The Avenue – Washington, D.C.
Methodology for Landscape Performance Benefits
Prepared by:

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Environmental

Prevents 76,000 gallons of annual stormwater runoff from entering the city's aging combined sewer system by collecting and reusing runoff from a 40,000 sf area of the courtyard and office building roof and reusing it in the courtyard for irrigation and water feature replenishment.

Stormwater runoff in Washington, D.C. frequently exceeds the capacity of the combined sewer system. This overflow leads to periodic flooding of the National Mall and low-lying areas, and contributes to pollution of the region's rivers and streams. By capturing, collecting and reusing stormwater on site, runoff is prevented from entering the city's system, helping to reduce flooding and the problems it causes.

None of the streetscaped areas are irrigated. Captured stormwater supplies all of the courtyard irrigation and replenishes the water feature. Stormwater is collected from the 40,000 ft^2 area of the office-building roof and the courtyard and directed into the filtration system and 7,500 gallon storage cistern located in the underground parking garage. Collected and filtered water is then pumped back to the courtyard for irrigation and to replace water lost to evaporation in the water feature. To determine the total amount of water reused annually, and therefore potable water saved, the amount of water needed per year for irrigation was added to the amount of water lost per year due to evaporation.

To calculate the volume of water lost due to evaporation for each of the six months the water feature would be operational, the local monthly evaporation rate was converted from millimeters to feet and multiplied by the area of the water feature (1,935 ft^2). The table below shows the calculation for each month:

	MAY	JUN	JUL	AUG	SEP	OCT
Evaporation	55	80	90	70	50	28
Convert to inches	2.1654	3.1496	3.5433	2.7559	1.9685	1.1024
Convert to feet	0.1804	0.2625	0.2953	0.2297	0.1640	0.0919
CF/mo (evap. water)	349	508	571	444	317	178
gal/mo	2612	3799	4274	3324	2374	1330

Total water lost per year to evaporation = 2,612 + 3,799 + 4,274 + 3,324 + 2,374 + 1,330 = 17,713 gallons

Total water needed per month for irrigation is 9,670 gallons per month, as calculated below, in bullet point two. The total required per year is 9,670 gallons per month × 6 months of irrigation = 58,020 gallons

See methodology of previous benefit for calculation of monthly courtyard irrigation.
(maximum irrigation demand was calculated – demand may be less is some months)

Total potable water saved = Water lost to evaporation + Water needed for irrigation
75,733 gallons = 17,713 + 58,020
Convert gallons to cubic feet (7.48 gallons = 1 ft^3)
75,733 gallons = 10,125 ft^3

Table provided by Mark Delaney, Sasaki Associates, Inc.
2012 Water and Sewer rates for the city of Washington, D.C. obtained from:
http://www.dcwater.com/customercare/rates.cfm#currentrates

Eliminates the use of potable water in the landscape, saving 76,000 gallons of water and approximately $730 per year. The use of native and drought-tolerant plants, as well as high-efficiency irrigation systems, helps by reducing the amount of water needed for irrigation by 62%.

To determine the savings incurred from potable water, refer to the calculations above and continue as follows:

Total potable water saved = Water lost to evaporation + Water needed for irrigation
75,733 gallons = 17,713 + 58,020
Convert gallons to cubic feet (7.48 gallons = 1 ft^3)
75,733 gallons = 10,125 ft^3

Cost savings per year = Total potable water saved $\times$ (Water rate + Sewer rate)
\$729.00 = 10,125 $ft^3 \times$ (.0324 \$/ ft^3 + .0396 \$/ ft^3)

The irrigation requirements calculation was then completed as part of the project's LEED for Core and Shell Gold certification. In order to achieve the point for the WE Credit 1: Water Efficient Landscaping, the project needed to demonstrate at least a 50% reduction in water used for irrigation. A baseline case of water consumption for irrigation was calculated for the site using average values representative of conventional equipment and design practices. The amount of water that would be used for irrigation in the designed landscape was then calculated and the percent reduction in the total amount of water use from the baseline to the design case was determined. Both cases were calculated using the month with the highest irrigation demand (July) and since the streetscape is not irrigated, it was not included in either case.

The total water use of each area of vegetation was calculated in both the baseline and design cases using the following formulas:
KL = Species Factor $\times$ Density Factor $\times$ Microclimate Factor
ETL = ETO $\times$ KL
Total water use = Area $\times$ (ETL/IE) $\times$ 0.6233
[KL = Landscape Coefficient, ETL = Landscape Evapotranspiration rate, ETO = Region Evapotranspiration rate for July, IE = Irrigation Efficiency]
The table below shows the calculations for the baseline and design cases:

Design Case (July)

LandscapeType	Area [sf]	Species Factor (k_s)	Density Factor (k_d)	Microclimate Factor (k_{mc})	KL	ETO	ETL	IE	Total Water use [gal]
Trees & Groundcover	1,981	Avg. 0.5	High 1.3	Avg. 1.0	0.65	5.35	3.48	Drip .90	4,771
Trees & Lawn	2,657	Avg. 0.5	Avg. 1.1	low. 0.5	0.28	5.35	1.47	Sprinkler .625	3,898
Groundcover	2,704	Low. 0.2	Low .5	Avg. 1.0	0.10	5.35	0.54	Drip .90	1,002
Totals	7,341								9,670

Baseline Case (July)

LandscapeType	Area [sf]	Species Factor (k_s)	Density Factor (k_d)	Microclimate Factor (k_{mc})	KL	ETO	ETL	IE	Total Water use [gal]
Trees & Groundcover	1,981	Avg. 0.5	Avg. 1.1	Avg. 1.0	0.55	5.35	2.94	Sprinkler .625	5,813
Lawn	5,361	Avg. 0.7	Avg. 1.0	Avg. 1.0	0.70	5.35	3.75	Sprinkler .625	20,022
Totals	7,342								25,835

% Reduction = (Baseline Water use – Design Water use)/Baseline Water use × 100
62% = (25,835 – 9,670)/25,835 × 100

Table provided by Mark Delaney, Sasaki Associates, Inc.
Information on the WE Credit 1: Water Efficient Landscaping obtained from:
U.S. Green Building Council. *LEED 2009 for Core and Shell Development Rating System* (p.25)
http://www.usgbc.org/ShowFile.aspx?DocumentID=8870

Reduces summer rooftop temperatures by using a combination of vegetated and light-colored roofing materials. Air temperatures above the green roof were an average of 3.5°F cooler than above the light-colored roof areas and overall peak roof surface temperature is estimated to be approximately 40°F cooler than a conventional black roof.

The 81,000 ft^2 of combined office and residential building roof area consists of light reflective materials and a green roof. Approximately 10% (8,000 ft^2) of the roof is an extensive green roof. Approximately 12% (10,000 ft^2) is patio space primarily constructed of light-colored pavers. The remaining 78% (63,000 ft^2) is constructed of light-colored stone ballast and contains the HVAC equipment. Temperature readings were taken on both the office and residential building roofs to compare the performance of the green roof and the light-colored materials. Readings were taken between 2:30 – 3:30pm on July 17th, 2012 with mostly sunny conditions and air temperatures in the range of 95 – 100°F. An ambient thermometer was used to take readings approximately 12 inches above each surface in multiple locations on both roofs. The average green roof temperature was 3.7°F cooler than the average pavers/ballast temperature on the residential building roof and 3.3°F cooler on the office building roof, for an average of 3.5°F cooler. As the plantings on both roofs continue to mature over time, the gravel/growing medium will be less exposed, which could increase the cooling abilities of the green roofs. Additional temperature readings should be taken in the future to assess the impacts of any changes in vegetation.

Evidence demonstrates that vegetated and light-colored roofing materials can substantially reduce peak surface temperatures compared to a conventional black roof. Cool roofs are typically constructed of materials that, like green roofs, lower building temperatures and consequently reduce energy demand, decrease greenhouse gas emissions and improve air quality while saving money on air-conditioning. Cool roofs and green roofs stay cooler than conventional black roofs by reflecting light. A related benefit is that these types of roofs better regulate interior building temperatures by reducing heat flux into buildings.

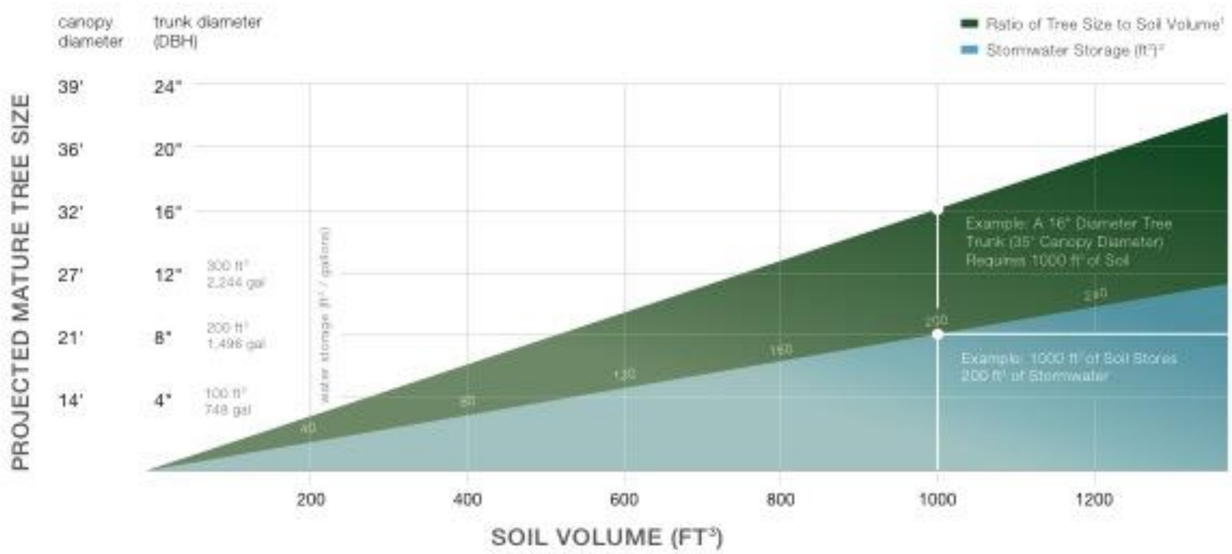
The green roof located on top of the American Society of Landscape Architects (ASLA) headquarters in Washington, D.C. (less than 2 miles from The Avenue) has recorded temperatures as much as 43.5°F cooler than conventional black roofs on neighboring buildings. Similarly, a study conducted in Tennessee by the Oak Ridge National Laboratory found that roofs with pavers or stone ballast had peak surface temperatures of 43°F – 56°F cooler than a black membrane roof. Based on this information, the overall peak roof surface temperature for the site, which has a combination of vegetated and light-colored roofing materials, is estimated to be about 43°F cooler than a conventional black roof.

Additional temperature readings were taken at the same time at ground level to determine if there were any cooling effects of courtyard vegetation and materials, however, differences between average surface temperatures did not exceed the ±2°F thermometer accuracy.

Green roof and cool roof performance information obtained from:
Natural Resources Defense Council Report. June 2012.
Looking Up: How Green Roofs and Cool Roofs Can Reduce Energy Use, Address Climate Change, and Protect Water Resources in Southern California. R:12-06-B (p.13)
http://www.nrdc.org/water/pollution/files/GreenRoofsReport.pdf
ASLA green roof performance data obtained from:
http://www.asla.org/ContentDetail.aspx?id=28758
Paver/ballast roof performance data obtained from: Oak Ridge National Laboratory Report.
April 2008. *Evaluating the Energy Performance of Ballasted Roof Systems* (p.10)
http://www.spri.org/pdf/Thermal%20Performance%20of%20Ballast%20Study%20Final%20Report%2005%2008%20.pdf

Will sequester over 12,000 lbs of carbon annually and supply an estimated 24,000 sf of shade, when the 34 street trees reach their mature size, as projected by the 900 cu ft of structural soil available per tree.

One of the most important elements for the survival and growth of urban trees is soil availability. Adequate soil volume sustains healthy root development, allowing trees to live longer and grow larger. Evidence supports the general guideline that trees need approximately 1 to 2 ft^3 of soil for each square foot of mature tree canopy. Using this guideline, the graph below demonstrates how mature tree size is projected based on the volume of soil available. As the graph demonstrates, if trees are provided with 900 ft^3 of soil, they are projected to reach a canopy diameter of approximately 30 ft and a trunk diameter at breast height (DBH) of about 14 inches.



To estimate the amount of shade provided and amount of annual carbon sequestered once the street trees reach their projected mature size, the following calculations were completed:
Projected mature tree size = 30’ canopy diameter = 15’ canopy radius

Area = πr^2
Canopy area per tree = $\pi \times$ (canopy radius)^2
706.5 ft^2 = 3.14 $\times$ (15)^2
Total area of shade = Canopy area per tree $\times$ # of trees
24,012 ft^2 = 706.5 $\times$ 34

Projected mature tree size = 14" DBH (Trunk diameter at breast height – 4.5' above ground)
34 street trees = 10 Kentucky coffeetrees + 6 Willow oaks + 18 American elms
Kentucky coffeetree sequesters 358 pounds of CO^2/year
Willow oak sequesters 378 pounds CO^2/year
American elm sequesters 358 pounds of CO^2/year
Total carbon sequestered = Sum of (pounds of CO^2/year $\times$ # of trees)
12,292 pounds = (358 $\times$ 10) + (378 $\times$ 6) + (358 $\times$ 18)

Carbon sequestration amounts obtained from: National Tree Benefit Calculator
http://www.treebenefits.com/calculator/
Graph of relationship between soil volume and tree size (credit: James Urban) obtained from:
http://www.deeproot.com/blog/blog-entries/how-much-soil-do-you-need-to-grow-a-big-tree
Information on the relationship between soil volume and tree size obtained from:
Casey Trees. 2008. *Tree Space Design: Growing the Tree out of the Box* (p.2-3)
http://caseytrees.org/wp-content/uploads/2012/02/tree-space-design-report-2008-tsd.pdf

Social

Provides a space of respite and relaxation for visitors, office workers and residents, with users observed to spend an average of 21 minutes in the courtyard.

Four hours were spent observing courtyard users over two consecutive weekdays. Observations took place between 12:15 – 1:15pm and 5:30 – 6:30pm on July 12th, 2012 and between 11:30am – 1:30pm on July 13th. Weather conditions were mostly sunny with air temperatures in the range of 85 – 90°F. The following attributes were recorded for users observed spending time in the space – gender, grouping, activity and adult or child. For 35 out of 43 of the observed courtyard users, both an arrival and departure time was also recorded and used to calculate the total amount of time spent in the space. Visits ranged from 5 to 40 minutes with users spending an average of 21 minutes in the courtyard.

Several factors may encourage users to spend time in the courtyard including the variety of seating provided by 17 benches and 175 linear feet of seat wall. The sights, sounds and potential evaporative cooling of the courtyard water feature may also contribute to longer visits. Temperatures measured above the water feature were an average of 2°F less than adjacent hardscape areas, suggesting a cooling effect, however, this temperature difference did not exceed the ±2°F thermometer accuracy. See methodology of previous benefit for how and when temperature readings were taken.

The timing of the observations may have affected the average courtyard stay that was calculated. For example, almost 75%, or 32 out of 43 users, were observed eating lunch, which may have meant a longer stay. Additional observations during different seasons, days or hours should be conducted to obtain a more comprehensive result.

Provides 34% of residential units with views of the green courtyard, which has been shown to reduce mental fatigue and restore attention.

% Residential units with green view = (# of units with view/total # of units) $\times$ 100
33.7% = (113/335) $\times$ 100

Research demonstrates that viewing nature, including green spaces, reduces stress within five minutes or less. Evidence also suggests that viewing nature elicits positive physiological and emotional changes such as decreasing negative or stressful emotions while increasing pleasant feelings (Ulrich, Quant & Zimring 2010 and Ulrich 2002, both cited in Environmental Health Research Foundation, 2011: 24-25). Studies on attention fatigue indicate a correlation between views to nature and improved attention (Berto, Baroni, Zainaghi & Bettella 2010, cited in Wolf & Flora, 2010: 2). Research also suggests that office workers having nature views demonstrated higher levels of enthusiasm, patience, and satisfaction at work and lower levels of frustration, anxiety, and tension as well as fewer health problems (Kaplan 1993 and Chang & Chen 2005, both cited in Wolf & Flora, 2012: 3).

Classifying and quantifying which offices on the project site had courtyard views was difficult. This was due to varying space configurations on each floor and to the additional number of green views that were not to the courtyard, but were views to Washington Circle from the northern portion of the office building. In addition, determining the economic benefits also proved challenging. Although evidence suggests that views to parks offer a greater economic benefit to property values, the building units with views facing the courtyard do not command a higher rental price per square foot than other units.

Benefits of green views obtained from:
Environmental Health Research Foundation. April 2011.
Benefits of Green Space – Recent Research. Author: John Heinze
http://www.ehrf.info/wp-content/uploads/2011/09/BenefitsofGreenSpace.pdf
Berto, R., M.R. Baroni, A. Zainaghi & S. Bettella. 2010. An Exploratory Study of the Effect of High and Low Fascination Environments on Attentional Fatigue. *Journal of Environmental Psychology* 30, 4: 494-500.
Chang, C.Y. & P.K. Chen. 2005. Human Response to Window Views and Indoor Plants in the Workplace. *Hortscience* 40, 5: 1354-59.
Kaplan, R. 1993. The Role of Nature in the Context of the Workplace. *Landscape and Urban Planning* 26, 1-4: 193-201.
Green Cities: Good Health – University of Washington, College of the Environment. 2010.
Mental Health and Function – A literature Review. Authors: K.L. Wolf & K. Flora
http://depts.washington.edu/hhwb/Thm_Mental.html
Layout of residential units by floor obtained from:
http://theavenueliving.com/#floor-plans
Information on residential unit rental prices provided by a manager at The Bozzuto Group

Creates an active streetscape with a 58 foot wide landscaped sidewalk where an average of 90 individuals were observed using the space for outdoor dining. The pedestrian friendly environment of the spacious promenade provides gathering places while also allowing for efficient movement through the site.

The sidewalk promenade running along I street on the south edge of the site is approximately 58 ft wide. Over half of the sidewalk width (32 ft) is used for outdoor dining space adjacent to the restaurants, while the remaining 26 ft accommodates heavy pedestrian traffic, street trees, plantings and additional seating. Capacity for outdoor dining is approximately 188 total seats. The environment is geared to pedestrian activity, attracting visitors to the shared space and increasing opportunities for social interaction.

Five separate observations were completed on two consecutive weekdays to determine the average number of outdoor diners spending time in the space. Counts of the total number of users took place at 1:45pm, 5:25pm and 7:00pm on July 12th, 2012 and 11:25am and 1:35pm on July 13th. Weather conditions were mostly sunny with air temperatures in the range of 85 – 90°F. The timing of the observations affected the number of outdoor diners using the site with the total ranging from 22 to 163 individuals to get an average of 90. Additional observations during different seasons, days or hours should be conducted to obtain a more comprehensive result.

Information on streetscape design obtained from:
City of Cheyenne. 2009. *What Makes A Great Streetscape*. Author: Jan Spires
http://www.cheyennecity.org/DocumentCenter/Home/View/2954

Economic

Generates an estimated $11.5 million in annual city tax revenue.

The $11.5 million in annual tax revenue is an estimate of the amount of property and sales taxes that the mixed-use development will generate. This projection is based on full occupancy of the project's 450,000 square feet of commercial office space, 84,000 square feet of retail space and 335 residential units. Actual annual tax revenues cannot yet be measured because construction was completed less than a year ago in fall 2011. Once the project has been fully occupied for at least a year or perhaps several years, it would be beneficial to determine the amount of tax revenue generated and to examine other potential economic impacts of the development, including how neighboring property values have been affected.

Annual city tax revenue estimate and development information obtained from:
George Washington University. *The Avenue (Square 54) Spring 2011 Update* (p.2)
http://neighborhood.gwu.edu/campusdev/docs/Fact%20Sheets%20Spring%20%20Summer%202011/GW_Square54FS_sm2011.pdf

Methodology for Cost Comparison

Stormwater on the site is collected, filtered and stored in a cistern under the central courtyard. This water is utilized in lieu of potable water for the irrigation of plants and to replenish water lost to evaporation in the water feature. The storage tank, pumping and filtration system cost approximately $42,000 to install and has an initial maintenance cost of $500 per year. With 76,000 gallons of stormwater collected and reused annually, the cost of the system could be offset with savings in potable water in approximately 33 years.

To determine the amount of time it will take to pay off the cost of the stormwater system with savings in potable water, the projected net savings were calculated for each year, beginning when the project was completed in 2011. These annual net savings were then totaled to get a cumulative savings for the project and the system was considered paid off once this sum exceeded the $42,000 cost.

The net savings were calculated for each year using the following formulas:
Annual Net savings = Water savings – Maintenance cost
Annual Water savings = Annual amount of potable water saved × Water and Sewer Rate
The table below shows the calculations for 2011 through 2043:

Year	Water'and' Sewer'Rate' ($/cubic'foot)	Water' Saved' (cubic'feet)	Annual' Water' Savings'($)	Annual' Maintenance' Cost'($)	Annual'Net' Savings'($)	Cumulative' Savings'($)
2011	$0.0689	10,125	$698	$500	$198	$198
2012	$0.0720	10,125	$729	$515	$214	$412
2013	$0.0767	10,125	$777	$530	$246	$658
2014	$0.0805	10,125	$815	$546	$269	$926
2015	$0.0857	10,125	$868	$563	$305	$1,231
2016	$0.0913	10,125	$924	$580	$345	$1,576
2017	$0.0973	10,125	$985	$597	$388	$1,964
2018	$0.1017	10,125	$1,030	$615	$415	$2,379
2019	$0.1057	10,125	$1,070	$633	$437	$2,816
2020	$0.1105	10,125	$1,119	$652	$466	$3,282
2021	$0.1182	10,125	$1,197	$672	$525	$3,808
2022	$0.1265	10,125	$1,281	$692	$589	$4,396
2023	$0.1354	10,125	$1,371	$713	$658	$5,054
2024	$0.1448	10,125	$1,467	$734	$732	$5,786
2025	$0.1550	10,125	$1,569	$756	$813	$6,599
2026	$0.1658	10,125	$1,679	$779	$900	$7,499
2027	$0.1774	10,125	$1,797	$802	$994	$8,493
2028	$0.1899	10,125	$1,922	$826	$1,096	$9,589
2029	$0.2031	10,125	$2,057	$851	$1,206	$10,795
2030	$0.2174	10,125	$2,201	$877	$1,324	$12,119
2031	$0.2326	10,125	$2,355	$903	$1,452	$13,571
2032	$0.2489	10,125	$2,520	$930	$1,590	$15,161
2033	$0.2663	10,125	$2,696	$958	$1,738	$16,899
2034	$0.2849	10,125	$2,885	$987	$1,898	$18,797
2035	$0.3049	10,125	$3,087	$1,016	$2,070	$20,867
2036	$0.3262	10,125	$3,303	$1,047	$2,256	$23,123
2037	$0.3490	10,125	$3,534	$1,078	$2,456	$25,579
2038	$0.3735	10,125	$3,782	$1,111	$2,671	$28,250
2039	$0.3996	10,125	$4,046	$1,144	$2,902	$31,152
2040	$0.4276	10,125	$4,329	$1,178	$3,151	$34,303
2041	$0.4575	10,125	$4,633	$1,214	$3,419	$37,722
2042	$0.4896	10,125	$4,957	$1,250	$3,707	$41,429
2043	$0.5238	10,125	$5,304	$1,288	$4,016	$45,445

See methodology of Landscape Performance Benefit #2 for calculation of the total amount of potable water saved per year and conversion from gallons to cubic feet. The Water and Sewer Rates for 2011 and 2012 reflect the true Washington, D.C. city rates, while the rates from 2013 through 2020 reflect proposed rates. After 2020, estimated rates were calculated based on a 7% increase every year. The initial annual maintenance cost of the system was estimated at $500 for 2011 and was calculated with a 3% increase every year after that due to projected inflation. Cumulative savings were calculated by adding the annual net savings to an ongoing total savings for the project. Based on these calculations, the system savings will surpass the $42,000 cost at 33 years.

System installation cost, annual maintenance cost, 7% yearly rate increase and 3% yearly inflation rate for maintenance costs were provided by Mark Delaney, Sasaki Associates, Inc.
Water and Sewer rates for the city of Washington, D.C. were obtained from:

District of Columbia Water and Sewer Authority. 2012-2013. *Operating Budgets* (p.13)
http://www.dcwater.com/investor_relations/budget_sections/2012/Rates_and_Revenue.pdf