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Integrating Extension, Teaching, and Research for Stormwater Management Education

David P. Shelton[1], Steven N. Rodie[2], Kelly A. Feehan[3], Thomas G. Franti[3], Katie A. Pekarek[3], and Bobbie A. Holm[4]

[1]Professor Emeritus, University of Nebraska – Lincoln , [2]University of Nebraska – Omaha
[3]University of Nebraska – Lincoln, [4]University of Nebraska – Lincoln (former)

Abstract: Stormwater management is a concern for communities in the United States, particularly those with populations over 10,000 because of mandates to reduce runoff volumes and associated pollutants. An extension Stormwater and Greenspace Work Group was organized at the University of Nebraska–Lincoln (UNL) in 2006 to develop educational programs addressing municipal stormwater runoff using green infrastructure and other best management practices. A USDA-NIFA integrated grant was received in 2009 which greatly expanded the audience and scope of programming to include extension, education, and research components. Extension programming was targeted at design and green industry professionals, MS4 stormwater program managers, municipal officials, Master Gardeners, and homeowners. Extension activities included: meeting presentations; all-day rain garden workshops/installations; green infrastructure tours; rain barrel construction workshops; web-based resources; interactive rain garden models; youth activities; and publications. Academic programs in landscape architecture and landscape horticulture expanded curriculum in green infrastructure, low impact development, and stormwater best management practice design and construction. Efforts have culminated in new course lectures as well as studio design projects that conceptually addressed real-world clients and stormwater management projects. Project research studies evaluated in-situ rain garden hydrologic and plant growth attributes, homeowner perspectives on rain garden installation programs, and current regional bioretention design standards. The strong integration of extension, teaching, and research, which can often be a significant challenge, is a primary key to the success of UNL stormwater management programming. The resulting synergy has helped communities and individuals more effectively manage stormwater quantity and quality while building a knowledge-base that will support future initiatives and programs.

Keywords: *phase II community, MS4, green infrastructure, low impact development, rain gardens, water quality, service learning, youth education*

Traditional management approaches treat stormwater in developed landscapes as a nuisance to be conveyed away as quickly as possible with curbs, gutters, and storm drains, often referred to as "gray infrastructure." The new paradigm, in common practice today, views stormwater as a resource to be retained and used on-site or allowed to infiltrate. Management practices and green infrastructure such as rain barrels, rain gardens, bioretention cells, green roofs, and pervious pavement manage stormwater close to where it falls. These practices and structures conserve water, increase groundwater recharge, and improve surface water quality by retaining and filtering runoff that can contain a wide range of contaminants.

The Environmental Protection Agency (EPA) promulgated rules establishing Phase I of the National Pollutant Discharge Elimination System (NPDES) stormwater program in 1990 as part of the Clean Water Act. This program generally required that municipalities with populations of 100,000 or greater implement a stormwater management program as a means to control

polluted discharges. The Stormwater Phase II Rule, issued in 1999, extended requirements to municipalities with populations between 10,000 and 100,000 as well as certain other urbanized areas. In Nebraska, there are two Phase I and ten Phase II municipalities as well as several other Phase II entities. Public education and outreach are major components of Phase II implementation.

This federally-mandated stormwater management ruling generated a significant need for public education in communities of all sizes across the United States. In Nebraska, the Phase I cities of Omaha and Lincoln have implemented a variety of programs primarily using city personnel and consulting firms, although University of Nebraska–Lincoln (UNL) Extension has frequently been a partner in these outreach efforts when green infrastructure was proposed as a lower-cost alternative to traditional gray infrastructure practices. The smaller Phase II municipalities generally have more limited staff and budget resources to meet stormwater management mandates. Consequently, these communities have actively sought extension leadership for stormwater management programming.

Requests from Nebraska municipalities, green industry professionals, and others for stormwater management training and educational materials led to the organization of a UNL Stormwater and Greenspace Work Group in 2006 to develop educational resources and programs. A USDA National Institute of Food and Agriculture (NIFA) National Integrated Water Quality Program (NIWQP) grant titled "Improving and Conserving Water Resources through Stormwater Management Education for Community Decision Makers of Today and Tomorrow" was received in August 2009 that greatly expanded the scope of stormwater management programming and audiences reached. Funding was initially granted for a three-year project, and two one-year extensions were received, with the project ending in August 2014. This manuscript focuses on the design, implementation, and evaluation of this grant-funded project, with the objective of providing the reader with concepts that can be applied to other projects addressing municipal stormwater management education.

Objectives

A USDA-NIFA project needs to consist of all three functions of agriculture knowledge (i.e., research, education, outreach/extension) to be classified as integrated (USDA-NIFA 2015). Projects frequently have research as the primary focus with extension and education secondary. In contrast, this project was designed from the outset with extension, education, and research comprising approximately 50%, 30%, and 20% of the effort, respectively. The overall goal was to improve water quality while conserving water resources through stormwater management and green infrastructure using a highly integrated approach of extension programming, classroom education, and field research (Figure 1). Specific objectives for the three components to achieve this goal were:

Extension

1. Provide science-based educational materials and hands-on learning experiences for municipal leaders and residents of Nebraska Phase II municipalities to:
   a. Increase the use of water-sensitive landscape design and best management practices.
   b. Assist in making viable, cost-effective decisions for municipal stormwater management.
   c. Help meet the public education and outreach measures as established by EPA.
2. Design and implement a multi-faceted experiential learning program that actively engages youth to increase their understanding and knowledge of stormwater hydrology and green infrastructure, and improve the skills needed for successful career preparation and as future decision makers.
3. Develop and deliver educational programs and hands-on learning opportunities for green industry and design professionals to help meet the growing demand for sustainable greenspace solutions.

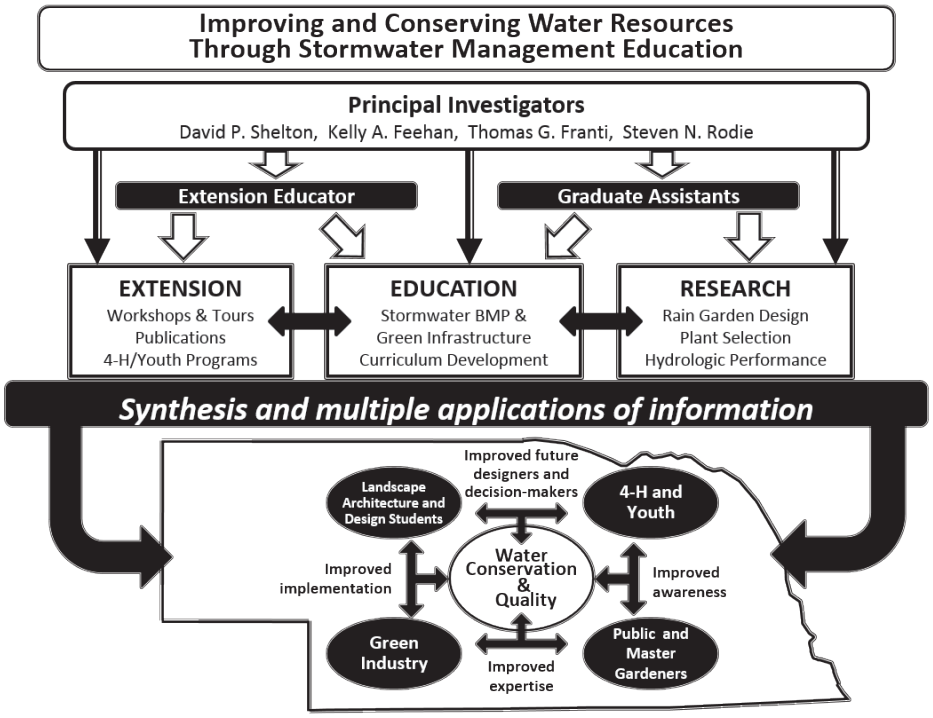

Figure 1. Schematic showing project integration, primary audiences, and selected outcomes.

4. Integrate stormwater hydrology and greenspace topics into Master Gardener training to prepare them for incorporating new water perspectives into their outreach programs.
5. Share information developed in this project to increase the knowledge base of green infrastructure methods for stormwater management.

Education

1. Integrate stormwater management and green infrastructure topics into new and existing Landscape Architecture, Landscape Design, and Turf/Landscape Management courses.
2. Develop a new professional elective course in the Landscape Architecture undergraduate curriculum that focuses on elements of stormwater management and green infrastructure.
3. Develop and coordinate interdisciplinary stormwater management and/or green infrastructure service learning projects for landscape architecture, civil engineering, water science, and planning students.
4. Educate and provide teaching and research opportunities for two Master's Degree students with a specific emphasis on green infrastructure components of stormwater management.

Research

1. Evaluate plant growth and performance in established rain gardens under Nebraska climate and conditions to enable revised plant selection and care recommendations.
2. Evaluate the hydrology of established rain gardens under Nebraska climate and conditions to enable revisions of design, installation, and maintenance recommendations.

Methodology

Numerous approaches were used to meet project objectives. Extension efforts ranged from conventional techniques such as news releases, meetings, and publications to focused, innovative

techniques that included day-long hands-on rain garden installation workshops, a 1:24 scale table-top working rain garden model, an interactive rain garden animation, and a multi-component youth education kit. New courses and lectures focusing on green infrastructure were developed for classroom education, and service learning projects involving real-world clients and real-world issues were used. Research efforts used a unique stormwater runoff simulator to evaluate hydrologic properties of existing residential rain gardens. Selected efforts are described below.

Extension

Rain Garden Installation Workshops. Ten workshops, with a total of approximately 200 participants, were held across Nebraska, primarily in Phase II municipalities. Participants included Extension Master Gardeners, landscape architects, engineers, landscape designers, UNL extension staff, municipal officials, and homeowners. The goals of the workshops were to: 1) provide participants with knowledge about green infrastructure methods for urban stormwater management and information on rain garden design, construction, and maintenance; and 2) develop a demonstration site in the community that could be used for future activities such as youth programming along with hydrologic or plant growth and survival evaluations.

The workshops were typically structured with a classroom-type setting in the morning where participants learned general information about stormwater management as well as information about rain garden sizing, plant selection and placement, construction, maintenance, and other related topics. Initial designs and plant selection were generally done by extension personnel prior to the workshop and presented during the morning session. The afternoon session was held outdoors, weather permitting, with participants partaking in each step of the rain garden installation including: marking of layout; sod removal; soil moving to level the bottom and build berms; creating and leveling inflow and overflow sites; incorporation of soil amendments (if used); planting; and mulching. Depending on specific site conditions, some of the work was done by extension and/or municipal personnel prior to the workshop. On three sites, one each in western, central, and eastern Nebraska, Master Gardeners assisted with maintenance and gathering information on plant performance using a "Green Observer" form that was developed to assist with uniformity of collected information.

A survey at the conclusion of three of the workshops completed by 34 of 45 participating Master Gardeners, landscape designers, landscape architects, engineers, and UNL Extension staff showed the following combined results:

- 100% reported an increased knowledge of how to design, install, and maintain a rain garden.
- 94% reported an increased awareness and understanding of stormwater runoff issues for water quality and stormwater best management practices.
- 90% planned to use at least one best management practice that reduces potential water pollutants.
- 83% planned to use practices other than a rain garden on their properties or properties they manage to reduce stormwater runoff.
- 81% planned to recommend and/or design/install rain gardens as part of their job.
- 77% planned to install a rain garden on their own property.

Rain Garden Model. A portable, 40 in. x 42 in., 1:24 scale model rain garden setting (including house, driveway, street, front yard, and surrounding landscape) was designed and built to demonstrate the layout and function of a residential rain garden. Water is poured through a "cloud" above the house and then runs off the roof through gutters and downspouts. Water from approximately one-half of the roof flows into a rain garden on one side of the property, while the remaining water flows onto a representation of a poor lawn or the driveway on the other side of the property and then into a street storm drain, contrasting the capture and slow infiltration of water in the rain garden with the runoff and erosion from impervious surfaces.

The model was designed to accurately reflect proper rain garden specifications such as proximity to the house, depth, berms, water entrance, overflow design, aesthetic and functional planting design, and aesthetic and maintainable integration into the surrounding landscape. The model has been

used to illustrate the concept and proper design of residential rain gardens to hundreds of students, home owners, and interested citizens at over 20 public events, including water festivals, school educational events, university service learning meetings, regional gardening shows, the Nebraska State Fair, Earth Day celebrations, and others.

Rain Garden Animation. An on-line, interactive rain garden animation was developed to engage homeowners and others interested in learning the basics of rain garden function and design (http://water.unl.edu/documents/RainGardenAnimation_9-30-09.swf). Using the rain garden model referenced above as a backdrop, viewers are able to click on labels throughout the images and bring up brief descriptions of nearly every aspect of residential rain gardens, including yard location, roof measurements for volume calculations, runoff routing into and out of the garden, depth and sizing of garden, soil testing, and plant selection and usage. The garden can be viewed in above-ground and below-ground perspectives to show both the aesthetics of the landscape features and the functional attributes of water infiltration, root growth, and garden excavation and depth. A simulated rain event can be viewed in either perspective to show the flow of water from the roof to the garden and through the soil.

The animation is used regularly in Master Gardener training sessions on green infrastructure and rain gardens, and has been a valuable "first reference" for people interested in learning about rain gardens. Requests from at least eight land grant universities, botanical gardens, and other educational organizations from around the country have been approved for linking to the animation from other websites.

Rain Barrel Workshops. Approximately 15 rain barrel construction workshops were conducted. Three of the workshops were specifically for Master Gardener training and two for youth and families. Two others for the general public were taught by Master Gardeners - an example of train-the-trainer. Similar to the rain garden workshops, these were also hands-on with participants doing most of the actual construction. Information on stormwater management, runoff pollutant reduction, and other best management practices was also presented in addition to rain barrel construction, use, safety, and maintenance topics.

Green Infrastructure Tours. Ten Green Infrastructure tours were held, having approximately 500 participants that included municipal employees, engineers, landscape architects, landscape designers, Extension Master Gardeners, Extension staff, and others. The tours were held primarily in the Phase I cities of Omaha and Lincoln due to a greater number and diversity of sites available. Sites covered a gamut of practices including bioretention gardens, bioswales, green roofs, rainwater harvesting, a pervious recycled glass patio, permeable pavement and pavers, constructed wetlands, curb-free site development, a green wall, and others. Tours typically started at 9:00 a.m. and ended at approximately 3:30 p.m. The registration fee was usually $30 which included lunch and transportation by chartered bus. A survey designed to evaluate knowledge gain and potential practice change was distributed at the end of the tours. Surveys were completed by 65 participants of the tours held in 2011, with the following combined results:

- 100% reported an increased understanding of the basic design concepts and principles of best management practices for stormwater management.
- 98% reported an increased knowledge of how to design, install, and maintain green infrastructure practices.
- 98% planned to change a practice they currently use to a practice that would improve stormwater management.
- 94% planned to seek opportunities to design/install green infrastructure practices for improved stormwater management.

These tours are continuing as an annual event in both Lincoln and Omaha, well beyond the scope of the original project - a testament to their value and popularity.

Youth. A wide range of activities including hands-on rain barrel building workshops, the rain garden model, "Water Explore Mini Camps," hands-on learning sessions at water festivals, and others

have provided approximately 6,000 youth with an increased awareness and understanding of stormwater issues and green infrastructure. At most events, youth were asked the pre and post-session questions: "What is a watershed?;" "What is stormwater runoff and where does it go?;" "What is nonpoint source pollution?;" and "What is gray versus green infrastructure?." At the beginning of the event, 100% of participating youth indicated they did not know what a watershed is; what nonpoint source pollution is; or what is meant by gray and green infrastructure. Only a few knew that stormwater typically flows directly to water bodies, transporting pollutants. Following the event, over 85% indicated they now understood what a watershed is; described at least two examples of water pollution; and named at least two practices they could implement to help reduce water pollution and/or slow runoff water from the property where they live.

Another approach to youth-oriented stormwater management education was the creation of comic-type characters "Stormwater Sleuth" and "Running Rain" (Figure 2) as mascots for youth educational programming. Stormwater Sleuth teaches from a watershed perspective as she views the landscape from overhead, while Running Rain teaches with his experiences as stormwater runoff flowing over surfaces, into storm drains, soaking into soil, etc.

These characters were used in the development of a 16-page, comic-style booklet (Feehan et al. 2012) where the reader can follow their adventures to learn about stormwater runoff, water pollution from runoff, and practices such as sweeping up grass clippings, using rain barrels, rain gardens, green roofs, and permeable pavement to help slow stormwater and keep runoff clean. The booklet also includes inquiry-based activities, a maze, and crossword puzzle. In 2014, the Sleuth booklet was downloaded 30,545 times from the UNL publications website.

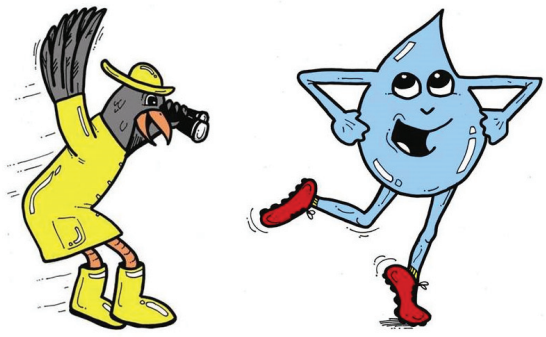

Figure 2. Stormwater Sleuth and Running Rain characters.

The booklet was included in an educational kit that also contained a magnet in the shape of a water droplet, a bookmarker to promote awareness, a water droplet-shaped sponge to illustrate that stormwater should be soaked up rather than allowed to run off, a rain gauge to track rainfall amounts, a specially-developed card game (120 cards each with stormwater terminology and a different photograph) to teach about pollution threats and practices to help reduce these threats, six stormwater activity sheets and a companion educator information sheet, and a specially designed drawstring bag to hold kit contents.

Funding was received from the Nebraska Environmental Trust through the Nebraska Academy of Sciences Public Information and Education Grant Program in 2014 to provide one of these kits to each public and private elementary school in each of the ten Nebraska Phase II communities, and conduct an evaluation of kit usage by educators using the kits. Approximately 125 kits and evaluation surveys were distributed in late 2014. Survey completion requests and subsequent reminders were sent in early 2015. As of mid-2015, 29 primarily 4th and 5th grade teachers, representing a total of 1,201 students, had responded to survey requests. Of the respondents, 12 had used kit resources and 28 indicated that they either plan to use kit resources in the future, or would share the kit with another teacher. Of the 12 who had used kit resources, all indicated that their own awareness and understanding of stormwater management and green infrastructure had increased, all planned to continue using kit resources in the future, and 11 said their students planned to make a change in habits such as sweeping grass clippings off pavement, picking up litter, recycling leaves, etc. Four used the pre- and post-tests that were provided, with all indicating that their students showed an increased awareness of both stormwater and green infrastructure as a result of using kit resources.

Professional Education Credits. During 2012 and 2013, engineers, landscape architects, and other professionals could have earned up to 46 hours of credits to meet professional license continuing education requirements by participating in Extension programs such as tours, workshops, a post-construction symposium, and other events. These professionals expressed appreciation for being able to receive quality continuing education at a low price without the added expense of long distance travel, which was an additional incentive for their participation.

Website. UNL Extension maintains a comprehensive water-focused website http://water.unl.edu. Considerable effort was devoted to developing and maintaining up-to-date stormwater-related items for the Stormwater Management page. Subtopics included: Low Impact Development; Green Roofs; Rain Gardens; Stormwater Regulations; Publications; Online Learning; Stormwater Education for Kids; and others.

Printed Publications. UNL Extension has two main categories of printed publications: *NebGuides*, which are limited to four printed pages and generally cover a single, specific topic; and *Extension Circulars* which can have more than four printed pages and provide more comprehensive coverage of a topic or topics. Considerable emphasis was placed on developing printed publications during this project. Twelve stormwater-related *NebGuides* and four *Extension Circulars* were developed. Selected *NebGuide* titles include: "What Stormwater Management Is and Why It Is Important;" "Rainwater Harvesting in Residential-Scale Landscapes;" "Rainwater Harvesting with Rain Barrels;" "Rain Garden Design for Homeowners;" "Disconnecting Downspouts and Impervious Surfaces;" and "Green Roof Basics." Similarly, *Extension Circular* titles are: "Stormwater Management Terminology;" "Stormwater Management on Residential Lots;" "How to Make a Rain Barrel;" and "Rain Garden Design - Site and Selection Guide." The latter circular is designed to be printed, similar to a conventional publication, or used interactively online by users seeking tailored design and other information generated from data specific to his/her own situation. These publications are also accessible online from the water.unl.edu/stormwater and UNL Extension webpages.

Education

Course and Lecture Development. Rain garden and green infrastructure curriculum in Landscape Horticulture and Landscape Architecture at UNL, as well as in Landscape Horticulture and Environmental Studies at the University of Nebraska at Omaha (UNO), have expanded significantly with a variety of new course lectures, case study assessments for existing and proposed green infrastructure projects, and student field tours of existing projects. Students from different backgrounds and disciplines were encouraged to take these courses, adding significant value and integration to class and other discussions. Additionally, studio design projects that addressed real-world clients and stormwater management projects have been completed, including the conceptual design of stormwater best management practices for the corporate headquarters of Cabela's in Sidney, NE.

Service Learning Projects. Several rain garden projects have been coordinated through the UNO Service Learning Academy. Each involved a unique blend of students, community projects, and outcomes. The following projects were initiated:

- UNO students worked with ninth grade science honors students from Ralston High School in Ralston, NE to identify native plants and plant communities and then design an outdoor classroom (including rain gardens and runoff management strategies) in Ralston's Oak Park.
- UNO students worked with sixth grade science students from Benson West Elementary school in Omaha to complete ten conceptual rain garden/prairie garden designs for the school site that were then integrated into a final design which was built with Nebraska Environmental Trust/Sustainable Schoolyard Partnership grant funding and in-kind Omaha Public School (OPS) and UNO donations.
- UNO students developed a detailed planting design (including four rain gardens and a bioswale) for an educational landscape

demonstration surrounding the UNO Glacier Creek Preserve Education Center at the Allwine Prairie preserve in Omaha. The plan helped facilitate discussions leading to a donation through the University of Nebraska Foundation for construction of the gardens.

These projects provided hands-on learning opportunities and significant community benefits leading to completed or in-process projects that illustrate creative, practical approaches to successful rain garden, pollinator garden, and sustainable landscape implementation. Rain gardens are also a strong real-world model for STEM-focused curriculum, and proposals are in place to build from these projects to expand rain garden projects for public schools and faculty training.

High school and UNO project personnel continue to participate in rain garden evaluations to learn more about garden function and design. Through a combined effort of the City of Omaha, OPS, and UNO, high school science students are working in water monitoring and assessment of city rain gardens. In addition, a UNO faculty member is helping train an OPS science teacher about rain garden and pollinator habitat design as well as research methods applicable to rain garden assessment that can be integrated into a high school science curriculum.

Graduate Students. Three graduate students completed their degrees in conjunction with this project. Degree types, titles, and awarding departments were:

- Master of Science - Horticulture. Hydrologic Effectiveness and Plant Survivability in the Holmes Lake Rain Garden Pilot Program: Year Three Lincoln, Nebraska. Agronomy and Horticulture, UNL (Liebsch 2011).
- Master of Science - Biological Systems Engineering. Hydrologic Evaluation of Established Rain Gardens in Lincoln, Nebraska Using a Storm Runoff Simulator. Biological Systems Engineering, UNL (Anderson 2011).
- Master of Community and Regional Planning. Assessing Impermeable Surface Area Impacts on Modeling: Implications for the Combined Sewer Overflow Long Term Control Plan in Omaha, NE. Community and Regional Planning Program, College of Architecture, UNL (Szatko 2012).

Research

Evaluation of Existing Rain Gardens - Plants and Aesthetics. A grant-funded cost-share program that began in 2007 supported the installation of 20 rain gardens on residential and school properties in the 3,460 acre Holmes Lake Watershed that drains into Holmes Lake, a 112 acre flood control reservoir in southeastern Lincoln, NE. A graduate student-led assessment of 18 of these gardens during the summer of 2011 focused on plant performance and aesthetics to establish a database standard for successful regional rain gardens. Visual inspections were performed to document the initial street view impression, followed by a summary of noted vegetative and/or hydraulic problems. Lastly, interviews were conducted with 14 of the garden owners to ascertain their thoughts and comments on several topics including: how well the garden was functioning, both hydraulically and aesthetically; if any previous drainage problems had been solved; if their knowledge of rain gardens had been enhanced; and if they had educated others about rain gardens (Liebsch and Rodie 2012).

Revisions by property owners to the original designs caused some compromises in garden success and function. There was a problem with plant survivability of some species in all but three gardens. Issues more closely studied included use of sprinkler systems, hydraulic function, and plant placement within the garden. Plant placement was a major concern relative to survivability. Study results indicated that plant recommendation lists need to be updated to include where a plant will do best within the different areas of a rain garden (i.e., bottom, interior berm sides, top of berm, and berm exterior); and installers need to be further educated on these findings. All 14 garden owners interviewed stated that they had educated others, and 11 indicated that their own knowledge had increased.

Evaluation of Existing Rain Gardens - Hydrology. A second graduate student-led investigation was also conducted in the summer of 2011 to evaluate in-situ hydrologic properties of 12 of the Holmes Lake Watershed rain gardens. A unique stormwater

runoff simulator (Franti et al. 2007a; 2007b), was used to apply a volume-based design storm of 1.2 inches (Water Quality Volume) as a 30-minute hydrograph to each garden. Data including ponding zone storage capacity, infiltration rate, time of complete drainage, soil characterization, berm and outlet construction, and bottom grading were collected and analyzed to evaluate performance characteristics (Anderson et al. 2012).

Every rain garden tested drained in 30 hours or less, with six gardens draining in less than one hour, indicating that these 2-4 year old gardens were not limited by infiltration rate, which met or exceeded performance standards. Water storage capacity was poor, with only two gardens able to hold the design storm volume. On average, the rain gardens studied were able to hold only 40% of the design storm volume. Poor basin grading, outflow structure construction and placement, and berm integrity were the primary reasons for the inadequate storage volumes. The results of the testing thus showed that accurate construction, including careful leveling of the garden bottom and berm grading, should be a high priority for rain garden installation.

Findings from both the plant and hydrology focused studies have been incorporated into several college courses and Extension rain garden programming, and used to update design, construction, and management recommendations.

Summary

A five-year University of Nebraska project strongly integrated extension, teaching, and research to address stormwater management education. Audiences included youth, college students, MS4 community stormwater program managers and residents, Master Gardeners, design and planning professionals, and green industry professionals. Innovative extension activities included: all-day, audience participation rain garden workshops/ installations; an on-line, interactive rain garden animation; and a youth-focused comic-style booklet where the reader can follow the learning adventures of the characters Stormwater Sleuth and Running Rain. Expanded curriculum addressing green infrastructure, low impact development, and stormwater best management practice design resulted in new course lectures for landscape architecture and landscape horticulture students. Studio design projects conceptually addressed real-world clients and stormwater management issues. Research studies evaluated in-situ rain garden hydrologic and plant growth attributes, with findings incorporated into college courses, extension programming, and updated design, construction, and management recommendations. The strong integration of extension, teaching, and research, which is often a significant challenge, is a key to stormwater management programming successes. As a result, communities and individuals are able to more effectively manage stormwater quantity and quality. Future efforts using a STEM-focused approach to illustrate creative, practical approaches to rain garden, pollinator garden, green infrastructure, and sustainable landscape implementation for public schools, municipalities, and other entities are planned, following up on successes of this project.

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Author Bio and Contact Information

David P. Shelton is Professor Emeritus, Biological Systems Engineering and Extension Agricultural Engineer in the Department of Biological Systems Engineering at the University of Nebraska–Lincoln. At the time of the work described, he had a 50% extension/50% research appointment. He can be reached at dshelton2@unl.edu.

Steven N. Rodie is currently Professor, Biology and Environmental Studies, and Director, Center for Urban Sustainability at the University of Nebraska–Omaha. At the time of the work described, he was Associate Professor and Landscape Horticulture Specialist in the Department of Agronomy and Horticulture at the University of Nebraska–Lincoln and had a 50% extension/50% teaching appointment. He can be reached at srodie@unomaha.edu.

Kelly A. Feehan is Extension Educator – Horticulture at the University of Nebraska–Lincoln. She can be reached at kfeehan2@unl.edu.

Thomas G. Franti is Associate Professor and Extension Surface Water Management Engineer in the Department of Biological Systems Engineering at the University of Nebraska–Lincoln. At the time of the work described, he had a 75% extension/25% research appointment. He can be reached at tfranti@unl.edu.

Katie A. Pekarek is Associate Extension Educator – Water Quality at the University of Nebraska–Lincoln. She can be reached at kpekarek2@unl.edu.

Bobbi A. Holm was Assistant Extension Educator – Stormwater Management at the University of Nebraska–Lincoln at the time of the work described.

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