Project Based Teaching: A Case Study from a Hydrology Class

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Abstract

Hydrology is currently taught as one-half of a 3-credit course in the Environmental Engineering Program at the Mercer University School of Engineering. The topics covered include the hydrologic cycle, predicting rainfall, estimating runoff volumes and rates, routing runoff hydrographs, and designing stormwater management structures. The first semester this course was taught, the material was presented topic by topic. This format did not demonstrate to the students how the course topics fit together as a whole and how they were used to solve real-world stormwater management problems.

The literature on project-based teaching suggested that this approach could be used to create a more cohesive course structure, help the course move more fluidly from topic to topic, and demonstrate to the students the application of the material they were learning. The challenge was to develop a project that was realistic, incorporated all of the course topics, and contained the appropriate level of complexity. The project utilized required the students to

1. predict the runoff volume and rates from an undeveloped piece of property which drained to a wetlands,
2. predict the runoff volume and rates from the property after it was developed into a residential subdivision,
3. design stormwater management structures for the subdivision, and
4. route the runoff from the development through a detention pond such that the runoff volume and rate discharged to the wetlands matched the pre-development condition.

This paper will present the project used to teach the hydrology class, a matrix demonstrating how the required course topics mapped to the project components, and a qualitative analysis of how the use of project-based teaching affected this class.

1.0 Introduction

Hydrology is currently taught as one-half of a 3-credit course in the Environmental Engineering Program at the Mercer University School of Engineering. The topics covered include the hydrologic cycle, predicting rainfall, estimating runoff volumes and rates, routing runoff hydrographs, and designing stormwater management structures. The first semester this course was taught, the material was presented topic by topic. This format did not demonstrate to the

students how the course topics fit together as a whole and how they were used to solve real-world stormwater management problems.

Literature on project-based teaching[1, 2] suggested that this approach could be used to create a more cohesive course structure, help the course move more fluidly from topic to topic, and demonstrate to the students the application of the material they were learning. The use of a project to drive instruction also seemed to be promising a method to approach an active learning format where the instructor is more of a facilitator than a lecturer. The challenge was to develop a project that was realistic, incorporated all of the course topics, and contained the appropriate level of complexity.

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2.0 Project Details

The project used in a project-driven course may or may not be used to cover all of the course material. The project used to cover the hydraulics section of this course did provide coverage of all of the required topics, see Table 1.

Table 1. Correlation between project topic and hydraulics material covered.

Project Topic	Hydraulics Material Covered
Design storm selection	Statistics, Frequency-Intensity-Duration (FID) curves, geographic dependency of precipitation
Generating rainfall data	Dimensionless rainfall curves
Estimating runoff volumes and rates	Infiltration, Rational Method, Soil Conservation Service SCS Curve Number Method, hydrograph selection, time of concentration, hydrograph routing
Stormwater management devices	Hydrograph routing open-channel flow, swales, gutters, culverts, mass balances, detention ponds

The following section presents the project as it was distributed to the students

2.1 Introductory Statement

A small development project has been planned near Savannah, Georgia and may be permitted in an area adjacent to a protected wetlands and estuary, Figure 1. The area to be developed

currently consists of forested, light brush, and grassed areas. A significant portion of this land drains to the protected area. If this area is developed with out appropriate stormwater control measures, the volume of runoff delivered to the protected area will increase drastically. Also, the quality of the runoff waters will change significantly creating potential pollutant loading problems, Figure 2.

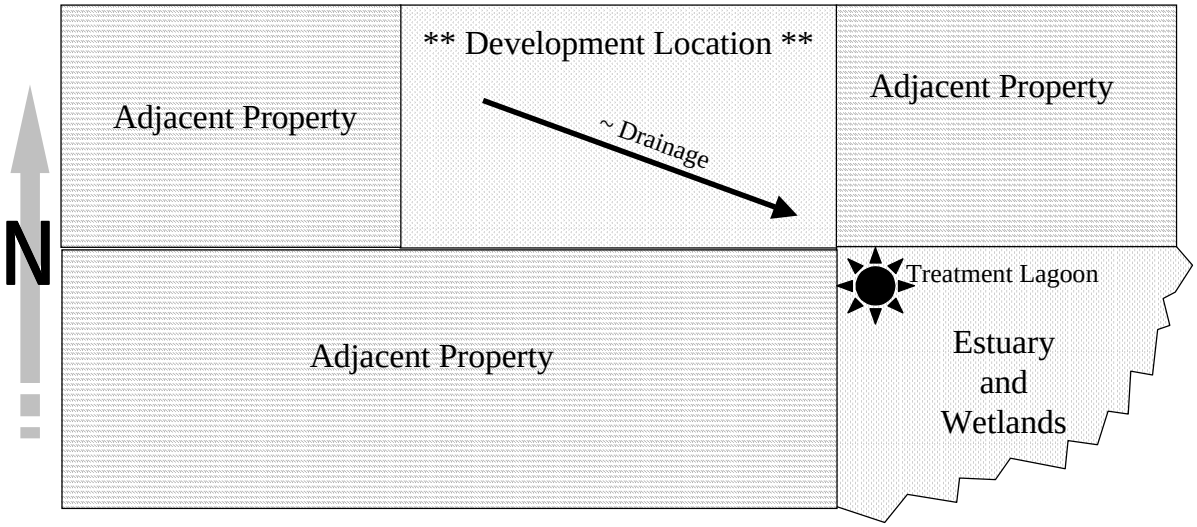

Figure 1. Development site location.

Your task as a junior project engineer is to conduct a preliminary design of the stormwater routing, management, and control devices for the planned development. The protected area must receive runoff waters from the development site in order to remain hydraulically and ecologically stable. Ideally, the stormwater management structures employed at the development site will result in similar pre- and post-development hydrographs, see Figure 3.

The pre- and post-development land-use conditions are shown in Figures 4 and 5, respectively.

You have been requested to design the stormwater management system, see Figures 6 and 7, using a 10 year, 24 hour design storm and to then evaluate the system's performance in the event of a 25 year, 24 hour storm. The design is to be done using the Rational Method to estimate runoff volumes and rates while the evaluation is to be done using the Soil Conservation Service (SCS) Curve Number Method to estimate runoff volumes and the SCS hydrograph to estimate runoff rates.

The required deliverables and grading matrix are shown in Table 2.

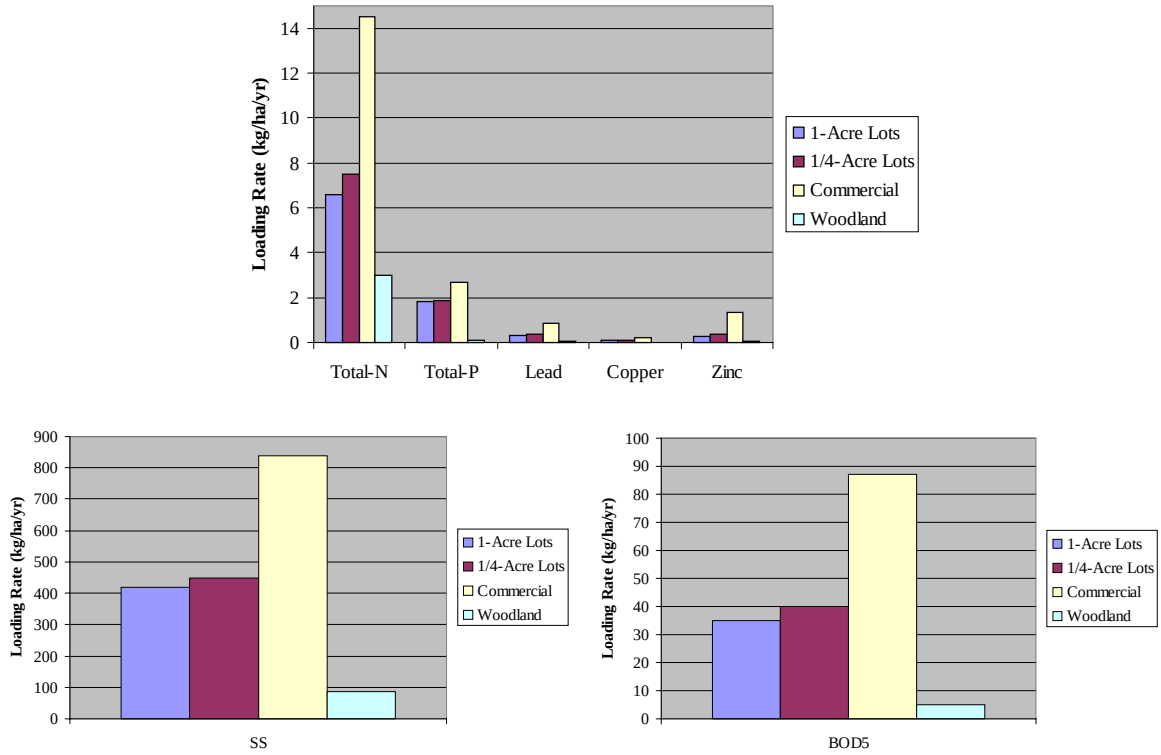

Figure 2. Example pollutant loadings from various land types[3].

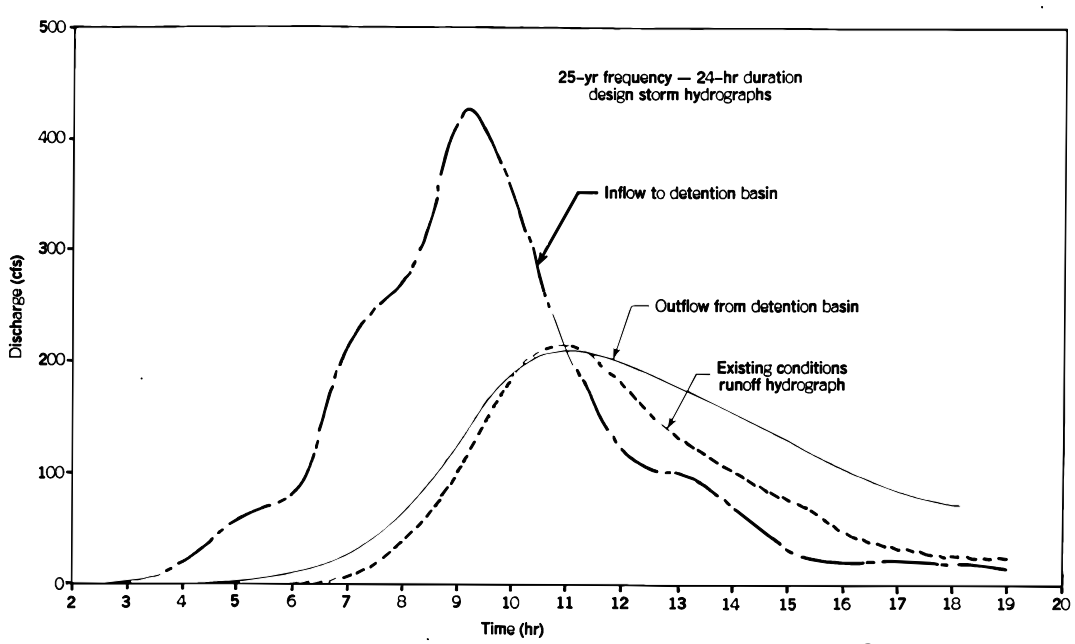

Figure 3. Example pre-condition, post-condition, and routed hydrographs[3].

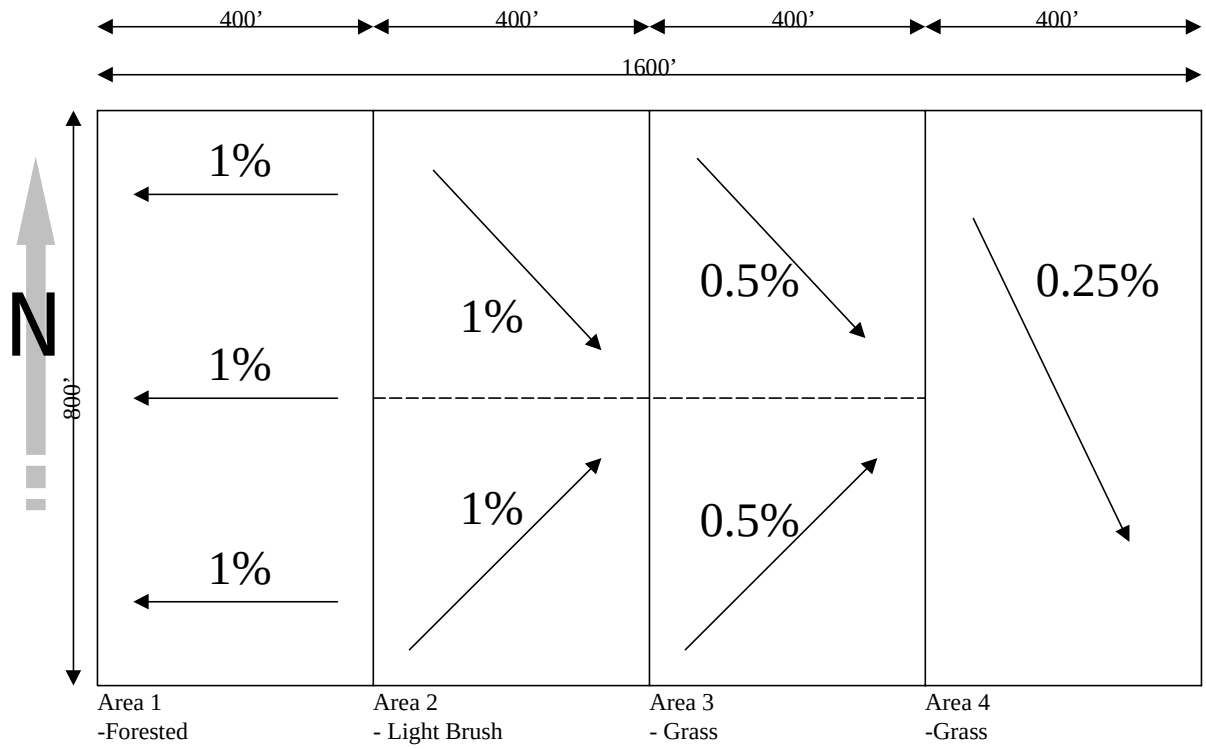

Figure 4. Development site pre-condition land use diagram.

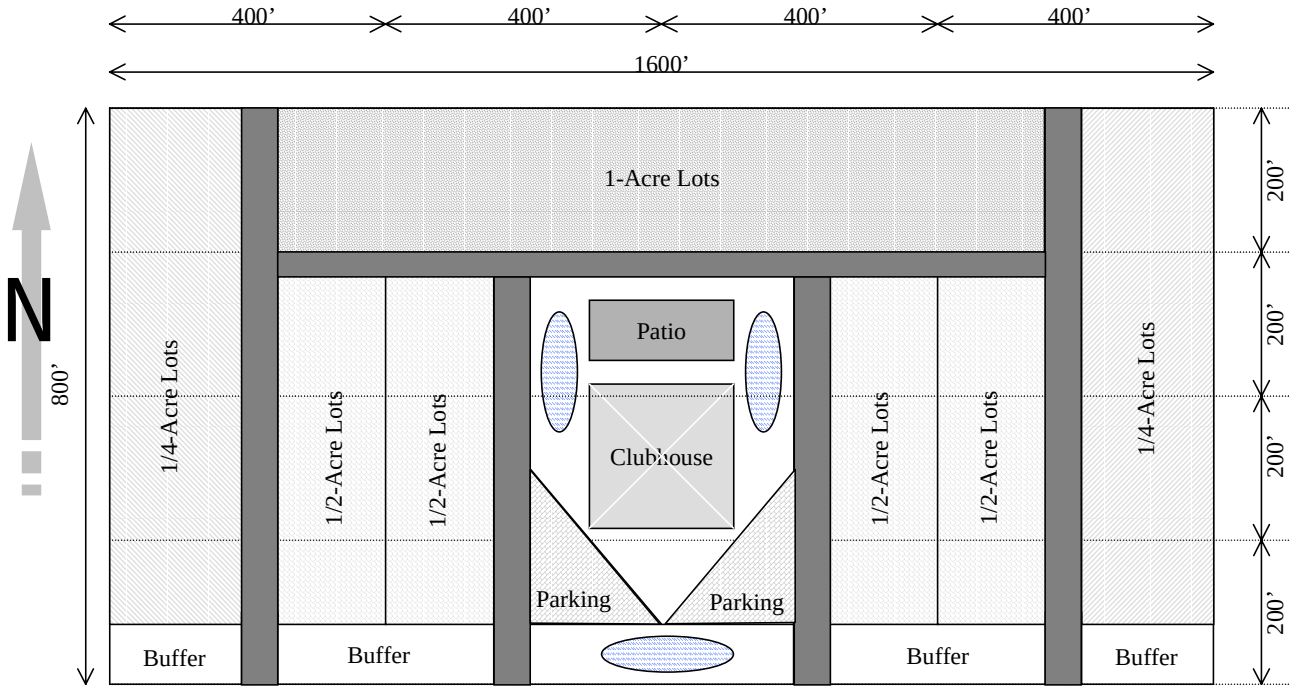

Figure 5. Development site post-condition land use diagram.

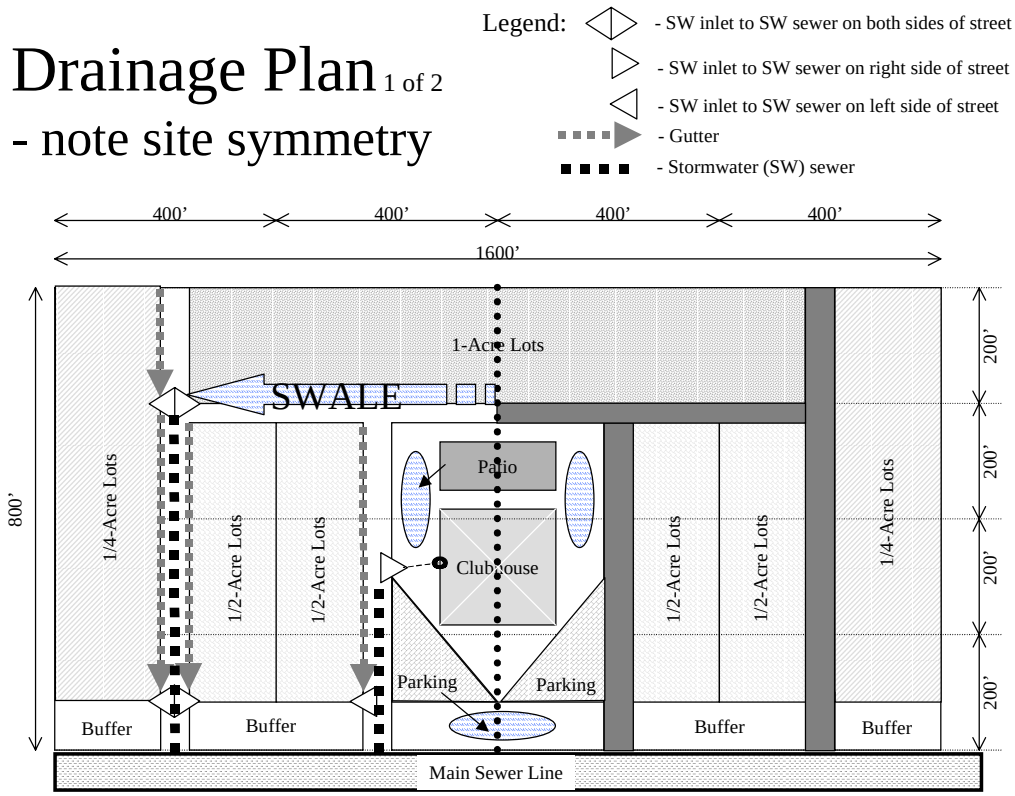

Figure 6. Post-condition drainage and storm water management plan.

Drainage Plan 2 of 2
- note site symmetry

- arrows indicate drainage of patio and parking area through drain pipes to ponds
- ponds route to closest SW sewer
- the clubhouse and the pervious area drain to the SW sewer inlet (▷)

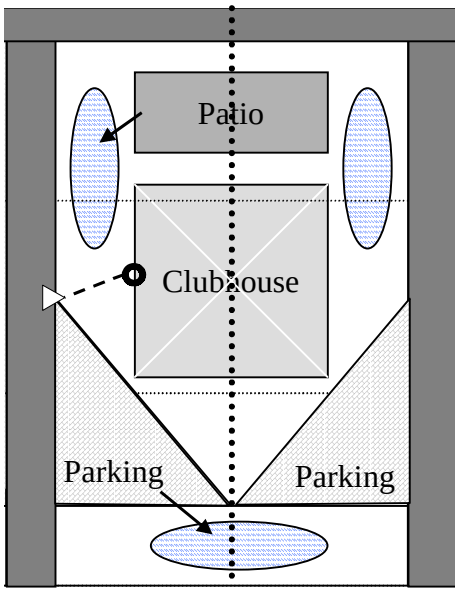

Figure 7. Post-condition drainage and storm water management plan for clubhouse area.

Table 2. Hydrology project deliverables and grading matrix.

Deliverable	Weight	Components:
Design Storm Information	15	• Basic Storm Info - Frequency, Intensity, Duration (FID or IDF) • Basis for selection of the dimensionless storm type • Synthetic storm information - cumulative and incremental rainfalls versus time

Pre-Development Evaluation	20	• Drawing of site
		• Site characteristics including assumptions made and reasoning.
		  • Specification of the time of concentration and the rationale for choosing it will be scrutinized closely.
		• Runoff hydrographs for the individual areas (cfs vs. t)
		  • for the 10 year storm using the Rational Method and of the 25 year storm using the SCS-CN Method and the SCS hydrograph
		• Runoff hydrograph for the south-east corner (cfs vs. t)
		  • for the 10 year storm using the Rational Method and of the 25 year storm using the SCS-CN Method and the SCS hydrograph
		• Total runoff volume from the individual areas and at the south-east corner
		  • for the 10 year storm using the Rational Method and of the 25 year storm using the SCS-CN Method and the SCS hydrograph

Post-Development Design	30	• All calculations should be done based on a 10-year design storm and the Rationale Method
		• Drawing of site
		• Site characteristics including assumptions made and reasoning.
		  • Specification of the time of concentration and the rationale for choosing it will be scrutinized closely.
		• Runoff hydrographs for each surface type (i.e. - 1/4 ac lots, 1/2 ac lots, parking lot, buffer, etc.) in inches/hr versus time. Careful choosing t_c.
		• Runoff hydrographs for individual contributing areas and for points discharging to the main stormwater sewer line in cfs versus time. Careful choosing t_cs and routing flow to the discharge point.
		• Total runoff (volume) from each surface type in inches and from each contributing area and discharge point in ft^3.
		• Discharge hydrograph for the main sewer line and total runoff volume from the site
		• Stormwater conveyance (drainage) device design information (dimensions and engineering calculations). These devices include swales, gutters, and stormwater sewers.
		• Design information (dimensions and engineering calculations) for the main stormwater sewer.
		• Detention pond calculations (on-site ponds and attenuation (routing) pond):
		  • mass balance calculations and assumptions
		  • inflow and outflow hydrographs and pond depths
		  • specification of outflow device(s) for the attenuation pond

Table 2 (cont'd). Hydrology project deliverables and grading matrix.

Post-Development Design Evaluation	25	• All calculations should be done based on a 25-year design storm and the SCS-CN Method and the SCS hydrograph
		• Note: the time of concentration will not change
		• Site characteristics including assumptions made and reasoning.
		• Runoff hydrographs for each surface type (i.e. - 1/4 ac lots, 1/2 ac lots, parking lot, buffer, etc.) in inches/hr versus time.
		• Runoff hydrographs for individual contributing areas and for points discharging to the main stormwater sewer line in cfs versus time. Careful routing flow to the discharge point.
		• Total runoff (volume) from each surface type in inches and from each contributing area and discharge point in ft^3.
		• Discharge hydrograph for the main sewer line and total runoff volume from the site
		• Stormwater conveyance (drainage) device design evaluation (flow depth and performance evaluations). These devices include swales, gutters, and stormwater sewers.
		• Evaluation of the main stormwater sewer (flow depth and performance evaluations).
		• Detention pond calculations (on-site ponds and attenuation (routing) pond):
		  • mass balance calculations and assumptions
		  • inflow and outflow hydrographs and pond depths
		  • evaluation of outflow device(s) for the attenuation pond

Clarity / organization	15	• Grammar, v • Organization, • Clarity, • Consistency

Grading Criterion:

Excellent (>90)	- correct theory, calculations, figures, assumptions
Good (80-90)	- correct theory and assumptions, Few calculation errors, mediocre Figures
Fair (70-80)	- correct theory, incorrect assumptions, calculation errors, poor figures
Poor (<70)	- incorrect theory, incorrect assumptions, calculation errors, poor figures, incomplete

3.0 Qualitative Analysis

The use of a project to teach hydrology was generally successful. The majority of the students demonstrated that they understood the concepts and were able to use them to solve hydrology design problems. Students commented that they liked the use of a project to teach the course and that they felt they came away with knowledge they will use in their professional career.

There were several issues that must be addressed in future offerings of the course. Many student projects suffered from excessive procrastination. The students had been required to submit two design updates during this project to assure that they were staying on track. The updates were a status report on what parts of the project had been completed, where they were going next, where they were stuck, and what (if any) help they needed. The students were not required to include calculations and results in these updates. It later became clear that while all of the students appeared to be making good progress based on these updates, many were significantly behind. The updates had essentially been falsified.

While the students had been provided with a deliverables matrix, many of the reports were not organized relative to the deliverables. Grading these reports was difficult and time consuming.

The post-development site had too many pieces to analyze and many of the calculations were excessively redundant. This resulted in the students spending a lot of time doing essentially busy work and the generation of a lot of extra data and paper in the reports.

Finally, this effort demonstrated that a project can be used to cover all of the materials in a course and link them together into one, cohesive unit. From the instructional theory perspective, this is obviously a very good idea and this effort demonstrated that it may be achieved.

4.0 Planned Modifications

In order to improve both the student and professor experience in this course, the following changes have been planned for the next course offering (Fall 2002).

Students will be required to submit three design checks with calculations for this project, Table 3. The implementation of these design checks should assure that the students are keeping pace with the project and identify any mistakes before submittal of the final project.

Table 3. Design check contents.

Check Number	Contents
One	Design storm information, pre-development runoff evaluation using the Rational Method
Two	Post-development stormwater management conveyance device design, pre-development runoff evaluation using the SCS Curve-Number Method and SCS hydrograph
Three	Detention pond design, evaluation of the performance of the stormwater management devices in the event of a 25 year, 24-hour design storm-

The development plan will be simplified so that there are fewer runoff hydrographs to generate and there are fewer repetitive calculations for the design and evaluation of the stormwater management devices. The new development plan is shown in Figures 8 and 9.

5.0 Conclusions

Project-based teaching is a very exciting and useful teaching technique that can be used to draw diverse course materials together into a cohesive unit. Furthermore, when the overall project is broken down into sub-tasks, a just in time teaching format quickly develops.

New challenges are also faced when utilizing project-based teaching. Many students will have to be motivated to keep pace with the design and encouraged to struggle when an answer does not readily present itself.

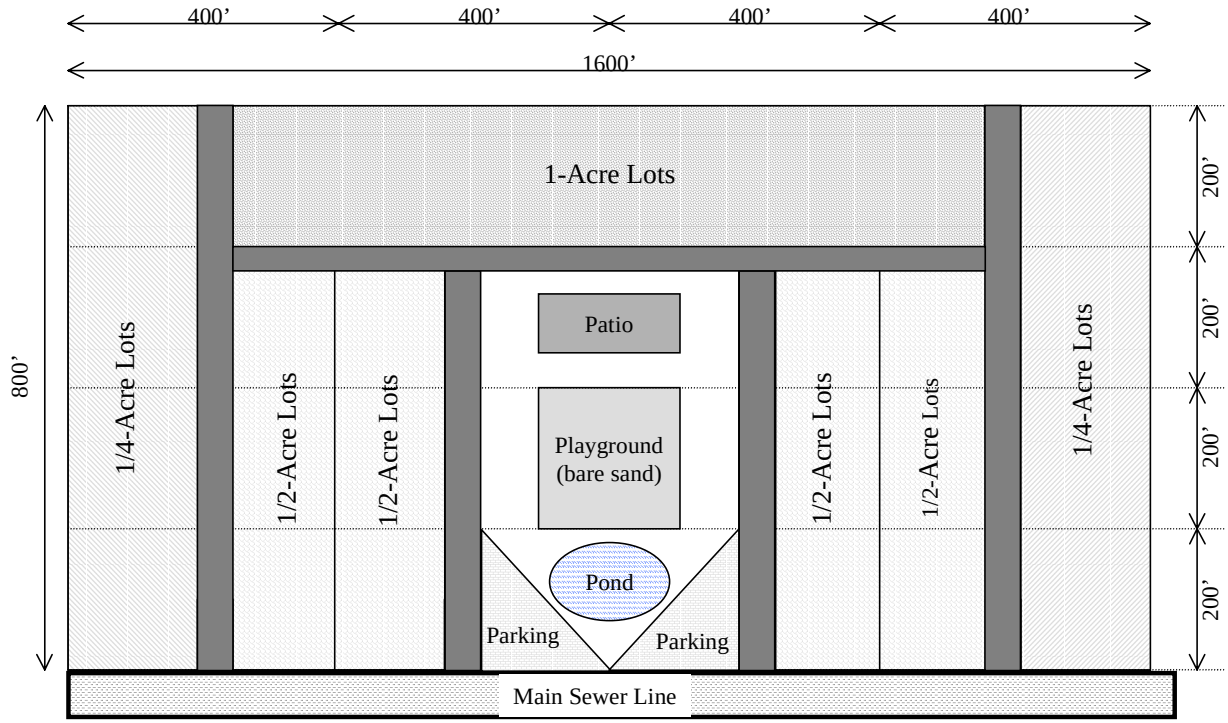

Figure 8. Amended post-condition site plan

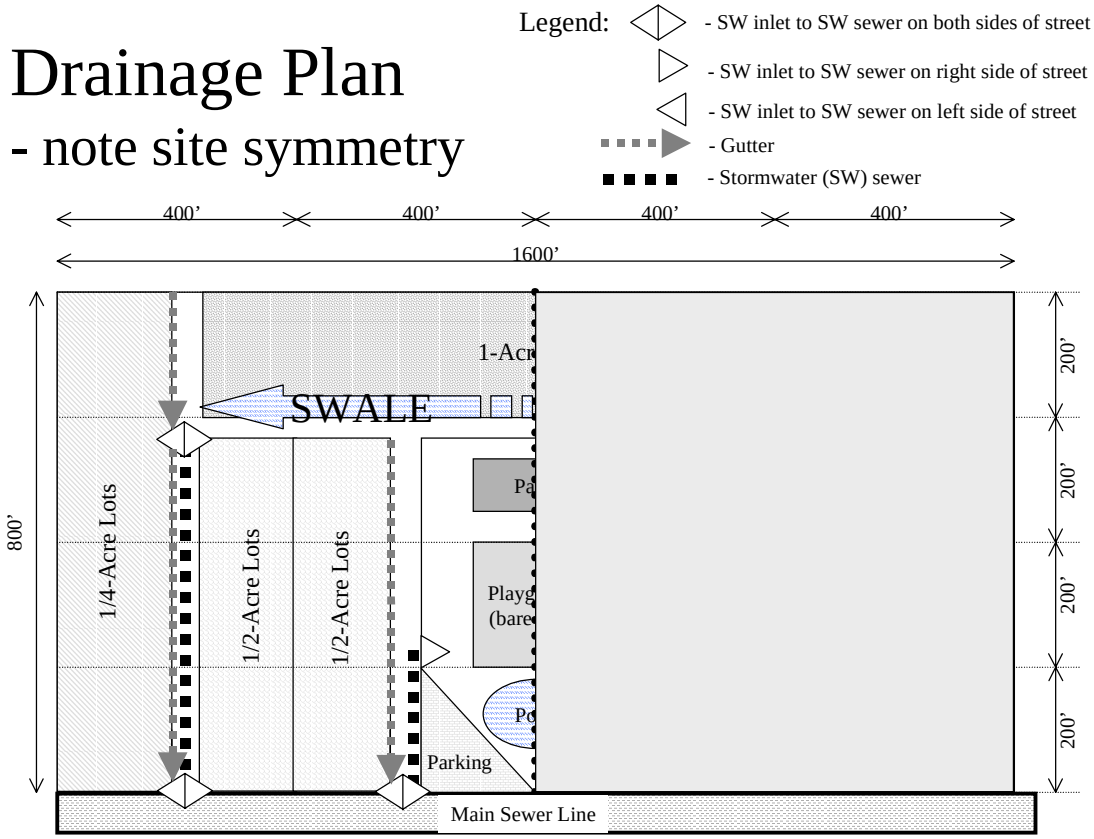

Figure 9. Amended post-condition drainage and storm water management plan.

References

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2 - Mahendran, M., "Project-Based Civil Engineering Courses," *Journal of Engineering Education*, July 1995.

3 - Wanielista, Martin P., Hydrology and Water Quantity Control, John Wiley & Sons, New York, NY, 1990.

Biographical Information

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