A Comprehensive Watershed Instrumentation Program for Multidisciplinary Undergraduate Education at Lafayette College

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Abstract

Multidisciplinary environmental problems associated with suburban sprawl are increasingly being addressed at the watershed scale. Consistent with this theme, Lafayette College (LC) faculty and undergraduate students are installing a comprehensive network of automated instrumentation to investigate hydrologic impacts of land use change in a 200-km^2 watershed adjacent to campus. When complete, the network will include six permanent stream gaging stations, two wellfields, and two weather stations. The project is a cooperative effort between engineering and geoscience faculty at LC; however, others may use the publicly accessible web database under development. We are incorporating a series of field-based exercises within existing civil engineering and geology courses, and encouraging students to pursue undergraduate research projects and honors theses using the equipment and data. In addition, we are working in close cooperation with community groups such as the Bushkill Stream Conservancy and the Jacobsburg Environmental Education Center. Some of the interesting features of our project are: (1) the comprehensive monitoring network and full watershed scale; (2) strong geologic and land use contrasts, and rapid development within the basin; (3) collaboration between engineering and natural science students and faculty; (4) emphasis on linking data to public policy issues such as stormwater management; and (5) the degree of involvement of the local community.

Background

Recent reviews on higher education in the U.S. have documented a lack of technical literacy and propose that institutions of higher education provide "opportunities for all undergraduates to study science, mathematics, engineering, and technology as practiced by scientists and engineers"[1]. Furthermore, it has been suggested that this literacy be acquired by "direct experience with the methods and processes of inquiry" and a linking of faculty research and teaching[2]. These recommendations point to the need for more hands-on, project-oriented learning experiences. Stream or watershed-based field studies have been used for this purpose at a number of K-12 schools, colleges, and universities in a variety of disciplines[3].

The emphasis on the watershed as a theme for teaching is also consistent with national trends in land-use planning and management. The U.S. Environmental Protection Agency (EPA) is advocating a watershed-based framework for protecting public health and the environment[4]. Much of this emphasis is a result of non-point source pollution, in which the cumulative effect of many diffuse pollutant and sediment sources throughout a watershed has significant impacts on water quality downstream. The rapid increase in the rate of land development (i.e., "suburban sprawl") adds to the already existing problem, because this tends to increase erosion, sedimentation, and flooding, and reduce groundwater recharge. The term "smart growth" has been coined to represent a concept of land-use planning that minimizes the impacts of development on the ecologic and hydrologic integrity of the watershed[5]. With these ideas in mind, faculty at LC have recently obtained a National Science Foundation Course, Curriculum, and Laboratory Improvement (CCLI) grant to create a watershed-based field laboratory comprised of a network of automated hydrologic and geochemical monitoring stations in the Bushkill Creek watershed. The project is patterned after similar projects at a number of small colleges and universities in the northeast U.S.[6,7] While some pieces of the network were already in place at LC (outlet stream gage, campus weather station, carbonate wellfield), the grant provides us with the opportunity to develop a full range of curricular and student research activities to assess hydrologic impacts in a comprehensive manner. This paper presents our progress on the project to date.

Watershed Description

The 200-km^2 Bushkill Creek watershed is located in north-central Northampton County, PA (see Figure 1). The watershed is bounded by Blue Mountain at its upper end, and drains southeast toward the Delaware River. The upper half of the basin consists of a deeply dissected upland surface underlain by shale and slate, and mantled with Berks shaley silt loam soils[8]. This portion of the basin has many abandoned slate quarries, but is currently dominated by woodlands, agriculture, and low-density residential land uses. The lower half of the basin is underlain by carbonates and Washington silt loam soils, and the karst terrain consists of gently undulating hills with low relief [8]. Agricultural areas in this area are experiencing rapid commercial and dense residential development, while the southernmost area of the watershed in and around Easton and Lafayette College has been suburban/urban for over a century. Many abandoned low-head dams on the lower 5 km of the stream are a testament to its former industrialization. Three main branches of the stream (mainstem, Sobers Run, and Little Bushkill Creek) drain the upper portion of the watershed. A fourth major tributary (Shoeneck Creek) drains the western carbonate portion, and has a history of poor water quality due to wastewater and quarry discharges[9]. A smaller unnamed stream drains the southwest urban area near Route 22 and Easton.

The combined influence of land use, geology and soils, and topography likely produce two distinctly different hydrologic regimes within the watershed. The upper (shale/slate) portion of the basin, although forested, is more responsive to rainfall with little deep groundwater recharge. The high runoff to infiltration ratio is suggested by a high drainage density of 1.44 km/km^2. The lower (carbonate) portion would naturally have extensive infiltration and groundwater recharge as evidenced by a lower drainage density of 0.44 km/km^2. However, this area is being transformed to curb, gutter, and detention pond drainage associated with development. Furthermore, near the transition from shale/slate to carbonates, streamflow dynamics are complicated by large-scale pumping from cement quarries near the stream. The long-term effects of these changes are unknown, but can be expected to result in more extreme floods and droughts. One of the scientific goals of the project is to document impacts to the watershed hydrology and stream channel integrity from landscape development.

The Monitoring Network

Undergraduate students in civil engineering and geology are currently installing the automated equipment. When completed, the monitoring network will allow a comprehensive assessment of hydrologic conditions throughout the watershed. This is critically important for understanding the watershed as a complete functioning system, as is the current practice[4,5]. For example, in order to effectively manage stormwater within the watershed, one must understand how runoff varies across the basin with topography, geology, soils, and land use. The monitoring equipment will allow us to measure flow directly, and then calibrate runoff models of the watershed that can be used to answer questions such as "what is the effect of paving 25% of the lower watershed?"

The network consists of six automated flow and water quality stations along the Bushkill Creek and tributaries (four completed), groundwater well fields located near the stream in both the shale/slate and carbonate geologies (one well field completed), a USGS-instrumented well in the shale, and weather stations at the center and outlet of the basin (both completed). We also purchased two programmable stormwater/sediment samplers that can be deployed anywhere along the stream network. Equipment locations are shown in Figure 1, and the instrumentation is summarized in Table 1 below.

To organize and present data collected from these installations in a publicly accessible format, a project website and GIS are under development. The website is currently located at ww2.lafayette.edu/~brandesd/bushkill/bushkill.html, and will serve as the principal means of disseminating project data and results for teaching and research to the campus and local community. In the future we plan to provide hotlinks from the GIS to digital pictures and data on the web, enabling the system to function as an interface for virtual exploration of the watershed.

Item	Description
Stream monitoring stations (6)	battery-powered datalogger in protective housing pressure transducer (for water level) specific conductivity/temperature/turbidity probes
Monitoring well fields (2)	three groundwater wells cased to bedrock battery-powered datalogger in protective housing two pressure transducers to monitor water levels
Weather stations (2)	tipping bucket rain gauge temperature, barometer, and relative humidity sensors wind speed and direction sensor
Portable Samplers (2)	programmable samplers for sampling water and sediment during storm events

Table 1. Bushkill Creek watershed monitoring equipment

Student Participation

A primary goal of the project is to involve our undergraduates in data collection, analysis, and synthesis on a field site relevant to them. During the installation phase of the project, three civil engineering students and three geology students have been working together on assembling, testing, siting, and installing the equipment (see Figures 2 and 3). The LC Excel Scholars program facilitates this involvement by providing an hourly wage for students who work with faculty on research projects. Two of these students are pursuing honors thesis research, one on linking streamflow recession rates to watershed geomorphic parameters, and the other on the correlation between stream chemistry and conductivity. Two more students have conducted independent studies investigating stormwater quality dynamics using the programmable samplers.

For the watershed GIS, another civil engineering student has taken the lead on developing data layers based on an existing GIS (see Figure 1), and linking these with a hydrologic model (HEC-HMS). One of the goals of her work is to provide a tutorial for future students on how to use GIS to extract the watershed parameters needed for hydrologic modeling. She will also be presenting her work at the 2002 ASCE conference on Water Resources Planning and Management.

Implementation of Curricular Improvements

The strength of the project is that local field exercises instill a sense of excitement and enthusiasm for curricular assignments that were formerly merely textbook cases. The physical connection to the site ensures that the students will regard their data as having real-world implications, not as cooked-up examples. The geosciences have a long history of fieldwork as an integral part of curriculum; however, this has not been the case in the field of civil engineering, even in a subdiscipline such as hydrology that is closely allied with the earth sciences. Because we are currently focused on the equipment installations, we have just begun to integrate new activities using the field equipment into our courses, as summarized in Table 2. In general, these initial projects were well received by our students.

Course	Topic
CE 221	Variations in stream water quality with geology and land use
CE 251	Using a control section (weir) to determine streamflow
CE 421	Application and calibration of stormwater models WinTR55 and HEC-HMS Development of stream rating curves (see Fig 4) Assessment of stormwater retention basin effectiveness (see Fig 5)
GEOL 110	Determination of groundwater flow directions
GEOL 210	Installation of monitoring wells (see Fig 6) Groundwater/surfacewater interaction - assessment of losing and gaining stream reaches by current measurements
GEOL 210 / CE 424	Determination of groundwater flow direction and gradient Groundwater pumping tests and slug tests (see Fig 7)
GEOL 300	Stream cross-sections and current measurement Measurement of sediment shear stress and calculation of bankfull shear stress

Table 2. Course activities completed using watershed monitoring equipment

Implementation of additional course improvements is slated for the second year of the grant, when considerably more effort will be spent on new homework assignments, projects, and laboratories that will utilize the project database. The upper level civil engineering courses do not include laboratories, so it may be necessary to adjust the typical lecture-based time slots to allow more time for field activities. One area of the Lafayette curriculum that will particularly benefit is the Environmental Science minor within the Interdisciplinary Studies program. Currently this program consists of a number of disparate courses falling under either the technical or policy components. The study of land-use change and its impact on the watershed will provide a much-needed central theme or case study for this program that we anticipate will lead to greater cooperation and interaction among faculty and students from different disciplines and departments.

Assessment

At this stage (project less than one year old), we have not yet had a formal assessment, although we are encouraged by the amount of student involvement in the project. We are using an outside panel of environmental scientists, hydrologists, and policy makers as well as student surveys to assess the progress and success of our project. At the end of each year of the grant, we will prepare a summary of our progress for the panel to evaluate, including copies of course projects and lab exercises that utilized the monitoring network. The panel will meet annually to provide us with suggestions for improvements. The panelists have diverse backgrounds, training, experience, and professional roles – all suited to evaluate the various aspects of our field laboratory.

Conclusion

The program as described above is providing significant new field experiences for engineering and geoscience undergraduates at Lafayette College. Dozens of students have already participated in exercises based on the new equipment, and several have been inspired to pursue undergraduate honors theses based on their work experience on the project. Because the system is installed permanently, future students will be able to add their own contributions to our study of long-term impacts in the watershed. Through the project, we have developed close relationships with the Bushkill Stream Conservancy (BSC), a group of local citizens that support programs of education and conservation, and the Jacobsburg Environmental Education Center located within the watershed. The College and BSC have recently received a second (joint) grant to develop a formal watershed assessment program.

Figures

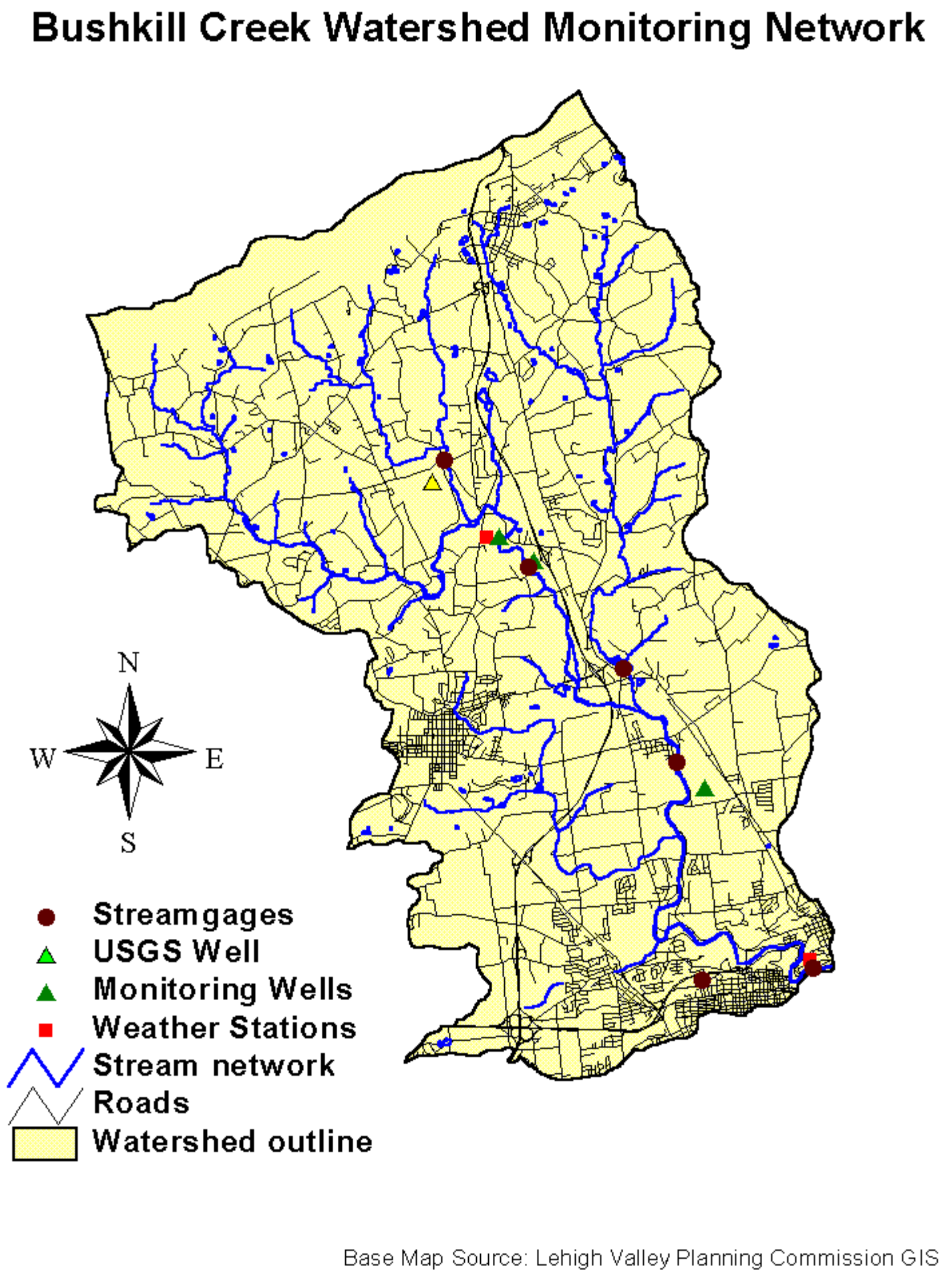

Figure 1. Map of the Bushkill Creek watershed, showing the monitoring network.

Figure 2. Civil Engineering Exc el Scholars installing streamgage electronics at Jacobsburg State Park.

Figure 3. Geology Excel Scholars installing monitoring well electronics at Metzgar Wellfield. A datalogger is housed in the steel box.

Figure 4. Students (CE 421) developing stream rating curves at the Henry Road gaging station.

Figure 5. Students (CE 421) surveying a detention basin near a shopping mall on a tributary of Bushkill Creek.

Figure 6. Students (GEOL 210) observing well drilling at Metzgar Wellfield.

Figure 7. Students (GEOL 210) conducting a slug test at Metzgar Wellfield.

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