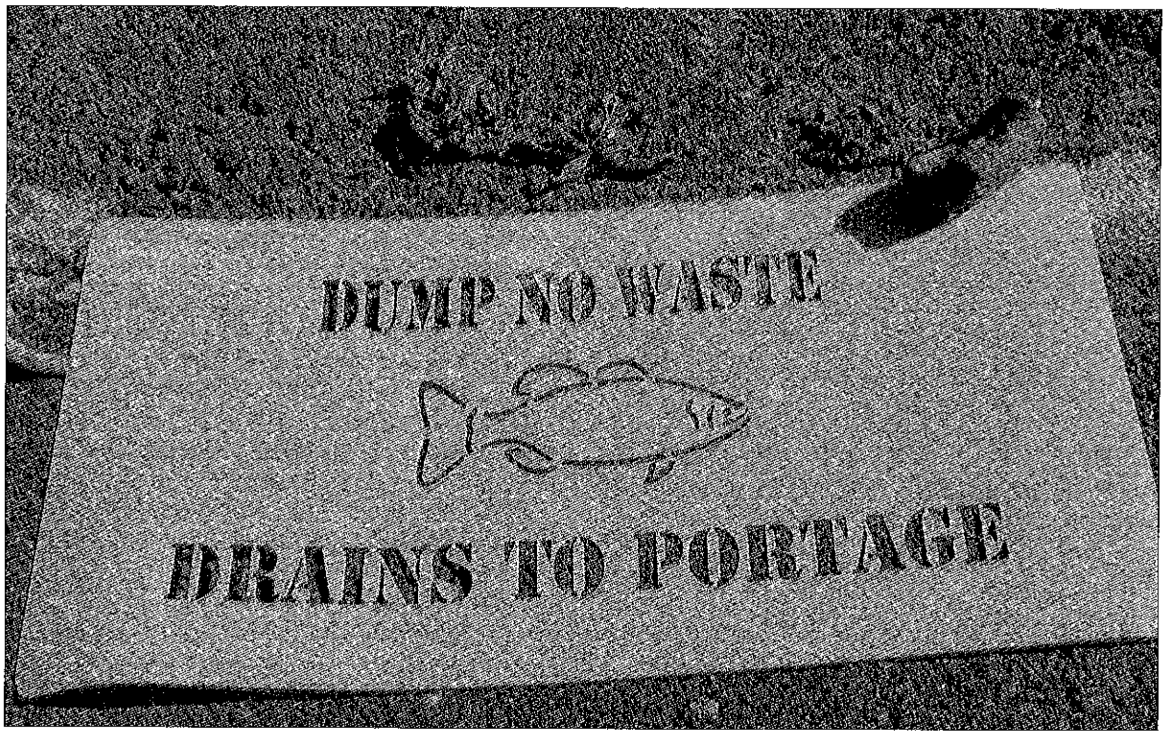
Stormwater Runoff:
Understanding the Ecological Impacts of Changing Land Uses



Joan Chadde

by **Joan Chadde**

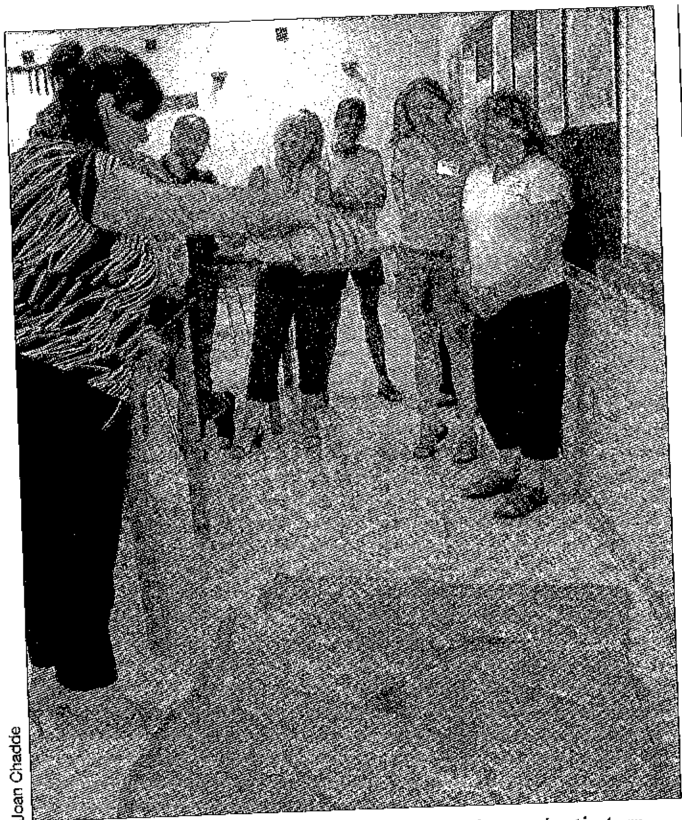
AS COMMUNITIES SPRAWL, new shopping malls spring up on their edges, big parking lots creep across the landscape and signage grows like weeds. Cookie-cutter architecture and big-box stores replace historic downtowns. As the built environment takes on a new look and feel, the natural environment changes too — but how?

I wanted to engage my middle school students in learning about these changes in their community so that they would better understand the consequences of wishing for another fast food restaurant or mini-mall. As a science teacher, I needed to find a way to connect learning about land use and community character with my middle school science curriculum. I decided to build a unit around stormwater, since a leading cause of water pollution is contaminants carried into lakes and rivers by stormwater runoff. Stormwater is also something that students can easily see and do something about.

Objectives

The stormwater unit brings up problems and solutions that students encounter every day, but rarely think about. Many students are not aware that land use changes in their communities are planned, or intentionally unplanned. By the end of our study, students are able to:

- describe ways in which humans change the environment and describe some of the possible consequences of those changes.
- explain the effects of agriculture and urban development on ecosystems.
- describe how changes in land use and land cover change community character and appearance and affect the environment.
- explain how pavement increases runoff into streams, lakes and coastal areas.
- describe how stormwater runoff can lower the water quality in streams, lakes and coastal areas, affecting sports and commercial fishing, altering picturesque waterfronts and causing beach closures.
- explain how increased stormwater runoff reduces groundwater recharge, potentially lowering the water table and impacting private drinking water wells.
- use measurement to describe the real world and to solve problems.



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Simple watershed demonstration model using a plastic tarp laid over crumpled newspapers

I begin the unit by asking students these questions:

- How does community growth change the land cover?
- How do these changes in land cover affect the quantity, quality and timing of stormwater runoff?
- How will creating more pavement affect the groundwater table and drinking water wells?
- How does the loss of natural vegetation along riverbanks and shorelines change the water quality of streams and lakes and alter the aquatic ecosystem?
- How do all of these changes affect a community's appearance and natural character?

Investigating runoff

Stormwater runoff occurs when water from rainfall or snowmelt flows over the surface of the ground instead of percolating down into soil. As water flows over roads, lawns, parking lots and construction sites, it picks up fertilizers, pesticides, dirt, road salt, motor oil and animal wastes. Often these contaminants are then carried into nearby lakes, streams, rivers, wetlands or coastal waters. In some cities, any rainwater that enters a storm drain is discharged untreated into local water bodies — the same ones that people use for swimming, fishing and possibly even drinking water. In cities that have a combined sewer and storm drain system, millions of gallons of untreated or partially treated sewage can be released into lakes and rivers during large rainstorms when wastewater treatment plants become overloaded.

I demonstrate the movement of runoff with a simple watershed model that I create using a plastic sheet (a picnic tablecloth or shower curtain also works) laid over balled newspapers (one can also use a ready-made EnviroScape® watershed model). I invite the class to gather around as I make it "rain" onto the model using water from spray bottles or cups, illustrating how runoff moves downhill into rivers and lakes.

Next, I use a "stormwater metaphor" game to get students thinking about the potential contaminants in stormwater. Each group of three to four students receives one of the following items and must tell the class how the item is related to stormwater:

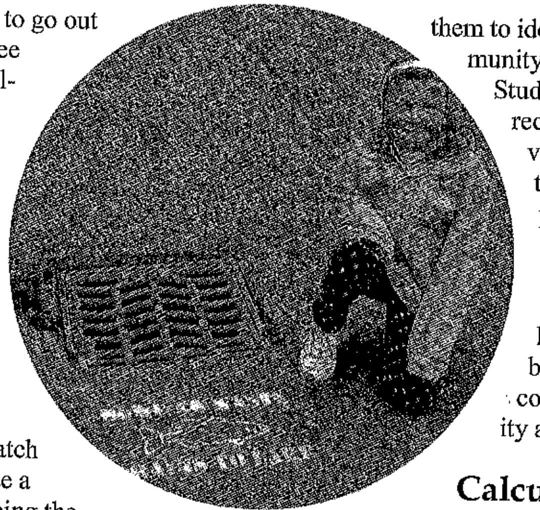
- toy car (motor oil, gasoline, antifreeze)
- pet leash (pet wastes)
- snow shovel (road salt)
- toy house (fertilizers and pesticides on lawns)
- fast food bag (litter/garbage)
- plastic turf or golf ball (fertilizers and pesticides from lawns, gardens, farms)
- paintbrush (paints and paint thinner poured down the storm drain)
- packet of seeds (exposed soil contributes sediments such as sand and silt)
- toy bulldozer (sediment from new construction)
- toilet paper (human wastes from wastewater treatment plant overflow)

After discussing stormwater — where it comes from and where it goes — I take my class on a short walk outside to identify areas that might contribute to runoff and to discuss the types of contaminants that could be carried from those areas to the nearest body of water. When possible, we take this walk during or right after a rainfall. I liken it to being environmental detectives and looking for clues or evidence. One day, as we walked to the river near our school, the maintenance department was painting the soccer field and a worker rinsed the paint sprayer in the parking lot. As they watched a plume of white paint come down the river, the kids quickly recognized the source of the pollution. It was a non-toxic, water-based paint, but we stenciled the storm drain and alerted the maintenance supervisor to the potential problem. If you can locate the pipes in your community that discharge storm water, you may have similar opportunities to see a plume of contaminated water outflow into the river or lake.

Using best management practices

Students investigate the potential impact of land use changes on the quality and quantity of surface water. As a class, we brainstorm different land uses and list potential contaminants associated with each. I remind students that land use changes aren't inherently bad, that it depends on how they are implemented. Best management practices (BMPs) are structural or nonstructural methods of preventing or reducing the movement of runoff carrying sediment, nutrients, pesticides and other pollutants from land to surface water. We identify several BMPs for each land use (see table "Runoff Control: Best Management Practices").

Students are given an assignment to go out into the community to photograph three BMPs being used to protect water quality, and three examples of sites where BMPs should have been put in place but are missing. Students learn to read the landscape as they identify sedimentation basins for catching runoff from large parking lots, vegetated or rock-lined drainage channels, and silt-control fences that keep soil from construction-related disturbances out of waterways. Some note the presence of vegetation buffers along shorelines, and rain gardens to catch runoff from parking lots. Students write a short description of each photo, describing the BMP or recommending a particular BMP if it is missing.



I review with students some of the planning and design decisions that have been made in our community, discussing local growth trends and how they directly affect our watershed. Using the guidebook *Design Guidelines to Enhance Community Appearance and Protect Natural Resources,* we look at examples of, and alternatives to, urban sprawl. (Other books or websites on community design or community character could be used, or students could be asked to do web research on urban sprawl and collect photos of it to share with the class.) It is important for students to understand sprawl visually, rather than only verbally. Therefore, I ask them to identify new development in our community and document it with digital photos. Students then select one photo and make recommendations for minimizing the visual and environmental impacts of the new development. They print the photo, lay tracing paper over it, draw in the parts of the scene they want to keep as is, and then add "best management" recommendations to show how the new development could be enhanced to better blend into the community and minimize water-quality and other environmental impacts.

Calculating runoff

If there is time, I have students calculate the amount of stormwater runoff from the school building. First, they measure the school building and transfer the dimensions to grid paper. Students then estimate the area of the building by counting the number of squares it occupies on the grid. To obtain the volume of water that falls on this area during a rain event, they multiply the area by the depth of the rainfall as follows:

U.S. measures (per inch of rainfall):

1. Rooftop area in square feet x 0.8333 feet (1 inch) = cubic feet
2. Cubic feet x 7.48 = volume in U.S. gallons

Runoff Control: Best Management Practices

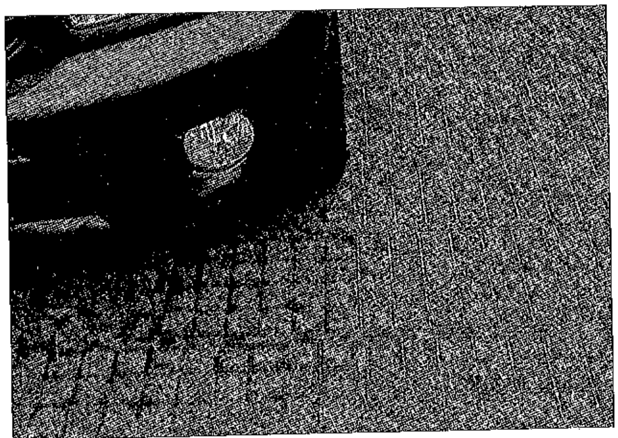
Land Use	Possible Pollutants	Best Management Practices (BMPs)
Urban/commercial (parking lots, city streets)	Road salt Sediment Automotive fluids Motor oil Thermal warming of runoff water	• Use porous asphalt or pervious concrete • Create vegetated islands in parking lots • Construct runoff retention ponds to collect runoff and allow time for infiltration • Leave parking lots unpaved • Create vegetated or rock-lined drainage channels so that runoff can slowly seep into ground
Managed forest (logging roads)	Sediment	• Maintain vegetation buffer along stream to filter out sediment • Do not locate roads immediately adjacent to streams
Residential (lawns, driveways)	Pesticides Fertilizers (nutrients) Pet wastes (bacteria) Road salt Detergents	• Use minimal amounts of pesticides and fertilizers on lawns • Pick up and dispose of pet wastes • Maintain areas of native vegetation to promote infiltration • Irrigate lawns sparingly • Wash car where soapy water will infiltrate into lawn, not run off
Agriculture (livestock grazing)	Animal wastes (bacteria, nutrients)	• Maintain vegetation buffer along streams to slow and filter runoff • Fence along streams to limit or prevent access • Provide off-stream water tank for livestock
Agriculture (cropland)	Sediment Fertilizer Pesticides	• Maintain vegetation buffer along streams to slow and filter runoff
New construction	Sediment	• Use erosion-control fabric to prevent soil from moving off site

Metric measures (per centimeter of rainfall):

1. Rooftop area in square meters x 0.01 meter (1 cm) = cubic meters
2. Cubic meters x 1,000 = volume in liters

I ask students, "Will all of the rain that falls on the school grounds reach the river or lake?" I display the table "Percent Runoff for Different Land Use Cover Types" to show that the type of ground cover determines how much precipitation infiltrates the ground and how much runs off. Other factors affecting runoff include the soil type and its infiltration rate; the intensity and amount of rainfall; whether the ground is frozen or saturated; whether the forest is a young, fast-growing forest that uses a lot of water or a slower-growing mature forest; the slope of the terrain; and the amount of soil compaction (high density residential lawns are quite compacted, greatly limiting infiltration). I show students aerial photos of our community taken in 1975 and in 2002, which clearly illustrate changes in land cover due to changes in land use (aerial photos may be obtained from local land management agencies or city planning offices and, in the U.S., from county offices of the USDA Natural Resources Conservation Service).

Lastly, the students tackle calculating the total volume of runoff from the school grounds in one year. We first look at an aerial photo or engineering sketch of the entire school grounds and note the different land covers: pavement/impervious parking lots, sidewalks and rooftops; football field/lawn; small wooded area. I let students loose with measuring tapes and calculators to measure the area of each cover type (measurements could be done from aerial photos if a distance legend is available). After obtaining these measurements, students calculate the total area of each cover type, which they multiply by the average annual rainfall and by the appropriate runoff factor (the percent of precipitation that runs off, as shown on the table "Percent Runoff for Different Land Use Cover Types"). Finally, students convert these volumes to liters or gallons of runoff. (See chart "Calculating Runoff from School Buildings and Grounds.")



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Permeable paving made of recycled plastic enables rain water to soak into the ground naturally, rather than into the municipal drain system.

We wrap up this unit by brainstorming ways to reduce runoff from our school grounds, such as by planting a rain garden, installing a green roof, using impervious asphalt in the parking lot, and planting shrubs and trees. We also do storm drain stenciling on the storm drains around the school. Many students are not aware that land use changes in their communities can affect the water quality of nearby streams, rivers and lakes. After this unit, they are better able to connect changes in community appearance to ecological changes resulting from changes in land cover.

More land-use investigations

The following are other science-based ideas for measuring the ecological impacts of changing land uses:

- Measure the difference in water quality at river sites upstream and downstream of a town, shopping mall, or other land use, using benthic macroinvertebrates as bio-indicators. The EPA website is a good place to start to learn about sampling methods, identification, state monitoring programs and more: <http://www.epa.gov/wbioindicators/html/invertebrate.html>.

Percent Runoff for Different Land Use Cover Types

Land Use	Description of Ground Cover	Percent Runoff
1. Agricultural	Row crops and crop residue cover	30%
2. Commercial	Buildings, sidewalks, paved parking areas	95-100%
3. Forest	Trees and shrubs	20-30%
4. Pasture/fields for livestock or wildlife	Grasses, legumes	10-30%
5. High density residential	Lot size smaller than 0.2 hectare (0.5 acre)	80%
6. Low density residential	Lot size equal to or larger than 0.2 hectare (0.5 acre)	50%
7. Industrial	Buildings and paved parking areas	70-90%
8. Open space/non-forested	Lawns, parks, golf courses	20-40%
9. Wetland	Standing water, vegetated	5%

Source: Urban Hydrology for Small Watersheds, USDA Natural Resources Conservation Service, 1986

Calculating Runoff from School Buildings and Grounds

Building or Other Location	Column A Area (square meters or square feet)	Column B Annual rainfall (meters or feet)	Column C Volume of annual rainfall Col. A × Col. B (cubic meters or cubic feet)	Runoff factor (%)	Volume of annual runoff Col. C × Runoff factor (cubic meters or cubic feet)
				Total school runoff	
				Convert cubic meters to liters: multiply total by 1,000 **Convert cubic feet to U.S. gallons:** multiply total by 7.48	

- Identify changing land uses in your community and discuss the potential visual and environmental consequences. See the "Changing the Land" activity in the *Looks Count!* curriculum unit at <http://wupcenter.mtu.edu/education/land_use/index_looks_count.htm>.
- Compare plant biodiversity in urban areas to plant biodiversity in undisturbed natural areas. See "Biodiversity Study: Disturbed vs. Undisturbed" from the *Looks Count!* curriculum unit at <http://wupcenter.mtu.edu/education/land_use/index_looks_count.htm>.
- Use artificial bird eggs (made of modeling clay and laid out in groups of three eggs in a series of parallel transects) to measure variation in predation on eggs laid by ground-nesting birds as the distance from human development is reduced. See "Artificial Nest Predation Investigation" from the *Looks Count!* curriculum unit at <http://wupcenter.mtu.edu/education/land_use/index_looks_count.htm>.

Joan Chadde is the education program coordinator for the Western Upper Peninsula Center for Science, Mathematics, and Environmental Education at Michigan Technological University in Houghton, Michigan. She thanks teachers Gary Cousino (Hart Middle School, Rochester Hills, MI), Betty Cangemi (L'Anse High School, L'Anse, MI) and Sharon Bajema (Ottawa Hills High School, Grand Rapids, MI) for their contributions to this lesson. Additional watershed and land use activities by Joan Chadde can be found in the Michigan Environmental Education Curriculum Support (MEECS) Water Quality unit, available on-line at <www.michigan.gov/deq/0,1607,7-135-3307_3580_29678---,00.html>

Resources

Chadde, Joan, Rulison, Linda, Smith, Ruth Ann, and Dunstan, Jean. *Design Guidelines to Enhance Community Appearance and Protect Natural Resources*, 2nd edition. Houghton, MI: Western Upper Peninsula Center for Science, Mathematics and Environmental Education, Michigan Technological University, 2004. Features line drawings and color photos that visually address 20 of the most common development issues. Contact jchadde@mtu.edu to order a copy (US$5 each).

Chadde, Joan, and Linda Rulison, Ruth Ann Smith, Jean Dunstan. *Looks Count! Community Planning, Natural Resource Protection and the Visual Landscape*, 2nd edition. Houghton, MI: Western Upper Peninsula Center for Science, Mathematics and Environmental Education, Michigan Technological University, 2002. An interdisciplinary middle school unit containing 15 science and social studies lessons that guide students in assessing their community's character, measuring changes and proposing community enhancements.

Michigan Department of Environmental Quality. *Water Quality — Pollutant Sources and Impacts.* Michigan Environmental Education Curriculum Support (MEECS). A Michigan Tech Alive interactive web module describing types of water pollutants, their sources, pathways, impacts, and strategies to control their impact, available on-line at <http://techalive.mtu.edu/meec_index.htm>.

West Michigan Environmental Action Council. *Rain Gardens of West Michigan: Beautiful Solutions for Water Pollution* <www.raingardens.org>. Information on planning and planting rain gardens as catch basins for runoff.

USDA Natural Resources Conservation Service <www.nrcs.usda.gov/>. Provides excellent resources on soils; regional offices can provide aerial photos (click on "service centers" and follow the links to obtain the phone and address for the nearest office).

U.S. Geological Survey. "Effects of Urbanization on Water Quality: Urban Runoff." On-line September 28, 2007, <http://ga.water.usgs.gov/edu/urbanrun.html>.