Appendix D: Documentation of the Sustainable Siting and Water-Savings Features Included in the Prototype Building Analysis[1]

This appendix documents the calculations used to estimate costs and cost savings associated with siting and water-efficiency technologies and materials described in Section 2.3 and 2.4: water-efficiency features (Section D.1), stormwater management (Section D.2), and landscape management (Section D.3).

D.1 Water-Efficiency Features

D.1.1 Domestic Water Technology Selection

Typical domestic fixtures that are found in an office building are faucets, toilets, urinals, and showerheads. For the prototype building, highly efficient fixtures were selected to exceed the minimum flow rate standards set by the Energy Policy Act (EPAct) of 1992. The following summarizes the advanced technologies that were selected (also see Table D-1).

- **Showerheads.** EPAct mandates that showerheads not exceed 2.5 gallons per minute (gpm) at a pressure of 80 pounds per square inch (psi) or less. Typical building pressure is between 40 and 80 psi. To exceed this standard, a showerhead of 2.0 gpm was chosen. More efficient showerheads are available, but the quality of the shower can be greatly diminished with less than 2.0 gpm.
- **Faucets.** EPAct sets standards that kitchen faucets cannot exceed 2.5 gpm at 80 psi and restroom faucets cannot exceed 2.2 gpm at 80 psi. For both the kitchen and restroom faucets, a 1.0 gpm model was chosen for the prototype building.
- **Toilets.** EPAct guidelines mandate that all toilets not exceed 1.6 gallons per flush (gpf). Two advanced technologies were analyzed for the prototype building: a dual-flush toilet and a 1.1-gpf model. A dual-flush toilet has two flushing options – liquid flushing at 0.8 gpf and solid flushing at 1.6 gpf. An analysis of the two toilets proved the dual-flush toilet to be the most economical option. The 1.1-gpf toilet is an emerging technology with a very high initial cost – the simple payback was calculated to be up to 30 years. The dual-flush toilet was only analyzed for the women's restrooms. It was assumed that when men use toilets (in combination with urinals), the 1.6-gpf option would always be used; therefore, no water savings would occur from the dual-flush toilet in the men's restrooms.
- **Urinals.** EPAct requires that all urinals not exceed 1.0 gpf. A no-water urinal was chosen for the advanced technology for this study. No-water urinals have a lower installation cost because no water supply line is necessary. Therefore installing a no-water urinal is less expensive than the low-flush model.

D.1.2 Incremental Costs and Annual Water Savings

For indoor domestic water technology, the incremental capital and installation costs, annual water consumption and cost savings, and the simple payback were estimated. For each domestic fixture found in typical office buildings (faucets, toilets, urinals, and showerheads), a more advanced fixture was chosen that exceeded the minimum flow rate standards set by the EPAct and that kept quality as a parameter. Maintenance costs were considered when analyzing urinals because of differing costs for standard urinals compared with no-water urinals.

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[1] Prepared by K. McMordie-Stoughton and G. Sullivan, Pacific Northwest National Laboratory.

Table D-1. Domestic Water Technology Overview

Equipment	Standard Equipment (set by EPAct)	Advanced Equipment
Showerheads	2.5 gpm	2.0 gpm
Faucets	2.5 gpm – kitchen 2.2 gpm – restroom	1.0 gpm (both kitchen and restroom)
Toilets	1.6 gpf	Dual flush: 0.8 and 1.6 gpf options
Urinals	1.0 gpf	0 gpf

When annual water cost savings were calculated for each fixture type, water rates were broken by low, high, and average, based on fiscal year 1999 water rates from General Services Administration (GSA).[2] Each fixture's water use was calculated by using the standard use frequency for each fixture type for the prototype building. The total water reduction for indoor domestic water using equipment was over 47%. Note that the energy cost savings from hot water savings were not calculated or included. All assumption and data sources used to calculate these values are detailed in Table D-2.

D.2 Stormwater Management

The goals of sustainable stormwater management are to maintain stormwater on site as long as possible to reduce runoff volume, to reuse the stormwater, and to ensure that it is clean before returning it to the natural system, which reduces nonpoint source pollution and sedimentation in natural water ways. For this analysis, an integrative stormwater management system comprised of a gravel-paved parking lot and underground rainstorm system was examined.[3]

This porous, gravel-paved parking area is a heavy load-bearing structure that is filled with porous gravel, allowing stormwater to infiltrate the porous pavement and to be moved into a rainwater collection system. This system will greatly reduce runoff and retain rainwater on site for landscape irrigation; by contrast, a conventional asphalt parking area would cause all stormwater to run off the site, increasing pollutant concentrations and eliminating the possibility of reusing the water. The porous gravel system was selected for several reasons:

- As an integrative system, it achieves the goals of maintaining and using stormwater on site.
- The materials are partly made from recycled material.
- Cost and maintenance data are reliable.
- It meets the Environmental Protection Agency's National Pollutant Discharge Elimination System (NPDES) Phase II requirements, which expand the existing NPDES to require a storm water management program for all new construction, including runoff control and post-construction stormwater management. (For more information, see http://www.epa.gov/fedrgstr/EPA-WATER/1999/December/Day-08/w29181a.htm.)

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[2] Personal Communications with A. Walker of General Services Administration, February 13, 2001.

[3] Invisible Structures, Inc., provided an integrative stormwater management system from Gravelpave and Rainstore products.

Table D-2. Assumptions and Data Sources

Assumptions	Data	Data Source
Number of working days per year	235	Based on 10 holiday days and 15 vacation days
Occupancy	97	Standard for prototype building
Distribution of women and men	50%/50%	
Restroom uses		Standard usage
Women's		
Toilet use/day/person	3	
Men's		
Toilet use/day/person	1	
Urinals use/day/person	2	
Faucets	3	
Faucet duration	30 sec	
Shower use/day	1	
Shower duration	7 min	
No. of fixtures in prototype building		Uniform Building Code (1997) and Dziegielewski et al. (2000)
Restrooms	4	
Toilets	8	4 in women's bathrooms and 4 in men's
Urinals	3	
Faucets	8	
Kitchen faucets	1	
Showers	2	
Water rates - $/1000 gallons		GSA Fiscal Year 1999
GSA Region 3 average (Baltimore is in Region 3)	$3.97	
Costs for fixtures (per unit)		
Showerheads		
Standard	$4.00	GSA's Federal Supply Service provided through website: https://www.gsaadvantage.gov
Advanced	$8.99	Catalog supplied by Niagara Conservation Company, Cedar Knolls, New Jersey, 2002
Faucets		
Standard	$3.40	GSA's Federal Supply Service provided through website: https://www.gsaadvantage.gov
Advanced	$9.27	GSA's Federal Supply Service provided through website: https://www.gsaadvantage.gov
Toilets		
Standard	$150.00	GSA's Federal Supply Service
Advanced	$200.00	Dual-flush toilet from Caroma: personal communication with representative of USA Caroma, Inc., May 2002
Urinals		
Standard	$216.78	GSA's Federal Supply Service provided through website: https://www.gsaadvantage.gov

Assumptions	Data	Data Source
Advanced	$127.60	GSA's Federal Supply Service provided through website: https://www.gsaadvantage.gov
Installation costs for urinals		Personal communication with Waterless urinal and Falcon Water Free Company, May 2002
Standard	$200.00	(Total cost for installation of unit and water supply line)
Advanced	$100.00	(No water supply line needed)
Annual maintenance costs for urinals		Based on information provided through personal communication with D. Zimmerman, Tennessee Valley Authority, regarding Johnson City Customer Service Center (see Appendix C)
Standard urinal	$119.00	
Blue seal fluid	$14.85	
Eco-trap	$11.44	
Savings for dual flush toilets	33%	Based on one 1.6 gpf/day and two 0.8 gpf/day/woman
Supply and distribution – typical	3	
Wastewater treatment – activated sludge	1.7	

D.2.1 Assumptions and Data Sources

To estimate the costs and annual savings associated with an integrative stormwater management system, detailed assumptions were made based on available data sources, which are described in the following sections.

Parking Area

For the parking area, the porous, gravel-paved lot was compared with a traditional asphalt parking area. The assumptions and data sources for the comparative analysis are as follows:

- Parking lot surface area assumptions:
  - The total lot size is 1 acre – A review of the zoning ordinances, including those in the Baltimore area, led to this size assumption.
  - The parking lot area will require 50 to 75 parking spaces.
  - The parking lot dimensions are assumed to be 140 ft by 180 ft, giving a total area of 25,200 ft^2.

- Installation costs for the porous, gravel-paved and asphalt parking lot came directly from communications from the products manufacturer:[4]
  - Gravel-paved – \$2.30/ft^2
  - Asphalt – \$2.11/ft^2.

- Maintenance costs were obtained from a University of South Alabama study (1999), which shows a comparison of maintenance costs between an asphalt parking lot and porous gravel and grass-paved system:
  - Gravel/grass paved parking area – \$0.296/yd^2/yr
  - Asphalt parking area – \$0.497/yd^2/yr.

[4] Direct communications with D. Glist of Invisible Structures, Inc., on June 28, 2002, provided estimated costs for Gravelpave product and conventional asphalt-paved surface.

This study examined the historical records of the University of South Alabama Grounds Department asphalt maintenance from 1993 to 1998 and compared those records with the maintenance costs for a porous gravel and grass-paved system that was installed on campus. For the asphalt parking lots, maintenance costs included coating, paint striping, patching and crack filling, and resurfacing. For the grass/gravel-paved parking area, maintenance included regular landscaping requirements of the grass and periodic raking and topdressing of the gravel.[5] A 20-year life span was assumed for both surfaces.

Rainwater Collection System

An integrated rain storage system, Rainstore, was compared with a conventional corrugated plastic pipe system. The conventional system simply moves the stormwater off the asphalt parking lot but does not include the opportunity to reuse the stormwater for irrigation. The assumptions and data sources for the comparative analysis are as follows. Both the Rainstore and corrugated pipe systems were sized for the site using Rainstore Materials Estimator, an online tool[6] that allows the user to input the site characteristics and stormwater storage needs to estimate the amount of materials required for a Rainstore system. Optional designs such as the corrugated pipe system can also be evaluated.

Installation costs associated with the Rainstore system were obtained from a quote[7] from a Northeast product dealer, based on the materials that were estimated in the Rainstore Materials Estimator. The Rainstore manufacturer provided costs for additional materials and fees:

- Rainstore modular units – $35,638[7]
- Geogrid and geotextile – $2519[7]
- Pump for feeding rainwater to irrigation system – $300[7]
- Freight for shipping Rainstore system – $7500.[7]

Installation costs for the corrugated pipe system were provided by the product manufacturer[7] and were based on the materials that were estimated in the Rainstore Material Estimator:

- Corrugated pipe – $37,310[7]
- Other materials and services required – $21,154.[7]

Labor costs for both the Rainstore system and corrugated plastic pipe were as follows:

- Labor cost – $70/hr[7]
- Total labor required for Rainstore – an estimated 45 hours (from the Rainstore Estimator tool)
- Total labor required for the corrugated pipe system – assumed to be 5% additional for extra welding of elbows and tees into the system that the Rainstore system does not require.[8]

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[5] Because the system examined in this analysis did not include a grass-paved system, the maintenance costs comparison can be assumed to be conservative.

[6] The website for the online tool is available at http://www.invisiblestructures.com/RS3/RS3_Est_Instruct.htm.

[7] ACF Environmental – a distributor in the Northeastern US for Rainstore products – quotation for Rainstore Stormwater Storage System, July 29, 2002.

[8] Direct communications with C. Spelic of Invisible Structures, Inc., on July 31, 2002, provided estimated costs for labor, freight, and other associated costs with the Rainstore system and for a corrugated pipe systems based on material prices for piped system.

D.2.2 Incremental Costs and Annual Savings Calculations

Tables D-3 through D-5 summarize the calculations that estimated the incremental cost for the sustainable stormwater management system. Table D-3 itemizes all individual costs and fees and shows how the total cost was calculated for each system (summation of the cost column in Table D-3). The total cost for the conventional corrugated pipe system was subtracted from the Rainstore system to calculate the incremental installation cost, as shown on the last row of Table D-3.

Table D-4 lists the installation and maintenance costs for the porous gravel parking area compared with the asphalt parking area. The installation cost per square foot was multiplied by the total area of the parking area, which is 25,200 ft^2, to calculate the total installation cost. To determine the incremental installation cost, the cost of the asphalt parking lot was subtracted from the gravel-paved lot. The incremental maintenance cost was determined in the same manner as shown in Table D-4.

In Table D-5, the total incremental cost for the entire system was calculated by combining the costs for the parking area and rainwater collection system for both the sustainable design and conventional design – as shown in the rows labeled "Total" in Table D-5. The incremental cost was then calculated by subtracting the two total costs. The simple payback of 5.59 years can be calculated by dividing the incremental installation cost by the total maintenance savings.

D.3 Landscape Management Overview and Assumptions[9]

Sustainable landscaping practices combine sound maintenance practices with a design that uses native plants. Conventional landscaping usually is comprised of turf, such as Kentucky blue grass, which requires an irrigation system to provide supplemental water, high maintenance to provide regular mowing, chemical herbicide application to reduce weeds, and fertilizer to maintain a healthy lawn in most regions of the United States. Planting native species greatly reduces the need for supplemental watering and regular maintenance. Native species will withstand the conditions of the area, so native plants can survive in both abnormally wet and dry conditions, whereas non-native plants do not adapt as well to extreme conditions. Also, with sustainable designed landscape, rainwater can be harvested to serve as supplemental irrigation. Specific plants can be selected to help clean rainwater's impurities such as oil from automobiles and salts from roadways to return filtered water to the groundwater or stormwater system.

The following "design" assumptions summarize the specifics of the landscaping area analysis of the site (more details on these features are covered in the next section):

- Landscaping area – 8,000 ft^2
- Landscape design – Native seed mixture combination of native warm weather turf and wildflowers create a natural "meadow" area.
- Irrigation system – Spot and periodic watering are required to establish the native plants. All of the the irrigation water required to establish the native landscaping will be harvested from the rainwater held in the stormwater management system.
- Landscape maintenance – The sustainable landscaping area requires very little maintenance, while the traditional turf landscaping requires regular maintenance and chemical treatment.

[9] K. McMordie, Pacific Northwest National Laboratory.

Table D-3. Installation Costs for Rainwater Storage and Conventional Stormwater Management Systems

	Type	Material Amount	Units	Unit Cost	Cost
Rainstore system	Rainstore modular units	2232	units	$15.97	$35,638.38
	Geotextile	1378	yd^2	$0.55	$760.00
	Geogrid	459	yd^2	$3.83	$1,759.04
	Pump for irrigation feed				$300.00
	Excavation	569	yd^3	14	$7,966.00
	Backfill	226	yd^3	$12.00	$2,712.00
	Area needed	1001	ft^2	NA*	No cost associated with area
	Cover	51	yd^3	$12.00	$612.00
	Freight	3	truck loads	$2,500.00	$7,500.00
	Labor	45	hours	$70.00	$3,150.00
Total					$60,397.42
Conventional system	Corrugated 48" plastic pipe	533	linear ft	$70.00	$37,310.00
	Tees	8	each	$900.00	$7,200.00
	Elbows	4	each	$700.00	$2,800.00
	Excavation	543	yd^3	14	$7,602.00
	Backfill	197	yd^3	$12.00	$2,364.00
	Area needed	2665	ft^2	NA*	No cost associated with area
	Cover	99	yd^3	$12.00	$1,188.00
	Freight	NA	No freight needed	No freight needed	No freight needed
	Labor	47.5	hours	$70.00	$3,325.00
Total					$61,789.00
Incremental installation cost (Rainwater minus conventional)					-$1,391.58
* NA – Not applicable.					

Table D-4. Installation and Maintenance Costs of Porous Gravel Parking Area and Conventional Asphalt Parking Area

	Installation Cost/Ft²	Total Installation Cost	Maintenance Costs ($/ft²/yr)	Total Maintenance Costs/Yr
Gravel-paved parking lot	$2.30	$57,960	$0.0329	$828.80
Asphalt parking lot	$2.12	$53,424	$0.0552	$1,391.60
Incremental cost (gravel minus asphalt)		$4,536		-$562.80

Table D-5. Total Stormwater Installation, Maintenance, and Incremental Costs

Total Stormwater Costs	Total Installation Cost ($)	Total Installation Cost ($/Kft²*)	Maintenance Cost ($/yr)	Total Annual Maintenance Cost ($/Kft²-yr*)
Sustainable system				
Rainstore	$60,397			
Gravel paved	$57,960			
Total	$118,357	$5,918	$829	$41
Conventional system				
Corrugated pipe system	$61,789			
Asphalt-paved parking area	$53,424			
Total	$115,213	$5,761	$1,392	$70
Incremental cost (sustainable minus conventional)	$3,144	$157	-$563	-$28

D.3.1 Assumptions and Data Sources

To estimate the installation costs and annual savings associate with landscaping at the site, the following assumptions and data sources were used in the analysis:

- Landscape area
  - Total lot size is 1 acre – A review of zoning ordinances, including those in the Baltimore area, led to this assumption.
  - The parking area – A total of 25,200 ft² based on 50 to 75 parking spaces.
  - Footprint of the building – 10,082 ft².
  - Landscaping area – 8000 ft² (with the remaining area of 278 ft² for sidewalks).
- Landscape materials and installation cost:[10]
  - $20,000/acre for native planting of seed mixture
  - $6667/acre for traditional turf (one-third the cost of native seed mixture).

- Irrigation system –Normally, no irrigation system would be installed for a native landscape, but because this landscape will be irrigated from rainwater in an underground storage system, a pump (costs for the pump was included in the stormwater management analysis) is required to

[10] Input on the design and installation costs for native plant and traditional turf material was provided by G. Gardner of Davis, Gardner, Gannon, Pope Architecture in Philadelphia, Pennsylvania. This firm has been involved in two Leadership in Energy and Environmental Design (LEED™) projects in the northeastern United States and is knowledgeable about the real costs associated with native plant species compared with traditional turf for the northeastern United States.

pump the water from the underground storage, and an irrigation system is required to provide a means to deliver the rainwater to the landscaping. This system is the same size required for a conventially-landscaped area; therefore, there is no incremental cost for the irrigation system.

- Maintenance services and costs[11]
  - Annual maintenance for the traditional turf area will require 6 applications of fertilizer and herbicides per year, 26 mowing and maintenance trips, and 1aeration.
  - The annual maintenance fee for the sustainable landscape is assumed to be 10% of that of the traditional landscape. While sustainable landscaping will not require routine maintenance such as mowing and fertilizing, it is not maintenance-free. Based on a review of the literature in this area, a traditional turf landscape area is estimated to require 10 days of maintenance, whereas a sustainable design will only require 1 day. The watering schedule for traditional turf landscaping is assumed to be 1 in. of water over the entire area at 30 applications per year.
  - The average FY 1999 GSA water rate for Region 3 (Baltimore is in GSA Region 3) was used to estimate the cost of irrigation for traditional turf area: $3.97/1000 gallons.
  - No water costs are associated with the native landscaping because all supplemental water will be supplied from the rainwater collection system.
  - Annual maintenance service fees for traditional turf landscape are assumed to be $2754 (a combination of all services listed and irrigation requirements). This cost does not include maintenance of the irrigation systems because the maintenance costs are assumed to be minimal and not a large factor in this study because both designs have irrigation systems.

D.3.2 Incremental Costs and Annual Savings Calculations

Table D-6 shows the individual installation and maintenance costs estimated for the sustainable and conventional landscape designs. The installation costs are a combination of design, implementation of landscape materials, and installation of the irrigation system. The maintenance costs are a combination of all routine maintenance (listed above) and cost of water to irrigate the landscaping. The incremental costs were determined by calculating the difference between the total costs for each design, as shown in the last row of Table D.6. The simple payback of 0.8 years can be calculated by dividing the incremental installation cost by the total maintenance savings.

[11] The cost for landscape maintenance for traditional turf was estimated by Trugreen Chemlawn Company, a division of the national franchise, located in Baltimore, Maryland.

Table D-6. Installation, Maintenance, and Incremental Costs of Sustainable and Conventional Landscape Area

	Site Design and Implementation ($/acre)	Site Design and Implementation ($ for this site)	Installation Cost ($/1000ft²*)	Maintenance Costs ($/yr)	Irrigation Water Use Cost ($/yr)	Total Maintenance Cost ($/yr)	Total Maintenance Cost ($/1000 ft²)
Sustainable Design							
Native planting	$20,000	$3,673.09	$183.65	$272.39	$0	$272.39	$13.62
Conventional							
Traditional turf	$6,667.67	$1,224.36	$61.22	$2,723.91	$593.91	$3,317.82	$165.89
Incremental cost (sustainable minus conventional)	$13,333	$2,498.73	$122.44	-$2,451.52	-$593.91	-$3,045.43	-$152.27