Water Muddle Up and Clean Up

In this activity, adapted from the lesson *There Is No Point to This Pollution* in the *Water Quality Educators Guide* by *Healthy Water, Healthy People*, students use critical thinking to predict how water becomes polluted. This activity is designed to safely model the ways in which pollutants and hazardous chemicals may react when they reach water and the cumulative effect of land uses on water quality. Common household items (food coloring, vegetable oil and corn syrup) represent pollutants and also hazardous chemicals that are commonly found at hazardous waste sites, including Superfund sites, across the country. By simulating the contamination of water by various kinds of chemicals, students are introduced to current information on hazardous waste sites in North Carolina and the clean up techniques being employed.

Alignment to North Carolina Standard Course of Study for Science

This lesson addresses the Science in Personal and Social Perspectives strand along with specific learning objectives:

8th Grade Science

Objective 3.07: Describe how humans affect the quality of water:

- Point and non-point sources of water pollution in North Carolina.
- Economic trade-offs.
- Local water issues.

Objective 3.08: Recognize that the good health of environments and organisms requires:

- Monitoring of the hydrosphere.
- Water quality standards.
- Methods of water treatment.
- Maintaining safe water quality.
- Stewardship.

Objective 4.01: Understand that both naturally occurring and synthetic substances are chemicals.

Earth and Environmental Science

Objective 1.01: Identify questions and problems in the earth and environmental sciences that can be answered through scientific investigations.

Objective 1.05: Analyze reports of scientific investigations and environmental issues from an informed scientifically literate viewpoint.

Objective 1.06: Identify and evaluate a range of possible solutions to earth and environmental issues at the local, national, and global level.

Objective 4.04: Evaluate water resources:

- Environmental impacts of a growing human population.
- Causes of natural and manmade contamination.

Essential Questions

- How do chemicals of varying properties and densities behave in water?
- How does water become contaminated by one or more chemicals?
- How does land use impact water quality?
- How can hazardous chemicals be removed from water?

Materials:

- Large clear bowl or clear 2-liter bottle
- Tap water
- Food coloring
- Gravel (optional)
- "Water pollutants/hazardous chemicals:"
    - two small dropper bottles of diluted food coloring (blue and red are easy to see)
    - one bottle of vegetable oil
    - one bottle of corn syrup
    - powdered cocoa or hot chocolate mix

- Transparent, small plastic cups (1 per student or student pair if working as partners; fewer if used as instructor demonstration)
- Copies of *Student Worksheet*, *Loop Lake Map*, and *Pollutant Description Sheet*, one per student or student pair

Duration

- One 50 minute class period or less, depending on how you utilize the lesson.

Teacher Preparation

1. Fill a large clear bowl (or clear 2-liter bottle) half-full with clear water and gravel (*optional*) to create a shoreline, and place it in a central location in the classroom. Tell students that this bowl of water represents a lake that is surrounded by properties with different land uses. This "lake" could also represent a local lake or stream and students could be prompted to consider the types of properties that surround this local water resource.
2. Ask students to brainstorm a list of land uses and the types of pollutants that might end up in this lake as a result of these different land uses. Write student responses on the board.
3. Next, explain the difference between point source pollution (pollution source is a known point, for example, an effluent pipe from a factory), and nonpoint source pollution (pollution source is not defined by a point, also called runoff, for example, oil and gas washed off city streets from cars).
4. Go through the list of pollutants on the board and have students identify whether each pollutant they listed would be classified as a point source or nonpoint source pollutant.
5. To conclude this discussion, introduce the following phrases that are often used to describe the chemical nature of water pollutants: water-soluble, light, non-aqueous phase liquids (LNAPLs), dense, non-aqueous phase liquids (DNAPLs) and ask the students to consider the chemical nature of each pollutant they listed in Step 2. LNAPLs and DNAPLs are commonly found at hazardous waste sites, including Superfund sites, across the country. A Superfund site is a hazardous wastes site that has been identified by the US Environmental Protection Agency (EPA) as a candidate for clean up because it poses a risk to human health and/or the environment. Additional details about these classes of water pollutants can be found on the *Pollutant Description Sheet.*

Option for Extension

- Ask your students to visit EPA's Drinking water website at http://www.epa.gov/safewater/index.html and identify chemical contaminants that arise from man-made sources/different land uses.

Procedure (Also works well as an instructor demonstration)

1. Distribute one copy of the *Student Worksheet*, the *Pollutant Description Sheet*, and the *Loop Lake Map* to each student or student pair.
2. Provide each student/student pair with approximately 25 ml of tap water in a small transparent cup.
3. Each student/student pair will represent one property owner and the water in their cup represents the water that flows across their property and into Loop Lake, which is surrounded by the various land uses.
4. Assign each student/student pair a property from the list below. One way to assign properties is by highlighting the property on the Loop Lake Map prior to passing out to students. The table below highlights each property (land use), provides examples of a pollutant that might result from such land use and indicates how the pollutant would be classified based on the phrases introduced in Step 5 above.

	Property (Land Use)	Example of Pollutant	Class of Pollutant
1	Older Housing Development	Pesticides and Fertilizers	Water-soluble
2	Plant Nursery	Pesticides and Fertilizers	Water-soluble
3	Strip Mall Parking Lot	Gasoline	LNAPLs
4	The Holstein Farm with a leaking underground fuel tank	Gasoline	LNAPLs
5	Electrical Transformer Factory	PCBs	DNAPLs
6	Dry Cleaners	TCE or PERC	DNAPLs
7	Subdivision (Under Construction)	Sediment	
8	Loop Lake Park and Dog Park	Sediment	

5. Ask students to complete questions #1 and #2 on the Student Worksheet. Depending on their assigned property, students may come up with a variety of pollutants; ask them to select one to focus on for the remainder of the activity.

6. For question #3 on the Student Worksheet, show students the "contaminants" they will select from to represent the pollution arising from the land use on their assigned property. Additional materials can be used to represent other common pollutants such as pet waste and litter.

Pollutant	Pollution Indicator
Water soluble contaminants *Examples: pesticides and fertilizers*	Food coloring – dilute 5 drops in ½ cup of water
Light non-aqueous phase liquids (LNAPLs) *Examples: gasoline, MTBE*	Vegetable oil
Dense, non-aqueous phase liquids (DNAPLs) *Examples: TCE, PCBs*	Corn syrup with red food coloring added
Sediment	Powdered cocoa or hot chocolate mix
Pet Waste/Sewage	Instant Coffee
Litter	Colored Sprinkles

7. Have each student/student pair place a **small** amount (e.g., a couple drops of diluted food coloring, cooking oil, or colored corn syrup or a pinch of cocoa) of pollutant into his or her cup. Depending on the available time and the level of students, students do enjoy selecting more than one "pollutant" to add to their cup.
8. Ask students to complete questions #4, #5, and #6 on the Student Worksheet.

Question #4 Observe your pollutant in water. Describe how it behaves and its chemical properties (solubility, density, etc.):

Water soluble chemicals easily mix with water.
LNAPLS are less dense than water and are not water soluble so they float on the surface.
DNAPLS are more dense than water and are not water soluble so they sink to the bottom of the cup.

Question #5 Locate your property on the Loop Lake Map; describe how your pollutant might travel from your property to Loop Lake: *Pollutants may travel to the lake by surface runoff (storm water moving over the surface) or subsurface flow (e.g., a leaking storage tank can release a pollutant that moves via groundwater, moving down-slope through the soil) and reach the lake directly or first enter a stream and then get transported by the stream to the lake. Depending on the level of students, you may also choose to prompt them to consider the topography of their property relative to Loop Lake.*

Question #6 Based on the behavior of your pollutant in water, how do you think a scientist would try to remove it from water? *For hazardous substances, students may discuss treatments for groundwater (pump and treat, containment, treat in ground through natural processes) or surface water (prevent spreading, treat with natural processes, or skim from surface). For sediment, students may discuss dredging, preventing erosion, etc. For more detailed descriptions about clean-up options, read below:*

Clean-Up of Water-soluble contaminants

One possibility might include dilution where the additional water is added to the existing groundwater and thus the pesticide is eventually present in fewer parts per million (ppm). Ask, "What are some of the disadvantages to this method?" Another possibility is the pump and treat method where groundwater is pumped out, filtered to remove the contaminant and then the cleaned water is returned to the ground. Ask, "What are some of the advantages and disadvantages to this method?"

Clean-Up of Light non-aqueous phase liquids (LNAPLs)

Possible answers include: drilling and then pumping out the oil, filtering, containing the oil from spreading, using absorbent materials to remove the oil, etc. Another method is bioremediation, which is the use of bacteria or plants to remove or neutralize pollutants. Dr. Mike Aitken and Dr. Fred Pfaender, scientists with UNC Chapel Hill's Superfund Research Program, study ways to use bioremediation to clean up a specific class of chemicals found in some LNAPLs, called polycyclic aromatic hydrocarbons (PAHs). PAHs are major contaminants in soil and groundwater at a number of sites across the U.S., and many of the PAHs are known or suspected carcinogens.

Clean Up of Dense non-aqueous phase liquids (DNAPLs)

Clean up of DNAPLs is challenging due to the density and insolubility of the chemicals. Because DNAPLs sink to the bottom of the aquifer, they are particularly hard to clean up. Clean up options include allowing natural processes to breakdown the contaminant, using a detergent to clean contaminated soil, applying thermal desorption technologies

(using high heat to remove contaminants from sediment), and isolating the contaminated area using concrete dikes or by capping with impervious layers of plastic/clay.

Clean Up of Sediment

To decrease the amount of sediment reaching our waterways and prevent unnecessary erosion, farmers use techniques such as contour tilling, loggers leave buffer zones of trees along rivers, lakes and oceans, and builders and homeowners plant or leave vegetation along stream banks.

An **interactive Superfund hazardous waste site activity** designed to help students read about how to clean up groundwater contamination, surface water contamination, soil and air contamination is available at: http://www.epa.gov/superfund/students/wastsite/index.htm

Option for Extension

- You may also choose to prompt students to identify any impervious surfaces that might be present on their property. The lesson *Rescuing Water from the Roof* http://www.niehs.nih.gov/health/docs/water-roof.pdf can be integrated into Water Muddle Up, Clean Up in order to emphasize the impact of impervious surfaces on water quality.

8. Next, ask each property owner either individually or grouped by contaminant to come to the front of the room and empty their cups containing their "contaminant" in "Loop Lake". This is a great time for a variety of discussions. *One way to conduct this portion of the activity is as follows:* Ask students who had a water-soluble contaminant to pour their water into Loop Lake, announcing their property and indicating which pollutant is present in their cup of water. Prompt students to identify some of the contaminant's properties, such as solubility and density, and describe how scientists might clean it up, and identify if their contaminant pollutes water via nonpoint or point source pollution.
9. Point out to the students that although each individual property contributed only slightly polluted water, once the whole class added their polluted water, the lake became very polluted. Students should be able to see through each of their individual samples, but the lake water should become murky and dark. This illustrates the cumulative effect of point and nonpoint sources of pollution.
10. If PCBs were released by the electrical transformer property, "Loop Lake" has now become a hazardous waste site; thus, this activity provides an engaging segue into a discussion of hazardous waste sites and the methods that can be used to clean up pollution of water, soil and sediment.
11. The following activities can be used to further explore hazardous waste sites, including Superfund sites, and to explore options for clean up (remediation).
    - Have your students use various items to try and clean up "Loop Lake" now that it is polluted. Provide them with paper towels, cups, pipettes, liquid pump dispensers, etc. Inform your students that scientists are researching the most effective ways to clean up chemical contamination of ground and surface water. This is also a good activity to illustrate that clean up is never one hundred percent efficient; there are always going to be chemicals left behind in water and soil (this may also be demonstrated by the amount of pollutant left behind in the students' cups after they pour their contaminated water into the lake).
    - Students can investigate the characteristics of specific Superfund sites in North Carolina by visiting http://www.epa.gov/region4/waste/npl/index.htm#NC and clicking on the site of interest. They may be surprised to learn that a Superfund site exists nearby! A worksheet that students can use to investigate a Superfund site of interest is available for download from LEARN NC: http://www.learnnc.org/lp/media/uploads/2010/12/investigating_a_superfund_site.pdf
    - Remind your students that scientists are also researching the health effects of exposure to hazardous chemicals. To find out the biomedical research taking place within the UNC Superfund Research Program, visit www.uncsrp.org

Additional Resources

EPA's Superfund Program
Resources for Students and Teachers
http://www.epa.gov/superfund/students/clas_act/index.htm

UNC Superfund Research Program
http://www.uncsrp.org/

Water Muddle Up and Clean Up
Adaptation of There Is No Point To This Pollution! Student Worksheet

Procedure: You will be given a map of Loop Lake Map along with a Pollutant Description Sheet; refer to these to fill out this worksheet. You will also be given a cup with water; this represents the water that flows across your property and into Loop Lake.

1. Observe the highlighted property on your map. Write the name of this property below:

2. Consider the activities that take place at this location and review the Pollutant Description Sheet. List one or more pollutants that your property might be responsible for generating:

3. Pick one of the pollutants from your list and place a small amount (e.g., a couple drops of diluted food coloring, cooking oil, or colored corn syrup or a pinch of cocoa) of pollutant into your cup according to the pollution indicators provided by your teacher.

Write the name of the pollutant you selected here: _____

4. Observe your pollutant in water. Describe how it behaves and its chemical properties (solubility, density, etc.):

5. Locate your property on the Loop Lake Map; describe how your pollutant might travel from your property to Loop Lake.

6. Based on the behavior of your pollutant in water, how do you think a scientist would try to remove it from water?

7. When instructed, pour the contents of your cup into Loop Lake.

Pollutant Description Sheet

Water-soluble contaminants

Many **pesticides and fertilizers** are water-soluble contaminants, meaning that they readily dissolve in water. Lawns may be one source of pesticides and fertilizers. Another source may be a nursery or farm. Barber Orchard is an example of a hazardous waste site, or Superfund site[1], contaminated with arsenic, lead, and pesticides. Located in Waynesville, Haywood County, NC, this property was used as a commercial apple orchard from 1903 until the mid 1980's. In the late 1980's, some of the land was sold and homes were built on it. In 1999, contaminants were found in the soil, and/or in the majority of drinking water wells.

Light non-aqueous phase liquids (LNAPLs)

LNAPLs do not dissolve in water and are less dense than water, and therefore, they float on top of the water table. Benzene, toluene, jet fuel and **gasoline** are all examples of a LNAPL. LNAPLs' low solubility contributes to their ability to remain as groundwater sources of contamination for extended periods. However, over time the liquids spread laterally and begin slowly dissolving into the water, making the chemicals harder to extract. Parking lots may be one source of gasoline and oil. Potter's Septic Tank Service Pits in Sandy Creek, Brunswick County, NC, is a hazardous waste site contaminated with LNAPLs. Nearby groundwater was contaminated with LNAPLs from an oil spill, which was traced to one of the four disposal pits at the site.

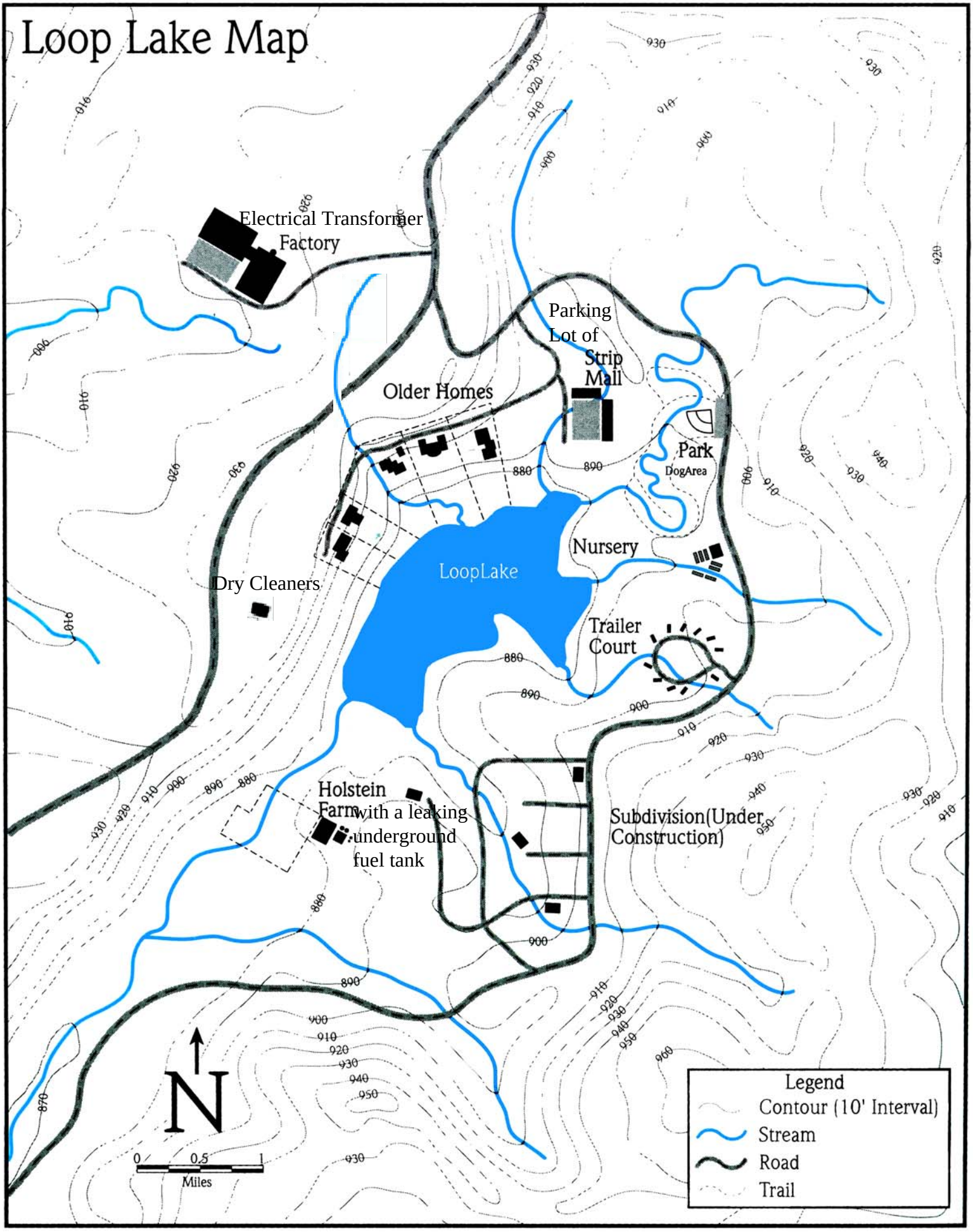
Dense Nonaqueous-Phase Liquids (DNAPLs)

DNAPLs do not dissolve in water and are denser than water. These toxic chemicals sink and form pools at the bottom of an aquifer. DNAPLs can enter moving groundwater and potentially pollute large areas over time. **Trichloroethylene (TCE)** and tetrachloroethylene (PERC) are examples of DNAPLs that are more commonly known as chlorinated solvents. They are often used in metal cleaning, degreasing, dry cleaning, leather tanning, pharmaceuticals and paints. They are highly carcinogenic chemicals that can be found at many Superfund sites including the Massachusetts site featured in the book and movie, *A Civil Action*. Both of these chemicals were also found at the Camp LeJeune Superfund site in Onslow County, NC. Another example of DNAPLs is **polychlorinated biphenyls (PCBs),** which were used as a coolant in electric transformers. PCBs are found at the Ward Transformer Superfund site in Raleigh, NC.

Sediment

Sediment is soil that can be transported in water. The leading water quality problem in many water ways is sediment coming from storm water runoff. Construction sites can be a significant source of sediment as can bare spots on lawns and stream banks. The particles in sediment may be suspended in the water, making it look cloudy, and over time they may settle to the bottom. Sediment can make it difficult or impossible for aquatic plants to grown and can destroy aquatic habitats. Chemicals may also bind to sediment particles and accumulate on the bottom of a lake or river, where they can adversely affect aquatic habitats.

[1] A **Superfund site** is a site where hazardous wastes are located and the US Environmental Protection Agency (EPA) has identified it as a candidate for cleanup because it poses a risk to human health and/or the environment.


Loop Lake Map
Electrical Transformer Factory
Parking Lot of Strip Mall
Older Homes
Park
DogArea
Nursery
LoopLake
Dry Cleaners
Trailer Court
Holstein Farm with a leaking underground fuel tank
Subdivision(Under Construction)
N
0
0.5
1
Miles
Legend
Contour (10' Interval)
Stream
Road
Trail