In cooperation with the Vermont Department of Environmental Conservation, and
The City of Burlington, Vermont

MONITORING THE EFFECTIVENESS OF URBAN BEST MANAGEMENT PRACTICES IN IMPROVING WATER QUALITY OF ENGLESBY BROOK, BURLINGTON, VERMONT

Increased peak (flood) flows and decreased base (dry weather) flows, erosion, and elevated concentrations of bacteria, nutrients, sediment, and other pollutants in the Englesby Brook watershed are water-related problems characteristic of urbanizing and urbanized areas. Substances carried by Englesby Brook are flushed into Lake Champlain (fig. 1), an important resource shared by Vermont, New York, and Quebec.

Some of the water-quality problems are caused or exacerbated by the effects of large areas of impervious surfaces in the watershed, which cause runoff from rainfall and snowmelt, along with any water-borne substances, to be channeled directly to the Brook rather than recharging the ground-water system. This results in rapid rises in streamflow that contribute to streambank erosion and channel instability. During dry periods, base flows are low because of the loss of ground-water storage, and streams may even go dry. Urban Best Management Practices (BMPs) are actions or procedures that are designed to minimize these problems and may include structural measures (stormwater retrofits and stream channel rehabilitation), source-reduction practices (street sweeping and litter clean-up days), regulatory measures (anti-littering laws), legal measures (enforcement of existing laws), and education. In 1999, the U.S. Geological Survey (USGS), in cooperation with the State of Vermont and the City of Burlington, with additional support from the Lake Champlain Basin Program, initiated a study of the effectiveness of urban BMPs in the Englesby Brook watershed.

Figure 1. Blanchard Beach, at the Englesby Brook outlet to Lake Champlain, has been closed for swimming since 1991 because of high counts of bacteria.

The objective of the USGS project is to assess the effectiveness of BMPs in improving the water quality of Englesby Brook. The USGS is monitoring streamflow, phosphorus, suspended solids, nitrogen, specific conductance, temperature, pH, dissolved oxygen, and turbidity. In addition, the City of Burlington is monitoring *E. coli* bacteria. The study is scheduled to continue for approximately 7 years to evaluate stream-water quality before, during, and after BMP implementation in the watershed. BMP implementation is planned to begin in 2001.

The concentrations of phosphorus in Lake Champlain is a primary consideration of the Lake Champlain Basin Program and the State of Vermont in monitoring the effectiveness of BMPs in the Englesby Brook watershed. Excessive amounts of phosphorus in lakes can lead to an increase in growth of algae and other aquatic plants, which can, in turn, adversely affect the aesthetic, biological, and recreational quality of the Lake. More than 80 percent of the phosphorus entering Lake Champlain comes from nonpoint sources (Lake Champlain Management Conference, 1996). An estimated 55 percent of the nonpoint-source load originates from agricultural activities, 37 percent from urban areas, and 8 percent from forestland (Hegman and others, 1999). The States of Vermont and New York, the province of Quebec, the U.S. Environmental Protection Agency, and the Lake Champlain Basin Program (Lake Champlain Management Conference, 1996) have set reducing phosphorous loading to the Lake as a high priority. Reductions in the amount of phosphorus reaching the Lake from nonpoint sources are being pursued through implementation of BMPs. The Lake Champlain Basin Program (2000) estimates that the targeted reductions in nonpoint-source

Evolution of the Englesby Brook Watershed Restoration Project

Clean-up efforts related to the Pine Street Barge Canal superfund site in Burlington lead to planned implementation of improvements in the Englesby Brook watershed, which is a heavily urbanized basin near the Canal site. The Restoration Project team (Vermont Agency of Natural Resources, City of Burlington, Lake Champlain Committee and U.S. Natural Resources Conservation Service) will plan, design, and oversee implementation of Urban Best Management Practices over the next 5 years in the Englesby Brook watershed.

phosphorus loading to the Lake will cost tens of millions of dollars; therefore, it is important to evaluate the effectiveness of BMPs.

Englesby Brook was selected for this study because of on-going efforts to improve the ecological health of the Brook. In 1999, the Englesby Brook Watershed Restoration Project team (sidebar) received funds to implement BMPs in the Englesby Brook watershed. The USGS, the Vermont Department of Environmental Conservation (VTDEC), and the City of Burlington recognized this opportunity to document anticipated improvements in water quality and to collect information that could be used to refine future estimates of phosphorus reductions in Lake Champlain.

Description of Study Area

The Englesby Brook drainage is a small (0.94 mi^2) urban watershed that drains directly to Lake Champlain (fig. 2). Eighty-four percent of the land area is in Burlington and 16 percent is in South Burlington. Land use within the watershed consists of residential (56 percent), commercial, industrial, and educational (23 percent, including parts of the University of Vermont campus), golf course (18 percent), forest (3 percent), and parks and recreation (less than 1 percent). Average annual precipitation in Burlington is 34.5 inches, with an average of 3.7 inches during each of the summer months and 2.0 inches during each of the winter months. Average annual temperature is 44.6º Fahrenheit (F), averaging 67.9ºF in the summer, and 19.2ºF in the winter. An estimated 24 percent of the Englesby Brook watershed is composed of impervious surfaces (Center for Watershed Protection, written commun., 2000).

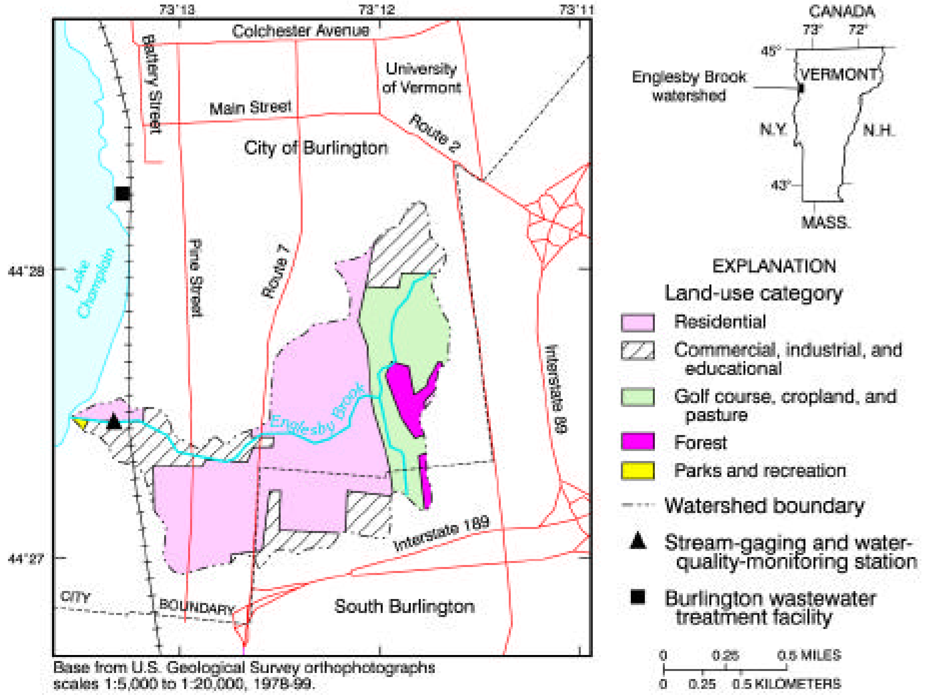

Figure 2. Location of the stream-gaging and water-quality-monitoring station and land-use areas in the Englesby Brook watershed.

Data Collection/Sampling Methods

During the summer of 1999, the USGS constructed a stream-gaging station with a concrete control and v-notched, sharp-crested weir about 1,200 feet upstream of the Brook's outlet to Lake Champlain (fig. 3). The weir enables collection of accurate, continuous stream-flow data. Water-quality data are collected at the same site using three methods. An automated, refrigerated sampler collects stream-water samples when streamflow increases during storms or periods of snowmelt. These samples are analyzed at the VTDEC Laboratory for total phosphorus, total nitrogen, and total suspended solids. A water-quality meter collects specific conductance, temperature, pH, dissolved oxygen, and turbidity data at 15-minute intervals. Water samples also are manually collected from the stream during selected storms and base-flow periods for analysis of *E. coli* bacteria at the Burlington Main Wastewater Treatment Facility (fig. 2). Precipitation is measured at the Facility, about 1 mile away from the USGS collection site, using a tipping bucket rain gage.

Initial Results of Water-Quality Monitoring

Provisional data on stream discharge and rainfall; concentrations of total phosphorus, total suspended solids, and total nitrogen; specific conductance and temperature; pH; dissolved oxygen; and

Figure 3. The USGS Englesby Brook monitoring station and site. The v-notch weir is in the lower right of the picture, and the stream-gaging station is on top of the high river bank to the left.

turbidity for selected storms from September 1999 through early January 2000 are shown in figure 4. Flows in Englesby Brook are highly dependent on rainfall, as shown in figure 4a, but not all similar storms produce the same discharge pattern.

Overall, the graphs of concentrations of phosphorus and suspended solids (figs. 4b and c) are similar. Concentrations appear to peak during storms, indicating that most of the phosphorus may be attached to the suspended solids; this has been observed elsewhere (Litke, 1999). Large values of suspended solids and phosphorus generally are detected in the stream during storms that follow relatively long dry periods (Storms 2, 4, and 6), because these substances accumulate in the watershed and then are "flushed out" by storm-induced runoff. In contrast, storms that closely follow previous storms (Storms 3 and 5) do not produce such large concentrations of suspended solids and phosphorus.

Nitrogen data (fig. 4d) follow a pattern inverse to that for phosphorus and suspended solids. Peaks in streamflow correspond to troughs in the nitrogen concentration, indicating that nitrogen may be diluted by high flows.

The pattern for specific conductance (fig. 4e) also is generally inverse to that for streamflow. Specific conductance values are high at the beginning of each storm, low during the storm peak, then high again as the stormflow recedes. Whereas temperature (fig. 4e) and pH (fig. 4f) do not show consistent patterns related to storms, dissolved oxygen (fig. 4g) and turbidity (fig. 4h) generally increase during storms and decrease after storms.

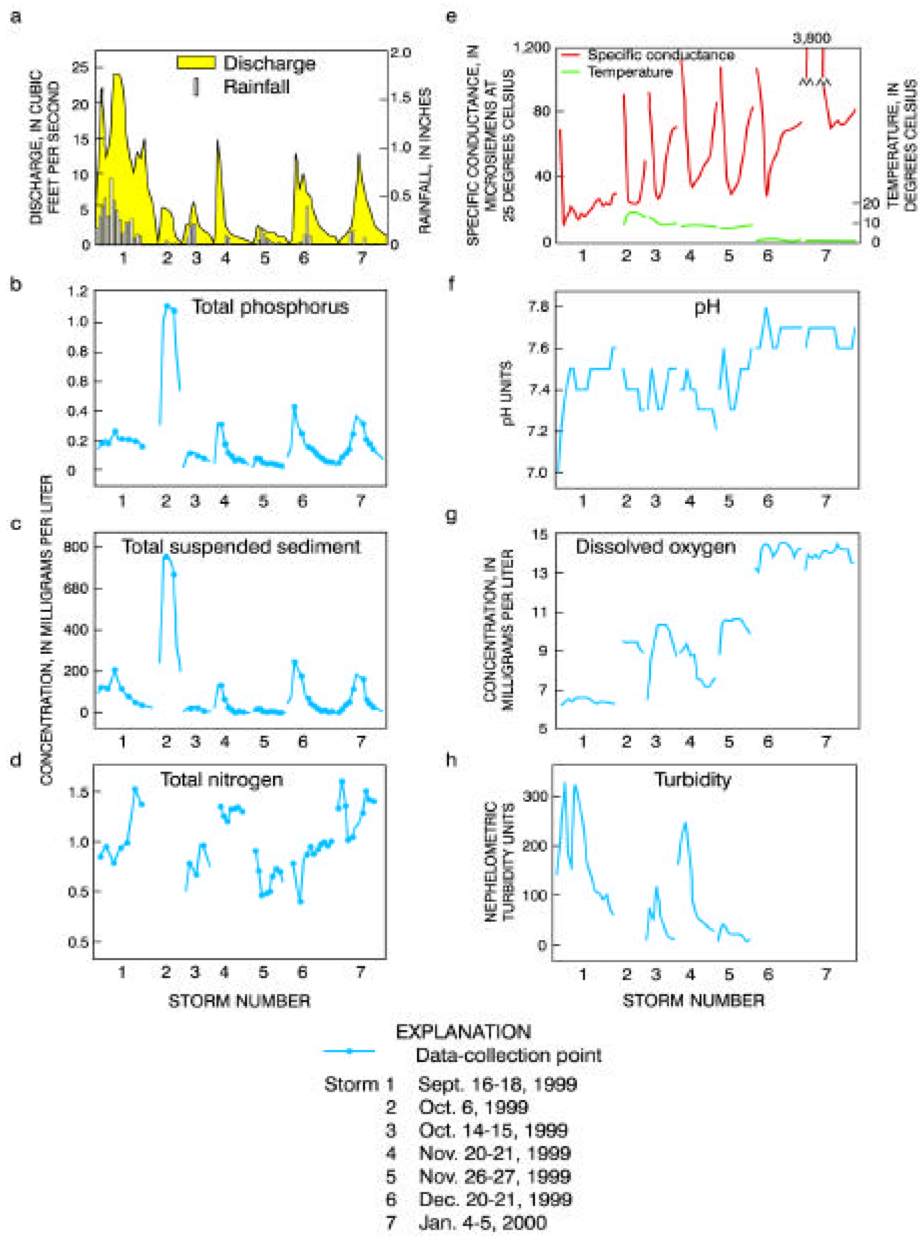

Figure 4. Stream discharge, physical and chemical characteristics of water, and rainfall at Englesby Brook for selected storms, September 1999 - January 2000. These data are **PROVISIONAL ONLY** (subject to review and revision). Each rainfall bar represents 2 hours. Data are for individual storms—gaps in data lines represent time between storm dates. Nitrogen data are missing for storm 2; temperature for storm 1; and turbidity for storms 2, 6 and 7.

SUMMARY

This study is designed to provide useful water-quality information to those involved in protecting and managing the quality of Lake Champlain and its tributaries. A long-term monitoring program to determine how tributary water quality changes with upstream BMP implementation will provide critical information for understanding the effect of management actions on streams and lakes.

—Laura Medalie

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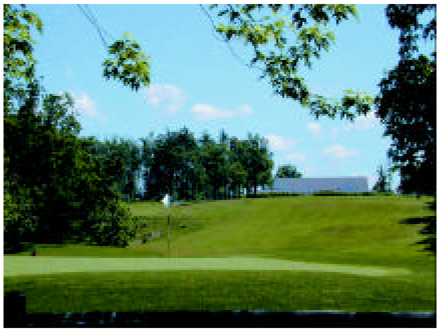
Layout and Design: Debra H. Foster, Ann Marie Squillacci *Graphics: Anita Cotton*



Golf Course

Figure 5. Examples of land use in the Englesby Brook watershed, Burlington, Vermont.

Provisional Data Availability

Real-time continuous streamflow data (subject to review and revision) can be found at the USGS Englesby Brook web site: *http://vt.water.usgs.gov/CurrentProjects/Englesby/Englesby.htm*. The site also provides a description of the study. Real-time hourly water-quality data will be available at that site in the year 2000.

Residential

Commercial

DEFINITIONS

Base flow—Streamflow coming from ground-water seepage into a stream.

Dissolved oxygen—A measure of the amount of oxygen that is dissolved in water. Dissolved oxygen is needed by fish and zooplankton to survive. Rapidly moving water, such as that found in a mountain stream, usually contains much more dissolved oxygen than stagnant water.

***E. coli* bacteria** (*Eschericia coli*)—A bacterial species that inhabits the intestinal tract of man and other warm-blooded animals. Although the coliform bacteria are not themselves directly harmful, their presence in excessive numbers suggests the possible presence of other species that are harmful to human health.

Impervious—A term used to describe certain types of solid material, such as rock, clay, asphalt, or concrete, which prevent water seepage into the ground.

Lake Champlain Basin Program—A federally-funded initiative working in partnership with agencies, organizations, and individuals to develop and implement concepts put forth in the comprehensive planning document, *Opportunities for Action: An Evolving Plan for the Future of the Lake Champlain Basin* (Lake Champlain Management Conference, 1996). The Basin Program is guided by the Lake Champlain Steering Committee, which represents a broad spectrum of Lake-Basin interests and organizations from New York, Vermont, and Quebec, including local government and citizen representatives, scientists, state government, and federal agencies.

Lake Champlain Management Conference—A 31-member board representing various interests in the Basin, which led the Lake Champlain Basin Program during the development of Opportunities for Action (Lake Champlain Management Conference, 1996).

Load—The material that is moved or carried by a natural transporting agent, such as a stream, a glacier, or the wind.

Nitrogen—Nitrogen, in the forms of nitrate, nitrite, or ammonium is a nutrient needed for plant growth. Excessive amounts in water can lead to over-productive aquatic growth. Nitrogen is naturally abundant in the environment and also is introduced through sewage and fertilizers.

Nonpoint-source pollution—Sources of pollution such as atmospheric deposition, agricultural runoff, or seepage from septic systems that contribute pollutants to rivers and lakes at numerous and widespread locations rather than at a single discharge point.

pH—pH is a measure of how acidic or basic water is and ranges from 0-14. A pH of 7 is neutral, less than 7 is acidic, and greater than 7 is basic. pH is a measure of the relative amount of free hydrogen and hydroxyl ions in the water and is an important indicator of chemical changes in water.

Phosphorus—Phosphorus is an essential element for plant life, but when there is too much of it in water, it speeds up the aging process of lakes. Phosphorus enters streams from point sources, primarily wastewater-treatment facilities, and from nonpoint sources, such as applications of lawn fertilizers and disposal of animal wastes.

Runoff—That part of precipitation, snow melt, or irrigation water that enters streams, rivers, drains, or sewers without first infiltrating the ground.

Specific conductance—A measure of the ability of water to conduct an electrical current. Specific conductance is related to the type and concentration of ions in solution and can be used for approximating the total dissolved solids (such as salt) content of water by testing its capacity to carry an electrical current.

Suspended solids—Solids that are not in solution and can be removed by filtration.

Turbidity—Turbidity is a measure of the cloudiness of water. Water cloudiness is caused by material, such as dirt and residue from leaves, that is suspended in the water. Clear water has low turbidity. Brown, silt-laden water, such as a river during a storm, has high turbidity.

Watershed—The land area that contributes water to a particular stream, river, or lake. It is a land feature that can be identified by tracing a line along the highest elevations that enclose a land area on a map around the designated point on the stream, river, or lake (usually the outlet or mouth).

For more information, please contact:

District Chief
U.S. Geological Survey
361 Commerce Way
Pembroke, NH 03275
(603) 226-7807 Phone
(603) 226-7894 FAX
or E-mail: dc_nh@usgs.gov

Visit the USGS web site at URL:
http://vt.water.usgs.gov or
http://www.usgs.gov