Green Roof

[STRATEGY]

BRIEF DESCRIPTION

Green roofs consist of a layer of vegetation installed on top of a conventional roof that filters rainwater through the engineered soil media. Some stormwater is taken up and transpired by the vegetation, and the remainder discharges to the roof drain system with improved water quality. A green roof system typically includes waterproofing material, root permeable filter fabric, drainage materials, growing media, and selected landscaping. Types of green roofs include intensive and extensive, ranging from deep, heavier growing media to shallower, lighter growing media.

Green roofs retain and filter rainfall, thereby reducing runoff, and provide new opportunities for biodiversity preservation and habitat creation. They generate aesthetic benefits and help to reduce the urban heat island effect (the over-heating of cities in summer from dark roof surfaces, which contributes to air pollution and increased energy consumption).

Figures 1a & 1b Green Roof, District Department of the Environment Offices, Washington, D.C.
(Source: USACE, Baltimore District)

Purpose

The purpose of a green roof is to maximize nutrient and pollutant removal and reduce runoff volume, as well as reduce amount of impervious area on the site. A portion of the captured stormwater evaporates or is taken up by plants and transpired, which helps reduce runoff volumes, peak runoff rates, and pollutant loads on development sites. The reduced impervious footprint also reduces runoff rate and volumes.

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Applications

Army Installation Facilities

- Industrial
- Institutional
- Municipal
- Residential
- Commercial
- Parking Garages

Urban Areas

- Both new Development and redevelopment sites
- Sites where surrounding site area is limited, the green roof creates pervious area

Design Notes

Intensive Type

- Growing media depth, between 6 inches to 4 feet
- Limited to flat roof applications only
- System requires greater structural capacity to support the designed system load
- Vegetation includes trees, shrubs, and grasses
- Permanent irrigation system usually required

Extensive Type

- Shallow growing media depth, 6 inches or less
- Vegetation includes herbs, grasses, mosses, and drought tolerant succulents such as sedum
- Flat and slightly sloped roofs can accommodate extensive type
- Require relatively simple maintenance plans
- Does not require permanent irrigation
- Required structural capacity support extensive type: typically 15 to 30 psf

Related Technologies **Stormwater Management and Heat Island Mitigation**

References/Useful Resources:

[1] Green Roofs for Healthy Cities, http://www.greenroofs.org/
[2] American Hydrotech, Inc., http://www.hydrotechusa.com/
[3] Green Roofs - EPA, http://www.epa.gov/heatisland/mitigation/greenroofs.htm
[4] Green Roofs - EPA - Stormwater Menu of BMPs,
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=114

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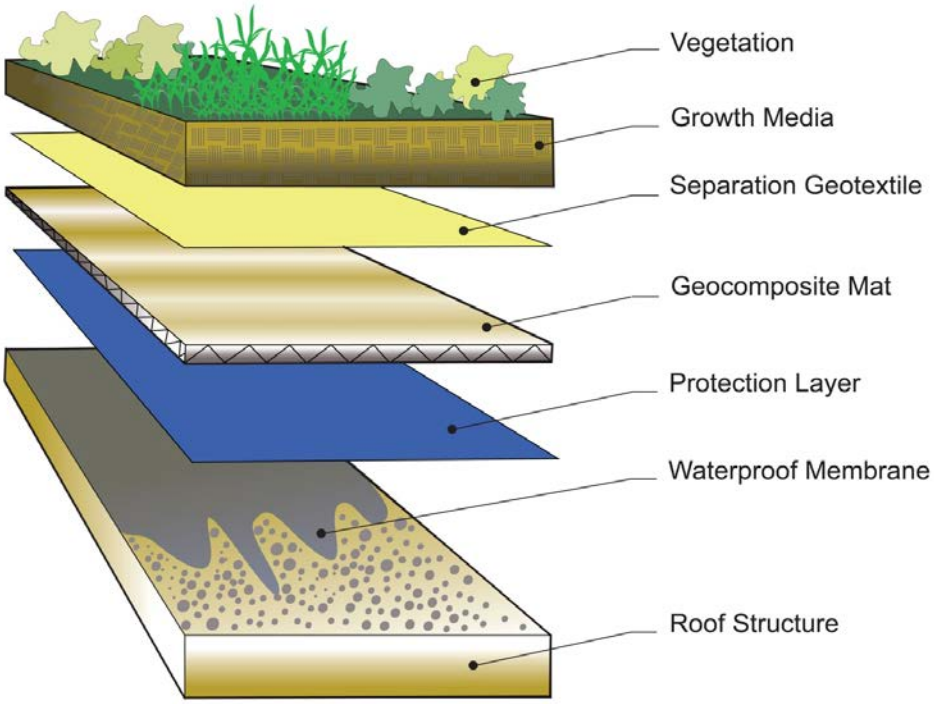

Figure 2. Cross Section of an Extensive Green Roof
(Source: SEMCOG, 2008)

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Energy Savings

Cooling Energy

- Reduces heat gain from the heat island effect on the building roof, which in turn reduces cooling energy during the summer.

Heating Energy

- Reduces heating demand during winter due to the thermal insulation provided by the green roof system.

Social Benefits

Occupant Health and Well-Being

- Traditionally unused roof areas can be used by occupants when green roofs are incorporated with patio or break areas.
- Green roofs have aesthetic benefits when located in a visible portion of the roof.

Guiding Principles[1]

Protect and Conserve Water

- Employ design and construction strategies that reduce storm water runoff and discharges of polluted water offsite. Per EISA Section 438, to the maximum extent technically feasible, maintain or restore the predevelopment hydrology of the site with regard to temperature, rate, volume, and duration of flow using site planning, design, construction, and maintenance strategies.

Associated LEED Credits (NC 2009)[2]

EAc1: Optimize Energy Performance (1-19 points)

- Green roof system provides insulation and reduces head load on the building, which reduces heating and cooling demand, respectively.

SSc6.1: Stormwater Design - Quantity Control (1 point)

- Rainfall is absorbed by green roof vegetation and is retained in the green roof system. This reduces the stormwater runoff peak discharge rate from the roof as compared to a traditional roof.

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[1] Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings www.wbdg.org/pdfs/hpsb_guidance.pdf

[2] USGBC LEED Reference Guide for Green Building Design and Construction, 2009 Edition

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SSc6.2: Stormwater Design - Quality Control (1 point) Engineered soil media filters stormwater runoff, which removes pollutants and improves stormwater quality.

- To earn this credit, the green roof design must comply with state and/or local stormwater management performance standards, OR field performance monitoring data can demonstrate compliance with the performance standards listed in the LEED Reference Guide.

SSc7.1: Heat Island Effect - Roof (1 point)

- Green roofs reduce building heat absorption.
- In order to earn this credit, the green roof must cover at least 50% of the roof area. Or the credit gives the option of combining high solar reflective index (SRI) roofing material and green roof.

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EXCERPTS FROM MODULAR TRAY VEGETATIVE ROOF SYSTEM SPECIFICATION (EXTENSIVE TYPE):

PART 1 GENERAL

1.1 **SYSTEM DESCRIPTION**
All components of vegetated roof assembly shall be provided by or approved by manufacturer of the modular tray vegetative roof system. Modular trays to include growth media and plants. Modules shall have positive drainage holes at the lowest point in module. Module tray assembly shall include edge treatment; custom shaping of trays if needed based on manufacturer's standard sizes and the dimensions shown on the contracting drawings; and temporary irrigation system.

1.6 **PROJECT CONDITIONS**
Proceed with installation of modules on roof deck only when existing and forecasted weather conditions permit installation to be performed when optimum results may be obtained. Weather shall be above 35 degrees F and there shall be no ice on roof or modules. Apply products during favorable weather conditions according to manufacturer's written instructions and warranty requirements.

1.7 **WARRANTY**
1.7.1 Special Warranty for Vegetated Roof Assembly
Installer agrees to repair or replace vegetated roof assembly and components that fail in materials or workmanship within specified warranty period.

1. Failure includes, but is not limited to, ponding water or prolonged wetness of growing medium caused as a result of failure of the assembly to properly drain.
2. Warranty Period: Two years from date of Substantial Completion.

1.7.2 Special Warranty for Plant Growth
Installer agrees to repair or replace plantings and accessories that fail in materials, workmanship, or growth within specified warranty period.

1. Foliage Cover: Planted materials shall grow to achieve and maintain at least 95 percent foliage cover over planting area upon installation and through the duration of this warranty.
2. Failures include, but are not limited to, death and unsatisfactory growth except for defects resulting from abuse, lack of adequate maintenance, neglect by Owner, or incidents that are beyond Contractor's control.
3. Warranty Period from Date of Substantial Completion: Two years.
4. Include the following remedial actions as a minimum:
    a. Immediately remove dead plants and replace unless required to plant in the succeeding planting season.

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b. Replace plants that are more than 25 percent dead or in an unhealthy condition at end of warranty period.

1.8 **MAINTENANCE SERVICE**
1.8.1 Initial Maintenance Service
Provide maintenance by skilled employees of modular tray vegetative roof system manufacturer. Maintain as required in Part 3. Begin maintenance immediately after plants are installed and continue until plantings are acceptably healthy and well established but for not less than the following maintenance period: 24 months from date of Substantial Completion.

1.8.2 Continuing Maintenance Proposal
From modular tray vegetative roof system assembly Installer approved by manufacturer to Owner, in the form of a standard yearly (or other period) maintenance agreement, starting on date initial maintenance service is concluded. State services, obligations, conditions should be included.

PART 2 PRODUCTS
2.1 **MODULAR TRAY VEGETATIVE ROOF SYSTEM**
2.1.1 Modular Tray Vegetated Roof Assembly
Modular assembly consisting of manufacturer's standard vegetated roof assembly components for installation over PVC roof system. Submit tray plant layout drawing for approval.

a. Assembly Depth, Nominal: 4 inches , including growing medium, not including height of plants.
b. Assembly Weight: Maximum total weight of module assembly, including growing medium and plants, and saturated with captured water, shall not
exceed 30 pounds per square foot.
c. Assembly Material: Shall be 100% recycled polypropylene 100 mil thick wall or matched similiar. Shall be no VOC content.
d. Assembly Water Dispersal: Water dispersal shall be approximately 10 gal per linear foot.
e. Assembly Color: Gray

2.2 **ACCESSORIES**
2.2.1 Edge Treatment
Edge treatments shall be co engineered with the module trays and shall have aluminum edging that completely covers the module's height and contains the soil. No drainage perforations are required. Edge treatment is to be factory primed and painted to match the modular tray color: gray

2.2.2 Temporary Irrigation System
Shall be an automatically controlled system of a surface applied SCH 40 PVC green painted PVC piping for irrigation lines, with SCH 80 solvent welded PVC fittings MP Rotator or equivalent irrigation head

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or a system of equivalent standards. The system shall be a temporary removable system that is utilized during the initial maintenance period. The system shall be removed once establishment and maintenance period have been completed.

2.2.2.1 Controls
Controls shall be an automatic rain sensor of outdoor - type and durability. All sprinklers to have matched precipitation on the same zone.

2.2.2.2 Piping and Valves
Surface applied irrigation piping and fittings must be UV resistant, painted green. Use a chalk line for layout to ensure straight rows. See manufacturer's written requirements for additional coordination with module tray assembly.

A master valve shall be installed on mainline after backflow device. All valves to be covered by a 6 inch valve box. All wire connections to be waterproof and UL Approved. To be a manual drain type. Install automatic freeze protection drain valves on all main and lateral piping.

2.3 **MANUFACTURED GROWING MEDIUM**
Modular tray vegetated roof system manufacturer's lightweight, manufactured soil mixture designed for project location and indicated plants.

a. General Condition of Growing Media at Time of Planting: Free of stones 1/2 inch or larger in any dimension; free of roots, plants, sod, clods, clay lumps, pockets of coarse sand, paint, paint washout, concrete slurry, concrete layers or chunks, cement, plaster, building debris, oils, gasoline, diesel fuel, paint thinner, turpentine, tar, roofing compound, acid, and other extraneous materials harmful to plant growth; free of weeds and other botanical pests; not infested with nematodes, grubs, or other pests or pest eggs; free of disease-causing plant pathogens and other undesirable organisms; friable and with sufficient structure to give good tilth and aeration.
b. Maximum Media Density: ASTM E2399, 45 lb/cu. ft. for basic growing-medium mixture.
c. Maximum Media Water-Retention: ASTM E2399, 72 lb/cu. ft. volume for basic growing-medium mixture at maximum media density.
d. Water Permeability: ASTM E2399, in/min. for basic growing-medium mixture at maximum media density.
e. Organic Material Content: ASTM F 1647, Method A, organic material as measured using the loss-on-ignition procedure.
    (1) Minimum: 6 percent.
    (2) Maximum: 10 percent.
f. Chemical Properties:
    (1) Growing-Medium pH (Reaction): Value of 6.5 to 8.0.

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(2) Nitrogen: Minimum .15 percent by weight.
(3) Phosphorous: Minimum 26.5 mg/L.
(4) Potassium: Minimum 194.2 mg/L.
(5) Sodium Absorption Ratio: 500 ppm.

2.4 **PLANTINGS** (selected for the Mid-Atlantic region, will differ depending on project location)
Sedum varieties as follows: Sedum kamtschaticum, Sedum spurium 'John Creech', Sedum spurium 'Tricolor', Sedum spurium 'Red Carpet', Sedum spurium 'Fuldaglut', Sedum rupestre 'Angelina', Sedum album, Sedum reflecum 'Blue Spruce'.

PART 3 EXECUTION

3.3 **INSTALLATION**
Install assembly according to manufacturer's written instructions.

3.4 **PLANTING**
Verify that no foreign or deleterious material or liquid such as paint, paint washout, concrete slurry, concrete layers or chunks, cement, plaster, oils, gasoline, diesel fuel, paint thinner, turpentine, tar, roofing compound, or acid has been deposited in growing medium within a planting area. Do not mix or place growing medium during frozen, wet, or muddy conditions. Suspend spreading, grading, and planting operations during periods of excessive moisture until the moisture content in growing medium reaches acceptable levels to attain the required results. Uniformly moisten an excessively dry growing medium that is too dusty or not workable.

3.5 **PLANT MAINTENANCE**
3.5.1 General
During maintenance period, maintain plantings by pruning, cultivating, watering, weeding, fertilizing, mulching, adjusting and repairing devices, resetting plants to proper elevations or vertical position, and performing other operations as required to establish healthy, viable plantings.

3.5.2 Growing Medium
Replace growing medium that becomes displaced or eroded because of settling or other processes.

3.5.3 Pest Management
Spray or treat plantings as required to keep plant materials, planted areas, and growing medium free of pests and pathogens or disease. Use integrated pest management practices whenever possible to minimize the use of pesticides and reduce hazards. Treatments include physical controls such as hosing off foliage, mechanical controls such as traps, and biological control agents. Use only products and methods acceptable to membrane roofing manufacturer.

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3.5.4 Maintenance Plan Submit recommended maintenance plan including procedures for inspection and care of modular tray vegetative roof assembly and plants during a calendar year. Submit before start of required warranty and maintenance periods.

Maintenance Requirements

Vegetated roofs are designed to have minimal maintenance requirements. Plant species are selected so that the roof does not need supplemental irrigation or fertilization after vegetation is initially established.

Green roof maintenance includes watering, fertilizing and weeding, and is typically greatest in the first two years as plants become established. Maintenance largely depends on the type of green roof system installed and the type of vegetation planted. The use of native vegetation cannot be overemphasized in planting vegetation on roofs and is highly recommended in order to reduce plant maintenance in both extensive and intensive systems.
The use of herbicides, insecticides, and fungicides should be avoided, since their presence could hasten degradation of the waterproof membrane. Only non-chemical fertilizers may be used. Also, power-washing and other exterior maintenance operations should be avoided so that cleaning agents and other chemicals do not harm the vegetated roof plant communities.

Suggest Maintenance Activities for Extensive Green Roofs:

Inspect Vegetation	• Twice during growing season. Hand weed to remove invasive plants. Fill in bare spots with soil media.
Inspect for Leaks, Drainage Problems, Structural Concerns	• Inspect biannually, repair as needed
Vegetation Maintenance	• Regularly
Watering for Plant Establishment	• Regularly during first two years

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VEHICLE STORAGE FACILITY

Washington D.C.

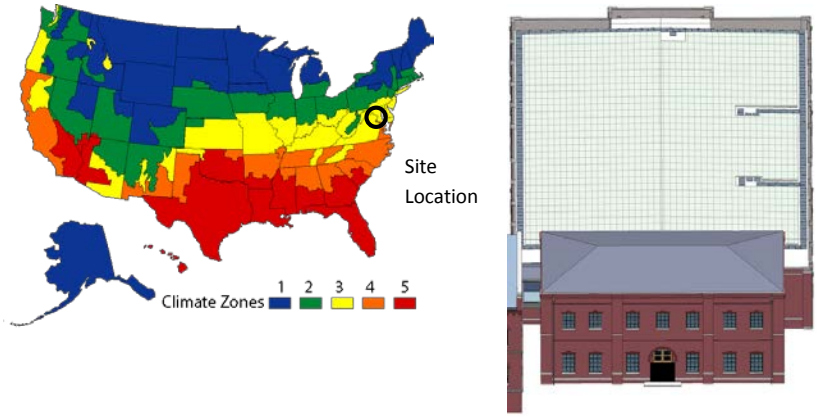

Figure 3. Case Study 1 Building
(Source: USACE, Baltimore District)

Facility

- Currently under design by USACE, Baltimore District Military Design Branch, this 20,125 gross square foot vehicle storage facility will be constructed in 2014. A majority of the roof area, approximately 11,000 square feet, is a modular vegetated roof system.

Approach

- The roofing consists of a metal deck, roof board, rigid insulation, and PVC waterproof membrane. The vegetative roof is a modular tray system with an additional slip sheet/root barrier underneath. Each 2'x2' tray has 4" growing medium and is vegetated with sedum grasses.
- The contract specifications require the Contractor to provide a 2-year warranty. During that time, the Contractor is responsible for maintenance, repair and replacement of the vegetated roof assembly and plant growth.
- A temporary irrigation system will be used during the sedum establishment period. After the required 2-year maintenance period, no permanent irrigation will be necessary.
- Although referred to as a "flat roof", the roof has minimal slope (1/4" in 12") in order to allow drainage. Crickets, scuppers, and downspouts will drain any roof runoff not retained by the green roof.

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- Total weight of vegetated roof assembly, including growing medium and plants, and saturated with water, will not exceed 30 pounds per square foot.
- The architect, structural engineer, and civil engineer worked closed in designing the green roof and coordinating each discipline's requirements.

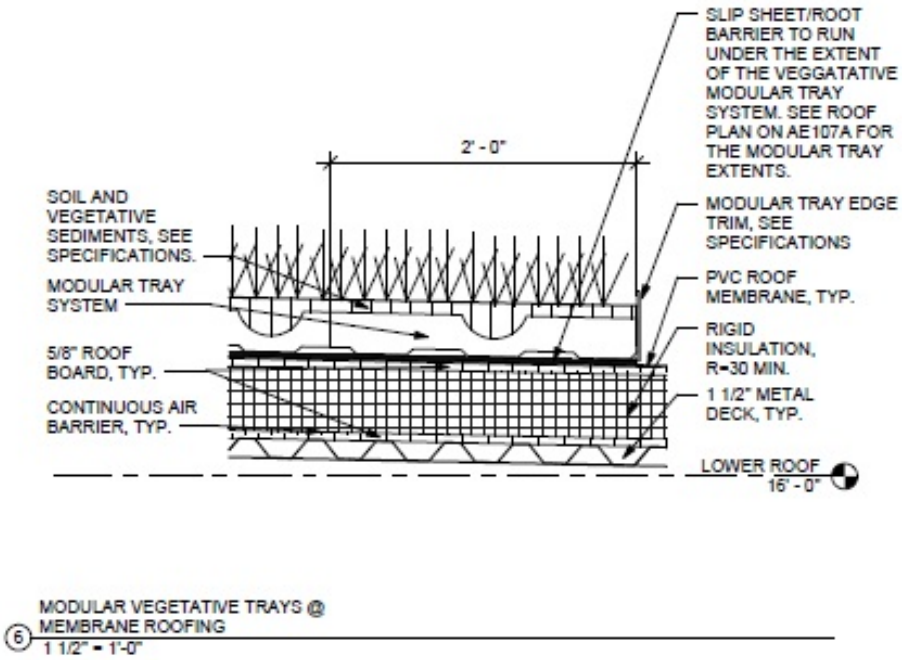

Figure 4. Green Roof Detail from Contract Drawings
(Source: USACE, Baltimore District)

Results

- The Independent Government Estimate (IGE) estimates the contract cost of the modular vegetated roof tray system to be approximately $36 per square foot installed. The entire building's roof assembly (including waterproof PVC membrane, insulation, rubber mats, hatches, railings and ladders, and the 6,300 square feet portion of the roof that is not green roof) is approximately $43 per square foot.
- In addition to bioretention cells on the site, the green roof contributes to the project's compliance with the District Department of the Environment's stormwater management regulations and EISA Section 438 (the federal stormwater management requirement). The green roof

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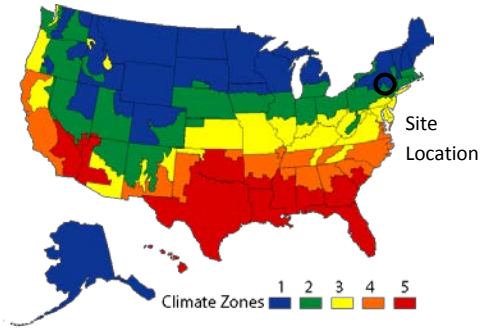
retains approximately 1” depth of runoff in the soil media and vegetation, which equates to a total of 925 cubic feet of stormwater storage volume.

GREEN ROOF RETROFIT PROJECT

Tobyhanna Army Depot, Pennsylvania



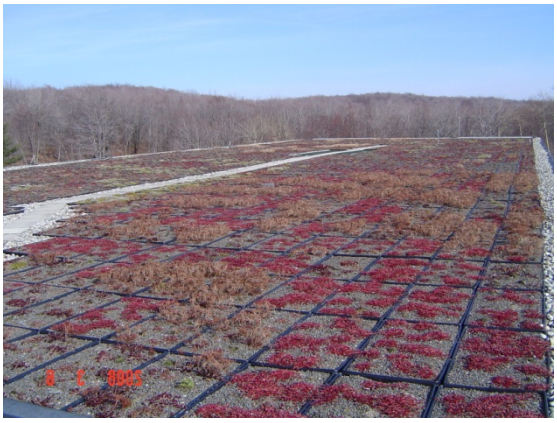


Figure 5. Modular Green Roof trays
(Source: USACE, Baltimore District)

Facility

- The project included retrofitting two large warehouse building roofs with modular vegetated roof systems.
- Approximately 65,000 square feet of vegetated roof was installed on one building and 100,000 square feet on the second.

Approach

- A combination of 2’x2’ and 2’x4’ modular vegetated trays were installed.
- Due to the region’s climate, snow load on the existing roofs was a major design constraint. Therefore, the tray depth was limited to 4” soil media with planted succulents. The added load of the vegetated roof system is 15-17 pounds per square foot.
- A slight slope is provided to allow drainage to the interior roof drains.

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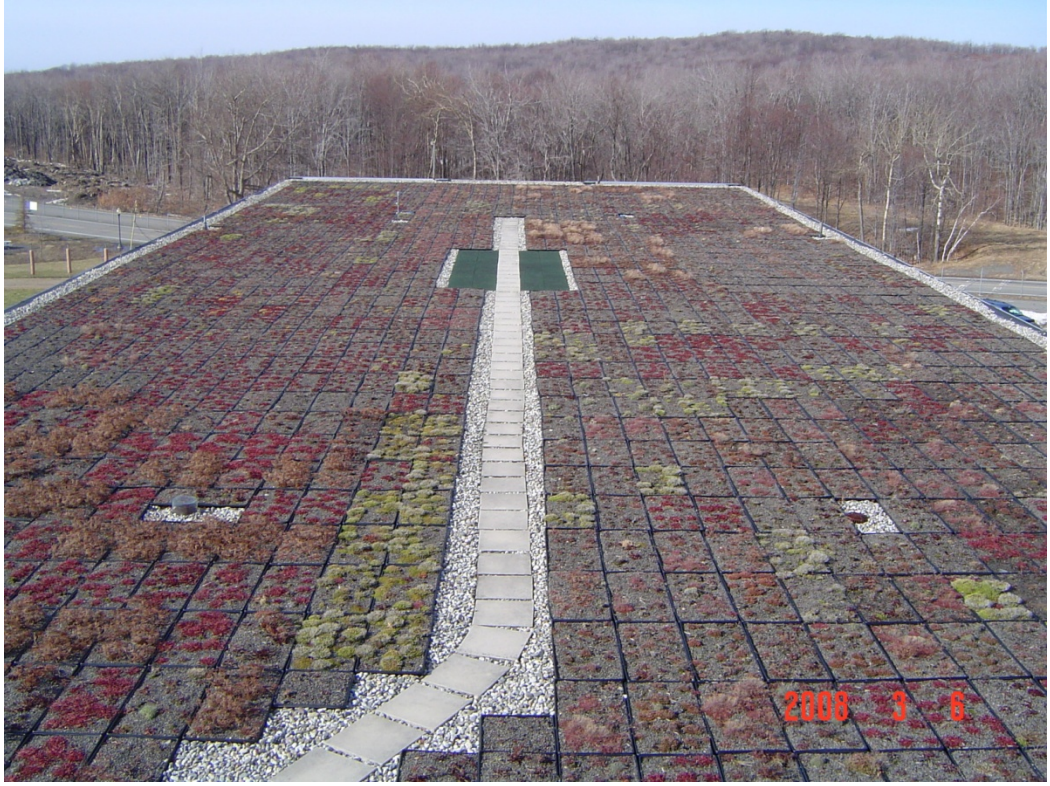

Figure 6. Green Roof on Industrial Building
(Source: USACE, Baltimore District)

Results

- This project is a model retrofit application to reduce impervious area and the urban heat island effect by installing green roof trays over large areas of industrial flat roofs.
- The Installation will be monitoring energy use to evaluate the heating and cooling energy savings the green roof provides. During the summer months, the air intake temperature readings show a decrease from 125°F to 87°F, which demonstrates the reduction in heat loading provided by the green roof retrofit.
- The contract cost was approximately $4M, which translates to approximately $24 per square foot of green roof installed.
- The stormwater runoff from the roof has decreased considerably since the green roof was installed. The temperature of the roof runoff has also cooled in temperature, to 75°F, which benefits the nearby surface waters.

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