AC 2010-2221: WATERSHED IMPERVIOUS SURFACE STORM WATER ASSESSMENT

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Abstract:

The Sustainable Development and Next Generation Buildings class worked with Arlington County Virginia to assess impacts and alternatives for a sensitive storm water project in the county. This was a real world application of the subjects and technologies used in the class room for storm water management and planning. Within Arlington County there is an enhanced awareness of the potential to restore urban watersheds through the application of low impact development (LID) and best management practices (BMP). Some of these options include localized use of small-scale bioretention systems, rain barrels, permeable paving, rainwater collection, and vegetated roofs and incremental impervious cover reduction. To understand the potential for LID and BMP applications current condition and location of impervious surfaces in a watershed is necessary. This study collected imagery and conducted data analysis on the Little Pimmit Run watershed as part of a flood control project. High resolution airborne photography was collected during the spring of 2007. The photographic data was converted to digital imagery, geo-rectified, boundary corrected and translated into polygon data for entry into a Geographic Information System (GIS) data management system. Seven impervious surface land use characteristics were selected for evaluation. They included roofs, alleys, handicap ramps, driveways, paved medians, road ways, sidewalks and parking lots. The total impervious surface area in the watershed was determined to be 36.11% of total area. These findings are being used for exploring LID and BMP options that will have the best potential for application in this watershed.

Key Words: GIS system, map data sharing, GIS analysis tools, impervious surface analysis, and information sharing

Course Description

The course introduces the concepts, applications and tools for analysis and decision making in support of sustainable environmental development and next generation communities and building design. Students are introduced to a variety of challenges related to environmental protection, stewardship and management of air, soil, and water. The underlying principals of ecological protection, stewardship, reduced environmental footprint, ecosystem capital, sustainable economic development and globalization impacts are reviewed. The integration of actions that are ecologically viable, economically feasible and socially desirable to achieve sustainable solutions is evaluated. Within this context sustainable building concepts are explored that are intended to provide though out their lifetime a beneficial impact on their occupants and their surrounding environment. Such buildings are optimally integrated on all parameters-initial affordability, timeliness of completion, net life-cycle cost, durability, functionality for programs and persons, health, safety, accessibility, aesthetic and urban design, maintainability, energy efficiency, and environmental sustainability. The principles of LEED building design and certification are introduced and example projects reviewed. Integrated design and construction practices that significantly reduce or eliminate the negative impact of buildings on the environment and occupants are assessed in the broad areas of: 1) sustainable site planning, 2) safeguarding water and water efficiency, 3) energy efficiency and renewable energy, 4) conservation of materials and resources, and 5) indoor environmental quality. A critical element for a successful sustainable building policy and program is an integrated building planning and design process. Integrated planning and design refers to an interactive and collaborative process in which all stakeholders are actively involved and communicate with one another throughout the design and construction practice. These processes provide a broader understanding of sustainable options for infrastructure changes that may occur in various Base Realignment and Closure (BRAC) planning and implementation situations. A number of case studies are examined to gain an understanding of application issues.

Course Goal
To introduce the concepts, applications, tools and environmental understanding for analysis and decision making in support of sustainable environmental development and next generation building design.

Course Objectives

- Acquire an understanding of the principals of ecological protection, stewardship, reduced environmental foot print, ecosystem capital, sustainable economic development and globalization impacts
- Learn the variety and character of the challenges related to environmental protection, stewardship and management of, air, soil, and water.
- Understand the Leadership in Energy and Environmental Design (LEED) principles for building design and the certification process
- Gain an understanding of the options for sustainable site planning, water and energy efficiency, storm water management and conservation of materials in building applications

Topics Covered

- Ecosystems and Sustainability
- Ecosystem Functions and Changes
- Human Population Dynamics and Into to Next Gen Building Concepts
- Renewable Resources and green materials
- Low impact development principles
- Low impact stormwater management
- Biodiversity and LEED concepts
- Sustainable Energy Systems
- Environmental Hazards and LEED case studies
- Pollution Prevention and Sustainability
- Building Deconstruction Principals
- Economics of sustainability and LEED case studies
- Public Policy and community case studies

This course is one of five core courses in a new post-masters program at Johns Hopkins University in Climate Change, Energy, and Environmental Sustainability.

Class Project Development

Working with Arlington County the instructor explored current projects on stormwater management and flood control. There were a number of consideration in the selection of the project to best meet the class objectives and would generally apply to class projects in this area. They included: 1) a project that was currently in the planning stage but very close to implementation, 2) a project that included low impact development and storm water components, 3) a project that the county (or government organization) had a strong interest in and have a significant amount of data and study information already available and 4) a county government team that was collaborative, interested in working with a university class and open to additional input and suggestions. In this case the Little Pimmit Run flood control project presented some good opportunities to evaluate the amount of impervious surface in the water shed as a way to better understand low impact water management options for the project. The county had an up to date comprehensive digital data base of land use features in the watershed from their bi-annual imagery collection program. The data base had also been transported into the Environmental Science Research Institute (ESRI) GIS information system. Working with the county GIS Center the polygon information for various land use characteristics in the watershed were defined and segregated to allow more detailed evaluation of the respective amounts of impervious surface in each category of land use. Students participated in the selection of land use categories and in the evaluation of the water shed impervious surfaces. The analysis results are presented in a later section of the paper.

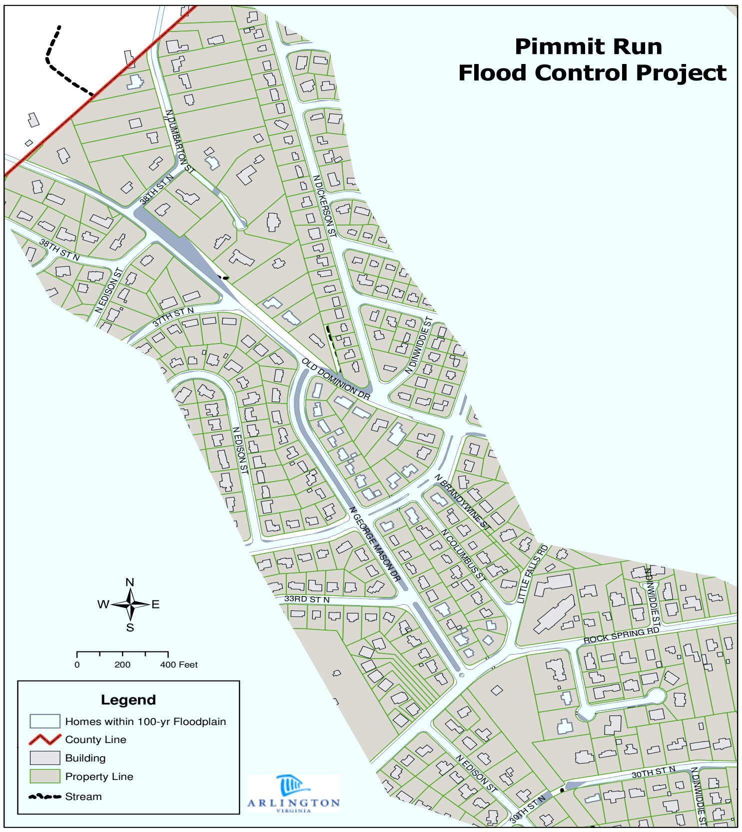

Figure 1: Little Pimmit Run showing homes that were flooded in the summer of 2006 in black

Project Objective:
The objective of the project was to give students experience in using real project data to assess impervious surface challenges for a flood control project and to provide insights for low impact water management options.

Background on the Little Pimmit Run Flood Control Project

The Little Pimmit Run project involved a culvert replacement project under a major state road to reduce flooding potential in a residential neighborhood that had experienced extensive flooding in 2006. Approximately 30 homes along Little Pimmit Run fell within the Federal Emergency Management Agency (FEMA) 100-year floodplain (figure 1). Many of these homes have been subjected to flooding over the past 40 years, including most recently during the storm events of July 2001 and June 2006. The stream is typical of most streams in Arlington County, exhibiting erosive velocities and ongoing stream bank erosion, areas of channel hardening, degraded habitat and water quality, and surcharging into the floodplain during severe storms.[1, 5, 6]

An important factor that makes these typical problems more acute in this watershed is the

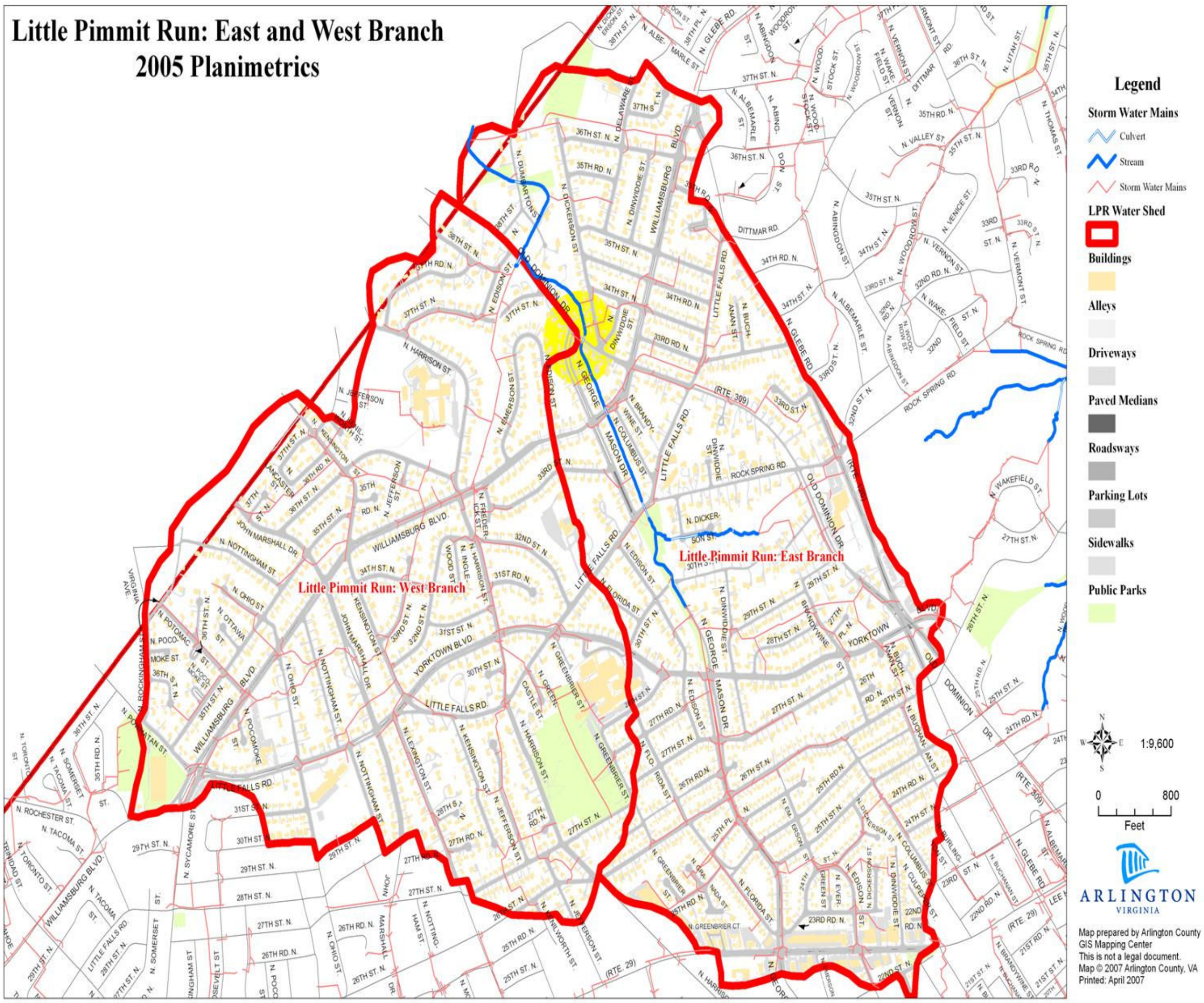

Figure 2: The Little Pimmit Run Watershed (southern and northern branch) outlined in red. The phase I flood control project is highlighted in yellow. Little Pimmit Run is shown in blue.

extensive residential development that has occurred within the stream's active floodplain both upstream and downstream of Old Dominion Drive. Most of Arlington's streams are contained within parkland, where stream erosion and over bank flooding, while often responsible for damage to utility and park infrastructure, generally do not impact private properties. In this watershed the encroachment of homes along the stream not only lead to greater frequency and impact of flooding and other problems, but the encroachment also severely restricts the opportunity and available methods for stream restoration (figure 2).

This watershed was originally identified in the County's Capital Improvement Plan (CIP) in the mid 1980's for a flood control project, and originally funded for a study in 1994.[4, 1] In 1998, the County issued a Request for Proposal (RFP) and selected Michael Baker, Inc., to provide a hydrologic/hydraulic analysis of the watershed and stream and to identify alternatives to address the flooding problems between Little Falls Road and the County line.

The study included an extensive public process with at least five public meetings and the guidance of a Citizen Advisory Committee which included residents from both upstream and downstream of Old Dominion Drive. More than a dozen potential solutions were evaluated, including watershed-scale stormwater controls such as stormwater detention. Ultimately, the consultant recommended the replacement of existing culverts beneath Old Dominion Drive and Williamsburg Blvd as well as channel improvements upstream of Williamsburg Blvd as the most feasible and cost-effective solutions to address flooding problems.[3, 7] The consultant's recommendation was approved by the Rock Spring Civic Association.

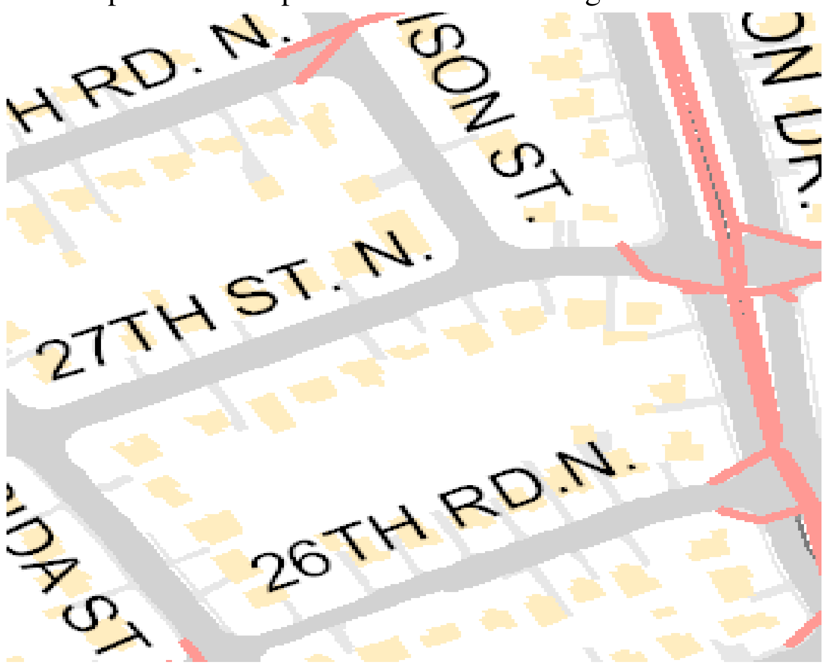

Figure 3: Detail of polygon characteristics for the identifying different land use features in the Little Pimmit Run Watershed

Because the great majority of the significant property flooding issues along Little Pimmit Run are located in the blocks between Old Dominion Drive and Williamsburg Boulevard, most of the alternatives identified by the consultant were focused on reducing flood water elevations upstream of Old Dominion Drive.[7, 1] Of the 29 homes within the FEMA 100-year floodplain, 25 of them are located upstream of Old Dominion Drive, and these homes have historically been most susceptible to flooding at intervals far more frequent than 100 years. Phases I and II of the proposed project will remove twelve of these homes from the floodplain, and will reduce the flood risk at an additional ten.

Impervious Surface Assessment

Within Arlington County and across the region, there is enhanced awareness of the potential to restore urban watersheds through the implementation of multiple stormwater storage and retention projects distributed across the watershed. These options could include small-scale or site-level stormwater storage (e.g., bioretention systems, permeable paving, rainwater collection, and vegetated roofs) and incremental impervious cover reduction (e.g., by narrowing certain streets, where feasible), in combination with more conventional underground and (where land is available) aboveground stormwater storage and treatment systems.

However, due to the concerns of many of the downstream residences a thorough geospatial analysis was needed to get an understanding of the amount of impervious surfaces present in the Little Pimmit Run watershed at the present time. This could be used to evaluate the potential for best practices for runoff management such as holding ponds, rain barrows and water gardens. Figure 3 illustrates the detailed information for different land use characteristics that was extracted from the remote sensing and GIS data bases for the watershed.[5, 2, 7] In this figure the roads, sidewalks and driveways are colored gray. Home roof top areas are colored yellow and the storm drain system is red.

Table 1. Impervious surface in the Little Pimmit Run watershed based on geospatial analysis of the GIS polygon data files derived from aerial imagery

Little Pimmit Run: East and West Branch Statistics		
Little Pimmit Run Shed Area	Area(sq. ft.)	Houses (#)
East Branch	22983003.9327	1862
West Branch	21300929.3217	1286
Total Area	44283933.2544	3148
Impervious Areas within Little Pimmit Run East & West Branch	Area(sq. ft.)	Coverage Percent
Roof Top Area	5539877.6845	12.51%
Alleys	12823.9232	0.03%
Handicap Ramps	15857.1361	0.04%
Driveways	2181138.2765	4.93%
Paved Medians	42392.7232	0.10%
Road Ways	6179775.1325	13.95%
Sidewalks	1179988.5999	2.66%
Parking Lots	838822.9408	1.89%
Total Paved Area	10450798.7322	23.60%
Total Impervious Area	15990676.4167	36.11%

Students participated in selecting and collecting the polygon data to get a better understanding of the potential for various options the water shed uses of impervious surfaces for roofs, roads, driveways, sidewalks, alleys, handicapped ramps and paved medians were segregated and their total area calculated by category. Table 1 summarizes the results of this analysis.
The water shed has a total area of 4.4 billion square feet and 3,148 homes plus a school and a limited number of commercial structures. It is divided into two relatively equal segments the East Branch and West Branch. The flood control project is located in the East Branch. The East Branch has almost 2.3 billion square feet of surface area and 1,862 homes. The percentage of impervious surface for the water shed is 36.11 percent. An example of the close proximity of homes to Little Pimmit Run in the area of the flood control project is shown in figure 4. This has largely result from the early development of most housing and land development in Arlington being constructed by the 1950s before environmental constraints and regulation. In the case of this project the property lines for homes along Little Pimmit Run extend to the center of the stream with no set back.

Figure 4: A section of Little Pimmit Run within the flood control project showing closeness of

Roads and roof tops were the two largest sources of impervious surface followed by drive ways and sidewalks. The watershed is very stressed being well over the 20% threshold for impervious surface coverage. The analysis and outcome were shared with the community both at public meetings and through the GIS interactive Web site. The ability to demonstrate this application and share the results broadly was a significant contribution to gaining support for the project both from the residents and the County Board.

The analysis by the class did identify some areas for potential reduction of stormwater runoff through better management of roof runoff using rain barrows and water gardens. To have any significant impact a high percentage of the home owners in the watershed would need to install and manage rain barrow systems around their homes. More aggressive measures such as underground storage, converting street parking areas to bio-retention areas would be quite costly to the county. One of the best approaches from and environmental standpoint discussed would be county purchase of all the homes next to Little Pimmit Run, remove the structures, and create a park with three to four water retention ponds. A gross cost estimate for this approach was in excess 800 million dollars and significantly beyond county budget constraints.

However, with this awareness of the more doable options also comes the recognition that most of these techniques will provide stormwater quality and quantity benefits gradually over the long-term (e.g., 20+ years), as locations are identified for specific small-scale projects and individual properties are redeveloped with improved stormwater controls.

Conclusions

The opportunity to participate in a real world project and contribute to the data analysis was very well received by the students. It also gave them an appreciation for the constraints that stormwater management projects can have from a governmental budget standpoint. Over all the project objective for the course (to give students experience is using real project data to assess impervious surface challenges for a flood control project and to provide insights for low impact water management options) was met and was reflected in very high class evaluation ratings in this area at the completion of the course. This project also presented the students with the challenges that local governments often must address between longer term better environmental solutions and near term flood management requirements. In this case the near term need (with budget constraints) to reduce the flooding risk for the impacted neighborhood led to changes that were not the best long term low impact development option. The impervious surface analysis in the Little Pimmit Run watershed did allow for a better understanding of flood risk reduction and can be used as a tool for future programs in the watershed to reduce flooding risk regardless of the near term project decision.

Within Arlington County there is an enhanced awareness of the potential to restore urban watersheds through the application of low impact development (LID) and best management practices (BMP) which led to more pressure on the county to seriously consider these practices in the design of local stormwater projects. Some of these options considered in the study included localized use of small-scale bioretention systems, rain barrels, permeable paving, rainwater collection, and vegetated roofs and incremental impervious cover reduction. To understand the potential for LID and BMP applications current conditions and location of impervious surfaces in the watershed was necessary. To address this high resolution airborne photography that was collected during the spring of 2007 was used in the analysis. The county's photographic data was a rich source of information for the study. The raw photographic information was converted to digital imagery, geo-rectified, boundary corrected and translated into polygon data for entry into a Geographic Information System (GIS) data management system. Seven impervious surface land use characteristics were selected for evaluation did work well for identifying flood control options. They included roofs, alleys, handicap ramps, driveways, paved medians, road ways, sidewalks and parking lots. The methodology developed for this study provides a good framework for future watershed assessments for flooding risks and planning option development for Arlington County.

For the Little Pimmit Run application, unfortunately, incremental implementation of the various strategies over decades will not provide immediate solutions to today's flooding, environmental, and infrastructure damage problems. These strategies may not be sufficient to restore stream ecology and protect valuable infrastructure in the near term, due to the significant level of development and floodplain encroachment that already exists in this watershed. Therefore, near-term and long-term solutions were recommended in parallel with the County's urban watersheds management plan because of the range of acute conditions that exist. The impervious surface analysis will continue to be a very useful tool for assessing alternatives in the future for watershed planning and implementation in the Little Pimmit Run watershed.

Bibliography

1. Arlington County Board Report, April 16, 2007, Approve the Award of a Contract to Sagres Construction Corp. for the construction of Phase I of the Little Pimmit Run Flood Control Project, Arlington County, Virginia

2. Arlington County GIS Mapping Center Handbook, Department of Environmental Services, Arlington County, Virginia, September, 2005

3. Arlington County Home Page, June 2007, http://www.arlingtonva.us/Departments/EnvironmentalServices/cpe/PimmitRunProject.aspx

4. Arlington County New Directions: A Strategic Plan for Arlington County's Geographic Information System, February ,1994

5. Fletcher, Mary Beth and Roper, William E., June 19, 2007, Implementation of a Fully Integrated Web-GIS Solution, ESRI Users Conference Presentation, San Diego, California

6. Notice of Public Meeting and Background Material, February 8, 2007, Little Pimmit Run Flood Control Project, Yorktown High School, Arlington, Virginia

7. Roper, William E., Presentation to the Arlington County Board, April 24, 2007, Little Pimmit Run Flood Control Project, Arlington, Virginia