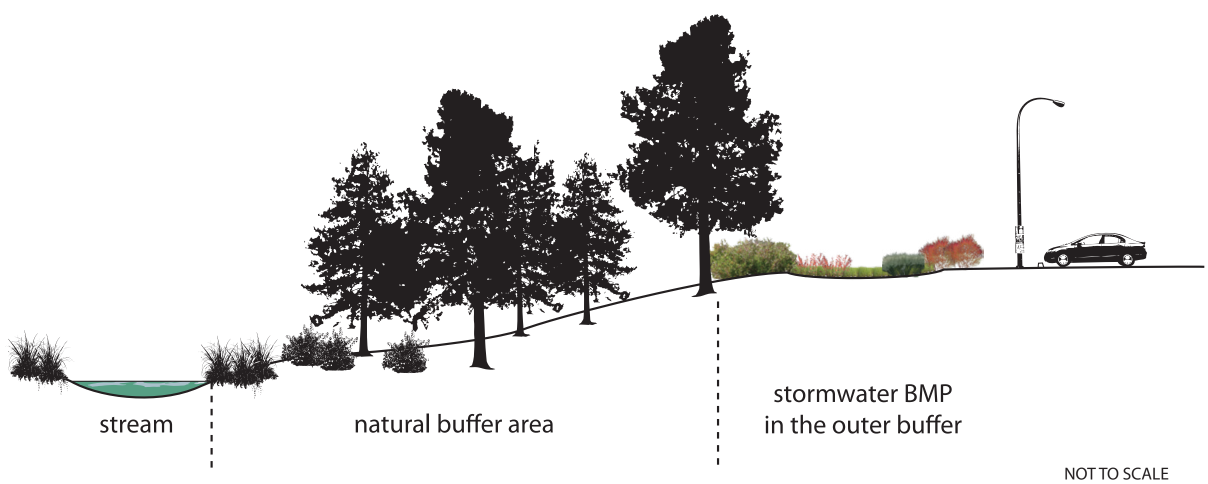
The ultimate target for the vegetation in the buffer should be specified. In general, this target should reflect the predevelopment, natural vegetative community present in the area. The target can be met by either preserving the existing vegetation or managing a disturbed buffer. To preserve existing buffers, these areas should be well marked on site plans, as well as in the field during construction. Disturbed areas should be either planted with native species or allowed to revert to the natural vegetation over time, with an aggressive invasive species management plan. Some selective clearing may be allowed in the outer portion of a buffer; in particular, to allow owners to remove dead or diseased trees that endanger personal property.

Buffer Uses

While the ultimate goal of a community buffer program is to create a continuous vegetated area adjacent to resources, certain uses can be allowed. Buffer crossings (by utilities, roadways or pedestrian bridges) will be necessary in certain areas, and a buffer program should specify performance criteria that address items such as crossing width, angle, frequency, and elevation. The allowable crossing width should be the minimum required for maintenance. Direct right angles are preferred since they require the least amount of clearing in the buffer. Only one road crossing per project should be allowed, and all utility crossings should be at least three feet below the streambed to prevent exposure by future channel erosion. The road crossing should be designed to pass the flow from the 100-year flood event. Bridges should be used for the crossing to the maximum extent practicable and if culverts are unavoidable, arch or box culverts should be used to minimize impact on wildlife. Communities must understand that all crossings are subject to RI DEM/CRMC review. For more information regarding techniques to avoid and minimize impacts to riparian buffers and wetlands refer to the *Wetland BMP Manual: Techniques for Avoidance and Minimization* (RI DEM, 2010).

Another potentially acceptable use within the buffer is for stormwater treatment; however, it is important to note that small scale LID practices located upgradient of buffer areas are preferable. Stormwater Best Management Practices (BMPs) should not be used in buffers where they significantly compromise the buffer's existing functions, and should only be used when no practical alternative exists. The outer portion of buffers can be utilized for stormwater management facilities, as long as sites are chosen carefully, located outside of State jurisdictional areas, and clearing of vegetation is minimized. One potentially effective way to use the edge of the buffer areas is to disperse channelized stormwater flow, which can be accomplished with small amounts of grading. Stormwater facilities should be designed with LID techniques and use the natural topography and undulating features that incorporate existing trees. See the RI Stormwater Manual for more information on how to properly design stormwater treatment practices.

Figure 3-4 Example of Stormwater BMP in the Outer Buffer Zone.



(HW graphic)

The red triangles in the graphic below represent the location of stormwater BMPs. Some of these have been effectively implemented in the very outer edge of the vegetated buffer (green area) along the riparian corridor in Montgomery County, MD. The shaded blue area indicates a buffer zone of 100 feet on either side of the stream as a reference.

Figure 3-5 Locations of Stormwater BMPs Relative to Stream Buffers.

The red triangles represent stormwater BMPs; the green area represents the vegetated riparian buffer; and the shaded blue area indicates a buffer zone of 100 feet on either side of the stream as a reference.   (HW graphic)

Development Standards

When discussing development criteria for buffer zones in the context of the urban environment, it is important to understand many of the site limitations that could exist by virtue of an existing development. Industrial structures that were developed many decades ago were constructed as close as possible to adjacent waters in order to take advantage of hydraulic power opportunities and the ability to dispose of waste into rivers and streams. In these cases, existing structures may severely inhibit the ability to restore any vegetated buffer adjacent to surface waters.

Due to these potential constraints, it is important for local review agencies to approach redevelopment situations with a flexible mindset. Re-establishing buffers where there are severe site restrictions should be considered under the 'maximum extent practicable' approach. Where minimum buffer widths are in place, these values should be seen as guidance principles within the context of urban redevelopment and should not preclude the possibility of redevelopment if specific buffer standards cannot be attained. Moreover, communities should be very flexible with other local regulations that may force development into buffer areas. These local regulations include, but are not necessarily limited to, parking requirements and front yard setbacks.

Figure 3-6 Typical Subdivision Design Impacting Wetlands.

Uniform requirements for lot size and setbacks cause small subdivisions like the one in this aerial photo to consume far more land than necessary. This subdivision has encroached into wetland and pond buffer areas causing visible signs of eutrophication. (Google Maps)

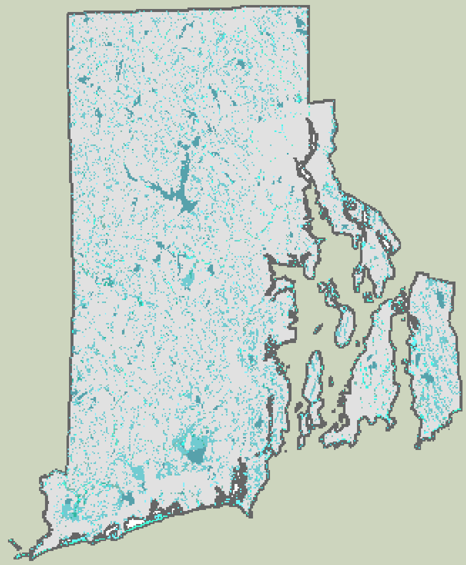
General Guidelines

1. *Minimum Width:* See Table 3-1 for recommended minimum widths to achieve various buffer functions.

   As mentioned above, this width represents an "ideal" condition that may not be achievable on all urban sites. However, the greatest buffer width that is practical should be maintained and restored and should not be reduced to less than 25 feet from wetland edge or below State regulatory requirements. **It should also be noted that both RI DEM and RI CRMC have regulatory jurisdiction for fresh and coastal wetlands and surface waters including buffer requirements that may be greater than 100 feet. Local buffer programs should augment existing requirements.**

2. *Buffer Delineation and Mapping:* Preliminary mapping of surface water buffers can be performed through the use of readily available data from Rhode Island Geographic Information Systems (RIGIS, www.edc.uri.edu/rigis/). Although the accuracy of these features from RIGIS is not adequate for site-specific design, it can be used as an indicator of the presence of hydrologic features and can be useful during a pre-application conference or other preliminary discussions with municipal officials. These delineations are appropriate for conceptual site designs. Site designs for master plan review or beyond should include mapping of buffer delineations performed by a qualified wetland scientist in conjunction with a registered surveyor and be field verified by RI DEM or RI CRMC. Communities may want to consider requiring a RI DEM verified wetland edge at the pre-application phase, depending on the extent of potential impacts and scale of the project. A verified wetland edge should be required for any variance or special use permit application.

Figure 3-7 State of Rhode Island Wetland Coverage.



(Rhode Island Geographic Information System)

3. *Protecting Buffers During Construction:* Although buffer areas can be set aside as "undisturbed" on site plans and development applications, it is important for local officials and developers to understand the construction process and what risks could be posed to on-site vegetated buffer zones. **See Chapter 4 for more information on clearing and grading guidance.** To minimize risks during the construction phase, the following precautionary measures can be required as part of a construction plan:

    - Buffer zones and limits of disturbance should be required on every drawing within every set of construction plans including, but not limited to, clearing and grading plans and sediment control plans;
    - Buffer limits should be staked out in the field prior to any construction activity;
    - Limits of disturbance can be marked with orange construction fence barriers with accompanying signs to prevent storage of construction materials and intrusion of vehicles, or any work beyond the limit;
    - A pre-construction walk-through should be performed with the municipal official or representative responsible for construction inspections and the person who was responsible for delineating the resource areas; and
    - Third-party inspectors can be hired by the community, at the applicant's expense as authorized within the Subdivision and Land Development Regulations, to conduct site visits during and after construction to insure construction activity does not impair surface waters, wetlands, or buffers. **Refer to third-party review fees guidance in Chapter 9.**

4. *Landscaping:* Landscaping on a site already containing an existing vegetated buffer should use only plant and tree varieties specifically cited as native species in Sustainable Trees and Shrubs for Southern New England, prepared by the University of Rhode Island, University of Massachusetts, and the United States Department of Agriculture, 1993 or in another credible scientific document that

specifically lists any proposed planting (genus and species) as being indigenous to the region. Appendix B in the RI Stormwater Manual also provides guidance on native landscaping. **In addition, refer to Chapter 8 for guidance on how to implement landscaping requirements on the local level.**

5. *Prohibited Activities:* Activities which can be typically prohibited by a local ordinance in the buffer include: land disturbing activities that may result in erosion or sedimentation, structures, impervious surfaces, application of fertilizers, herbicides and pesticides (except as needed to restore a buffer), storage tanks for petroleum products, septic system tanks/ leach fields (where applicable), clear cutting of vegetation other than maintenance mowing. Different levels of restriction can be placed in different regions of a buffer depending on how wide and densely vegetated the buffer zone is. In general, the shoreline region should serve as a "no-touch" zone, though uses such as passive recreation, including limited access paths for walking and canoe launches, can be allowed. The second zone should be limited to passive management and consist of shrub land and trees. The third and final zone, farthest from the surface water resource, would consist primarily of wooded canopy and can be managed for heavier foot and bicycle traffic and may be acceptable for stormwater BMPs with an LID design.

6. *Public Access or Recreation:* In both urban and rural settings, river corridors provide good opportunities for trails, or where appropriate, canoe/kayak launch sites. No proposed development adjacent to a vegetated buffer should prevent existing and, where appropriate, new public access to the resource. Any proposed public access or recreation should be consistent with the Community Comprehensive Plan, the State Comprehensive Outdoor Recreation Plan (SCORP) State Guide Plan 152 (RI DEM, 2009), and applicable State regulations.

7. *Redevelopment Criteria:* Any proposed redevelopment of a site containing a buffer zone to an existing surface water or wetland resource should demonstrate that post-development conditions will improve the capacity of the buffer to provide continued public access to the resource (assuming access exists), protection of the resource area from stormwater runoff, and/or wildlife habitat. Improvement strategies can include, but would not be limited to:

   - The maximum extent practicable, re-establish vegetation in areas of the buffer that were previously developed or impervious. A minimum of 25 feet beyond jurisdictional wetlands is recommended. This can be accomplished by requiring a mitigation planting ratio based on new impervious area proposed within an existing degraded buffer (e.g., 3:1).
   - Provide pre-treatment of stormwater runoff directed to the buffer zone, and design site runoff to enter the buffer as sheet flow. Where necessary, incorporate water quality BMP's into the buffer zone to treat concentrated inflow.
   - Maintain historic public access points to surface water resources.
   - Consolidate access points and restore the buffer zones in old access areas.
   - Enhance the existing buffer vegetation with native vegetation and remove exotic and invasive species. Special care should be taken when removing invasive species to compensate for any loss of pollutant attenuation or habitat.

Invasive species removal should be performed by a qualified professional[8] and only if a sustainable future condition with native species is assured.

Figure 3-8 Buffer Zone Planting.

Careful placement and installation of native vegetation is required for restoring buffer areas that were cleared. (http://www.shorelandmanagement.org/s2s/category/care-of-shoreland-property/)

8. *Buffer Flexibility:* Building flexibility into buffer zone guidelines allows developers to creatively address existing site constraints and, by providing developers with different options, avoids any claims that buffering criteria are too restrictive. Provisions for flexibility relative to buffer zone criteria can include one or more of the following:

    - *Preserving or Restoring Buffer Zones as Open Space:* The applicant may enter into negotiations with the municipality to dedicate a buffer area to the City or Town along with access rights across the property as a potential improvement to the buffer. This situation may be particularly attractive in areas where the resource already provides a significant level of recreational opportunity to the general public. Conservation easements are also an option that a landowner could use as a tax benefit by either donating the land to a land trust or to the community.
    - *Buffer Averaging:* Local criteria for buffer zones can use an averaging approach where the average width of the buffer across the site is either optimized or reaches the specific target.
    - *Density Compensation:* If buffer restrictions render a significant amount of land as "undevelopable," provisions in local zoning could allow for increased density on the remainder of the site to add value to the development provided that there is adequate infrastructure (water, sewer, and stormwater) to support the increase. An example of density credit calculations can be found in Article 39 of The Practice of Watershed Protection "The Architecture of Urban Stream Buffers" (Schueler et al., 2000).
    - *Waivers or Deviations:* As a rule of thumb with any ordinance or land

[8] A qualified professional has the educational background and/or experience to properly identify and remove invasive species.

development regulations, language should provide the permitting authority the power to waive a portion of, or reduce a particular criterion where legally permitted by an enabling local ordinance.

- *Off-Site Buffer Restoration:* If the establishment of a buffer on an existing site is not possible, communities can consider requiring a developer to restore a buffer area off-site or place money for restoration in a restricted receipt account, referred to as "fee-in-lieu." In any case the restoration should be in the same watershed. This requirement should be based on clearly stated public needs and policy goals outlined for the community buffer program within the Comprehensive Plan and clear standards would need to be specified in the subdivision and land development regulations.
- *Net-Improvement to the Site:* Examine the quality of existing stormwater discharge or other conditions such as hardened shorelines to find other areas that might be improved in lieu of enforcing stringent buffer width restriction.

Perceptions and Realities about Buffer Programs

Perception	Reality
Buffer standards will result in a loss of developable land.	A 100-foot wide stream buffer typically consumes only 5% of land in a watershed. In addition, flexibility can be incorporated into local regulations to protect property owners.
Landowners with buffers are required to provide public access.	Public access is not necessary for an effective buffer program; instead, they can be maintained in private ownership through deed restrictions and conservation easements.
Buffer programs will be a hardship on a community's staff and resources.	In a survey by Heraty (1993), most government participants stated that their staff spent only 1 – 10% more time to administer a buffer program.
RI DEM and RI CRMC already protect all buffers	RI DEM regulations are limited in some cases, and enforcement of buffers over time is challenging when lots are created adjacent to sensitive buffers.

Successful Buffer Programs

The key to a successful buffer program is education and flexibility. Buffers should be well demarcated by permanent boundaries and/or signage and also clearly noted on all deeds and recorded site plans and subdivision / land development plans. Buffer owners should be educated about their responsibilities and the benefits of buffers. Most encroachment issues are due to ignorance about the buffer program rather than complete disregard. In addition, flexible measures can be incorporated in a buffer program with many of the techniques described above (e.g., buffer averaging, conservation easements, and variances) and can go a long way to gaining the support of the public.

Figure 3-9 Wetland Buffer Signage.

(A. Kitchell)

Benefits of Resource Buffer Program

Buffer zones to fresh and saltwater resources—whether they are rivers, streams, bays, ponds, or wetlands—play an integral role in both protecting these resources and providing habitat for wildlife. The use of local land use authority to preserve or restore vegetated buffers is critical to the overall health of watershed systems and to public health and safety. The following table is taken from the Center for Watershed Protection's The Practice of Watershed Protection (Schueler et al., 2000) and clearly illustrates the myriad of benefits derived from proper buffer management and restoration. Specific benefits as related to stormwater and economics are listed below Table 3-2.

Table 3-2: Twenty Benefits of Urban Stream Buffers
(ƒ) = Benefit Amplified by or Requires Forest Cover

1. Reduces watershed imperviousness by 5%. An average buffer width of 100 feet protects up to 5% of watershed area from future development.

2. Distances areas of impervious cover from the stream. More room is made available for placement of stormwater practices, and septic system performance is improved. (ƒ)

3. Reduces small drainage problems and complaints. When properties are located too close to a stream, residents are likely to experience and complain about backyard flooding, standing water, and bank erosion. A buffer greatly reduces complaints.

4. Stream "right of way" allows for lateral movement. Most stream channels shift or widen over time; a buffer protects both the stream and nearby properties.

5. Effective flood control. Other, expensive flood controls not necessary if buffer includes the 100-yr floodplain.

6. Protection from streambank erosion. Tree roots consolidate the soils of floodplain and stream banks, reducing the potential for severe bank erosion. (ƒ)

7. Increases property values. Homebuyers perceive buffers as attractive amenities to the community. 90% of buffer administrators feel buffers have a neutral or positive impact on property values. (ƒ)

8. Increased pollutant removal. Buffers can provide effective pollutant removal for development located within 150 feet of the buffer boundary, when designed properly.

9. Foundation for present or future greenways. Linear nature of the buffer provides for connected open space, allowing pedestrians and bikes to move more efficiently through a community. (ƒ)

10. Provides food and habitat for wildlife. Leaf litter is the base food source for many stream ecosystems; forests also provide woody debris that creates cover and habitat structure for aquatic insects and fish. (ƒ)

11. Mitigates stream warming. Shading by the forest canopy prevents further stream warming in urban watersheds. (ƒ)

12. Protection of associated wetlands. A wide stream buffer can include riverine and palustrine wetlands that are frequently found along the stream corridor.

13. Prevent disturbance to steep slopes. Removing construction activity from these sensitive areas is the best way to prevent severe rates of soil erosion. (ƒ)

14. Preserves important terrestrial habitat. Riparian corridors are important transition zones, rich in species. A mile of stream buffer can provide 25-40 acres of habitat area. (ƒ)

15. Corridors for conservation. Unbroken stream buffers provide "highways" for migration of plant and animal populations. (ƒ)

16. Essential habitat for amphibians. Amphibians require both aquatic and terrestrial habitats and are dependent on riparian environments to complete their life cycle. (ƒ)

17. Fewer barriers to fish migration. Chances for migrating fish are improved when stream crossings are prevented or carefully planned.

18. Discourages excessive storm drain enclosures/channel hardening. Can protect headwater streams from extensive modification.

19. Provides space for stormwater BMPs. When properly placed, the outer zone of the buffer can be an acceptable location for stormwater practices that remove pollutants and control flows from urban areas.

20. Allowance for future restoration. Even a modest buffer provides space and access for future stream restoration, bank stabilization, or reforestation.

Stormwater Benefits

Effective resource buffers minimize the need for flood control by helping to attenuate stormwater flows before they reach a water body and allowing the lateral movement of streams. By preventing development in the buffer area, the overall quantity of stormwater in the watershed is reduced, which will also help to reduce streambank erosion and flooding. Finally, vegetated buffers function as a natural filtering mechanism for removing sediment, nutrients, bacteria and other pollutants typically found in stormwater runoff.

Buffers can be very important for coldwater trout streams in particular, not only providing shade for the stream itself but also by helping to cool and infiltrate stormwater before it reaches the stream, and as a source for large woody debris, which is very important for trout habitat. By infiltrating stormwater runoff, buffers increase groundwater recharge, which in turn helps to maintain the baseflow of the stream.

Economic Benefits

Stream and wetland buffers can actually have economic benefits to communities in the long run. The presence of buffers improves the market value of adjacent properties. As listed in the Better Site Design Handbook (1998), examples of the positive market influence of buffers include:

- When managed as a "greenway," stream buffers can increase the value of adjacent parcels as illustrated by several studies. Pennypack Park in Philadelphia is credited with a 33% increase to the value of nearby property. A net increase of more than $3.3 million in real estate is attributed to the park (Chesapeake Bay Foundation, 1996).
- Nationally, buffers were thought to have a positive or neutral impact on adjacent property in 32 out of 39 communities surveyed (Schueler, 1995).
- Effective shoreline buffers can increase the value of urban lake property. A recent study in Maine found that increased water clarity (visibility depth increased by three feet) resulted in $11 to $200 more per foot of shoreline property, potentially generating millions of dollars in increased value per lake (Michael et al., 1996).

In addition, buffers help save municipalities money by reducing the need for floodwater storage and stormwater treatment. Drainage problems and thus complaints from the public are reduced by buffers, which saves municipal staff time and money. Examples of cost saving which may be realized due to buffer presence include:

- The Minnesota Department of Natural Resources (MN DNR) estimated cost savings of $300 per acre-foot associated with a minimized need for floodwater storage due to the preservation of riparian wetlands;
- Forested stream and shoreline buffers situated on the flat soils of the coastal plain have been found to be effective in removing sediment, nutrients, and bacteria from stormwater runoff and septic system effluent in a wide variety of rural and agricultural settings along the East Coast (Desbonnet et al., 1994);
- Buffers can sharply reduce the number of drainage complaints received by municipal public works departments; and
- Buffers are often an effective means to mitigate or even prevent stream or shoreline erosion.

Case Studies

Within Rhode Island, most communities rely on RI DEM or RI CRMC to regulate buffers to wetlands and surface waters instead of exercising local regulatory authority to help guide new development away from these resources. However, there are some communities that are applying unique strategies within the regulation of wetland, riparian or coastal areas to increase protective measures. There are a variety of approaches for regulating buffers such as: enforcement through zoning overlay districts, applying additional standards on certain uses through special use permits, or addressing the various impacts of wastewater within the buffer area. The standards from two Rhode Island communities, Barrington and South Kingstown, are reviewed here as two different approaches to wetlands protection in local ordinances.

Barrington, Wetlands Overlay District

The Town of Barrington has adopted an overlay district within its zoning ordinance to provide additional protection to its wetland areas. The overlay is described as follows:

> *The Wetlands Overlay District shall consist of coastal wetlands, defined as salt marshes bordering on tidal waters, and freshwater wetlands, defined as those areas of 1/2 acre or greater, that are inundated or saturated with surface and/or ground water at a frequency or duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. (Zoning Ordinance Section 185-171)*

The regulations within the overlay are triggered by new construction, reconstruction, or expansion of existing buildings, or new, expanded, or modified uses of property within 100 feet of the overlay district. One of the primary mechanisms used to protect wetland resources is the list of prohibited activities including:

A. The discharge or introducing of any organic or inorganic chemical or biological pollutants.
B. The storage of any hazardous, toxic or infectious materials or wastes.
C. The placing or depositing of any solid waste or debris.
D. The discharging of any effluent creating a thermal gradient deleterious to indigenous plants, fish or wildlife.

In addition to the prohibited activities, any activity that falls within 100 feet of the overlay district must meet several development standards to be eligible for a special use permit under the overlay regulations. These development standards are provided to minimize, to the degree possible, any negative impacts to the wetlands through the following provisions:

A All new structures and expansions, paved areas, and land disturbances will be set back at least 100 feet from the wetland edge.
B The proposed project will not obstruct floodways in any detrimental way, or reduce the net capacity of the site and adjoining properties to retain floodwaters.
C The proposed project will not cause any sedimentation of wetlands, and will include all necessary and appropriate erosion and sediment control measures.
D The proposed project will not reduce the capacity of any wetland to absorb pollutants.
E The proposed project will not directly or indirectly degrade the water quality in

any wetland or water body.

F The proposed project will not reduce the capacity of any wetland to recharge groundwater.

G The proposed project will not degrade the value of any wetland as a spawning ground or nursery for fish and shellfish or habitat for wildlife or wildfowl.

These regulations provide an additional layer of protection above and beyond the jurisdiction of RI DEM and RI CRMC. The overlay district method is a very straightforward approach for local communities that have the capacity for a comprehensive wetlands mapping process to determine appropriate boundaries for the district.

Readers interested in looking more closely at this suite of strategies can review the ordinance through the Town's website: http://www.ci.barrington.ri.us/. The applicable text of the Zoning Ordinance begins in ARTICLE XXV, § 185-169 — § 185-179.

South Kingstown, Special Use Permits

The Town of South Kingstown provides addwebsitesitional protection to wetlands through identifying uses that trigger a special use permit within the Town's Zoning Ordinance. Several items have been identified for this additional permitting requirement, such as: individual sewage disposal systems (ISDS)[5] , hazardous waste management facilities, and accessory apartments. The regulations for such uses are as follows:

No ISDS shall be allowed within:

- 150 feet from a fresh water wetlands
- 150 feet from a river
- 200 feet from a flowing body of water having a width of 10 feet or more
- 150 feet from a floodplain
- 150 feet from a coastal wetland

No hazardous waste management facility shall be allowed within 500 feet of areas identified as freshwater wetlands or areas in a special flood hazard district.

An accessory apartment which is not serviced by a public sewer system may be established by special use permit only, and the accessory apartment along with the associated ISDS must meet heightened standards relative to its location near wetland resources.

Readers interested in looking more closely at this suite of strategies can review the ordinance through the Town's website: http://www.southkingstownri.com/town-government/municipal-departments/building-inspection-and-zoning. The applicable text of the Zoning Ordinance begins in Section 504.

[5] Since the adoption of this ordinance, RI DEM has changed their official name for septic systems from Individual Sewage Disposal Systems (ISDS) to On-site Wastewater Treatment Systems (OWTS).

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The Need to Reduce Impervious Cover to Prevent Flooding and Protect Water Quality

May, 2010

The Need to Reduce Impervious Cover to Prevent Flooding and Protect Water Quality

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Revised May, 2010, based on
materials developed as part of
the Scituate Reservoir Watershed
Greenspace Protection Strategy,
Rhode Island Department of Environmental Management, 2008

Original Project Funding:
Providence Water Supply Board
and the National Park Service

Contents:

Introduction

Impervious cover, also referred to as impervious surface, refers to anything that water cannot penetrate. Ranging from residential rooftops, patios and driveways to town roads, public buildings, commercial structures and parking lots, impervious cover prevents rain and snow from soaking into the ground, turning it into stormwater runoff. Stormwater runoff carries organic matter, fertilizers, pesticides, oil and grease and other contaminants into our ponds and streams. In addition to changing the *quality* of the water running into our waterbodies , impervious cover changes the *quantity* of runoff, eroding and changing the physical structure of existing streams. Because water runs more quickly off of an impervious area, flooding becomes both more common and more intense downstream. Meanwhile, because less water is soaking into the ground, water tables can drop and streams and wells fed by groundwater begin to dry up.

All of these effects can be observed in developing areas of Rhode Island towns, even if there is enough open land remaining to absorb the extra runoff and dilute the pollutant load so that impacts are minimized. But at some point, the balanced is tipped and permanent damage to water quality and habitat can occur. The direct cause of the damage depends on the nature of the runoff and the particular topography, soils and vegetation on a site. When the native trout vanish from a stream, for example, it is often very difficult to pin down the cause. Is fertilizer in the runoff creating algal blooms that deplete the oxygen in the water? Are flash floods spoiling gravel spawning beds? Are water temperatures rising? Or is it some combination of factors? As scientists worked to understand these processes, it became clear that in most cases there is a direct correlation between the degree of water impairment and the overall amount of impervious cover in the watershed. While it is difficult to predict which factor will come into play in any particular situation, as impervious cover rises above 10% there is almost always a measurable loss in water quality. Between 10% and 25% these impacts increase, and pollution and flooding are both evident. Above 25% impervious cover, water quality impacts can be so severe that it may not be possible to restore water quality to pre-existing conditions.

The impact of impervious cover is obvious near a typical commercial area: both the quantity and quality of runoff are impacted, and infiltration is greatly reduced.

For towns interested in protecting water quality, natural ecosystems, and the prevention of flooding, it is very hard to measure, let alone manage, the dozens of separate factors that can impact small watersheds. However, because of the well documented correlation between impervious cover and stream health, there is an opportunity to use impervious cover as a surrogate for both measuring and managing water quality and watershed health. By keeping overall impervious cover below 10%, towns can ensure that the land will be able to absorb and filter runoff from developed areas and prevent excessive flooding, ecosystem impairment and contamination of water supplies.

Approximately 75% of the stream miles that feed our waterbodies with clean water are small headwater streams that are often small enough to be straddled by a child. These streams are extremely sensitive to land use changes and are therefore very susceptible to contamination. If the level of impervious cover rises too high in these areas, irreversible damage can occur to drinking water quality, to groundwater supplying private wells, and to aquatic wildlife habitat. As towns grow, there will be increasing pressure to replace natural areas with more impervious cover. Even when best management practices are widely used when attempting to mitigate the impacts of impervious cover, a threshold of

Even rural large-lot development can create long impervious roads and driveways, and mowed lawn areas can create almost as much runoff as pavement.

impervious cover is eventually crossed, beyond which predevelopment water quality cannot be maintained. (CWP 2000)

Now is the critical time to evaluate the impacts of potential future development and associated impervious cover on the health of the Rhode Island's Watersheds. . It is important to note that it is not growth itself that is the problem; instead it is the way that communities require growth to occur that is the issue. By adopting more creative land use techniques and development standards, towns can guide growth away from sensitive areas to those sites that can better accommodate it. Furthermore, by reducing impervious cover using a range of better site design and construction practices, the health of the watershed can be protected and flooding minimized even as growth continues.

The purpose of this report is to provide an overview of the scientific research on impervious cover and to recommend tools for managing development in sensitive watersheds so that impervious cover is minimized. It reviews the literature documenting the connection between impervious cover and stream health and describes efforts to measure existing impervious cover and to predict future impervious cover as development continues. It describes what a variety of communities are doing to incorporate impervious surface management into local zoning ordinances. Finally, it details the extent of impervious cover in Rhode Island, reviews predictions of future impervious cover and its likely effects on water quality, and lays out some recommendations for what towns can do to limit impervious cover.

The Connection between Impervious Cover, Flooding, and Water Quality

The expansion of impervious cover is part of a greater set of changes that occurs as land is converted from agriculture or forest to residential or other uses. Each of these changes has an impact on what happens to rainwater once it reaches the ground.

These impacts can be placed in four categories: hydrological, biological, chemical, and physical, each of which has implications to watershed health and our own well being.

Hydrological

Under natural forested conditions, only about 10% of precipitation runs off the surface of the site, 50% soaks into the ground, and a surprising 40% is taken up by trees and other vegetation and sent back into the atmosphere through the process of evapotranspiration (Figure 1). As roads and houses are built, this ratio starts to change, with runoff increasing as the amount of impervious cover increases. For example, the total runoff volume for a one-acre parking lot is about 16 times that produced by an undeveloped one-acre meadow (CWP 2000). Therefore it's understandable why suburban and urban communities have more severe flooding than undeveloped areas. Because the water is spending less time on site, infiltration declines dramatically. This is a particular concern in many urban and suburban regions, where groundwater has been reduced because there is not enough rainfall soaking into the ground. The increase in runoff that occurs during this process, combined with the loss of recharge to groundwater, has dramatic impacts on streams.

Biological

The decline of biological indicators is the first sign of stream degradation, and has been the most commonly studied result of increased impervious cover. As a result of a high percentage of impervious cover, naturally occurring aquatic insects, wetland plants, and amphibians decline and are gradually replaced by species that are adapted to pollution and flooding (Schueler 2000). The most common standard measure of biological degradation is the Index of Biotic Integrity (IBI) (Karr, 1987, quoted in Brabec, 2002). The IBI measures species richness and composition, local indicator species, trophic composition, fish abundance and fish diversity. Brabec's team looked at several dozen studies and found that there was a broad range of impervious cover thresholds associated with stream degradation, ranging from 4% to 50%, but that biotic integrity seems to be the most sensitive: "aquatic communities change at a level of impervious surface much lower than that which affects water quality measures" (Brabec, et al, 2002). Looking at a range of studies, they found that impacts on overall biotic measurements were seen within a range of 3.6% to 15% impervious cover; the threshold for fish population health ranged from 3.6% to 12%, and macroinvertebrate health declined between a range of 8% to 15%.

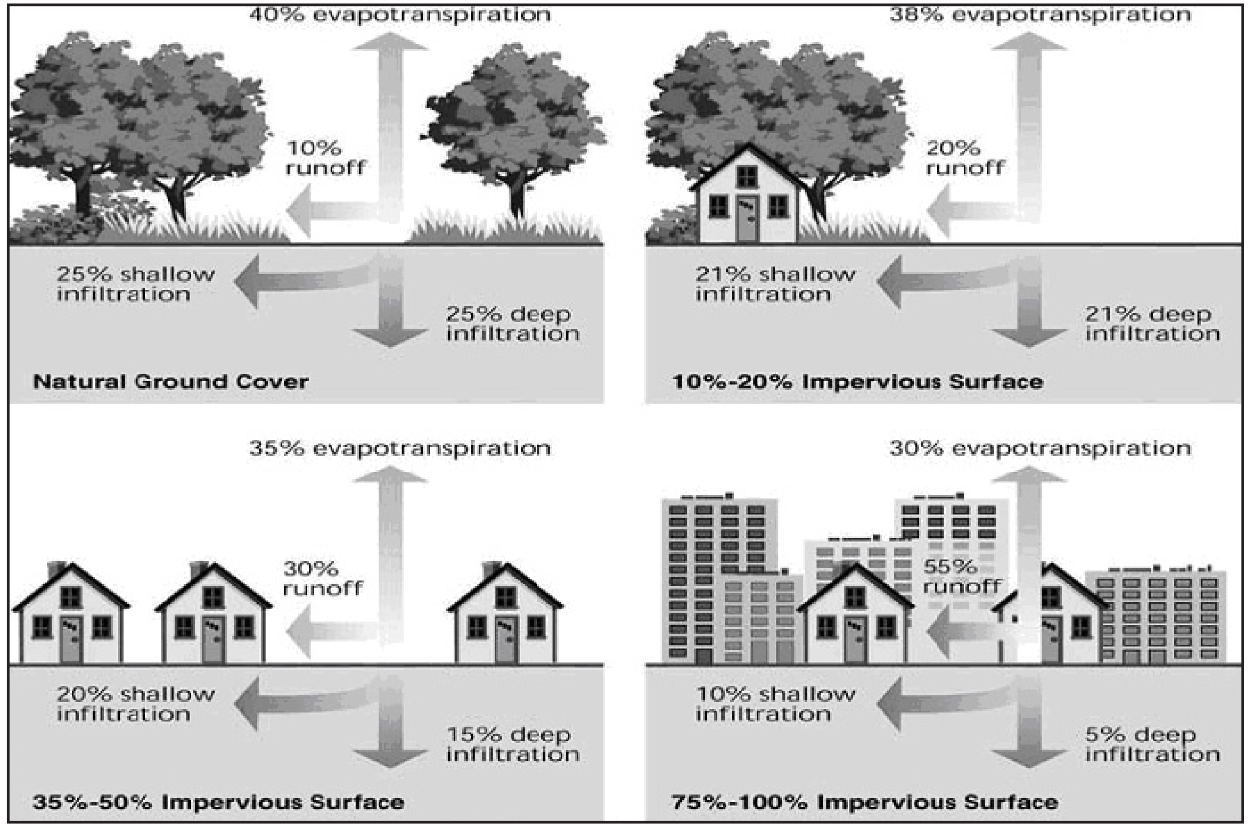


Figure 1: Changes in site hydrology with increasing impervious cover (US EPA)

Chemical

Impervious surfaces such as roads, driveways and parking lots collect a variety of chemical pollutants and hydrocarbons and discharge them to aquatic systems with every heavy rain. Fertilizer, herbicides and pesticides run off of lawns, and household cleaning products and even pharmaceuticals find their way into groundwater from septic systems. The most common disturbance in the chemical make-up of streams is the elevated levels of nitrogen and phosphorus. Other common contaminants include calcium, sodium, potassium, magnesium and chloride from road salt. Metals found in streams due to runoff include nickel, chrome, lead, copper and zinc (Paul 2001). Meanwhile, the only chemical that should be found in healthy streams is dissolved oxygen, which declines due to warming and eutrophication, or nutrient enrichment.

In Connecticut, Clausen et al. surveyed 15 streams and collected data on the effects of impervious cover on stream quality. The study found a strong correlation between water quality and percent impervious cover across a range of contaminants, including organic residue, nitrogen, phosphorus, dissolved chloride, and fecal coliform. In each case, as impervious surface increases so does the contaminant of concern.

Physical

In undeveloped watersheds, precipitation is slowed by vegetation and organic matter, and stormwater runoff volumes are reduced and delayed before reaching streams and waterbodies. As impervious cover increases, so does both the volume and the velocity of runoff, resulting in a large volume of water reaching the stream system soon after a storm. Undeveloped wetlands and stream systems can generally absorb flooding without extensive erosion or loss of vegetative cover. Development of impervious cover in a watershed can happen so quickly that stream systems can't adjust, resulting in erosion of stream banks and alteration of the stream bed, which tends to become straighter, deeper, and more U-shaped. This degrades in-stream habitat and sends organic matter and silt downstream, creating further damage (Schueler 2000). Figure 2 illustrates how a stream dramatically changes as a watershed increases impervious cover.

In another review of stream data, Paul et al. (2001) found that channel enlargement begins to be observed at only 2% impervious cover. Temperature, critical to the success of native trout and other species, is also affected. A study on Long Island found urban streams to be 5-8^{o}C higher in the summer and 1.5-5^{o} lower in the winter than in undeveloped watersheds (Paul et al. 2001).

Health Risks

There is a strong correlation between increased impervious cover and increased risk to human health. A variety of chronic and acute illnesses are caused by microorganisms that either are swept into water bodies by increased runoff, or flourish because of increased nutrient pollution. People can contract these illnesses through direct contact or through the consumption of tainted seafood. Elevated levels of nitrogen in drinking water are associated with a number of health risks, including methomoglobineamia, shortness of breath, blueness of skin (especially in infants), along with various threats to pregnant women (Carson 2005).

Hydrologic, Physical, Water Quality, and Biological Impacts Associated with IC (ENSR, USEPA, 2005)

Hydrologic Impacts
- Increased runoff volume (flooding)
- Increased peak flow rates
- Increased bankfull flow
- Decreased baseflow

Physical Impacts
- Modified sediment transport
- Channel enlargement
- Channel incision
- Stream embededness
- Loss of large woodsy debris
- Changes in pool/riffle structure
- Loss of riparian cover
- Reduced channel sinuosity
- Warmer in-stream temperatures

Biological Impacts
- Reduced aquatic insect diversity
- Reduced fish diversity
- Reduced amphibian diversity
- Reduced wetland plant diversity

Water Quality Impacts
- Increased sediment concentrations
- Increased nutrient concentrations
- Increased trace metal concentrations
- Increased hydrocarbon concentrations
- Increased bacteria and pathogens
- Increased organic carbon concentrations
- Increased MTBE concentrations
- Increased pesticide concentrations
- Increased deicer concentrations

In watersheds with less than 5% impervious cover, streams are typically stable and pristine, maintaining a good pool and riffle structure.

At 10% impervious cover, this stream has doubled its original size and the pool and riffle structure is lost.

This stream is approximately 20% impervious cover and shows erosion due to an absence of vegetation to stabilize the bank.

This stream has a 30% impervious cover. The size of the stream channel has increased by five to ten times.

Figure 2: Relationship between percent imperviousness and stream morphology (All images Copyright 1999, Center for Watershed Protection).

The most common health risk is fecal coliform bacteria, which are a normal occurrence within the intestinal tracts of animals. While acceptable at very low levels in recreational waters, coliform bacteria is very dangerous when introduced into drinking water. Coliform bacteria find their way into our water by way of substandard septic systems, agricultural runoff, and animal waste. The rapid runoff from impervious surfaces increases the likelihood that every heavy rain will wash bacteria-laden waste directly into streams. Similarly, waterborne parasites such as Giardia and cryptosporidium become much more mobile as flooding increases in developing watersheds.

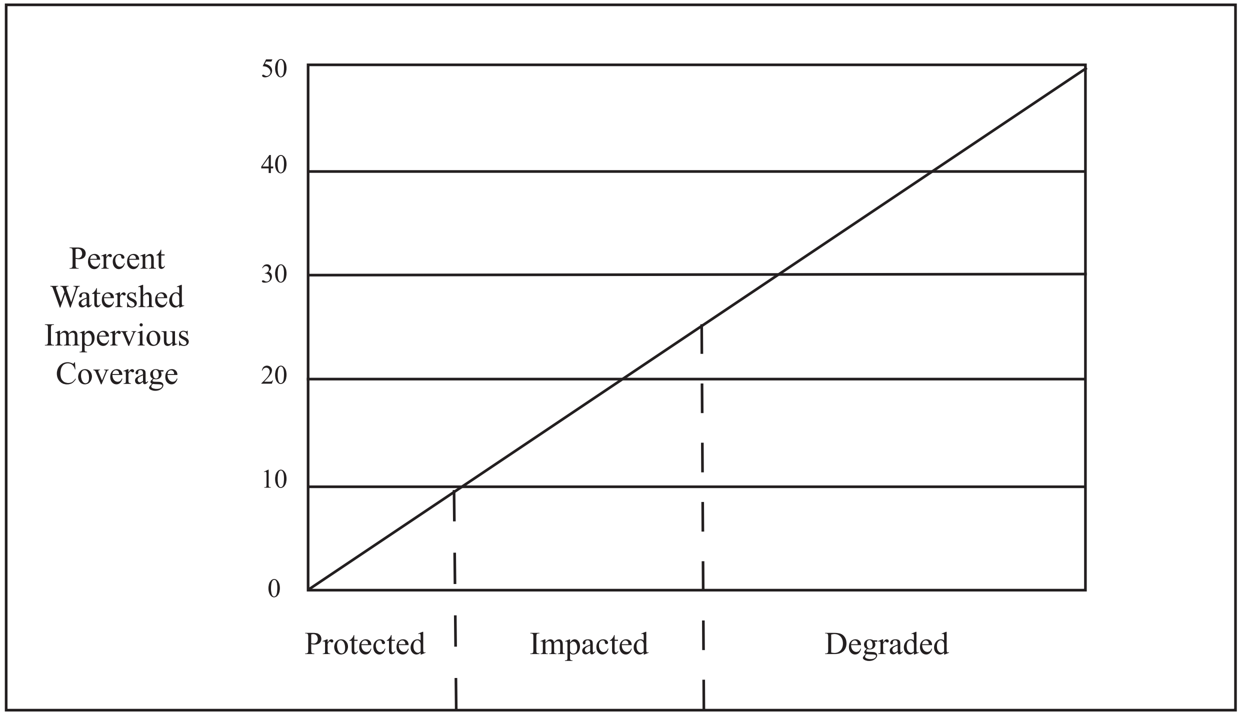


Figure 3: Relationship between percent imperviousness and environmental quality (Arnold & Gibbons, 1996, Schueler, 1992).

The Impervious Cover Model

Based on a review of hundreds of studies, Tom Schueler and others at the Center for Watershed Protection (CWP) in Maryland developed what they called the "Impervious Cover Model" (Model). The Model is based on the average percentages of impervious cover at which stream quality declines, and classifies the impacts to streams into three categories. Sensitive streams are those within watersheds which are still below 10% impervious cover, where impacts are generally minor. These streams are relatively pristine and can be preserved through a variety of conservation measures. Impacted streams are found within watersheds with between 10% and 25% impervious cover, and can still be restored. Non-supporting streams are found within watersheds with over 25% impervious cover, and are not considered suitable for restoration. Obviously these ranges are part of a single continuum, and there is much variation between regions and even individual streams. But the Model allows streams and watersheds to be generally categorized, making management decisions clearer. In their "Rapid Watershed Planning Handbook" and other publications, CWP provides a detailed methodology for using the Model to more effectively plan for the restoration of damaged streams and in protecting those that are still below the key thresholds.

Measuring Impervious Cover

Using the Impervious Cover Model (Model), towns can evaluate the present health of their rivers and streams, as well as predict future impacts as growth and development continue. In both cases, sound decision-making requires accurate measurements of impervious cover. An enormous amount of research effort over the last ten years has contributed to the development of efficient ways to measure impervious cover. The most accurate is a ground survey of existing roads, buildings, driveways, sidewalks, etc. However, this may be very expensive at the watershed scale. Alternately, impervious surfaces can easily be traced using aerial photography, but this can be incredibly time-consuming when applied to a large area. Since most states have compiled detailed land-use maps that delineate various land use types in a fair amount of detail, planners can calculate the acreage of land in various categories, such as commercial, industrial, and low-, medium-, and high-density residential, and multiply it by typical averages for impervious cover. The averages, in turn, are developed based on detailed surveys of real-world examples of each cover type.

The most common reference for relating the percentage of impervious cover to land use type is Technical Release 55: Urban Hydrology for Small Watersheds (TR-55; USDA 1986), which was developed to help engineers calculate the amount of stormwater runoff from development sites. As part of TR-55, the percentage of impervious cover was calculated for typical development types and densities. The standards were based on a series of research projects conducted in the 1960s and 1970s, many of which used direct measurement to establish the basic relationships. Under TR-55, residential development at a ¼ acre lot density results in 38% impervious cover; ½ acre lot, 25%; 1 acre lot, 20%, and 2 acre lot, 12%. Several studies have extrapolated from these percentages levels of impervious cover for larger lots, with three acres corresponding to 8% impervious cover, 5 acres, 5%, and 10 acres, 2.4% (Huron River Watershed Council 2003). While it is difficult to reconstruct the methods used to develop the original TR-55 numbers, various recent studies have produced similar results (Table 1). The range of imperviousness most likely reflects differences in local requirements for development in each zoning category (lot frontage, road width, sidewalk requirements, building setbacks, etc.) as well as differences in calculating residential density.

Minimum Lot Size	Density in Dwelling Units/Acre	Percent Impervious Cover
10 Acres	0.1	2.4[b]
5 Acres	0.2	5[b], 8[e]
3 Acres	0.333	8[b], 7[e] (2-3 acres/unit)
2 Acres	0.5	12[a], 15[c], 13-16[d] (1-2 units/acre)
1 Acre	1	20[a]
.5 Acre	2	25[a], 22-31[d] (2-4 units/acre)
.25 Acre	4	38[a]

Table 1: Percentage of Impervious Cover Associated With Various Residential Lot Sizes

[a] Source: USDA Soil Conservation Service (USDA, 1986).
[b] Source: Huron River Watershed Council (Wyckoff, et. al, 2003).
[c] Source: Taylor, 1993.
[d] Source: Alley and Veenhuis, 1983.
[e].Source: Prisloe, et al, 2000.

Assumptions of the Impervious Cover Model

The Impervious Cover Model has proven to be reliable when applied correctly – but it includes a number of assumptions (Center for Watershed Protection, 2002):

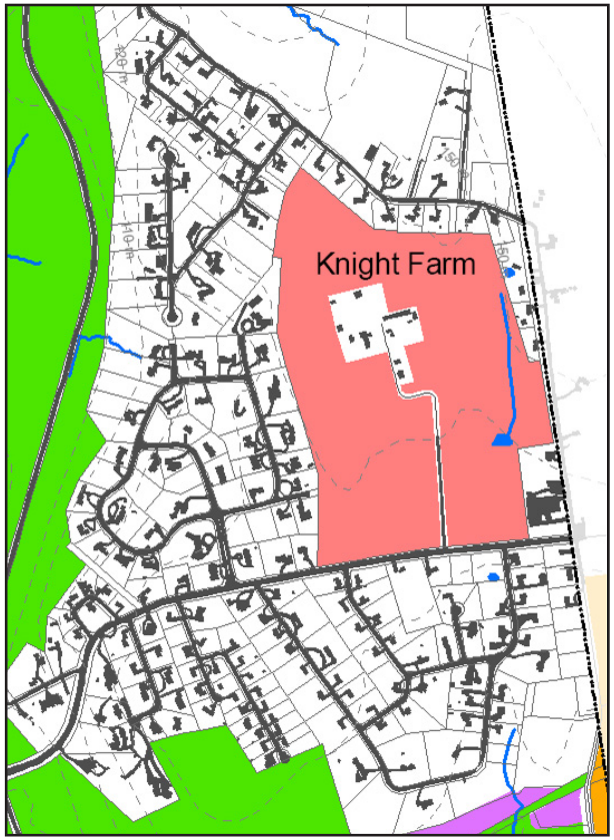
- It should be applied only to smaller 1st, 2nd and 3rd (low) order streams, since these are the types of streams involved in most of the research that supports the model Most of the streams in the Scituate Reservoir Watershed are low order streams.
- It requires accurate estimates of percent impervious area.
- It predicts potential rather than actual steam quality, so field monitoring is recommended to confirm any predictions made.
- It does not predict the precise level of any individual stream indicator, but rather the average of a group of indicators.
- 10% and 25% thresholds are not sharp breakpoints, but reflect a range where transitions in stream quality become apparent.
- It should only be applied within the areas where it has been tested, which includes the Northeast.
- It has not been validated for non-stream conditions like reservoirs and groundwater aquifers.
- The relationship between impervious cover and stream quality is weakest in watersheds with less than 10% impervious cover. Under 10%, other factors such as the amount of forest cover, continuity of vegetated stream buffers, soils and land use activity can play a significant role.

Fortunately, help is available for Rhode Island towns needing more accurate measurements of impervious cover. Rhode Island contracted with the Sanborn Map Company to develop a statewide impervious cover dataset that is available through RIGIS. Sanborn used color photography acquired as part of a statewide orthophoto mapping initiative. A semi-automated process was used where the computer is programmed to recognize impervious surfaces.. The great advantage of this process is its speed, cost, and high resolution (two feet), which allows roads, buildings and parking lots to be shown in great detail.

The Providence Water Supply Board is using an even more accurate survey process with a resolution as high as six inches. Called LIDAR, for "light detection and ranging", it uses the same principal as radar. Housed in an airplane, the LIDAR instrument sends pulses of laser light, at up to 100,000 pulses per second, down to the ground surface. The light, which can penetrate clouds and foliage, reflects back to a collector which registers the differences in each pulse. The result is an accurate survey of surface features, from which it is fairly easy to separate out impervious cover.

Predicting the future amount of impervious cover

The measurement of existing impervious cover is relatively straightforward if you have the right information and enough time to use it. Knowing the amount of impervious cover allows you to



LIDAR survey showing impervious roads, houses and other structures in a corner of Scituate.

predict, based on hundreds of scientific studies, whether a particular stream or subwatershed is likely to decline in health in the near future. However, in order to manage that watershed, you also need to know what is likely to happen as development continues in the watershed. Many towns have prepared "build-out" analyses, for example, which predict the number of future homes and businesses that are theoretically possible if all of the buildable land is developed to the maximum allowed by the town's zoning ordinance and development regulations. Build-out analyses help towns plan for additional schools and town services and used to model the amount of impervious cover that is likely to be created.

However, most build-out analyses do not have the level of detail where new roads, houses and driveways are shown. Therefore, researchers have attempted to define how much impervious cover is likely to result from development under the common range of lot sizes and zoning densities, using averages from TR-55 and other sources as multipliers. Logically, the results are most accurate where future development is similar to the studies from which the original numbers were developed. Towns can look at development within their own borders and calculate their own percentages. For example, TR-55 predicts that a development with two acre lots will result in 12% impervious cover. We can test this with a simple example: if zoning requires a two acre lot and 200 feet of frontage, and we assume that the dwelling is built 100 feet from the front lot line, we could predict the following amount of impervious cover:

House and garage:	3000 square feet.
Patios, pool, outbuildings, etc:	2000 s.f.
Driveway (100' x 12'):	1200 s.f.
Sidewalk (200'x 5'):	1000 s.f.
Roadway (30'x 200/2):	3000 s.f.
Total:	10,200 s.f.

10,200 s.f./ 2 acres (87,120 s.f.)
= 11.7% impervious cover

This demonstrates that there are multiple factors beyond simple lot size/density that affect the amount of impervious cover. Because the size of houses and any additions tend to be driven by the marketplace rather than regulations, towns will have little control over the amount of impervious cover they create. Moreover, lawn area is considered to be semi-impervious and does not function as well as undisturbed natural areas in infiltrating precipitation into the ground (Schuler 2000). What towns can control are elements codified in zoning and subdivision regulations, such as lot width, setbacks, roadway width and sidewalk standards. To define the percentage of impervious cover associated with each zoning district, towns can use a similar calculation to predict the impact of required road width and lot frontage on the amount of impervious cover associated with each building lot. For towns with GIS capability, this can be compared with the actual amount of impervious cover measured in areas that are already fully developed.

Impervious Cover in Rhode Island

Rhode Island is one of the most densely populated states in the Country resulting in a statewide average impervious cover of 12% (Figure 4). However, Figure 4 also shows large areas outside of the urban services boundary that are 4% impervious cover, which is below the 10% threshold. The urban services boundary (USB) was established by the Statewide Planning Program as part of the State Land Use Plan to recommend where future growth should be directed to achieve more efficient ("smarter") future growth. The area within the USB has an impervious cover of 25%. Therefore from a water quality and smart growth perspective it makes sense to encourage future growth within the USB.

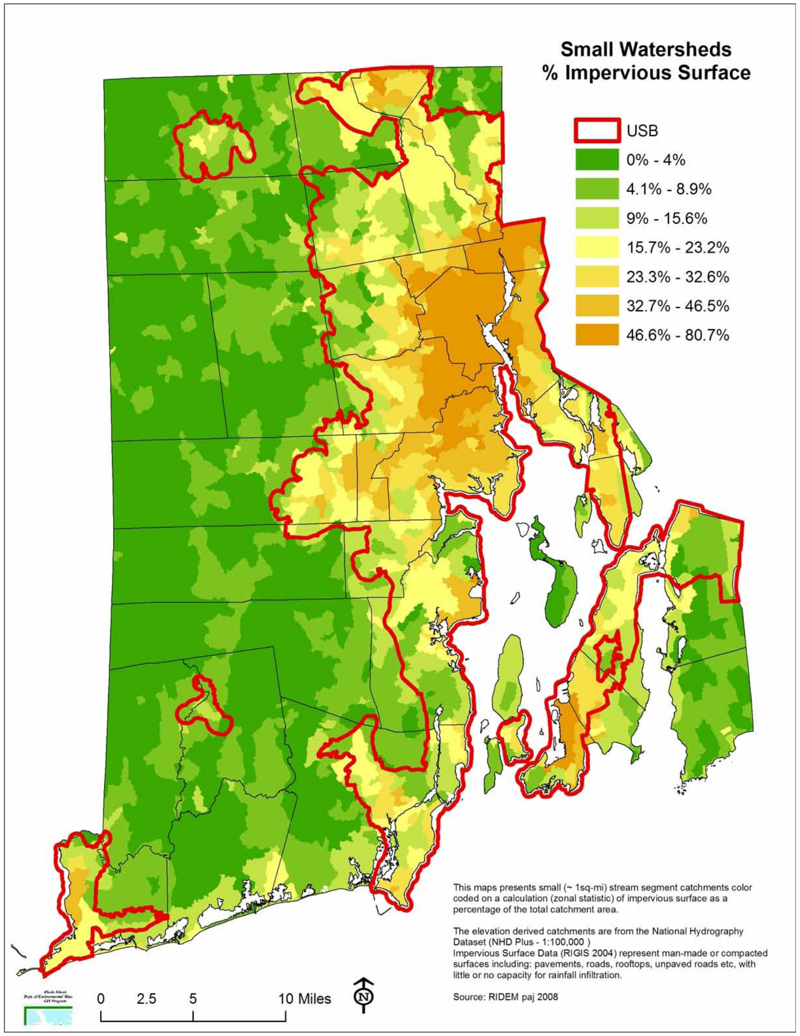


Figure 4: Percent Impervious Cover in the State of Rhode Island with Urban Service Boundary

Research clearly indicates that the protection of small headwater streams is essential to achieve water quality objectives in the larger rivers and coastal waters they feed. These headwater streams are extremely vulnerable to direct and indirect impacts of land use. Most headwater streams are located in areas outside of the USB in subwatersheds that have a small amount of impervious cover and are considered to be healthy. However, headwater streams are less likely to be adequately protected from new growth by Federal, State and local regulations than larger stream and river systems (CWP, 2007). Moreover, Federal and State regulations provide no authority for state agencies to regulate impervious cover at a watershed scale, nor to effectively control many of the diffuse non-point pollution sources directly related to land use.

Extensive research has enabled scientists and engineers to empirically relate how watersheds with high percentages of impervious cover exhibit negative impacts to hydrology and water quality, reducing or destroying aquatic habitat quality and biodiversity (CWP 2000, Coles 2004, Morse 2003). It has been documented that, for a given amount of new development, higher density can significantly reduce impervious cover on a watershed basis compared to the same amount of new homes and businesses laid out in a low-density development pattern (EPA 2006). Therefore the current Rhode Island trend of large-lot, low-density development with segregated uses is creating significantly more impervious cover than necessary to meet our growth needs. More creative land use techniques such as conservation development and compact mixed use (village-style growth) can significantly reduce impervious cover.

Applying Impervious Cover to Land Use and Water Quality Regulations

Given the clear usefulness of impervious cover as a predictor of water quality and ecosystem health, why is it not used more often in land use regulations? The answer is that in order to comply with constitutional protections of private property rights, zoning and other regulations must justify the use of the "police power" of the state, which is "the power of government to intervene in the lives of private citizens for the protection of public health, safety and welfare" (The Practice of Local Government Planning, 2000). The State Zoning Enabling Act specifies exactly how towns may exercise their police power. Section 45-24-30 of the Rhode Island Zoning Enabling Act allows communities to provide for orderly growth and development by recognizing in part "the natural characteristics of the land, including its suitability for use based on soils characteristics, topography, and susceptibility to surface or groundwater pollution". It also allows communities to control surface and groundwater pollution, soil erosion and sedimentation. Therefore, communities do have the authority, if they choose to exercise it, to establish reasonable standards via zoning regulations to protect water quality.

> A recent study in Chesapeake Bay determined that new development was increasing nutrient and sediment loads at rates faster than restoration efforts were reducing them. Developed lands within the Chesapeake Bay Watershed contribute less than one third of the Bay loading of pollutants, but would require approximately two thirds of the overall restoration costs. This study concluded that the most cost-effective approach to reverse the trend of increasing pollutant loads from new development was by forming strong partnerships with communities to encourage them to adopt and implement more environmentally sensitive development techniques and reduce impervious cover. -EPA 2007

In order to use zoning and other regulations to directly control the amount of impervious cover, towns will have to demonstrate that defensible, objective standards have been established to guide the administration of such regulations. Therefore, any standard for impervious cover must be backed up with the objective data cited in this report. Zoning also needs to be supported by the town's comprehensive plan, which combines data analysis and mapping with a process of public deliberation and collective decision-making.

Until very recently, the science behind impervious cover analysis was extensive, but the connection between the amount of impervious cover and specific zoning densities was difficult to pin down. The many variables of soil, topography and land use introduce many uncertainties in establishing regulations that are fair to all landowners in a town. However, as we have seen, advances in data collection and mapping are making it easier to arrive at more defensible conclusions about what level of impervious cover is acceptable while water quality as well as public health, safety and welfare is still protected.

Reducing Impervious Cover through Land Use Planning

Community zoning and subdivision regulations and the patterns of land use they forge are directly responsible for the amount of impervious cover in a watershed. Generally speaking, as density increases, the amount of impervious cover also increases. However, the overall pattern of development is also important. Although a few rural communities have residential zoning densities that would, at build-out, keep impervious cover below a 10% threshold, the large-lot zoning currently used to accommodate growth requires houses to be far apart, creating unnecessary impervious cover and encouraging more off-site impervious infrastructure, such as roads and parking lots (US EPA 2006). Moreover, many of the surfaces remaining after large-lot development that are believed to be pervious actually behave like impervious surfaces. Research indicates that the volume of runoff from highly compacted lawns is almost as high as from paved surfaces (Shueler 1995, 2000; USDA 2001). Lawns clearly do not function as well as undisturbed natural areas and can contain contaminants such as nutrients, herbicides and pesticides. Unlike undisturbed natural areas, development of a typical large lot subdivision changes pre-existing hydrology due to site gradation, the removal of topsoil, and soil compaction by heavy equipment (Schueler 1995, 2000). Due to these development impacts, even if you reduce impervious cover by limiting the number of houses, you cannot compensate for the loss of watershed services that were provided before development. The solution is to maintain the overall density allowed by current zoning while encouraging the use of more compact growth techniques that can reduce impervious cover on a per unit basis.

Village Development

Development or redevelopment within a compact mixed-use village is the most efficient means to reduce impervious cover on a per unit basis. In their 2006 report "Protecting Water Resources With Higher-Density Development", the US Environmental Protection Agency reinforces this common-sense approach to accommodating development in sensitive watersheds (www.epa.gov/smartgrowth/pdf/ protect_water_higher_density.pdf). There is no need to stop development outright, or even to reduce the overall number of proposed dwelling units. Rather, towns can have the benefits of both growth and conservation if development is directed to the areas best suited for it.

The EPA study demonstrated, as can be seen in Figure 5, that if a watershed is built out at a one housing unit per acre density, the total impervious cover will be 20%, significantly above the 10% threshold for protecting water quality. However, if the same number of houses that would be allowed at the one acre density were clustered on smaller lot sizes of four and eight units per acre, the impervious cover for the watershed is reduced to 9.5% and 8.1%, respectively. Although the impervious cover for the particular clustered development is higher than the one dwelling per acre scenario, the overall watershed impervious cover is greatly reduced and is maintained at a level that protects water quality. Compact development yields less impervious cover on a per unit basis since most of the impervious cover is related to the transportation infrastructure (roads, driveways and parking lots) needed to support growth. Transportation-related impervious cover typically comprises 65-70% of the total impervious cover associated with development (CWP 2000). Obviously, the key to taking advantage of this reality is to increase densities in some areas, while maintaining the same overall number of new units that could be built under the conventional scenario.

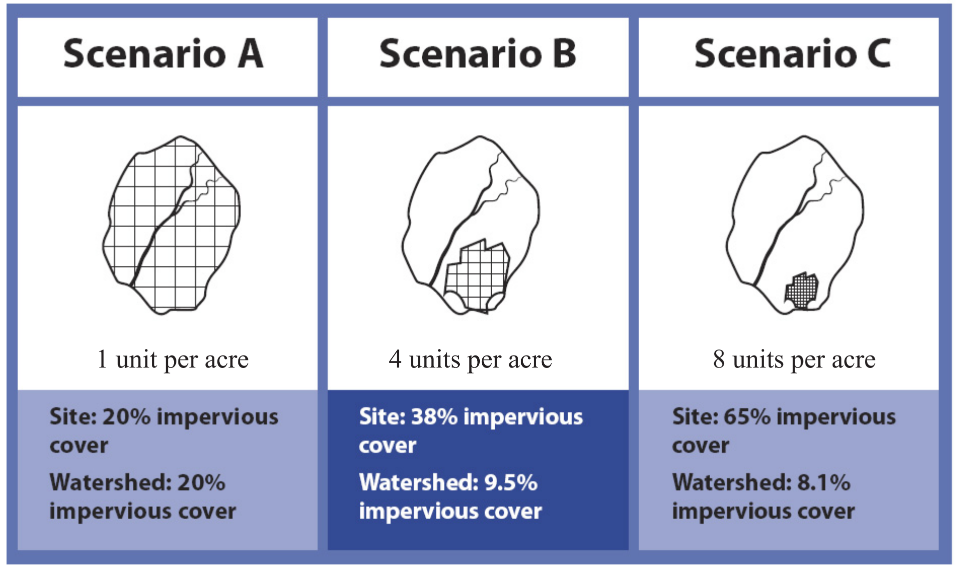


Figure 5: Overall impervious cover for the watershed decreases as site density increases given the same amount of growth (USEPA).

Continuing this analysis at the town and watershed scales, the study found that the results were consistent regardless of the size of the area:

- "For the same amount of units, higher-density development produces less runoff and less impervious cover than low-density development; and
- For a given amount of growth, lower-density large-lot development impacts more of the watershed."

These findings show that large lot development, even though it can reduce impervious surface on an individual property, it is not the preferred strategy for reducing flooding or protecting water resources on a town or watershed level. There will be far less negative impact on the watershed if the same number of units are concentrated together in compact neighborhoods and village centers. Moreover, by greatly reducing roads, utilities and other infrastructure costs, this approach can be profitable for developers while reducing house prices for consumers.

This approach can be the foundation of a "smart growth" strategy for our communities, in which a mix of residential, commercial and community uses are combined in traditional towns and villages instead of sprawling over the landscape. The result is a walkable, liveable community surrounded by open space, with low energy costs and assured water supplies. As the market for large houses in the countryside decreases, developers and consumers are both returning to traditional neighborhoods, which can offer a range of house styles and prices, along with various shared amenities. Furthermore, travel to work, school, stores, and recreational areas is reduced, saving gas and further helping the environment. These are the communities that will be able to weather the impacts of climate change and energy costs, and adapt to changing economic circumstances.

Conservation Development

Zoning that limits the overall percentage of impervious cover is useful, but should be combined with Conservation Development ordinances that provide design flexibility and other incentives to encourage village-style development. Conservation Development is a creative land use technique that allows a community to guide growth to the most appropriate areas within a parcel of land to avoid impacts to the environment and character-defining features of the property. Typically, the same number of units as permitted under conventional development are built on a portion of the property, leaving at least 50% of the site as permanent, protected open space. Conservation Development is a step-by-step design process that begins with analysis of the site and its context. The most environmentally sensitive areas as well as those areas most valuable for public recreation, etc. are identified first, then streets and building sites are laid out in a way that avoids these important resource areas.

Conservation Development allows for growth to continue, even while important features of a site are protected. In reducing the amount of pavement per unit, it also allows for significant reductions in impervious cover.

The Conservation Development design process is an ideal way to continue development while protecting the headwater streams that are most vulnerable to the impacts of runoff from impervious surfaces. Just as important, by reducing the overall footprint of development, these projects can significantly lower the total amount of impervious cover across the watershed. As part of the Scituate Reservoir Source Water Assessment, University of Rhode Island Cooperative Extension compared predicted impervious cover under conventional development to that created by more compact conservation development projects. Their projections showed an increase in impervious cover across the watershed from 3% (existing) to 7% (future), enough to cause impairment of aquatic life in many streams and other waterbodies. If 50% of future development follows the Conservation Development process, overall impervious cover can be reduced to 5%, a significant benefit, particularly if Conservation Development is applied in the most sensitive areas. This does not include the additional benefit of reducing lawn area, which would be an anticipated result of smaller house lots.

Establishing Impervious Cover Limits through Zoning Ordinances

Historically, community zoning regulated the amount of development that could be located in a given area, but ignored the transportation component needed to support development. Since impervious cover associated with transportation (roads, driveways and parking) can be 60-70% of the total impervious cover, towns and county governments around the country have started to incorporate limits on impervious cover into their regulations. Most commonly, these have been adopted in specific overlay districts, typically to protect public water supplies or groundwater recharge areas. Increasingly, towns are adopting zoning regulations to limit impervious cover across entire communities.

The Town of Washington, Connecticut has established maximum lot coverage requirements within its zoning regulations to limit impervious cover. The ordinance states:

> "In residential districts, the maximum land coverage for all buildings and structures (principal and accessory uses) including paved, impervious, or traveled surfaces shall not exceed:
>
> a. 15 percent of the total land area for lots less than 2 acres,
>
> b. 0.3 acres for lots between 2 acres and 3 acres [about 12%], and
>
> c. 10 percent for lots 3 acres and larger."

This recognizes that while smaller lots have a higher percentage of impervious cover, they have a lower average percentage of impervious cover per dwelling unit.

The ordinance limits impervious cover in business districts to a maximum of 25%. In all cases, lot coverage is defined as:

> "the percentage of the lot, which is covered by structures including (but not limited to) buildings, swimming pools, swimming pool equipment, decks, porches, patios, sports courts, chimneys, air conditioning equipment, generators, utility meters, transformers, above ground propane tanks, and most man made impervious surfaces. Driveways, parking areas, and parking lots are included in the lot coverage calculation whether or not they are paved. Pedestrian walkways are included unless they are made of pervious materials such as gravel, pea stone, or randomly spaced stones set in grass." (*http://www.washingtonct.org/zoning.pdf*)

On a larger scale, New Castle County and the City of Newark in Delaware have adopted Water Resource Protection Area ordinances that include overall limits on impervious cover (Kaufman & Brant 2000). Functioning as zoning overlay districts, these ordinances limit the amount of impervious cover to a maximum of 10% to 20% in (sensitive aquifers, wellhead, recharge and reservoir water resource protection areas-). In the reservoir district, new single-family development is limited to a maximum impervious cover of 10%, which is calculated to equate to a gross density of two to three dwellings per acre. Based on this model, Kaufman & Brant proposed watershed zoning for the entire Christina River Basin, covering parts of Maryland, Pennsylvania and Delaware (the latter containing the only drinking water supply streams in Delaware, its only six trout streams, and a growing population of 400,000 people). The zoning ordinance would characterize each portion of the watershed as urban, suburban or open space district, and limit impervious cover to corresponding ranges of 40-55%, 20-35%, and 10-15%.

In an example from North Carolina, Moore County has established impervious cover limits for zoning overlay districts associated with water supply watersheds. (http://www.co.chatham.nc.us/dept/planning/planning_dept/watershed_review_board/supporting_documents/10-70_Rule/Planning_Board_10-70/moore_cnty_watershed.pdf)

The county has four different densities within these overlay zones:

- One dwelling unit per 80,000 s.f., or 6% maximum built-upon area
- One dwelling unit per 40,000 s.f., or 12%

maximum built-upon area

- One dwelling unit per 20,000 s.f., or 24% maximum built-upon area
- One dwelling unit per 14,000 s.f., or 36% maximum built-upon area

The "built-upon area" includes "that portion of a development project that is covered by impervious or partially impervious cover including building, pavement, gravel areas (e.g. roads, parking, lots, paths), recreation facilities (e.g. tennis courts), etc." The interesting thing about this ordinance is that it ties watershed protection to traditional lot size/zoning density with a cap on impervious cover. Within the 40,000 and 80,000 s.f. zones particularly, developers will have to substantially decrease road widths and other impervious surfaces to remain under the 12% and 6% impervious caps. These per-lot impervious cover ratios must be used with caution since they would preclude a mixed-use compact growth development that would significantly decrease the percentage of impervious cover on a per unit basis and help to reduce overall impervious cover within a watershed.

Since the early 1980's, the City of Austin, Texas has been adopting watershed ordinances that are customized for 45 watersheds within the city planning area (www.ci.austin.tx.us/news/sg_history.htm). Impervious cover limits range from 15% in sensitive resource areas to up to 30-40% for more urban watersheds. A provision for transfer of impervious cover rights (TICR) allows for increased impervious cover in appropriate areas through transfers from more sensitive locations. The system has withstood numerous legal challenges, and seems to have strong support in an area where natural springs and watercourses can disappear quickly when their recharge areas are paved over.

Incorporating Impervious Cover Management into a Comprehensive Program to Protect Watershed Health

It is important to keep in mind that like any regulatory strategy, zoning limits on impervious cover must be supported by larger planning, education and outreach efforts, as well as specific design practices that can mitigate the impacts of development. The Center for Watershed Protection (CWP) has compiled a useful list of Watershed Protection Strategies ranging from watershed planning to site design (CWP 1998):

1. **Watershed Planning:** Establishing the location and amount of existing and potential future development, and the impervious surface that results, is the foundation of any watershed protection effort. The planning process involves data collection and analysis, testing and selection of management alternatives, and creation of policies and strategies to guide implementation.

2. **Land Conservation:** Conservation efforts include identifying critical habitats and aquatic corridors and the water sources and recharge areas that sustain them, as well as cultural and historic landscapes that are important to a sense of place. Protection strategies often involve partnerships with landowners, towns, non-profit conservation groups and state agencies.

3. **Aquatic Buffers:** Stewardship of the area where land and water meet is critically important, especially in rural watersheds.

4. **Better Site Design:** Innovative approaches to the design of subdivisions, parking lots, streets and buildings can greatly reduce stormwater impacts.

5. **Erosion and Sedimentation Control:** Control of erosion and unnecessary site disturbance during the relatively short period when a project is under construction can prevent permanent impacts to water quality.

6. **Stormwater Best Management Practices:** A range of BMPs, from simple grass swales to complex filtering systems, are increasingly applied to reduce the impacts of new construction and to mitigate existing problems.

7. **Non-Stormwater Discharges:** Discharge from private septic systems, municipal wastewater plants and other sources is regulated by state and federal agencies, but often without reference to an overall plan for the watershed.

Conclusions

While the immediate cause of stream degradation varies from place to place, including physical changes and flooding, loss of habitat and biodiversity, and chemical contamination, there is a consistent correlation between rising levels of impervious cover and stream degradation. While you may not be able to predict exactly what will happen to a stream when impervious cover exceeds 10%, you can be fairly certain that negative impacts will result.

Close attention to impervious cover when formulating planning and management strategies has great potential for helping Rhode Island towns prevent flooding, protect low-order or small streams and ultimately the health of its watersheds. Lacking data about physical or biotic health of small streams, communities have a hard time knowing which are the most sensitive or most important to protect. Towns can use impervious cover to assess threats to sensitive streams and to prioritize conservation activities. Managing the impact of incremental growth on those resources may be harder, but by predicting future levels of impervious cover at build-out, towns can predict whether future growth will likely impact ecosystems or water supplies.

The inclusion of impervious cover in the regulatory process at the municipal level must be used carefully. Towns need to establish a clear link between specific impervious cover thresholds and the protection of public health, safety and welfare. Indeed, communities should look at the specific characteristics of their streams and watersheds and adopt thresholds appropriate for their community, ranging from 4% in sensitive areas to 10% where there are more favorable soil conditions. However, on the watershed scale, the 10% threshold can be a valuable benchmark.

As a practical matter, using impervious cover as a surrogate for all of the various water quality impacts allows towns to avoid the cost of tracking dozens of indicators independently. By keeping impervious cover below the threshold where flooding occurs or water quality is impacted, towns can avoid having to pursue costly mitigation when it may be too late to provide much benefit.

Keeping the level of impervious cover in a watershed below 10% will establish an overall safeguard for the watershed, but it won't prevent some degradation of the most sensitive resources, especially if development occurs in unsuitable areas. Therefore, towns should combine overall limits on impervious cover with policies and regulations that promote Conservation Development, which allows developers the flexibility to cluster new homes and businesses on the portion of the site that is best suited for development, while providing conservation buffers around sensitive areas. Another benefit of Conservation Development is that it reduces road, sidewalk and driveway lengths, further limiting the amount of impervious cover on a per unit basis.

Finally, towns should require the use of design and construction practices that reduce runoff at the source. Known as "Low Impact Development" (LID), these include a suite of techniques that catch stormwater as it flows off roofs and driveways and divert it to areas where it can soak back into the ground. Combined with low overall density and the use of Conservation Development to provide flexibility in locating new roads and homes on a site, LID has the potential to keep runoff from most storms entirely within the boundaries of a site, mimicking the site's pre-development hydrology.

Recommendations for Rhode Island Towns:

- Encourage growth to be located within the Urban Services Boundary wherever possible.
- Promote compact mixed-use development to accommodate larger numbers of dwellings in a traditional village context, which reduces the amount of impervious cover per unit of development.
- Adopt 10% as the upper limit of impervious cover as a policy to be incorporated into the Comprehensive Plan, where applicable.
- Make a strong policy connection in the Comprehensive Plan between the need to limit impervious cover and the designated zoning density for various areas.
- Adopt Conservation Development ordinances that reference the town's impervious cover policy and make it clear that calculations for conservation developments should be based on the average percentage

of impervious cover across the entire site. Require the amount of impervious cover per dwelling unit be available when comparing conventional and conservation subdivision plans.

- Adopt the better site design practices from the *Rhode Island Community LID Guidance Manual* (DEM 2010) to more effectively reduce impervious cover from all development.

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Water Quality Protection

SAFE AND HEALTHY LIVES IN SAFE AND HEALTHY COMMUNITIES

Rhode Island Department of HEALTH

UNIVERSITY OF Rhode Island

Residential Series
March 2004

Household Hazardous Products

RHODE ISLAND IS A STATE RICH IN WATER RESOURCES. From our freshwater lakes and ponds, rivers and streams, and abundant groundwater resources to our coastal ponds, estuaries, Narragansett Bay, and the Atlantic Ocean, our water resources sustain our livelihood. Our land use activities affect the quality of these water resources. There are many things that each of us can do to protect water resources. In this factsheet, we focus on Household Hazardous Products.

What Is A Household Hazardous Product?

We all use a variety of household products that are potentially hazardous—pose a potential risk to people, animals and the environment **(See Table 1 on page 3)**. Many cleaning products, solvents, and pesticides contain moderately to highly toxic chemicals, which can be a threat to our health and environment. The average home can collect as much as 100 pounds of household hazardous waste. The dangers of improper use, storage, and disposal of these hazardous products is an issue of growing concern. For each chemical or product, there are many questions to consider. Which products best meet your needs? Are there safer alternatives? What is the best way to store it? How can you use it safely? What are the proper disposal methods?

A substance is considered hazardous if it is corrosive, explosive, flammable, or if it contains toxic chemicals or any other potentially harmful materials. Unlike most hazardous wastes, which are byproducts of industrial and commercial operations, many household products contain only small amounts of toxic substances. Although they may be disposed of in small amounts, these hazardous substances can have significant cumulative effects on our environment.

Motor oil, pesticides, discarded paint cans, mothballs, flea collars, weed-killers, medicine, and household cleaners may seem like everyday items, but are examples of household hazardous products, which can become hazardous waste when improperly disposed.

Why Should I Be Concerned?

Household hazardous products that are improperly used, stored or disposed can enter groundwater and surface water supplies and be harmful to your health. In addition to polluting water resources, human health problems can also result from exposure due to improper use and storage of household hazardous products. Exposure can occur if you eat, drink, or smoke when a substance is on your hands, through breathing in dust or fumes, or through direct skin and eye contact. Health effects can range from irritated skin or watery eyes to burns, poisoning, and cancer.

THE STATE OF RHODE ISLAND DEPARTMENT OF HEALTH AND THE UNIVERSITY OF RHODE ISLAND
COOPERATIVE EXTENSION DEPARTMENT OF NATURAL RESOURCES SCIENCE

Purchasing Tips

Carefully selecting the products you purchase will allow you to control the types of hazardous products you bring into your home.

- Read the label to assure that the product you are buying is suitable for your needs.
- Look for words like CAUTION, WARNING, FLAMMABLE, HARMFUL, DANGER, POISON. These can tell you if a product is hazardous.
- Buy only the amount of the product that you need.
- Compare products and brands to find the least hazardous chemical that will do the job you need.

Proper Use of Potentially Hazardous Household Products

- Read and follow the label directions carefully. Using more of the product is not better.
- Wear protective equipment as recommended by the manufacturer.
- Handle products carefully to avoid spills.
- Use products in well-ventilated areas. When working indoors, open windows and use a fan to circulate the air toward the outside. Take plenty of fresh-air breaks.
- Do not eat, drink, or smoke while using hazardous products. Traces of chemicals can be carried from hand to mouth.
- Do not mix products unless directions say that you can do so safely. Even different brands of the same product may contain incompatible ingredients.
- If you are pregnant, avoid exposure to toxic chemicals.
- Do not wear soft contact lenses when working with solvents and pesticides. They can absorb and hold the chemicals next to your eyes.
- Carefully and tightly seal products when you finish to prevent escaping fumes and spills.

Proper Storage of Potentially Hazardous Household Products

Follow label directions.

- Leave the product in its original container with the original label.
- Do not store near food and/or beverages.
- Make sure lids and caps are tightly sealed.
- Store hazardous products on high shelves or in locked cabinets out of the reach of children and animals.
- Store incompatible products separately. Keep flammable products away from corrosive products.
- Keep containers dry to prevent rusting.
- Keep flammable products away from heat, sparks, or other sources of ignition.
- Know where flammable materials are located in your home, and know how to extinguish them. Keep a fire extinguisher or materials to control fires where you can access them.

Proper Disposal of Potentially Hazardous Household Products

- Share leftover product(s) with someone who can use it.
- Take leftovers to a community hazardous waste collection point for proper disposal. Contact the Rhode Island Resource Recovery's Eco-Depot for their collection schedule, to make an

appointment, and find out which products they will take and what you may do with products they will not accept. See the For More Information section at the end of the factsheet.

- Follow the disposal instructions on the product label.
- Never burn hazardous products.

Proper use, storage and disposal of fuels and petroleum products

Motorized equipment that is not regularly and properly maintained can result in gasoline or oil leaks. As little as one gallon of gasoline can contaminate groundwater above health advisory levels. Gasoline may also contain additives like MTBE, which is highly soluble in water, and once in the groundwater, can move quickly and be very difficult to clean up.

- Store small amounts of fuel (a couple of gallons at a time) for motorized equipment in a dry, well-ventilated space away from the house and in an UL-approved container.
- Use all stored fuel for motorized equipment by the end of each season.
- Examine storage containers and equipment often for leaks and repair promptly.
- Do not fill machines with fuel or perform maintenance near drinking water wells, storm drains and surface waters and be mindful of spills.
- Recycle used motor oil at the oil igloo located at the town landfill or transfer station.
- Consider replacing underground fuel tanks (for home heating fuel) with properly contained above-ground tanks. Check all laws that apply, contact your local town hall building official.

Electronic Household Hazardous Waste

Roughly 1.5 million computers are thrown away annually. Unfortunately, computers pose a solid waste and recycling problem due to the toxins they, and other electronic equipment, contain. The cathode ray tubes found in computer monitors and televisions contribute roughly 40 percent of all lead in landfills. Due to advances in electronic technology, there is a new face to household hazardous waste. These include:

Cadmium - rechargeable batteries
Lead - cathode ray tubes in monitors and televisions
Mercury - some electronic equipment
Nickel - rechargeable batteries
Chromium - cathode ray tubes

Are There Alternatives?

If you would like to find alternatives to the products you normally use, follow the tips below. Additional suggestions are provided by EnviroSense, a Consumer's Guide to Safer Alternatives to Hazardous Household Products available on-line at http://es.epa.gov/techinfo/facts/safe-fs.html.

Looking for an alternative?

Adhesives - Use a water-based or latex adhesive.

Batteries - Choose rechargeable batteries (removable, so they can be recycled) and mercury-free batteries when possible.

Cleaners - Choose soap- or detergent-based cleaners when possible. Avoid non-water-soluble and corrosive cleaners when others offer an effective substitute.

Household pesticides - Look for ways to reduce your need for these products through appropriate cleaning and maintenance habits.

Floor and wood-finish strippers - Use a detergent or water-based stripper.

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Table 1. Household products that could be hazardous if improperly managed

Building Supplies - Sealants, some adhesives, wood preservatives.

Vehicle-related products - Antifreeze, oil, cleaning solvents, lead-acid batteries, gasoline.

Home maintenance products - Oil-based paints, mineral spiritis, products that can remove difficult greases ro adhesives, paint stripper.

Hobby and recreational supplies - Photo developer chemicals, marine paints, electronic equipment cleaners, swimming pool chemicals.

Pesticides - Herbicides, insecticides, rodent poison, yard foggers, chemical strips, fungicides.

For More Information:

University of Rhode Island Cooperative Extension Home*A*Syst Program
Offers assistance, information, and workshops on residential pollution prevention including private well water protection, septic system operation and maintenance, landscaping for water quality protection, and actions residents can take to reduce pollution.
401-874-5398 www.uri.edu/ce/wq

Refer to our website www.healthylandscapes.org for more information on sustainable landscaping and stormwater runoff control.

RI Department of Health, Office of Drinking Water Quality
Offers assistance and information on private well water testing and state certified water testing laboratories.
401- 222-6867 http://www.health.ri.gov/environment/dwq/Home.htm
For a listing of HEALTH's certified private laboratories in Rhode Island http://www.health.ri.gov/labs/instate.htm

Rhode Island Resource Recovery Corp.,
Rhode Island Eco-Depot
for information on household hazardous waste disposal, non-toxic alternatives and recycling.
(401) 942-1430 ext. 241
www.rirrc.org/site/ecodepot/eco_main.asp

The Massachusetts and Rhode Island Poison Center
Phone: 1 (800) 222-1222
www.maripoisoncenter.com

Adapted from: Managing Hazardous Household Products by Elaine Andrews, Environmental Resources Center, University of Wisconsin Cooperative Extension. Home*A*Syst: An Environmental Risk Assessment Guide for the Home. 1997.

This project is a collaboration of the staff at the Rhode Island Department of Health: Dana McCants, Clay Commons, and the University of Rhode Island Cooperative Extension Water Quality Program: Alyson McCann, Holly Burdett, Brianne Neptin. Issued in furtherance of Cooperative Extension work and Acts of May 8 and June 30, 1914. Jeffrey Seemann, Dean and Director, College of the Environment and Life Sciences. The University of Rhode Island U.S. Department of Agriculture, and local governments cooperating. Cooperative Extension in Rhode Island provides equal opportunities in programs and employment without regard to race, sex, color, national origin, sex, or preference, creed or disability. This is contribution number 3997 of the College of the Environment and Life Sciences, University of Rhode Island.

Funding for this project is supported by HEALTH.

This project is a collaboration of the staff at HEALTH and the University of Rhode Island Cooperative Extension Water Quality Program.

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