2006-673: STUDENT ENGAGEMENT ACROSS THE CIVIL ENGINEERING CURRICULUM

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Student Engagement Across the Civil Engineering Curriculum

Abstract

Engineering students at our university experience a project-based curriculum and work on many community projects during their academic careers. The civil engineering program has been able to engage students from freshmen to seniors in projects that are badly needed by the local community. Our city engineer wanted a device to record high water marks (crest gages). Ten were constructed by two civil engineering freshman experience classes learning to use machine shops. Several of the gages have been installed at locations around the city and are providing data that will be used to calibrate watershed models developed by a senior hydrology class. Elementary surveying students (freshmen) and advanced surveying students (sophomores, juniors, and seniors) developed topographic surveys of sinkholes prone to flooding. These maps were used by hydrology classes for models to improve flood maps for the community. These maps are sorely needed because of the poor quality of existing maps. For example, when flood zones were superimposed on topographic data, one end of a sinkhole flood zone was 6 m higher than the other end. Once the flood maps are revised, several homes will be moved into flood zones and residents with federally-backed mortgages will be required to obtain flood insurance. To assist the residents, surveying classes performed surveys so the residents could estimate the cost of flood insurance. All of these projects engage students at all levels and provide valuable learning experiences. In particular, freshmen gain a better understanding of the work of civil engineers through these projects.

Introduction

Our university is a strong proponent of student engagement and of project-based learning. The ultimate aim of engagement is to perform projects of community interest that enhance student learning experiences. A very successful example of this paradigm is described here.

The university is situated in one of the best-known karst (cave and limestone) areas of the world. Most flood problems in the area are associated with sinkhole flooding, but many sinkhole flood zones are inaccurate. Often the zones do not conform to topography (one sinkhole flood zone is 6 m higher on one end than the other). Remapping of four sinkhole flood zones was selected as a project for a senior hydrology class. Arising out of this community need for improved flood maps, 10 different undergraduate classes with a total of 105 students were engaged in projects. The engagement of freshmen to senior engineering students will also be used as a springboard for launching one of the first floodplain management minors in the country.

These multi-class projects had many benefits, but some pitfalls were encountered. The purpose of this paper is to share these experiences with the general academic community and to offer this as a teaching paradigm that can be implemented by others.

Background

Flood maps are the most basic tool in this country for floodplain management. Almost 20,000 communities participate in the National Flood Insurance Program. Each of these communities has, or soon will have flood maps that they will use to control development in the floodplain. The ability of a community to protect new construction without stifling development is a direct function of the accuracy of flood maps. The quality of these flood maps varies widely. Some flood zones (AE or VE zones) are determined after detailed hydrologic and hydraulic modeling of watersheds. If these models are done accurately, everyone benefits. Resident's homes, businesses, and churches are built in a way to minimize flood damage, and the job of floodplain management is made easier for the community.

Other flood zones are determined based on observations of historic floods and from other considerations. These zones are called approximate A zones and provide no flood elevations. Consequently, required elevations for new development in these zones are not available. Many poorer communities have many of these A-zones.

Some of the sinkhole A zones in the city were not made AE zones because standard methods gave 100-yr flood zones much lower than those observed in large events. Figure 1 shows three sinkhole flood zones, of which two are approximate A zones.

Accurate determination of flood zones requires several things: 1) accurate topographic survey data, 2) application of appropriate hydrologic and hydraulic models, 3) good calibration data, and 4) familiarity with the watershed. Each of these four requirements for good flood maps is a link in a chain. Failure to provide any one of the links can significantly reduce the accuracy of the map.

A flood map is only as good as the topographic data on which it is based. The best modeling in the world cannot overcome inaccurate topographic data. Use of appropriate models is critical. No matter how good the model, if it is not properly calibrated, results will be disappointing. Familiarity with the watershed involves walking over the terrain. Many embarrassing results can be avoided if the engineer spends time meeting and talking with long-term residents. One casual observation by a resident can identify problems with models.

Next in importance to flood maps for floodplain management is the elevation certificate. Figure 2 shows the portion of a Federal Emergency Management Agency (FEMA) elevation certificate used nationwide that must be completed by a licensed engineer, surveyor, or architect.

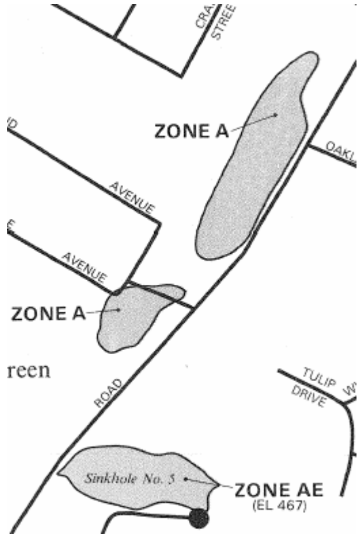

Figure 1. Section of a flood map panel showing A and AE sinkhole flood zones

B4. MAP AND PANEL NUMBER	B5. SUFFIX	B6. FIRM INDEX DATE	B7. FIRM PANEL EFFECTIVE/REVISED DATE	B8. FLOOD ZONE(S)	B9. BASE FLOOD ELEVATION(S) (Zone AO, use depth of flooding)

B10. Indicate the source of the Base Flood Elevation (BFE) data or base flood depth entered in B9.
|__| FIS Profile |__| FIRM |__| Community Determined |__| Other (Describe): ____________________

B11. Indicate the elevation datum used for the BFE in B9: |__| NGVD 1929 |__| NAVD 1988 |__| Other (Describe): ____________

B12. Is the building located in a Coastal Barrier Resources System (CBRS) area or Otherwise Protected Area (OPA)? |__| Yes |__| No
Designation Date:________________________

SECTION C - BUILDING ELEVATION INFORMATION (SURVEY REQUIRED)

C1. Building elevations are based on: |__|Construction Drawings* |__|Building Under Construction* |__|Finished Construction
*A new Elevation Certificate will be required when construction of the building is complete.

C2. Building Diagram Number _____ (Select the building diagram most similar to the building for which this certificate is being completed - see pages 6 and 7. If no diagram accurately represents the building, provide a sketch or photograph.)

C3. Elevations – Zones A1-A30, AE, AH, A (with BFE), VE, V1-V30, V (with BFE), AR, AR/A, AR/AE, AR/A1-A30, AR/AH, AR/AO
Complete Items C3.a-i below according to the building diagram specified in Item C2. State the datum used. If the datum is different from the datum used for the BFE in Section B, convert the datum to that used for the BFE. Show field measurements and datum conversion calculation. Use the space provided or the Comments area of Section D or Section G, as appropriate, to document the datum conversion.
Datum ___________ Conversion/Comments ________________________________
Elevation reference mark used____________________ Does the elevation reference mark used appear on the FIRM? |__| Yes |__| No

- ❏ a) Top of bottom floor (including basement or enclosure) ____________ . ___ ft.(m)
- ❏ b) Top of next higher floor ____________ . ___ ft.(m)
- ❏ c) Bottom of lowest horizontal structural member (V zones only) ____________ . ___ ft.(m)
- ❏ d) Attached garage (top of slab) ____________ . ___ ft.(m)
- ❏ e) Lowest elevation of machinery and/or equipment servicing the building (Describe in a Comments area.) ____________ . ___ ft.(m)
- ❏ f) Lowest adjacent (finished) grade (LAG) ____________ . ___ ft.(m)
- ❏ g) Highest adjacent (finished) grade (HAG) ____________ . ___ ft.(m)
- ❏ h) No. of permanent openings (flood vents) within 1 ft. above adjacent grade ________
- ❏ i) Total area of all permanent openings (flood vents) in C3.h ________ sq. in. (sq. cm)

License Number, Embossed Seal, Signature, and Date

SECTION D - SURVEYOR, ENGINEER, OR ARCHITECT CERTIFICATION

This certification is to be signed and sealed by a land surveyor, engineer, or architect authorized by law to certify elevation information.
I certify that the information in Sections A, B, and C on this certificate represents my best efforts to interpret the data available.
I understand that any false statement may be punishable by fine or imprisonment under 18 U.S. Code, Section 1001.

CERTIFIER'S NAME LICENSE NUMBER

Figure 2. Portion of an elevation certificate (FEMA, 2006)

Elevation certificates or their equivalent are required for monitoring compliance with local and federal floodplain regulations. The figure shows that completion requires a survey of property around a building as well as determination of the 100-yr or base-flood elevation (BFE). The elevation certificate can be used as evidence that a house in the floodplain should not be in the floodplain if the elevation of the lowest adjacent grade is higher than the BFE. Elevation certificates are used by at least three groups: 1) lenders to determine if flood insurance is required for a mortgage, 2) by communities to determine compliance with federal, state, and local flood regulations, and 3) by insurance agents to determine flood insurance premiums.

The discussion of the two most important tools for floodplain management, flood maps and elevation certificates was necessary to provide the background for engagement of civil engineering students across the curriculum. The need for model calibration provided a third opportunity for student engagement in a meaningful project. Model calibration data can be provided by systems expensive to install and maintain, or by very inexpensive systems called crest gages. A crest gage records the high water mark in a flood. These are commonly used by the U.S. Geological Survey. The construction and use of these devices to provide student engagement opportunities will be discussed below.

The administration at all levels of our university strongly encourage all engineering faculty to seek community engagement projects for students. Consequently, most faculty do involve students in projects with local agencies, companies, and communities. Table 1 is a summary of the projects relating to water resources performed in the last two years. They are a subset of projects done by civil engineering undergraduates. The water resources area is especially fortunate in the number of projects available because of the karst landscape.

Student Engagement Projects

Our city provides many opportunities for student engagement in projects important to the community. Of particular importance is the need for better flood maps. Table 1 provides a summary of projects related to the development of improved flood maps performed by university students.

Project 1, topographic surveys were performed by both elementary and advanced surveying students (see Figure 3). The advanced students surveyed a large sinkhole prone to flooding. The elementary surveying students surveyed a smaller sinkhole. Both surveys provided data that allowed the hydrology students to develop improved stage-storage data for two critical sinkholes in a large watershed model.

At the start of the first sinkhole flooding project, it was not clear how much the flood maps would be changed. Figure 4 shows the changes in one sinkhole flood zone. The existing flood zones in the figure do not conform to topography and the north sinkhole shows one end of the existing flood zone 6 m (20 ft) higher than the other end. This clearly illustrates the need for new flood maps in the city.

Table 1. Summary of flood map-related projects performed by students

No.	Project	Class	No. of Students	Level
1.	Topographic surveys	Elementary Surveying*, Advanced Surveying	40	Freshman To Senior
2.	Elevation certificates	Elementary Surveying*	15	Freshman
3.	Crest gage construction and installation	University Experience*	28	Freshman
4.	Leveling survey of storm sewers	Elementary surveying*	30	Freshman
5.	Hydrologic modeling of sinkhole flooding	Hydrology*	15	Senior
6.	Hydraulic modeling of sinkhole flooding	Engineering hydraulics	4	Senior

* Required courses

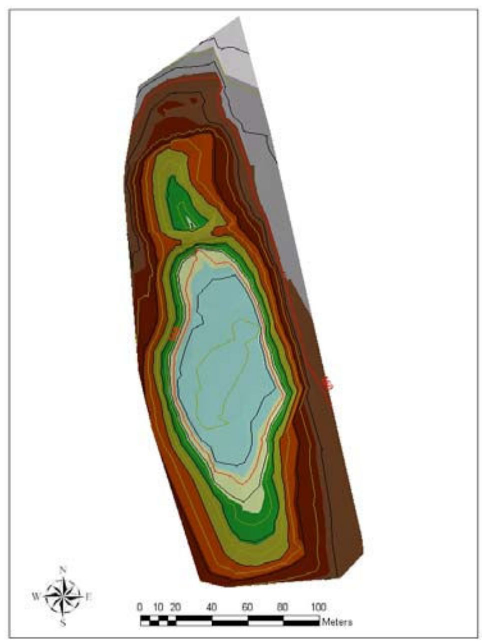

Figure 3. Students performing a topographic survey and the finished product

From the figure, several buildings previously not in the flood zone will be moved into the flood zone if the maps are approved. If the residents have a federally-backed mortgage, they will be required to have flood insurance. The residents allowed access to their property for the survey and now might be required to pay several hundred dollars a year for flood insurance. One of the residents, a professor at our university, was especially helpful. To help him, an elementary surveying class performed the survey necessary for completion of an elevation certificate. Palmquist and Campbell (2006) provide more details of this project. The certificate was completed by one of us (SP) and provided to the resident. From the certificate and the expected new base flood elevation, the flood insurance premium could be determined from the *Flood Insurance Manual* (FEMA 2003).

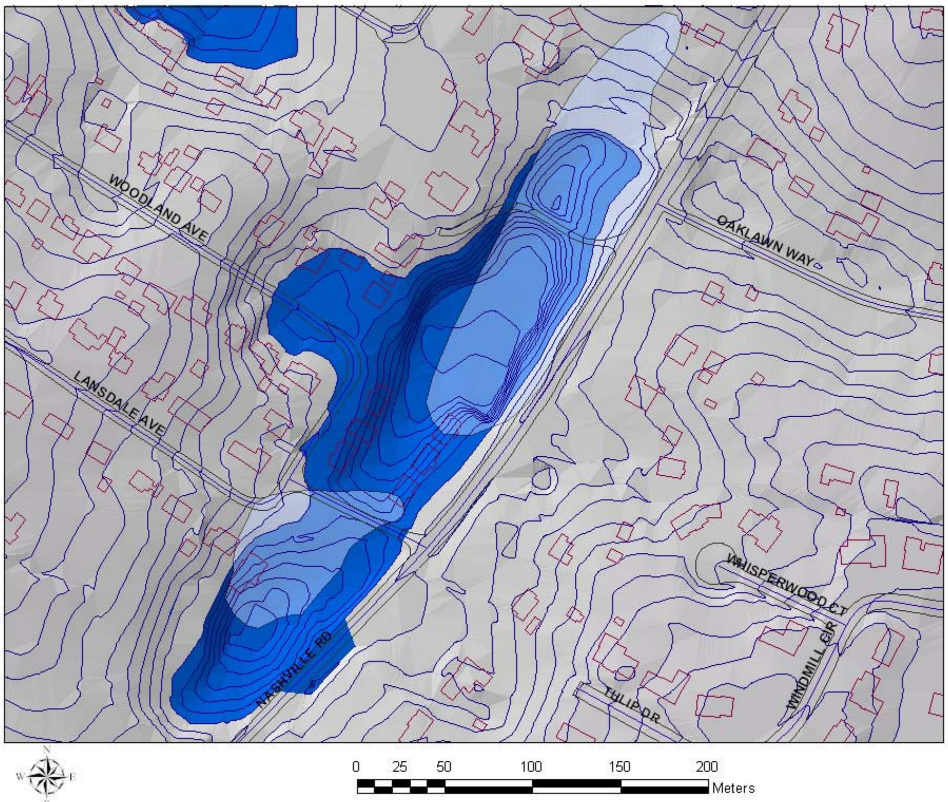

Figure 4. Preliminary changes in flood maps (light shading – existing flood zone)

The survey for an elevation certificate proved to be an excellent project for an elementary surveying lab. If an accurate vertical control point is available near the property, the project can be completed in one two-hour lab. If an elevation must be transferred from some distance away, two labs may be required. Both give an excellent real-world experience for a surveying class. Many professional surveyors include elevation certificate surveys as a significant portion of their practice.

Project 3 from Table 1 was the construction and installation of crest gages by the civil engineering University Experience Class. The purpose of this class is to introduce freshman students to engineering, to skills they will need in college, and to increase student retention in engineering. As a part of this class, students took a five-lecture introduction to machine shop practice. Our city engineer asked us for a device that could be used to record storm high water elevations. We described crest gages to him and then decided that it would make a good project for this class. Incomplete plans were downloaded from the Rickley Hydrological Company (2006) web site. The plans were not complete, so details were worked out by experiment. The gage consists of a 5 cm (2 in) galvanized pipe with both ends capped. Holes are drilled in the side of the bottom end cap to allow water in, and another hole is drilled in the upper cap for venting of air. A stick with a cup containing granulated cork is placed in the pipe. As the water rises, so does the granulated cork. When the water falls, the cork adheres to the stick leaving a clear high water mark. Figure 5 shows one of the crest gages installed in a manhole during a storm and details of the recording stick showing clearly the high water mark after the storm. The metal object at the lower end of the stick is the cup that holds the granulated cork.

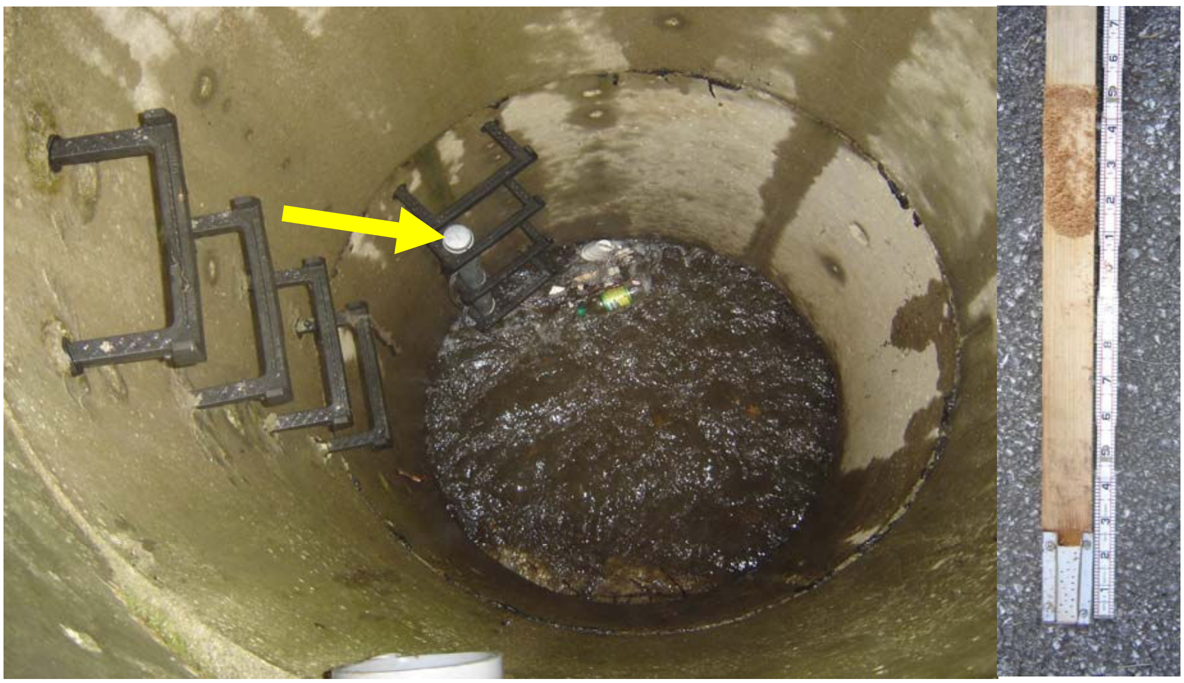

Figure 5. Crest gage installed in a manhole indicated by arrow and the recording stick showing high water mark after a storm.

Students constructed the crest gages and assisted in their installation. Students can reasonably be expected to complete a project like this. They see an important water resources application and information gained from the gages provides calibration data for senior hydrology classes. The city also benefits from this project; everyone wins.

The new flood elevations expanded flood zones so that several homes were added to the floodplain. This meant that some of the residents who allowed access to their property would be required to have flood insurance once the new flood maps became official. To help some residents, an elementary surveying class provided surveys for elevation certificates that will allow estimates of the cost of flood insurance to be made. This is a benefit to each homeowner of several hundred dollars. We found that performing the survey for an elevation certificate can be done in a single lab.

Project 4 was a leveling survey of a storm sewer system done by elementary surveying labs. Previously, our leveling survey lab involved a survey of PK nails placed in sidewalks by faculty. The lab had no real application other than teaching students the basics of a leveling survey. Our university is blessed with nearby project opportunities. One project by a senior hydraulics class involved modeling a storm sewer system that delivered runoff to a cave. Survey data for the pipe system was needed for the model. This project was within easy walking distance of the engineering building. Students performed a leveling survey of part of the pipe and channel system, and the data was applied by hydraulics students (Project 6 from Table 1) to complete a hydraulics model of the system. This model was used to size a water quality unit that will be installed outside the entrance of the cave to remove debris and hydrocarbons.

Project 5 in the table involves watershed modeling by engineering hydrology classes. City planning commission personnel including the community floodplain manager met with faculty and students. This was a valuable instructional project from several viewpoints. The class modeled the watersheds for four different sinkholes. Of these, two models gave results consistent with observed flooding. However, two of the sinkholes gave 100-yr flood elevations that were much too low. Within a single term, the students were unable to complete the models for the problem sinkholes because uphill sinkholes were overflowing into the downhill sinkholes. However, the experience of seeing how a project that seemed well-defined can expand to a much more involved project must be considered a valuable learning experience. In addition, the city hydrologist came to almost every class and provided valuable experience and data to the students.

Project 6 was performed by hydraulics students who modeled flow from a watershed to a water quality unit that is to clean up water that is then discharged into a cave entrance. The city engineer was very concerned about city modeling results that gave much higher flows than commonly observed. He met with students and faculty, provided data, and followed progress on the modeling very closely. The students completed the project and produced a calibrated model that seemed to match observed results closely. However, the model gave large spikes in water elevations that were not possible. The Winter 2006 hydrology class picked up the project and produced a model that overcame these problems. The city engineer sized the water quality device based on these modeling results. As this is being written in early March 2006, the water quality unit is currently being installed. As a consequence of this project, the city engineer became familiar with the capabilities of some of our students. Though at the time of graduation, he did not have a job opening, eight months later he was able to advertise a position and he specifically asked that one of our students (who had graduated and taken another position) apply for the job.

In all, the following students were involved in these water resources projects: 1) 28 entering freshman civil engineering class for Fall 2005, 2) 45 surveying students for Spring and Fall 2005, 3) all hydrology classes (a required course for CE students) for Fall 2004, Fall 2005, and Winter 2006 (15 students), and 4) all engineering hydraulics (an elective) students for Spring 2005. The Fall 2005 class of civil engineering students have all been introduced to water resources in projects important to the local community. As they progress through the curriculum, they will continue to receive exposure to these projects so that by the time they graduate, they will know local community officials including the city engineer, city hydrologist, and city floodplain manager. These officials will become familiar with students they might want to hire or recommend that local engineering firms hire. All of these outcomes are valuable to both the students and community.

The projects described had many benefits. The opportunities for these flood-related projects are very abundant. These will continue to be used in the curriculum for the foreseeable future.

Undergraduate students at every level were involved. Freshmen in the University Experience class were introduced to projects similar to those they will see as seniors. Freshmen, sophomores, and juniors in the surveying classes saw the critical need of hydrologic studies for accurate surveying data. The senior hydrology students were able to participate in a real-world problem of great community interest. They also had the experience of seeing how a project can go out-of-scope when something unexpected is encountered. The community, students, and faculty all benefited from these projects.

Lessons Learned

The lessons described here are based on student comments in anonymous questionnaires provided to students frequently, on comments by students, on faculty experience, and on the results of tests and homework.

Overall, this series of projects integrated throughout the civil engineering curriculum seemed to be a positive learning experience for students and is worthy of implementation in some form by other universities. However, some cautions and lessons learned should be considered.

A project-based curriculum provides valuable learning opportunities for students. However, even a project that seems very straight-forward can blossom into a monster causing significant headaches for faculty. Projects were used as 50 percent of the grade for our senior hydrology and hydraulics classes. These projects require significant pre-planning by faculty, and much class time was spent in teaching students how to use Geographic Information System (GIS) software and hydrology and hydraulics software (ArcGIS and E.P.A. Storm Water Management Model). Covering both the basic topics of hydrology or hydraulics and teaching students to use GIS and hydrology/hydraulics software is very difficult within the allotted time. It is best to introduce students to the project early in the term so they can complete them early. Projects from all their classes seem to pile up at the end of the term causing student and faculty dissatisfaction.

The process of developing and completing projects should be formalized by using project books and by requiring students to have team meetings (with and without faculty present). To help evaluate the contribution and grades of each student, attendance should be kept by the students and provided as part of the project book. Weekly project reports that record progress as opposed to the project plan should also be maintained by students. Gant charts and other project management tools and plans should be developed by students and approved by the instructor. If the class is centered on the project, for some classes it may be best to let the students assume some responsibility for determining the content of classroom lectures. That is, discuss with them pieces of the watershed modeling puzzle that are missing for them and adjust lectures accordingly.

The crest gage project for a freshman experience class and the elevation certificate survey for elementary surveying classes are highly recommended. These provided practical experience for students very early in the engineering curriculum.

Universities that require civil engineering students to take a GIS class will have an advantage in implementing this paradigm. Hydrology students mentioned that they wished they had a GIS class before taking hydrology. Without some knowledge of GIS, it will be difficult for water resources engineering students to be competitive. Watershed modeling is greatly simplified by competence in GIS. We developed a GIS for Engineers class and provided it as an elective. Unfortunately, the initial response to the class has been disappointing. However, student word-of-mouth, faculty encouragement, and the new floodplain management minor that requires a GIS course should increase enrolment in the class without adding another required course to an already full curriculum.

Summary and Conclusions

The student engagement/project-based paradigm offers many positives for engineering students. At our university, undergraduate students at all levels have been and will continue to be involved in water resources projects throughout their undergraduate careers. While our area is well suited for providing these projects, the approach can be emulated in many other universities. The integration of projects across the curriculum provides a better student experience and understanding of civil engineering practice. Projects in the classroom should be handled like projects in professional practice with students taking responsibility for planning and executing the projects.

Experience with freshmen students in these projects was particularly positive. The elevation certificate survey provides an excellent elementary surveying lab and provides knowledge that graduates can apply in practice. The construction of crest gages is also an excellent project for universities with freshman experience-type classes.

Working closely with community officials has many benefits. They provide data and projects of importance to faculty and students. The exposure of students to local officials also provided at least one job opportunity for one of our students.

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