Predicting Water Quality:
Understanding Sources of Pollution

Background Information

Rivers, streams, lakes and ponds are vulnerable to pollution coming from a variety of sources and the first step in a program of improving water quality depends on an understanding of both point and non-point sources of pollution. Point sources are those that can be traced to a single discharge point, and frequently straightforward although can be time consuming. If in compliance with the Clean Water Act, industrial discharges and wastewater treatment plants contribute known quantities of pollutants (in the United States such information is generally publicly available), or industry-wide averages are available through the EPA. Understanding the effects of non-point sources of pollution is more challenging, although again, much information exists to describe the effects of agriculture, urban runoff and other land covers within the watershed of the river or lake.

A point source and landscape analysis of the watershed is the first step taken by regulators to develop a program for testing the water quality of an aquatic system. This allows for a more efficient sampling strategy that will lead to a better understanding of the sources of pollution degrading the system. Conversely, water quality data can help identify likely sources and can allow regulators to take steps to prevent further contamination of the affected waters.

Frequently the most interesting results are those that compare different systems or different reaches within a stream or river. To do this researchers must study both the sources of pollutants and the characteristics of the waters. Large flowing systems can dilute wastes quickly; isolated pools can concentrate pollutants over a period of years. Rivers that are healthy during the spring floods can become dangerously polluted during the dry summer even if they receive similar discharges.

Procedure

Acquiring Base Maps

There are now several on-line resources that provide easy access to topographic maps, satellite images and land cover information. Students can delineate study areas, zoom to appropriate scales and save the maps, either for analysis using a computer program or as a base for producing a "pollutant loading map" using tracing paper.

Acquiring the base map using Google Earth

Google Earth version 4 has added some powerful features that allow for the production of good base maps with some possibility of analysis. This software allows for users to draw polygons on their maps representing different land covers, helpful in simplifying a complex landscape.

http://earth.google.com/

Acquiring the base map using ESRI's ArcExplorer (a powerful tool that will also allow for analysis of the map information)

Connect to ESRI's on-line GIS (Geographic Information System) for information about the products available for on-line use in the classroom.

http://www.esri.com/software/arcgis/arcgisonline/index.html

Navigate through to the ArcGIS online resource center linked in the sidebar to the left of the page. From here click on the link for ArcGIS Explorer maps and select "USA Imagery" if you are working in the United States or "Satellite World" for other countries. Note that ArcExplorer can either be used on stand alone machines after download or through a web-based server.

Acquiring Topographic Maps

All United States Geologic Survey maps are available at no charge through Topozone

http://www.topozone.com/

Analysis

Watershed delineation using tracing paper

Using a light table or a window, place the USGS map provided beneath a sheet of graph paper. Identify the river, stream, lakes or ponds that you will be analyzing and use a blue pencil to outline the banks of the water body or waterway.

You now need to determine the area of land that drains into the water body or waterway; this area is referred to as the watershed of the receiving water.. The topographic map provides you with all the information that you need to do this. Figure 1a shows a schematic topographic map with the high points identified with a star; look for the bulls-eye pattern in the topographic lines. Figure 1b shows these high points connected, with some guessed made about the location of the divide in between them. This is the preliminary delineation of the boundary of the watershed. Note other features: "V's" show stream channels with the water flowing from the angle to the opening. Straight lines suggest that humans have had a role in the transformation of the landscape, sometimes even creating new boundaries through the filling of large areas for highways or railroads. The delineation of the watershed required frequent assumptions and in the absence of field verification is only approximate. Nonetheless, this quick analysis provides good preliminary information about land covers and pollution sources potentially affecting a water body or waterway.

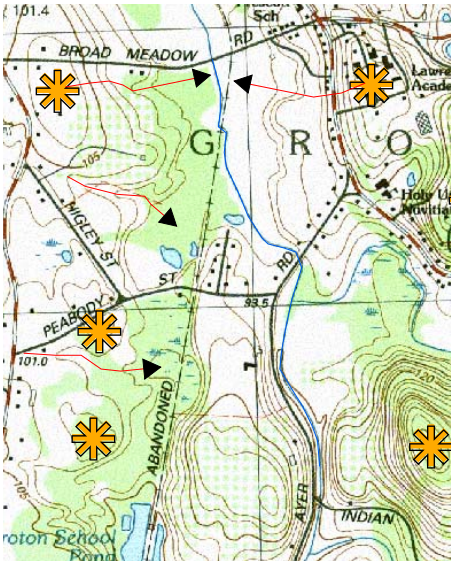

Figure 1a. Topographic map showing contours, high points and channels for water flow.

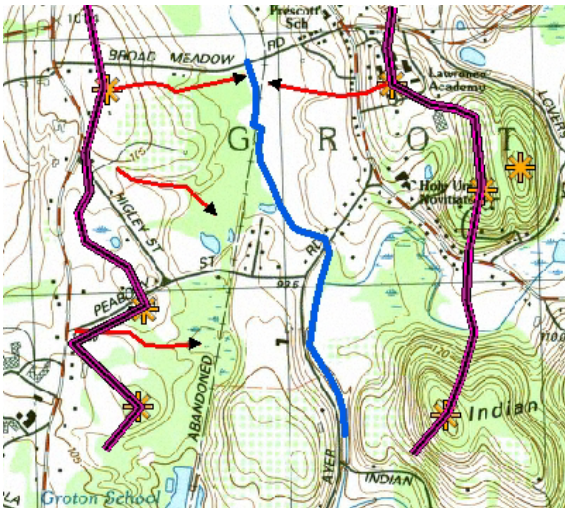

Figure 1b. Topographic map showing approximate watershed boundaries

Watershed delineation using image analysis software

There are several software products available for classroom use that will allow students to map land covers by drawing polygons which overlay the topographic maps and the aerial photographs. These are called Geographic Information Systems or "GIS".

A list of GIS providers and educational communities is provided at the end of this document.

Identification of pollutant sources

The next step in the analysis is the identification of land covers and point sources of pollution. Having the legend for the map is helpful in identifying the land uses, and some knowledge of the study are allows for a better understanding of point sources of pollution. Figure 2 is a topographic map of a rural area in central Massachusetts currently experiencing some residential, commercial and industrial development, while preserving some agricultural landscapes.

1. Prepare a table listing the types of land cover that exist in the watershed that you have mapped. You should include forests, grassy areas, open spaces like parks, agricultural fields, grazing lands (you may need to look at the aerial photos of the area to help determine the use of the area, and developed areas. For developed areas, classify the residential lands as rural (houses more than 300 m apart), suburban (houses between 100 and 300 m apart, urban (houses with 100 m of each other), and industrial (more than 50 percent of the area paved).

2. Using the topographic maps or the aerial photos, identify point sources of pollution within the watershed. These can include industrial sites, wastewater treatment facilities or other sources of pollution flowing out of a pipe.

3. Pick five to ten sites along the river (or several small pools or ponds) and predict the levels of the pollutants shown in Table 1. Your textbook and the information above provide the information needed to do this. For example, lead and mercury are likely to be associated with landfills and industrial area, whereas nutrients like phosphate and nitrate are likely to come from agricultural sources.

Table 1. Common pollutants and possible sources

Pollutant	Source
Turbidity	Runoff from streets, agricultural fields, possible industrial discharges.
pH	Industrial discharge, runoff from feedlots.
Conductivity	Associated with most types of pollution; high conductivity levels suggest that pollutants are reaching a water body, although naturally high levels can be found.
Nitrate	Industrial processes, fertilizers, feedlots.
Phosphate	Some detergents and cleaning agents, fertilizers
Iron	Industrial discharges and landfills; natural levels can very significantly.
Copper	Industrial discharges and landfills; natural levels can very significantly.
Lead	Industrial discharges and landfills; natural levels can very significantly.
Mercury	Industrial discharges and landfills; natural levels can very significantly.
Chromium	Industrial discharges and landfills; natural levels can very significantly.
Coliform Bacteria	Sewage disposal systems close to the water, feedlots and grazed areas, wastewater treatment plants that are not functioning properly.

4. Develop a sampling strategy to test your hypotheses. Testing of all possible pollutants in the environment is impractical both in terms of the level of effort required and the cost of the laboratory work. Over many years, scientists have developed lists of indicator pollutants that provide some information about the water quality in an area. Because some of the pollutants can come from a variety of sources, care must be taken in their analysis, but using the information above, rank concentrations of each of the pollutants below at each of the sampling stations

5. Go onto the next exercise and test your hypotheses! Move onto Water Quality Exercise 2: Assessing Water Quality.

For those wishing to look more closely at the situation in Kanpur, a map and aerial photograph of the area around the river can be found by following the links below:

GIS Providers and Educational Communities

ESRI (www.esri.com). ESRI produces the ArcMAP family of products, all of which are available for classroom use at discounted prices. The online community is active and can be found at http://edcommunity.esri.com/.

Google Earth (http://earth.google.com/). Beyond providing maps and images, Google Earth offers more advanced projects for analysis of spatial data. The Google Earth Community can be found at http://bbs.keyhole.com/ubb/ubbthreads.php/Cat/0.

IDRISI (http://www.clarklabs.org/). Less common in high school classrooms, IDRISI offers a comprehensive suite of GIS tools for analysis.