A designer's guide to small-scale retro-fit green roof planning, design, and implementation

Lee R. Skabelund and Dea Brokesh

Report prepared … for the Kansas Department of Health & Environment and U.S. Environmental Protection Agency, 28 June 2013.

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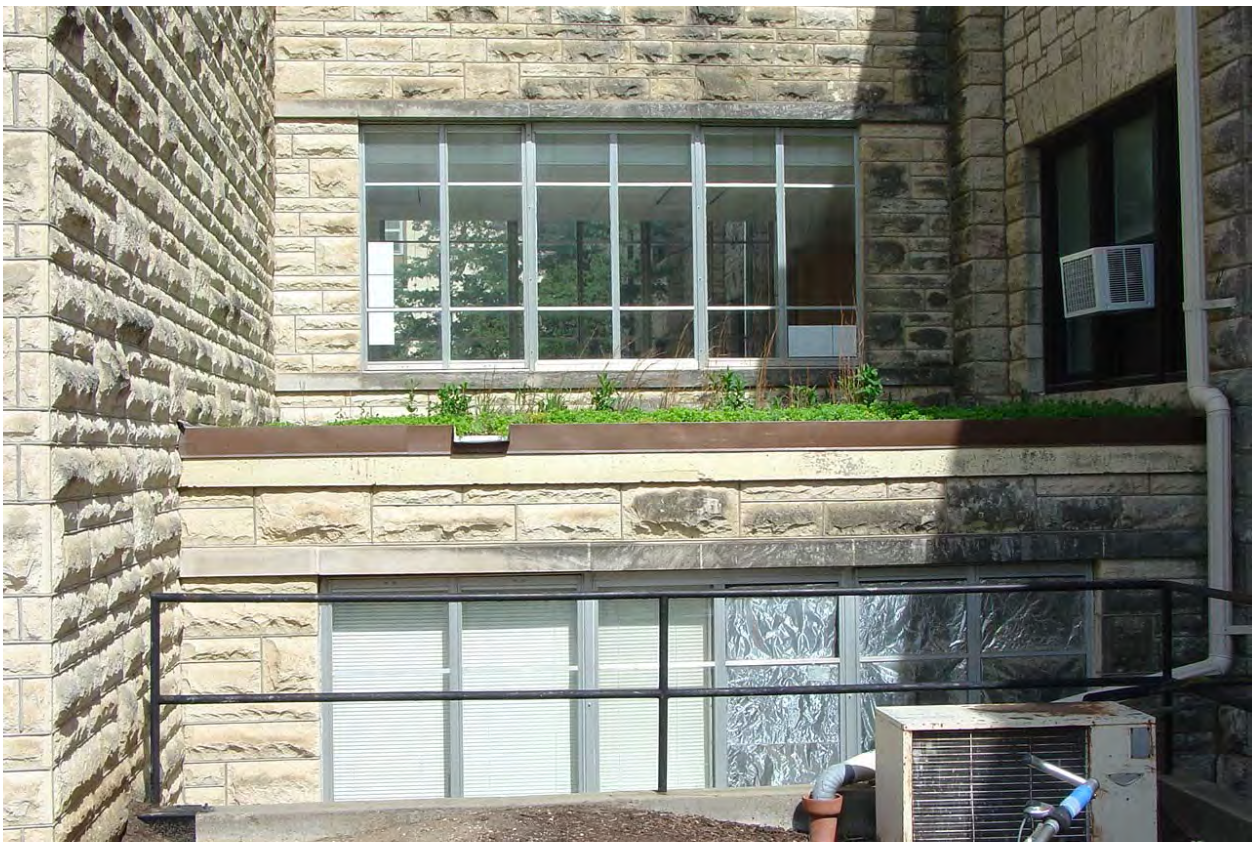

May 15, 2013 photo by Lee R. Skabelund

The Kansas Department of Health and Environment (KDHE) provided financial assistance to the Kansas State University Seaton Hall Lower Green Roof Demonstration Project through USEPA Section 319 Nonpoint Source Pollution Control Grant #C9007405 16 Funds (KDHE Funding Codes 3889 2643959) as part of the KDHE Clean Water Neighbor Program.

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Introduction & Literature Review

In many articles, documents, reports, and books the value of green roofs are described as a valuable tool for reducing stormwater runoff and urban heat loads, as well as increasing beauty and biodiversity in urban areas. Living roofs can help people make connections to the regional context, particularly when plants and other materials are wisely selected from the Eco-region.

Water conservation—which can be supported by creating regionally adapted green roof plant systems that need minimal supplemental irrigation once established—**has many positive effects, including energy and economic savings** (USEPA 2007).

In the book *Water Matters: Why We Need to Act Now to Save Our Most Critical Resource* we read of the need to act to protect our freshwater systems (Lohan 2010). When well-designed and managed, **urban watersheds can function as integrated systems that temper flooding and cleanse water**. Too often water flows swiftly off of paved surfaces while many landscapes have poor infiltration due to surface compaction by vehicles and people. In his essay "Water Matters" Brock Dolman (2010, 130) notes that we have a great opportunity to change undesirable urban conditions by implementing infrastructure and stormwater practices that **slow and harness water in living, dynamic plant-based systems**. Patchett & Wilhelm (2008), Condon (2010), Dinep & Schwab (2010), Douglas (2011), and Calkins (2012), discuss how **filtering water through soil-and-vegetation systems is vital to the health of watersheds**—providing cleaner and more stable water supplies for downstream ecological systems as well as for people with property, homes, and businesses in the community.

Green roof plants can offer high aesthetic value to people (Oudolf & Gerritsen 2003) while supporting essential ecological functions such as habitat for songbirds and pollinators. Nassauer (1997), Dreiseitl, et al. (2001). Echols (2007) highlight the importance of **creating artful stormwater management facilities for enjoyment, engaged education, and perceived value** by residents and stakeholders. Native songbirds depend on native plants (Tallamy 2007) and green roofs have the potential to provide habitat and increase biodiversity (Grant 2013).

Getter & Rowe (2006), Berghage, et al. (2007), Carter & Jackson (2007), Dunnett & Kingsbury (2007), Oberndorfer, et al. (2007), Werthmann (2007), Cantor (2008), Simmons, et al. (2008), Weiler & Scholz-Barth (2009), Dvorak & Volder (2010), Nagase & Dunnett (2010), Snodgrass & McIntyre (2010), Grant (2012), Sutton, et al. (2012), Strom, et al. (2013), and many others discuss what we can learn from green roofs implemented in the U.S. and other countries.

This guidebook shows how designers in the Kansas Flint Hills Eco-region were able to create an approximately 300 square-foot green roof in a highly visible part of the K-State campus. Given its sheltered location, this living roof needs less supplemental irrigation than an exposed roof.

Purpose of this Guidebook

This guidebook aims to benefit both property owners and planners/designers by describing important considerations related to small-scale green roof planning, design and management.

Primary Project Outcomes:

One Green Roof was installed in May 2012 to reduce runoff falling on the small KSU rooftop facing 17th Avenue (MLK Jr. Blvd.). This green roof is adjacent to the first-floor breezeway at Seaton Hall's West Wing making it highly visible to students, faculty and visitors.

An on-site education session was held in July 2012. Many other tours of this and the upper Seaton Hall green roof have been given to individuals and small groups, including to members of the public visiting K-State during the annual Spring Open House in April 2013.

Two succinct chapters are provided: the first addressing the green roof planning/design phase (focusing on the retro-fit green roof designed for the rooftop that is readily visible from Seaton Hall's West Wing first-floor breezeway—called the lower green roof); the second providing guidance for green roof implementation, with photos showing the implementation and establishment of the Lower Seaton Hall Green Roof.

May 31, 2013 photo taken from the Upper Seaton Hall Green Roof (with rain-gauge locations) – LRS

Chapter One: Green Roof Planning/Design

The most important idea we can share at the outset is that planners, designers and property owners should **seek to integrate a proposed green roof into both the larger eco-region** (with thoughtful consideration of the regional climate and of plants well-adapted to the region) **and to the specific location** (accounting for structural capacity, soil/grow media depth(s), roof slope, micro-climate, irrigation design, potential weed sources, and the needs and interests of the building owners and other stakeholders). Budgetary limits (time and financial resources) are inevitably an important factor and frequently determine how one proceeds during the planning/design process as well as during green roof implementation and management.

In regards to the **Lower Seaton Hall Green Roof** several options were considered by KSU faculty, students and staff between Spring 2008 and Spring 2012: 1) use of LiveRoof trays only; 2) use of an integrated system similar to the Upper Seaton Hall Green Roof (which was created in Spring 2009); or 3) a combination of a tray and integrated system. Due to budget constraints it became clear that the use of salvaged LiveRoof trays (saved by Diamond Roofing, Inc. from a Greensburg, Kansas project) should be used in combination with unused American Hydrotech LiteTop soils (surplus grow media saved from the Upper Seaton Hall Green Roof project). Of primary importance, there was the need to make certain that the new living roof was under the maximum allowable 51.6 pounds/square foot (calculated by the structural engineer) and that the green roof vegetation could handle the mix of sun-shade conditions with minimal irrigation.

May 31, 2013 photos taken of the Lower Seaton Hall Green Roof (with Penstemon digitalis in full bloom) – LRS

Important Planning/Design Considerations:

1) Create a green roof sized for the specific limitations and opportunities of the selected roof, accounting for the structural capacity of the existing structure, present and anticipated building conditions, the need to either replace or protect the existing waterproofing system, the need for a leak detection system, the type and depth of green roof grow media (manufactured soil) to be used, the desire for additional thermal insulation properties, the type and depth of green roof grow media (manufactured soil) to be used, sun-shade relationships and the influence of solar radiation (both intensity and duration) on plant selection, irrigation needs or requirements, wind patterns, ecological opportunities (especially the potential to create songbird and/or pollinator refuge or habitat), safety concerns, drainage, aesthetics, maintenance, and the timing of green roof implementation and establishment.

As noted in the Whole Building Design Guide (2012), well-designed extensive vegetative roofs (less than eight inches in depth) include subsystems beneath the vegetated cover that are responsible for appropriate drainage, plant nourishment and support/stability, protection of the underlying waterproofing systems, high-quality waterproofing, and, if needed, insulation.

Setting specific project goals will help a designer determine the range of acceptable design elements that could potentially be used for a green roof project.

As discussed in the Whole Building Design Guide, "Standard landscaping work considers plant hardiness; tolerance for sun and shade; and preference for wet, dry, rich, poor, alkaline, or acid soils as the major concerns to influence plant selection. Vegetative roof assembly design must consider important additional factors such as the loads of saturated growing media and mature plants on building structure, the effect of wind and erosion on lightweight growing media elevated above normal grade, the temperature of the growing media around plant root systems, the depths of the growing media appropriate for plant root systems, and the risk of fire posed by seasonal or drought-condition dieback of some plant varieties if they are unattended. The last factor explains why succulents, which retain water in their leaves, are often used in vegetative roofs." (http://www.wbdg.org/resources/greenroofs.php)

Strom, et al (2013, 173-174) present a series of excellent questions to help focus green roof planning, design and engineering to help create a successful project. Paraphrased, their questions are: Will the green roof offer public access? Will the roof be visible through nearby windows or from surrounding buildings? How important are aesthetics and ecological concerns such as providing habitat? Is a non- or minimally-irrigated green-and-brown roof acceptable? How large is the potential green roof surface? Are there local codes or project goals (including stormwater management and LEED certification) that would limit or warrant maximizing the size of the living roof? How deep of soil and what type of plant palette is preferred and why? Will the roof be sloped or level? What is the specific design load the existing or proposed rooftop can safely handle? Are roof penetrations, vents, or air conditioning units, factors? Have wind and sun-shade studies been performed to make sure that micro-climatic conditions are clearly understood? How important is optimizing energy conservation and performance?

Nine basic components may be used to create a green roof (from the roof structure upwards): 1) waterproofing; 2) protection board (optional during construction); 3) insulation (optional unless required by code or by the designer or client to improve the thermal characteristics of interior spaces); 4) root barrier; 5) drainage and moisture retention layer; 6) filter fabric; 7) grow media (soil system); 8) vegetation; and 9) blanket or mulch (if needed).

a.) Determine the structural capacity of the selected roof (existing or new structure). Then determine if the soil depths desired are possible given the structural capacity of the roof. <u>Without adequate structural capacity a green roof cannot be safely created.</u>

***Extensive** green roofs have lightweight soil systems (also called "grow media" or "substrate") that are typically 2 to 6 inches (5 to 15 cm) in depth which may come in pre-manufactured trays/modules or be applied as an integrated (uninterrupted) soil system. At least four (4) inches of soil is recommended in temperate climates with greater depths in arid locations (Grant 2012). Depending on the grow media used the weight per square foot (psf) for four inches of soil could range from about 25-30 psf. **Intensive** green roofs have soils at least eight inches (20 cm) deep and they are generally more organic-rich and planted with a wide range of plants, including trees and large shrubs where even deeper soils are possible. Some manufacturers make trays eight inches or deeper, but this guidebook focuses on extensive and semi-intensive green roofs. **Semi-intensive** green roofs have low to medium weight soil systems that are typically 4-1/2" to 7-1/2" inches (11 to 19 cm) in depth and have the capacity for greater plant diversity than extensive green roof systems.*

Given the selected location of the Lower Seaton Hall Green Roof, 50-51 psf could be placed on the existing roof. Sutton F. Stephens, PhD, Professional Structural Engineer and Associate Professor of Architectural Engineering/Construction Science at Kansas State University worked with one of his students to analyze the structural capacity of the roof. Dr. Stephens indicated that if existing waterproofing materials were removed we could apply 51.6 psf to the structure.

For the Lower Seaton Hall Green Roof we used the saturated weight of American Hydrotech's semi-intensive GardenRoof soil (donated for our Upper Seaton Hall Green Roof in 2009) to determine the heaviest part of the green roof. This semi-intensive grow-media weighs roughly seven (7) pounds per square foot (psf) per one inch depth (or 7.0 psf).

*The American Hydrotech GR 30 drainage layer (which holds water in small cups beneath the soil and filter fabric) weighs 3.8 psf; three layers of Derbigum waterproofing 3.75 psf; Derbicant wood cant strip where roof deck meets the building wall 0.57 psf ; American Hydrotech heavy duty root stop 0.2 psf; filter fabric 0.03 psf; and native plants approximately 3.0 psf. The **total estimated design load** associated with the American Hydrotech semi-intensive green roof assembly (with 5" depth of growing media) was 45.78 psf (saturated weight).*

Three different LiveRoof trays were used on the Lower Seaton Hall Green Roof. Saturated weights of fully vegetated LiveRoof trays are as follows: 6-inch deep LiveRoof trays weigh 41 psf, 4.25-inch trays weigh 27 psf, and 2.5-inch trays weigh 17 psf.

b.) Determine if the existing waterproofing and flashing system is adequate <u>*or*</u> needs to be replaced. If a new waterproofing membrane and waterproofing/flashing system is needed, determine what system will be both durable and cost effective. Find an experienced, well-qualified roofer to do the waterproofing work, checking on material types and total material-and-installation costs from more than one supplier and/or roofer. Refer to the "Waterproofing, Protection Course, Leak Detection, Root Barrier, and Insulation" section of the Whole Building Design Guide for Extensive Vegetative Roofs (www.wbdg.org/resources/greenroofs.php).

Also consider whether or not the project includes goals to improve the thermal qualities of the structure. If the structural capacity and budget allow, consider adding insulation layers throughout the roofing system and/or at specific areas of the roof. Vegetated systems alone can improve energy efficiency and thermal qualities of interior spaces. Adding layers of insulation under the vegetated system can improve the thermal qualities even more.

For the Lower Seaton Hall Green Roof we needed to replace the existing asphalt-and-gravel (pitch-tar) roof as it was more than 40 years old and in need of repair (especially the flashing). Fortunately, we were able to secure material donations from a supplier of Derbigum products, who had generously donated waterproofing materials for the Upper Seaton Hall Green Roof. Three roofers were contacted for bids, and two (Diamond Roofing and Danker Roofing) responded. Both roofing companies were considered by K-State to be experienced and well-qualified, however, only Danker Roofing was able to do the work within our project budget. Danker Roofing completed waterproofing and flashing work in March 2103. K-State Facilities donated copper flashing for the project (as they had done for the upper green roof). Copper flashing needed to be eight inches higher than the adjacent green roof to meet building codes.

The design and structural capacity of the existing building (Seaton Hall West Wing) did not allow the design team to include additional thermal insulation measures beyond the vegetation-and-soil- system and the insulated paver system.

c.) After considering the range of reasonable options, determine the specific type of soil system to be used given the roof's structural capacity and the design goals of the project.

For the Lower Seaton Hall Green Roof we desired to demonstrate the use of two well-known products: recycled trays (sedum-based green roof modules) marketed by LiveRoof, and the integrated soil system (root barrier, drainage layer, filter fabric, and grow media) marketed by American Hydrotech. We also desired to use materials that might otherwise go to waste so as to reduce environmental impacts and minimize project costs (particularly transportation costs, which can easily exceed material costs if products are sent long distances by truck).

d.) Determine how water will drain from the roof once it moves through the green roof system. Make sure that water will move off of the roof through an adequate drain and/or emergency scupper once the green roof soils are saturated. This is particularly important given heavy rains that may fall throughout the year as well as ice that may build up during winter months.

For the Lower Seaton Hall Green Roof we needed to create an emergency scupper on the west side of the roof to meet building codes. We retained the existing internal roof drain to handle day-to-day runoff, and given its visibility (the internal drain allows people to readily see if the drain is clogged) and the warmth of surrounding building mass (keeping the drain ice-free during winter months) it is unlikely that the emergency scupper will ever have to handle runoff.

e.) Identify plant material to be used. Per Calkins (2012, 230-231) variables to consider when selecting plants to use on a green roof include: water availability; available depth and type of soil system; wind velocities; soil temperatures; solar radiation; and climate (regional and local).

For the Lower Seaton Hall Green Roof we wanted to highlight both sedums and native Grasses and wildflowers, testing several species that prefer semi-shade conditions.

Four species that were used on the Upper Seaton Hall Green Roof (little bluestem (Schizachyrium scoparium), prairie dropseed (Sporobolus heterolepsis), purple prairie clover (Dalea purpurea), and common spiderwort (Tradescantia ohiensis) were planted on the lower green roof. In addition, prairie sedge (Carex bicknelii), nodding onion (Allium cernuum), roundleaf groundsel (Packera obovata), wild quinine (Parthenium integrifolium), foxglove beardtongue/penstemon (Penstemon digitalis), sky blue aster (Symphyotrichum oolentangiense), and American germander (Teucrium canadense) were planted on the lower green roof. Plants were selected based on several factors—partial shade tolerance, if they were a Kansas native, and if they were locally or regionally available.

Sedums in the LiveRoof trays were selected by RoofTop Sedums, the LiveRoof grower/supplier in Iowa in consultation with Lee Skabelund. Primary species included: Sedum floriferum, S. takesimense 'Gold Carpet', S. hybridum 'Czar's Gold', S. kamtschaticum, S. sexangulare, S. ellacombianum, S. ternatum, S. spurium 'Roseum', S. album, S. spurium 'Green Mantle', S. middendorffianum var. diffusum, and Sedum spurium 'Royal Pink'.

f.) Consider and appropriately address green roof access and building interrelationships.

At the Lower Seaton Hall Green Roof access to the rooftop requires opening one of two windows and stepping through the open window onto the roof. Concrete pavers and donated LiveRoof RoofStone pavers were used to allow for movement along three sides of the green roof.

g.) Determine the amount of irrigation needed to support the plants in the specified soil type and profile (depth or depths).

Based on the literature and experiences from the two green roofs implemented at K-State as well as other green roofs in the Great Plains and other parts of the U.S., ongoing irrigation when soils are dry will be needed to support native plants and a number of species of sedum.

h.) Consider sun/shade conditions and other microclimate attributes associated with the proposed site as well as potential invasive species concerns.

Selecting the right plants for the existing and envisioned microclimate is essential. As with most designs, there will generally be no perfect solution, but the fit between a plant species' soil moisture tolerances and on-site conditions is essential.

Given that its location on a lower roof is more sheltered from the wind and sun than some other locations and the majority of the plant selections are drought-tolerant sedums, the designers were interested to see how much supplemental irrigation would be required on this green roof.

Observations of plant material at the Lower Seaton Green Roof help one see the influence of reflected sunlight, a western exposure, strong wind patterns created as winds are deflected off of building facades, and related watering needs. After one-and-a-half growing seasons, it is quite clear that the two taller, broad-leaved natives are quickly stressed due to heat, wind, and lack of rain. Observations of plant material over four-and-a-half growing seasons on the Upper Seaton Hall Green Roof make it clear that supplemental irrigation is essential to preserve all of the native plants established on this highly exposed rooftop. (See June 2013 photos on page 13.)

At the Lower Seaton Hall Green Roof (and most other urban sites) there will inevitably be many invasive or unwanted plants that can influence ultimate plant composition in the green roof. Where there are large numbers of invasive or unwanted species, then regular, ongoing monitoring and management (weeding) are required.

Native and non-native woody plants can seed into a green roof and should be removed when they are small to minimize disruption to the green roof soil.

On June 16, 2011 over 210 woody plant seedlings were pulled from the Upper Seaton Hall Green Roof soils, including 115 Eastern red cedar and species such as bush honeysuckle, elm, Bradford pear, plum, hawthorn, and cottonwood. Many undesirable seedlings or seedheads were removed at other times in order to reduce competition with native plants and sedum on both green roofs between 2009 and 2013.

i.) Identify local and state regulations regarding implementation strategies, and siting criteria. Refer to the "Relevant Codes and Standards" section of the Whole Building Design Guide for Extensive Vegetative Roofs (www.wbdg.org/resources/greenroofs.php).

For the Lower Seaton Hall Green Roof design, Architecture, Engineering, Structural Engineering, and Landscape Architecture faculty and staff, plus K-State Facilities personnel, played important roles in determining codes and requirements to be met or considered.

Although a railing or safety harness and tie-offs are generally needed where maintenance personnel will be within six feet of the edge of a maintained green roof, the project budget did not allow for implementation of either a temporary nor permanent system. Also, the project liaison with K-State Facilities was not in favor of potentially creating a railing precedent for campus roofs because the majority of roofs on campus do not have railings. There is no public access onto the green roof, only visual access is allowed from the first-floor hallway along Seaton Hall's West Wing. As a result, those needing to be on the roof for maintenance and monitoring tasks are asked to stay away from the edge of the roof.

m.) Consider budget parameters. Determine all cost components prior to installation of the project including design, materials, labor, shipping, and short-term maintenance. Long-term maintenance costs should be considered during the design of the project. Careful design and material selection are important factors that can minimize long-term maintenance costs. Secure additional funding and/or donations if the proposed green roof exceeds the project budget. Relocate the proposed green roof if it is determined that the target site is not the best place for such a facility.

At the Lower Seaton Hall Green Roof, designers found the selected site to be an ideal location for a green roof given the part-sun/part-shade conditions. Donations by a number of suppliers and by KSU-Facilities made it possible to complete the green roof project.

m.) Collaborate with all disciplines needed to make the project a success.

At the Lower Seaton Hall Green Roof designers with expertise in architecture and landscape architecture consulted with structural engineers, engineers, climatologists, agronomists, and those with expertise in propagating and growing sedums and native plants.

2) Know your maintenance needs & capabilities

a.) Contact the property owner to determine maintenance expectations.
b.) Design the green roof with maintenance capabilities in mind.

At the Lower Seaton Hall Green Roof dialogue with KSU-Facilities staff (including landscape architecture and roofing personnel) gave everyone involved a clear picture of expectations and needs. Regular monitoring and weeding was performed by the lead designer, who had intimate understanding of the vision for the living roof and a number of the species planted. Where this kind of hands-on monitoring and management cannot be done by the green roof designer (including regular watering and weeding), training of staff or volunteers is needed. Large-leaved wildflowers such as quinine and penstemon seem to require more water than finer-leaved wildflowers such as purple prairie clover.

The Mid-America Regional Council's *BMP Manual* (2012, 8-143) indicates that green roofs should be designed to have "90 percent landscape coverage within 12 months of planting" and that vegetated roofs should be irrigated, weeded, and protected from wind erosion until plants cover at least 90 percent of the soil or grow media surface.

Source: http://kcmetro.apwa.net/chapters/kcmetro/specs/BMPManual_Oct2012.pdf

3) Determine a proposed soil mix (a suitable lightweight growing media or manufactured soil) that provides good drainage while also retaining sufficient moisture for plant survival and nutrient transmission to the specified vegetation.

a.) As needed, consult a soil scientist or soil testing facility to determine the composition and characteristics of the growing media/manufactured soil. Additionally, as needed, consult a landscape architect and/or civil engineer to help you determine the appropriate green roof soil mix related to your site and project goals and objectives. Most if not all successful green roofs utilize manufactured soil because our native clay and shale soils, typically, are too heavy for the structure and can be too dense to provide adequate drainage.

At the Lower Seaton Hall Green Roof we used proprietary mixes provided by nationally respected suppliers since donations were offered by each company.

b.) Consider budget parameters as well as availability of local materials.

At the Lower Seaton Hall Green Roof designers were able to use salvaged materials (namely LiveRoof® trays and American Hydrotech Garden Roof® soil leftover from other projects and available in Kansas). This helped reduce project costs and also minimized expenditures of fuel/energy.

c.) Consider which of the four possible methods for establishing plants in the grow media (soil) is desired: 1) living plant/plug installation, 2) direct seeding, 3) pre-vegetated mats and/or 4) modular or tray systems. As noted by the Whole Building Design Guide both the grow media (soil) and vegetative type need careful consideration.

In their book Green Roof Plants, Edmund and Lucie Snodgrass (2006, 30) argue that "most herbaceous perennials, including natives, that otherwise might work well for the hardiness zone of a given roof still will not be suitable for a vegetative roof microclimate. In addition, the average inorganic vegetative roof medium will not support most large root systems or their nutritional requirements, further limiting plant choices to those with shallow root systems and an ability to store water."

At the Lower Seaton Hall Green Roof the lead designer of the green roof desired to experiment with several larger-leaved herbaceous perennials given the more protected setting. In the five-inch integrated profile (three feet wide east to west, and 11 feet long north to south) the following species were planted as plugs: little bluestem (Schizachyrium scoparium), prairie dropseed (Sporobolus heterolepsis), and prairie sedge (Carex bicknelii), along with purple prairie clover (Dalea purpurea), wild quinine (Parthenium integrifolium), foxglove beardtongue (Penstemon digitalis), and sky blue aster (Symphyotrichum oolentangiense).

*Also a few other native plugs were planted, sparingly, within the sedum LiveRoof trays. Species selected included: nodding onion (Allium cernuum), American germander (*Teucrium canadense), *roundleaf groundsel (Packera obovata*), *common spiderwort (Tradescantia ohiensis), foxglove beardtongue (Penstemon digitalis), and wild quinine (Parthenium integrifolium).*

4) Specify non-invasive plant material that is well-adapted to the eco-region and specific selected soils and microclimate. Specify plant material according to the American Standard for Nursery Stock. Look closely at the plant pot and/or ball size, especially the depth of the pot. A larger root system typically means a healthier plant. Avoid pots where excessive root growth is visible outside of the pot. These plants should have been planted in a larger container earlier. Specify seed as "pure live seed" and obtain seed and live perennial plants from well-respected and State inspected nurseries or suppliers within the eco-region.

In the Flint Hills Eco-region we have few specialized native plant nurseries, so we often need to draw upon nurseries in nearby eco-regions when desired native grasses and wildflowers are not available from local sources. As noted on the following page, there are a number of good options to consider when specifying plants in central and eastern Kansas.

5) Choose plants that can handle water and drought and locate specific species in settings that are appropriate to their cultural needs (particularly soil type, texture, moisture, and sun-shade tolerances).

It is wise to provide some diversity in plant material so that the plant community that is formed can be more adaptive than would likely be possible with use of just two or three species. At the Lower Seaton Hall Green Roof designers selected eight (8) species of native wildflowers and three (3) species of native sedges and grasses. These perennials (planted as small live plants) were supplied by Kaw River Restoration Nurseries, approximately100 miles from Manhattan, Kansas. Ideally, plants and seed should come from local sources or from nurseries that grow plants within about 100 miles of a site, but this is not always feasible.

In Kansas our native prairie species are well-adapted to drought and many perennial plants (as seed or live plants) can be obtained from native plant nurseries such as Kaw River Restoration Nurseries in Lawrence, Kansas (http://www.restorationnurseries.com/index.cfm), *the Prairie & Wetland Center in Belton, Missouri* (http://www.critsite.com/)*, and Bluebird Nursery* (http://www.bluebirdnursery.com) *in Clarkson, Nebraska.*

For more native plant information and nursery/supplier options refer to:
http://www.kansasnativeplantsociety.org/plant_seed_sources.php
http://www.wildflower.org/collections/collection.php?collection=KS
http://www.bluebirdnursery.com/Products.asp
http://www.feyhfarmseed.com/index.html
http://dyckarboretum.org/
http://www.kswildflower.org/
http://plants.usda.gov/java/

RoofTop Sedums (http://www.rooftopsedums.com/)*, a grower for the LiveRoof tray system, supplied the one-by-two-foot modules fully vegetated. RoofTop Sedums were also the growers for the extra LiveRoof® modules not used for a green roof project in Greensburg, Kansas.*

Plantings can be hydro-seeded (this technique may be most practical for large green roofs), hand-seeded (quite reasonable for small to medium sized roofs if one is patient, and also willing to add a soil protection layer which will likely be needed with hand-seeding to reduce wind erosion), rolled out as mats, placed on the roof in various kinds of trays or modules (either pre-grown or planted by the installer by means of seed or plug), and/or planted as live plants as plugs, from containers, or as bare-root stock. Plugs can be very quick to establish if supplemental irrigation is provided whenever soils begin to get too dry during the first few months. Plugs are also quite cost-effective and they can be easily moved or shipped from nurseries, greenhouses, or other locations where they are grown.

6) Learn from others, and from your own experiences.
Design a way for water landing on the roof to safely flow through and off the green roof during a large storm event. Use a range of plants to provide biological diversity and varying rooting densities and depths, specifying those species that will handle periods of drought. Recognize that well-designed and managed green roofs are fairly porous and will likely need irrigation during dry spells. Weeding out undesirable species will likely be needed for the life of the green roof since birds and wind will bring weed seeds/berries to the roof.

Consider the following suggestions as you work through the planning/design process: think long-term and be bold (aim for zero waste and reduced life-cycle costs); consider the details (such as how micro-climatic changes will influence plant survival and health—select plants that match the bio-physical conditions of the place where they are to be planted); know your budget and the institutional capacity of the property owner/client; seek to understand soil, water and plant interrelationships; be practical, ambitious and creative (accounting for aesthetics and human needs and interests as well as ecological concerns); design to conserve water and energy; remember that planning/design is a process—learn all along the way (especially after you have implemented the project and you document successes and mistakes).


June 21, 2013 photos taken of the Lower Green Roof (above) and Upper Green Roof (below) – LRS



Chapter Two: Small Green Roof Implementation & Management

Steps in the Implementation Process

1. Consult with a structural engineer regarding the structural capacity of the target roof.
2. Consult with a roofer regarding the integrity of the existing waterproofing and flashing. Re-design the waterproofing and flashing systems as needed.
3. Design the green roof, including plant material, waterproofing, flashing and insulation to meet project goals and appropriately respond to the climate, micro-climate, grow-media (soils), and building structure.
4. Insure that the design meets all required codes and receives all necessary approvals.
5. Estimate costs throughout the design and approval process to stay on track with budgetary requirements.
6. Order/purchase materials and labor needed to install green roof system.
7. Know weights of materials and plan ahead to organize where to store green roof materials during construction. Do not exceed the design capacity of the roof structure when staging materials for installation.
8. Watch weather reports to help plan storage location and installation times. For example, wind can be a cause for loss of materials if stored on a roof overnight.
9. Make any necessary roofing repairs on existing roofs and ensure the integrity of its waterproof nature.
10. Install root barrier, drainage layer, and filter fabric.
11. Install growing medium (soil) such as trays and/or the integrated green roof system on the roof. Sweep excess soil/debris from root barrier prior to installing trays.
12. Install plants as needed (see plant handling notes below).
13. Observe and irrigate the green roof as needed (check at least weekly).
14. Remove undesirable plant species as needed (check at least monthly) being careful not to disturb the irrigation system, root barrier, drainage system, or waterproofing. Inform maintenance personnel of the components of the roof, especially the waterproofing system and root barrier, so that they can take care to not damage those components.

    Plant material (vegetation) handling techniques:
    a. Protect plants during shipment by placing in covered vehicle to avoid wind burn;
    b. Protect live plants on the job site by placing them in the shade (especially during the heat of the summer, covering them as needed to protect from cold or windy weather, and watering them as needed to keep plant roots moist.
    c. Install live plant materials according to State Extension services guidelines.

Note that native species will typically need at least two full growing seasons to establish their root systems, and that for extensive green roofs, supplemental watering will be needed to avoid brown out and/or death during long, dry periods. A number of species of sedum and other succulents will also need supplemental irrigation to avoid brown out and/or death during long, dry periods.

For a detailed and comprehensive review of green roof plants refer to Green Roof Plants: A Resource and Planting Guide (Snodgrass & Snodgrass 2006).

For a more detailed and comprehensive review of green roof design, implementation and management see the Whole Building Design Guide for Extensive Vegetative Roofs (www.wbdg.org/resources/greenroofs.php).

Also see the following texts – Green Roof Manual: A Professional Guide to Design, Installation and Maintenance (Snodgrass & McIntyre 2010) and Green Roof Systems: A Guide to the Planning, Design and Construction of Building Over Structure (Weiler & Scholz-Barth 2009).

ASTM International, formerly known as the American Society for Testing and Materials (ASTM), "is a globally recognized leader in the development and delivery of international voluntary consensus standards" and has produced a number of guidance documents for green roof systems. Five of these standards are noted in the references list (ASTM E 2396- ASTM E 2400) at the end of this document, and information about these standards can be found online. As one example, the ASTM guide addressing performance characteristics for green roof systems with respect to the planting can be found at (http://www.astm.org/Standards/E2400.htm).

Green Roofs for Healthy Cities also has a set of design standards relating to fire, wind uplift, and root repellency (http://www.greenroofs.org/index.php/resources/designstandards) that complement the internationally respected "German FLL Green Roof Guidelines":
http://www.greenrooftechnology.com/resources
http://www.greenrooftechnology.com/fll-green-roof-guideline
http://www.epa.gov/region8/greenroof/pdf/IntroductiontotheGermanFLL2.pdf

There are many videos showing green roof implementation (large and small), including:
http://youtu.be/pp79mGpomf4 - "Greenroofs 101 from Greenroofs.com"
http://www.youtube.com/user/greenroofsTV - hundreds of videos here

http://youtu.be/2zZddUy9tlc - Penn State Green Roof Research: "Green Roofs Part 1"
http://youtu.be/mO9_XK_L6Fs - Texas A&M Green Roof Research

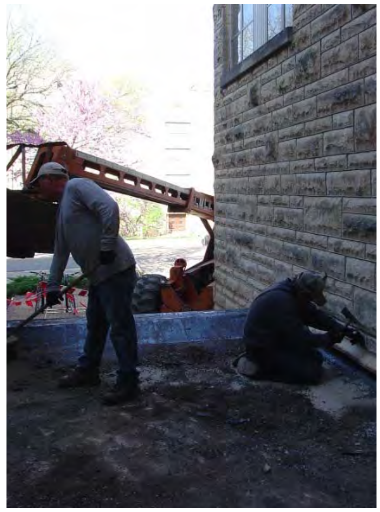
http://youtu.be/kQBd_ePVwuc - Swarthmore College's integrated green roofs
"Building a Green Roof Part 1: Introduction"

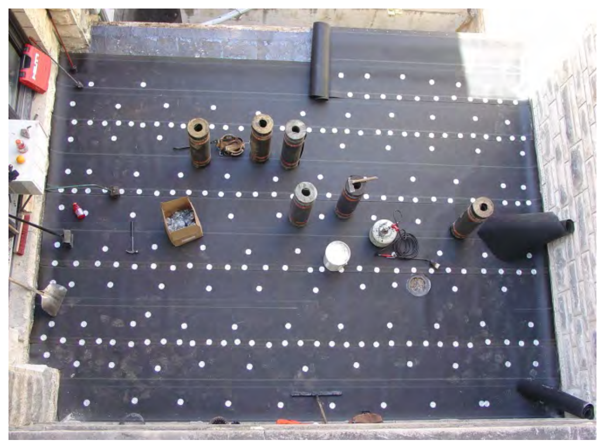
http://www.youtube.com/watch?v=68RZRgqWi0c – American Hydrotech GardenRoof Systems
"Sloped Garden Roof Application"

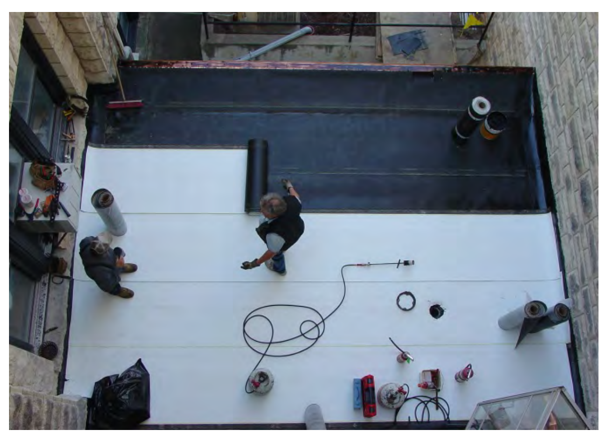
http://youtu.be/g0fwObYO9Bc - Ultralight Green Roof at Ford Motor Rouge River Plant
http://youtu.be/oCV9y1qJuqk - Panel Green Roof on a Garage
"Green Roof Panel Installation"

http://youtu.be/P2ibfEn1qo8 - Introduction to the LiveRoof System
http://www.youtube.com/watch?v=SAsBngnNvxo -
"Green Roof Installation by R&S Landscaping"

Selected KSU Seaton Hall Green Roof Waterproofing Images (photos by Lee Skabelund, March 2012)



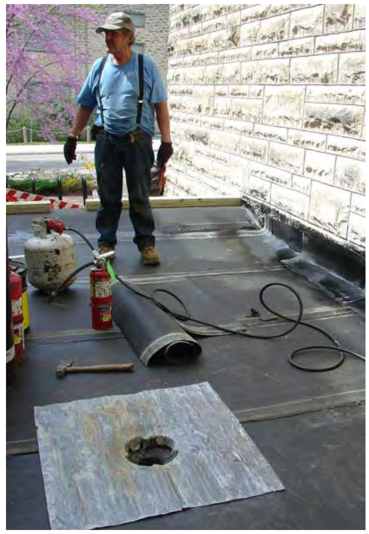


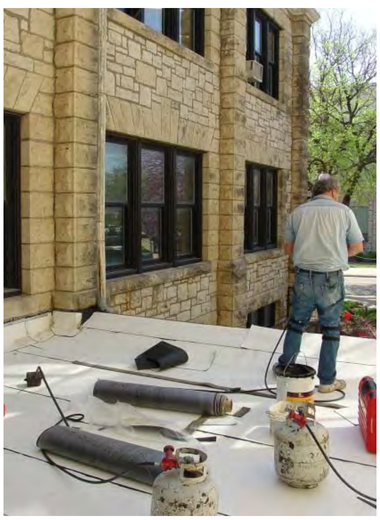


Removal of the existing pitch tar asphalt-and-gravel roof was completed on March 26, 2012. The lightweight concrete layer was left intact and patched (where needed), then swept clean.

Waterproofing for the Lower Seaton Hall Green Roof (including installation of copper flashing that rises eight inches above the adjacent green roof layers) was installed on March 26-27, 2012.

Selected KSU Seaton Hall Green Roof Waterproofing Images (photos by Lee Skabelund, March 2012)

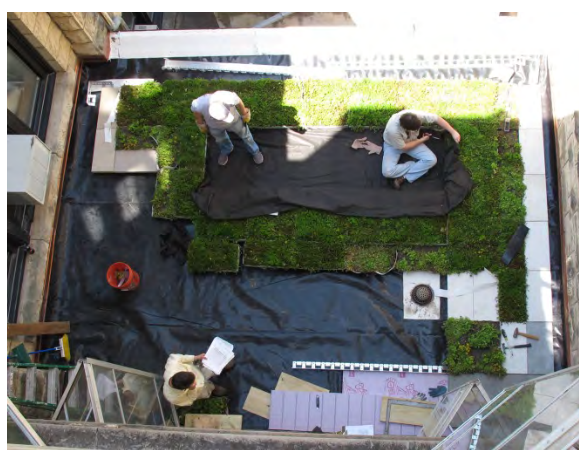




Three layers of waterproofing were used on the Lower Seaton Hall Green Roof. The roof slopes towards the existing drain, which was armored with a piece of sheet metal between the second (middle) layer and third (top) layer of waterproofing. KSU College of Architecture, Planning & Design faculty and staff met with KSU Facilities staff to discuss green roof design details and secure implementation approvals.

Selected KSU Seaton Hall Green Roof Implementation Images (photos by Dea Brokesh, May 2012)

Selected KSU Seaton Hall Green Roof Implementation Images (photos by Chip Winslow, May 2012)



KSU College of Architecture, Planning & Design faculty, staff and students worked with KSU Facilities staff and other KSU students to install the green roof, primarily on May 8, 2012.

Selected KSU Seaton Hall Green Roof Implementation Images (photos by Emily Vietti, May 2012)

Selected KSU Seaton Hall Green Roof Planting Image (photos by Tansly Skabelund, May 2012)

On May 11, 2012 Lee and Essen Skabelund planted two native grasses, prairie sedge, and eight forbs in the five inch deep 3x11-foot integrated soil system. They interplanted a number of native plants in salvaged 4.25-inch LiveRoof modules. Native plants came in two-inch pots (called "32s").

Selected KSU Seaton Hall Green Roof Images (photos by Lee Skabelund, Feb. 2008 to Apr. 2013)

Feb 1, 2008 – pre-existing asphalt-gravel roof

May 5, 2012 – root barrier atop waterproofing

May 16, 2012

Jul 21, 2012

Sep 22, 2012

Nov 9, 2012

Dec 31, 2012

Jan 30, 2013

Feb 24, 2013

Mar 15, 2013

Apr 28, 2013

Selected KSU Seaton Hall Green Roof Images (photos by Lee Skabelund, Feb 2008 to Apr 2013)

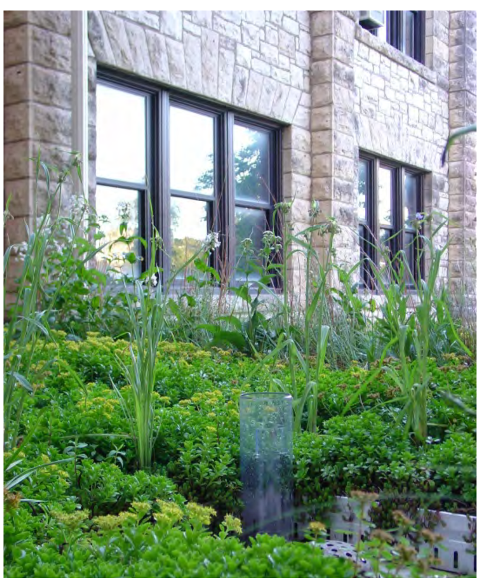
Feb 22, 2013 – snowfall in 2013 provided insulation and moisture

May 21, 2013 – the lower green roof just over one-year-old

Selected KSU Seaton Hall Green Roof Images (photos by Lee Skabelund, March 15, 2013)

Monitoring surface temperatures at nine points on the Lower Seaton Hall Green Roof was initiated in January 2013. These monitoring devices help track changes related to sun/shade and plant growth.

Selected KSU Seaton Hall Green Roof Images (photos by Lee Skabelund, June 9, 2013)



Large-leaved plants (penstemon and quinine) need more supplemental water than the other species.

Green Roof and Stormwater Management References:

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ASTM E 2397, 2011. Standard Practice for Determination of Dead Loads and Live Loads Associated with Green Roof Systems. ASTM International, West Conshohochen, PA.

ASTME 2398, 2011. Standard Test Method for Water Capture and Media Retention of Geo composite Drain Layers for Green Roof Systems. ASTM International, West Conshohochen, PA.

ASTM E 2399, 2011. Standard Test Method for Maximum Media Density for Dead Load Analysis of Green Roof Systems. ASTM International, West Conshohochen, PA.

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For more on the Seaton Hall Green Roof see: http://faculty.capd.ksu.edu/lskab/greenroof.html
For additional resources regarding green roofs in the Upper Midwest and Great Plains see also:

http://www.brit.org/BRITMakingaBuildingGreen – Fort Worth, TX - "BRIT: Making A Building Green"
http://www.greenroofs.org/index.php/events/awards-of-excellence/2012-award-winners/19-mainmenupages/awards-of-excellence/252-chicago-botanic-garden - Chicago Botanical Garden Green Roof
http://www.greenroofs.org/index.php/events/awards-of-excellence/2010-award-winners/19-mainmenupages/awards-of-excellence/207-2010-awards-of-excellence-target-center -Minneapolis, MN

http://agronomy.unl.edu/web/agronomy/greenroofs – Lincoln, NE - "Green Roofs for the Central Great Plains"
http://tamugreenroof.wordpress.com/2012/12/ - Texas A&M's Green Roof Project

http://sustainablecitiescollective.com/deeproot/83481/costs-and-benefits-green-roofs -
"The Costs and Benefits of Green Roofs" (an article by a firm who has worked on green roofs in Nebraska)

See also the Final Project Performance Report for the Seaton Hall Lower Green Roof Demonstration Project – addresses what was accomplished within the budget, lessons learned, and future tasks/plans/actions (including a discussion of our rainwater harvesting design work).