A Class Project Measuring Sustainability Metrics of the Green Roof on the New Business Instructional Facility

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I. Detailed Project Description:

A. Project justification and goals

Urban landscapes are relatively impervious. Consequently, they have traditionally been designed to drain water as quickly as possible to avoid water buildup and subsequent local flooding. Receiving water structures such as storm sewers have also been designed to drain water as quickly as possible to avoid local flooding. As a result, the peak discharge is considerably greater, and time of concentration is considerably shorter, for downstream receiving water bodies compared to pre-urbanization. This has two major consequences. There is a higher likelihood of catastrophic flooding during large rain events; there are higher sediment loads carried by storm water runoff into receiving water bodies. The latter is important both for biochemical oxygen demand, and because particles are the primary carriers of organic and inorganic pollutants (i.e., particle associated contaminants, PACs).

In an effort to reduce peak discharge and PAC runoff, best management practices are increasingly being used in urban areas. These technologies provide some on-site storage of stormwater, promote groundwater recharge and/or evapotranspiration, and capture PACs. One example is the green roof on the new Business Instructional Facility being constructed on the corner of Sixth and Gregory Streets on the UIUC campus. The intensive green roof (Figure 1) covers ~2300 ft^2, it captures, stores, and evapo-transpirates rainfall, and it acts as a filter to capture PACs deposited from the atmosphere. The green roof also has the added benefit that it provides insulation beyond a conventional roof and is expected to reduce heating and cooling loads

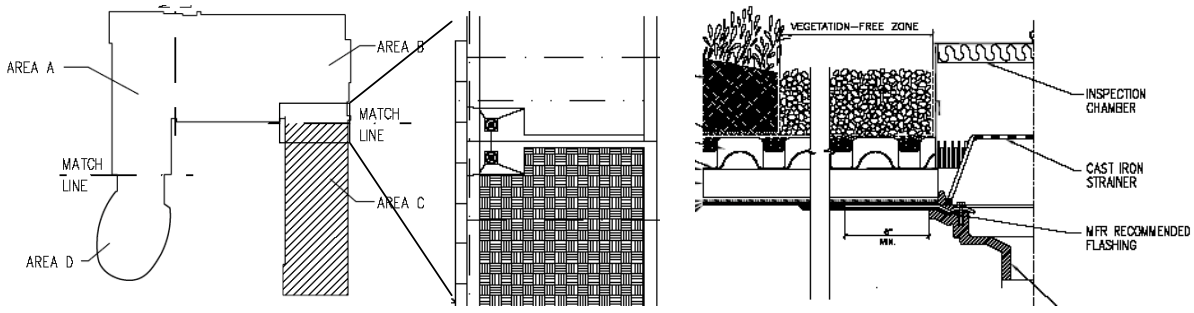

Figure 1. (left) Business instructional Facility with green roof location, (middle) plan view of green roof and conventional roof with two downspout locations, (left) cross section of green roof and drain.

While green roofs, and other best management practices, have been qualitatively shown to reduce runoff and capture PACs, little has been done to quantify their performance for rigorous design. As a result, their impact on downstream receiving waters is unknown, and their acceptance among developers, the building construction community, and regulators is marginal. Further, there are few opportunities for students to learn about design guidelines and quantitative impacts of green roofs on campus.

The **primary goal** of this project is to provide undergraduate and graduate students in Professor Werth's Hazardous Waste Management course (CEE440) in the Spring of 2009, and in his Sustainable Urban Engineering (CEE498SUE) course in the Fall of 2009, with the opportunity to quantify the environmental impacts of the green roof on the new Business Instructional Facility. The specific objectives of this project are for student to 1) apply principles learned in these courses to a real-world application, 2) become familiar with proper data collection and presentation methods, 3) learn how to maintain and operate various pieces of analytical equipment, 4) quantify the ability of the green roof to filter and transform pollutants deposited from the atmosphere, and 5) quantify the ability of the green roof to reduce runoff, and 6) quantify the ability of the green roof to reduce heating and cooling loads.

B. Project location, coordination with Facilities and Services, and overall approach

In coordination with Facilities and Services, Professors Werth and Schmidt purchased and installed monitoring equipment on the green roof at the new Business Instructional Facility that allows measurement of total rainfall for individual storm events, drainage from both the green roof and an adjacent conventional roof, soil moisture in the green roof, and roof temperature. They also installed a water-sampling device that allows them to capture the first runoff from all storm events for subsequent analysis to determine particle loads, and concentrations of polycyclic aromatic hydrocarbons (PAHs) and brominated flame retardants (BFRs) associated with the particles. While there are many other pollutants associated with particles, these two class of pollutants will serve as surrogate for other semi-volatile organic chemicals (e.g., pesticides, PCBs, solvents, etc.) deposited by wind-blown particles. Metals will not be studied at this time, but remain of future interest.

Equipment purchased includes a data logger to control instrument sampling /monitoring and data recording; rain gage; air temperature, relative humidity, wind speed, and solar radiation sensors to provide data to describe evapotranspiration; soil moisture and soil temperature sensors to describe the moisture and energy fluxes in the soil of the intensive green roof; flumes and water-level sensors to determine the flows into downspouts draining the roof; and samplers to capture runoff water from the conventional and green roof areas.

C. Definition of sustainability and relationship of project to this definition

The most accepted definition of sustainability comes from the Brundtland report, which defines sustainability as development that meets the needs of the present without compromising the ability of the future to meet its needs. This definition is broadly applicable and applies to this project as well. Specifically, we anticipate that green roofs

will reduce water and pollutant loads on down-stream systems, and reduce energy costs associated with building heating and cooling. This translates into less material and energy resources required per square foot of development space, and more material and energy resources available for future generations. On a larger scale, quantification of the water quality, water quantify, and energy metrics associated with green roofs identified in this proposal will allow determination of how the overall water quantity and quality budget of the campus will be impacted by additional green roofs, of how the overall energy budget of the campus will be impacted by additional green roofs, and whether additional green roofs are warranted. If obvious benefits are identified (which we expect), then additional green roofs will be installed on campus and around town and this will further reduce our material and energy needs per square foot of development.

One additional goal of this effort is to transform the green roof on the Business Instructional Facility into a campus laboratory that will allow generations of students to be trained in sustainable design practices. This includes students in Professor Werth's courses (CEE440, CEE498SUE), students in Professor Schmidt's courses (CEE453), and graduate student researchers associated with this effort. We anticipate that this will change how students approach and solve problems, and will ultimately result in more material and energy efficient designs for urban infrastructure.

II. Budget & Fundraising:

A. Detailed budget

The requested budget for this project is listed below. It includes support for 2 new atmospheric deposition samplers to capture dry and wet deposition of selected pollutants on the green roof, analytical costs in order for students to determine concentrations of the selected pollutants in the atmospheric deposition samplers and green roof run off water, and costs for a graduate student to help students in my courses with these efforts. Two new atmospheric samplers are needed, one to sample from another roof location and one as a backup because the devices are fragile and may break. The graduate student will be responsible for working with the students in my courses (CEE440 and CEE498SUE) during Spring 2009 and Fall 2009 to help them take samples, preserve and store samples, extract and concentrate pollutants from samples, and analyze the samples using the GC/MS (gas chromatograph/mass spectrometer). I estimate that this effort will take approximately 10 hours per week so I've requested support equivalent to a ¼ time research assistantship.

Description	Funding Requested	
New atmospheric monitoring devices	$800/item * 2 = $1600	
GC/MS Analytical Costs	$3000	
Graduate Student Support	$8532	
TOTAL REQUEST	$13,100	

B. Fundraising

Initial costs to install monitoring equipment on the green roof were obtained from a grant from the Environmental Council at UIUC, and from a teaching equipment grant from the College of Engineering. Approximately $3000 was obtained from the Environmental Council, and $10000 was obtained from the College of Engineering. These funds were used to purchase a data logger to control instrument sampling/monitoring and data recording; rain gage; air temperature, relative humidity, wind speed, and solar radiation sensors to provide data to describe evapotranspiration; soil moisture and soil temperature sensors to describe the moisture and energy fluxes in the soil of the intensive green roof; flumes and water-level sensors to determine the flows into downspouts draining the roof; samplers to capture runoff water from the conventional and green roof areas; and one atmospheric deposition sampler. These systems have all been installed on the roof of the new Business Instructional Facility in cooperation with UIUC Facilities and Services.

The graduate student, Najwa Obeid, is presently supported on a GAANN fellowship (Graduate Assistance in Areas of National Need) that the PI secured from the Department of Education. This fellowship provides partial support of approximately one dozen minority and women PhD students in Environmental Engineering. During the Spring 2009 and Fall 2009 semesters, the graduate student will received approximately $6000 from the GAANN program. I will supplement this with the support requested in this proposal.

III. Timeline

This project will take place during the Spring and Fall semesters of 2009. In the Spring semester, students in my Hazardous Waste Course (CEE440) will monitor green roof atmospheric deposition and runoff water for the pollutants identified in the project description. They will also monitor these same chemicals in runoff from a standard roof section on the same building, and they will monitor precipitation and runoff volumes. In the Fall semester of 2009, students in my Sustainable Urban Engineering course (CEE498SUE) will monitor for these same parameters at the same locations, and they will monitor temperatures above and below the green roof and a conventional roof to determine energy savings of the former.

During each semester the students will spend their time in the following manner:
Maintenance of sampling equipment: 20 hours
Sampling during dry and wet periods: 40 hours
Sample preservation, transportation and storage: 20 hours
Sample filtration, extraction, and cleanup: 40 hours
Sample analysis using GC/MS: 10 hours
Analysis and presentation of results: 40 hours
This comes to a total of 170 hours of student time. I anticipate that between 15 and 20 students will take each of my courses. This comes to between 8.5 and 11.3 hours of effort per students. My graduate student will assist the students in all of these duties.

These efforts are not possible without a graduate student, as it takes hundreds of hours for a student to become proficient in the various sampling and analysis activities.

IV. Energy, Environmental, Social and Economic Impact

Green roofs are becoming an increasingly common approach to showcase environmental efforts when constructing or renovating a building. However, very few green roofs are sufficiently monitored to determine if there are significant environmental impacts associated with their installation. Three environmental impacts will be quantified during this project. First, the ability of the green roof to filter pollutants that deposit on rooftops will be determined. Conventional roofs tend to divert water as quickly as possible to downspouts, providing a fast transport pathway for pollutants to enter ground and surface water resources. Green roofs act as filters, and initially retain these pollutants. Over time, these pollutants may then be transformed through biological activity in the soil, through metabolic breakdown in plants, and through photolysis. This project will allow students to learn about these processes, and quantify them using the green roof on the Business Instructional Facility.

Second, the ability of the green roof to capture and hold water will be determined. Conventional roofs divert water as quickly as possible to downspouts, providing little relief to down-stream water diversion and storage systems. During large rain events, and on a large scale, this practice can result in flooding. This project will allow students to quantify how much rain water is retained, evapo-transpirated, and conveyed to downspouts by the green roof, all as a function of rainfall intensity.

Third, the ability of the green roofs to decrease heat transmission and decrease heating and cooling loads will be determined. Green roofs provide earthen insulation that exceeds insulation standards on most conventional roofs. This can be monitored with temperature probes on top of and below the green roof, and below the ceiling of the roof inside the building. This project will allow students to measure these temperatures and to subsequently calculate decreases in heating and cooling loads.

Reduction of pollutant and water runoff, as well as money savings on heating and cooling loads, will be quantified and presented to UIUC Facilities and Services.

V. Outreach and Education

This project directly involves undergraduate and graduate students in Hazardous Waste Management (CEE440) and Sustainable Urban Engineering (CEE498SUE). Enrollment in CEE440 is typically 15 to 20 students, with at least half of these being undergraduates. Enrollment in CEE498SUE is averaging 25 students, with again approximately half of these being undergraduates. Students in these courses will directly participate in all activities related to monitoring, sampling, sample handling, preservation, and cleanup, sample analysis, and presentation of results. Najwa Obeid, a graduate student, will assist them in all of these activities. The principles underlying atmospheric transport and deposition of pollutants, filtration of pollutants in the green roof, and

transformation of pollutants in green roof soil and plants will be covered in course material in CEE440. The principles underlying green roof construction, rainwater retention capacity and runoff, downstream flooding, heat transfer through green roof material, and heating and cooling load calculation will be covered in course material in CEE498SUE. As a result, students in these classes will be able to put principles into practice with the green roof project. Also, students will have the opportunity to present their results to the classroom for discussion at the end of each semester.

UIUC Campus media representatives will be invited to end-of-semester presentations by the students. Also, the students will work in groups and each group will be required to develop a one-page media release sheet that highlights their project and any important results.