North Carolina Museum of Art

Methodology for Landscape Performance Benefits

Research Fellow: Andrew Fox, PLA, ASLA, Associate Professor/University Faculty Scholar, North Carolina State University

Research Assistant: Sadie Walters, Student ASLA, MLA Candidate, North Carolina State University

Research Volunteer: Pei Chi (Peggy) Huang, MLA Candidate, North Carolina State University

Firm Liaison: Walter R. Havener, PLA, LEED AP, Surface 678, PA

Overview of CSI: This investigation was conducted as part of the Landscape Architecture Foundation's 2015 *Case Study Investigation* (CSI) program. CSI matches faculty-student research teams with design practitioners to document the benefits of exemplary high-performing landscape projects. Teams develop methods to quantify environmental, economic and social benefits and produce Case Study Briefs for LAF's *Landscape Performance Series*.

The full case study can be found at: https://landscapeperformance.org/case-study-briefs/north-carolina-museum-art

Landscape Performance Benefits & Methodologies

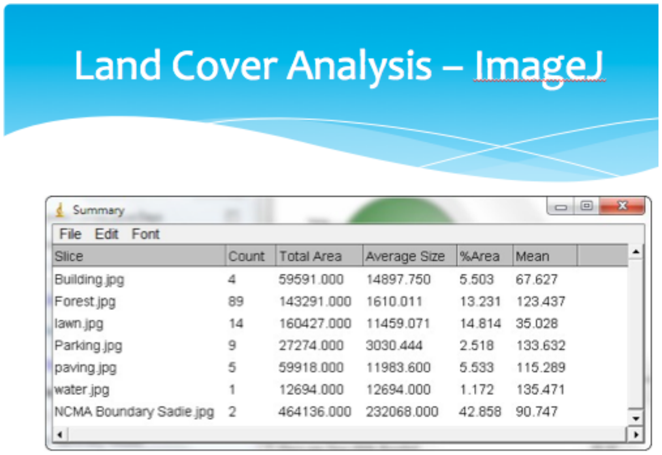
Environmental Performance Benefits

- *Reduces annual runoff by 84% or 2,663,872 gallons, equivalent to 4 Olympic-size swimming pools.*

Method:
Stormwater management of the site was designed to manage runoff from a 1.5-inch storm event. The site, a total of 42 acres, consists of approximately 13.5 acres, or 32%, non-permeable surfaces and 28.5 acres, or 68%, permeable surfaces. The water management systems consist of one 90,000-gallon cistern, 1.03 acres of stormwater wetland, .64 acres of bioretention, and 1.28 acres of wet pond. These known areas and quantities were modeled using the US EPA National Stormwater Calculator.

Data:
Runoff Reduction Totals:

Pre-development Average Annual Runoff = 30.82 in
Post-development Average Annual Runoff = 4.84 in
30.82 in – 4.84 in = 25.98 in; 25.98 in / 30.82 in = .843 (~84% reduction)



Slice	Count	Total Area	Average Size	%Area	Mean
Building.jpg	4	59591.000	14897.750	5.503	67.627
Forest.jpg	89	143291.000	1610.011	13.231	123.437
lawn.jpg	14	160427.000	11459.071	14.814	35.028
Parking.jpg	9	27274.000	3030.444	2.518	133.632
paving.jpg	5	59918.000	11983.600	5.533	115.289
water.jpg	1	12694.000	12694.000	1.172	135.471
NCMA Boundary Sadie.jpg	2	464136.000	232068.000	42.858	90.747

Figure 1: Land cover delineation table

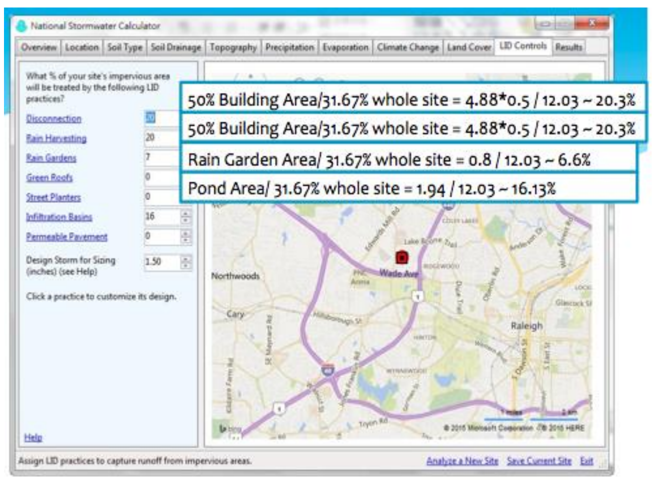


Figure 2: Defining and calculating the performance of various LID features in the US EPA National Stormwater Calculator

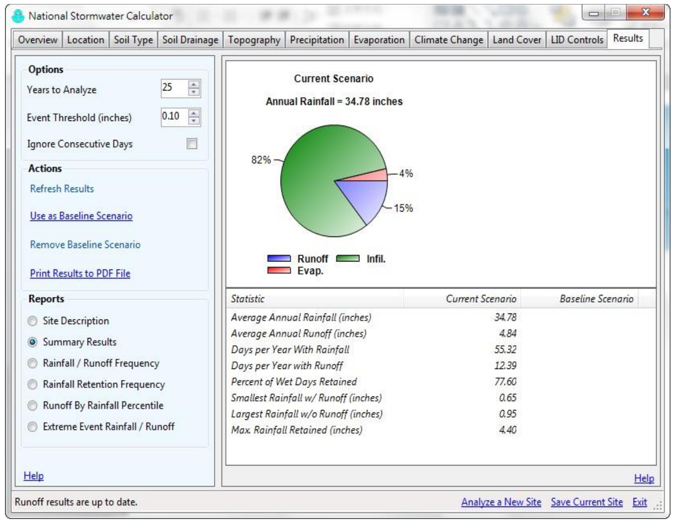


Figure 3: Post-development runoff model

Treatment Volume Conversion:

Total cistern capacity = 90,000 gallons

Annual Average Runoff Difference: 25.98 in

Runoff Volume = Runoff depth*drainage area

Reduction Volume = 25.298*1,644,840.09 sf = 3,561,078.79 cu ft, or ~2,663,872 gallons.

Pool Equivalency Conversion:

Olympic-size pools measure 50 m long, 25 m wide, and a minimum of 2 m deep (USA Swimming, 2015).

50 meters = 164 ft (a)

25 meters = 82 ft (b)

2 meters = 6.6 ft (c)

Volume = (a)*(b)*(c) = 88,286.7 cu ft

88,286.66721 cu ft = 660,430.3 U.S. gallons

2,663,872 / 660,430 = 4.03

Limitations:

Actual storm event collection data was not available; therefore all calculations and resulting conclusions were made using the US EPA National Stormwater Calculator. Per the EPA calculator, all calculations assume that the cisterns are completely emptied on-site during intermittent dry periods and, therefore, are capable of capturing their full capacity of 90,000 gallons during all rain events. However, the cistern does not contain monitoring devices and is buried underground, therefore there is no way to acquire specific data regarding the amount of water used, the associated draw-down time, and/or the total amount of water captured in the cistern.

References:

Artifex Environmental Design, Inc. (2012). *NCMA Pond Water Quality Improvement Project*.

Bass, Kris, Blackwell, Jaime, Spooner, Jean. (2012). *Stormwater Monitoring at the NC Museum of Art.* NCSU Biological and Agricultural Engineering Department. Print.

Surface678. (2015). *NCMA Pond Water Quality Improvement Project Description*.

USA Swimming. (2015). Available online: http://www.usaswimming.org/_Rainbow/Documents/d88245f7-325a-464b-84c6-7db3891422fc/Pool%20Dimensions%20and%20Reccomendations.pdf

US EPA. (2015). *National Stormwater Calculator*, available online: http://www2.epa.gov/water-research/national-stormwater-calculator

- *Increased stormwater pollutant removal by 10-35 percentage points for total suspended solids, nitrogen, and phosphorus.*

Method: Re-reporting the findings, including all associated methods and data, from the *Stormwater Monitoring at the NC Museum of Art* report (Bass, Blackwell and Spooner 2012), a study conducted by the NC State Department of Biological & Agricultural Engineering and North Carolina Cooperative Extension. The study assessed and reported the percentage of treated water, cfs flow-through, and resultant pollutant reductions.

The following excerpts describe the methods used in the study (Bass, Blackwell and Spooner 2012):

> "Pre-construction monitoring at the Art Museum was underway from 2006 to 2008. Initial sampling was collected at the pond outlet only [...] The general monitoring plan included the installation of three monitoring stations. Two monitoring areas were set up to gather data on the primary inputs to the pond. The third station was installed at the pond outlet. During the sampling period of 2008, the Art Museum expansion project was underway. This allowed sample collection to provide insight on the effect of upstream construction on stormwater samples. During pre-construction sampling a total of 40 samples were collected. Post-construction monitoring began in 2011 and continued through the summer of 2012. Sampling began once initial plantings had time to establish and the project could exhibit stormwater treatment functions. [...] Post-construction monitoring was conducted in two of the same locations as in the pre-construction period and one of the inlet stations was moved to better accommodate the new design. The same protocol of flow monitoring and flow-weighted composite sampling was collected during this period. A total of 46 samples were collected, including 14 paired sets."
>
> "Continuous automatic sampling machines were used to log flow data as well as to collect stormwater samples. [...] The samplers were programmed to begin sampling once they detected a pressure change indicating a change in water level depth. Composite, flow-weighted water quality samples were collected at specified volume intervals during storm events."
>
> "Flow data at each location was determined by the combination of level monitoring with weir and pipe flow equations. Flow at the pond outlet was calculated using a combined weir equation and flow at the inlets was calculated using a pipe flow rating curve generated with a computer model (HEC-RAS)."
>
> "Rainfall was collected on the NCMA property using an automatic tipping bucket rain gage which collected the amount and intensity of each rain storm and recorded the information on a data logger. A manual rain gage was used as a backup in case of malfunction and in order to calibrate the automatic gage."

Data:

NCMA Sites	TKN	NO_3+NO_2	TN	NH_3-N	TP	Ortho-P	TSS	Sample Size
	(mg/L)							
Outlet (2006-2008)	0.91	0.40	1.31	0.22	0.12	0.01	63	14
Outlet (2006-2007)	0.89	0.40	1.29	0.24	0.08	0.01	26	8
Outlet (2008)	0.93	0.40	1.33	0.19	0.16	0.01	118	6
Primary inlet (High Density, 2008)	1.52	0.32	1.85	0.17	0.34	0.01	397	9
Secondary inlet (Low Density, 2008)	1.07	0.96	2.03	0.14	0.12	0.01	57	3

Figure 4: Pre-development mean pollutant concentrations, with pre-construction data set highlighted in red (source: Bass, Blackwell and Spooner 2012)

	TKN	NO_3+NO_2	TN	NH_3	TP	# samples	TSS	# samples
	mg/l						mg/l	
Primary Inlet	1.2	0.6	1.8	0.3	0.17	20	260	13
Secondary Inlet	1.9	1.2	3.1	0.19	0.58	17	35	10
Weighted Input	1.2	0.6	1.8	0.3	0.18	14	--	--
Outlet	1.0	0.1	1.1	0.2	0.09	19	10	12
Efficiency Ratio	0.17	0.83	0.69	0.33	0.47	14	--	--

A reduction in concentrations is shown for all nutrients and TSS. The Efficiency Ratio (ER) is determined by the formula:

$$ER = \frac{\text{(inlet concentration - outlet concentration)}}{\text{inlet concentration}}$$

Figure 5: Post-construction mean nutrient and TSS concentration (source: Bass, Blackwell and Spooner 2012)

For the purposes of this case study, the landscape performance benefits were calculated using the 2006-2008 pre-development dataset. The data recorded from 2006-2007 (highlighted in Figure 4) predates construction activities, which began in 2008. The land disturbance that occurred during construction caused significant spikes in all recorded levels. For instance, Bass, Blackwell and Spooner (2012) reported, "As the construction activities increased, the mean TSS concentration at the Outlet increased nearly fivefold, from 26 mg per L to 118 mg per L in the spring of 2008. The mean TSS concentration at the main inlet was substantially higher, at 397 mg per L, clearly showing the impacts of the land disturbance."

Additionally, the system performance (nutrient capture measured by the Efficiency Ratio (ER)) was calculated using the data readings representing the highest level of treatment (primary or secondary inlets). The "Mean TSS, TKN and TP concentrations were highest for the High Density station. NO3, TN, and NH3 were highest at the Low Density inlet" (Bass, Blackwell and Spooner 2012).

Pre-development efficiency ratio calculations:

TKN: (1.52 - .91)/1.52 = .40 (primary inlet)

NO_3+NO_2: (.96 - .40)/.96 = .58 (secondary inlet)

TN: (2.03 - 1.31)/2.03 = .35 (secondary inlet)

NH_3: (.14 - .22)/.14 = -.57 (secondary inlet)

TP: (.34 - .12)/.34 = .65 (primary inlet)
TSS: (pre) 397 - 63=334; 334/397=.84 | (post) 260 - 10=250; 250/260=.96 (primary inlet)

Pre-/post-performance calculations:

TKN: .40 - .17 = .23 = 23% increase in treatment efficiency ratio
NO_3+NO_2: .83 - .58 = .25 = 25% increase in treatment efficiency ratio
TN: .69 - .35 = .34 = 34% increase in treatment efficiency ratio
NH_3: .33 - (-.57) = .9 = 9% increase in treatment efficiency ratio
TP: .84 - .65 = .19 = 19% increase in treatment efficiency ratio
TSS: .96 - .84 = .12 = 12% increase in treatment efficiency ratio

These findings are "an indicator that the BMP system is performing at least as well as similar BMP types in North Carolina" (Bass, Blackwell and Spooner 2012). Bass, Blackwell, and Spooner (2012) summarized their findings with the following statements:

> "The project has shown Efficiency Ratios that are comparable or better than similar stormwater treatment systems. In addition, outlet concentrations are in the range typical for high performing stormwater BMPs. It is likely that the design of this project using a treatment train approach has contributed to the results found. In most reported storms, it appeared that the capacity of the bioretention terraces was rarely exceeded. We also observed that these terraces were draining properly, which maximizes treatment potential. In addition, the attention to vegetative establishment, development, and maintenance of the BMP are all likely contributors to success."

Limitations: N/A

References:

Bass, Kris, Blackwell, Jaime, Spooner, Jean. (2012). *Stormwater Monitoring at the NC Museum of Art.* NCSU Biological and Agricultural Engineering Department. Print.

- *Eliminates the use of potable water for 3 reflecting pools using harvested roof rainwater runoff.*

Method: The cistern holding capacity is 90,000 gallons. The entire 90,000-gallon volume is dedicated to maintaining water levels in the 3 reflecting pools. The pools have never fallen below design levels, even during times of drought, thereby confirming the continual contribution of harvested rainwater and the resulting elimination of potable water demand that would be necessary without the continued performance of this feature.

Data:

Source of performance information was provided by observations made by the design team and client.

Limitations:

The cistern does not contain monitoring devices and is buried underground, therefore there is no way to acquire specific data regarding the amount of water used, the associated draw-down time, and/or the total amount of water captured in the cistern.

References:
Correspondence with Walt Havener, Landscape Architect, North Carolina Museum of Art, on May 6, 2015.

- *Avoids 9,000 lbs of CO2 emissions, 460 gallons of fuel, and 190 man-hours annually by eliminating 11 acres of fescue lawn that required regular mowing.*

Data:
The following calculations assume a 30 hp, 72-in mower over a Fescue turf lawn with no obstacles, no trimming, covering 3 acres per hour with a 6 in overlap at 5 mph (per Joyce 2015).

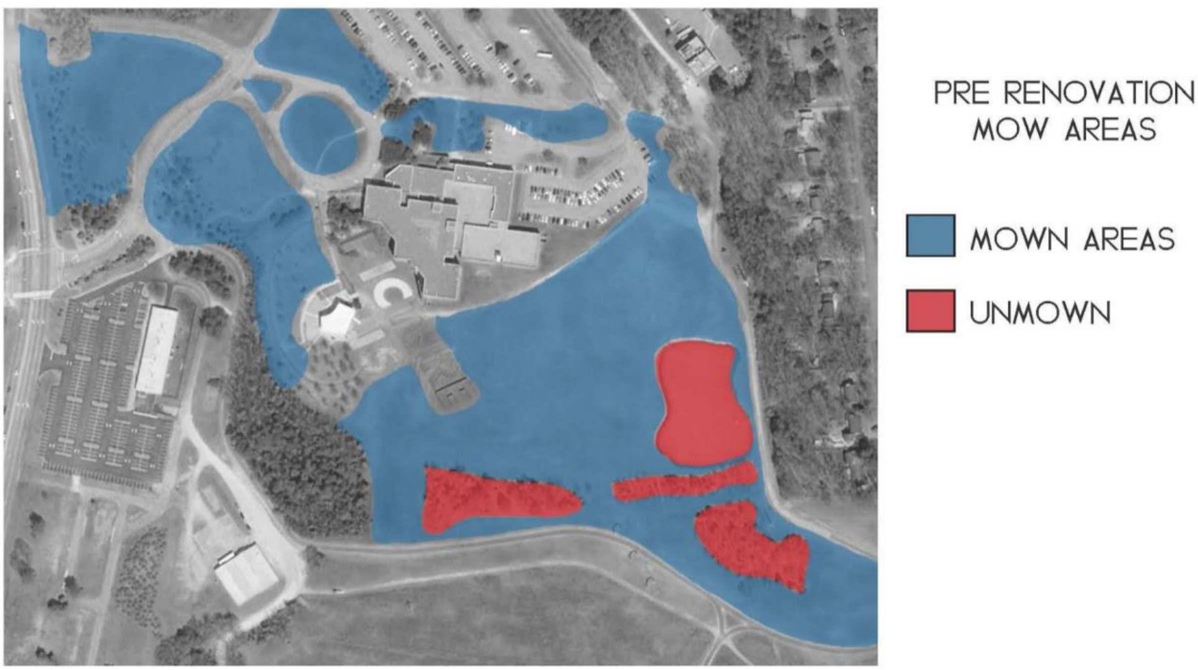


Figure 9: Before diagram of mown areas

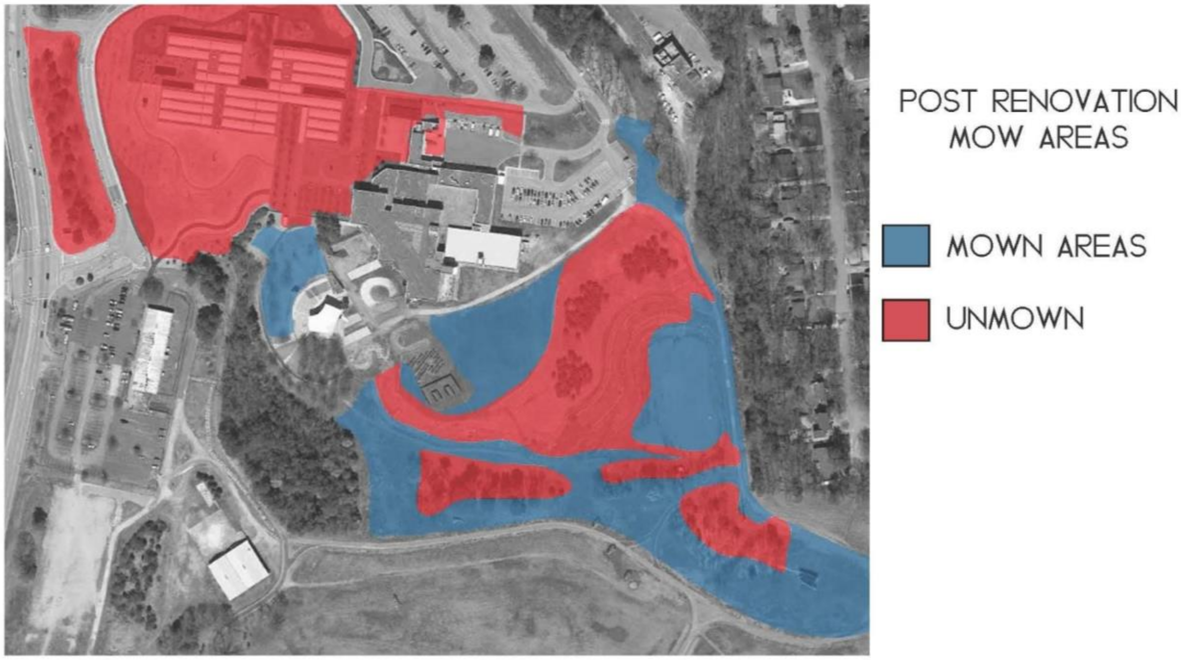


Figure 10: After diagram of mown areas

Calculations:

- Number of acres to mow time conversion
  - 72 in (30 hp) mower = 3 acres per hr (per Joyce 2015)
  - Mow area / 3 = mow hours
    - 20 acres / 3 = **6.7 hrs**
    - 9 acres / 3 = **3 hrs**
- Fuel burned per hour conversion
  - 30 hp gas mower x 10,000 BTU = 300,000 BTU/HR of operation (Thompson and Sorvig 2007)
  - 125,000 BTU per gallon gasoline
  - 125,000/300,000 = .42 hr or **25 minutes per gallon** of gasoline burned
  - 60 / 25 = **2.4 gallons** burned per hour
- Fuel burned in 6 hrs and 42 mins
  - 6.7 * 2.4 = **16 gallons** burned per mowing, or
  - 6.7 hrs * 300,000 BTU/HR = 2,01,000,000 BTU
    - 2,010,000,000 BTU / 125,000 BTU per gal = **16 gallons** burned per mowing
- Fuel burned in 3 hrs
  - 3 * 2.4 = **7.2 gallons** burned per mowing
  - 3hrs * 300,000 BTU per hr = 900,000 BTU
    - 900,000 / 125,000 BTU per gallon = **7.2 gallons** burned per mowing
- CO_2 emissions per area mown
  - 19.64 lbs of CO_2 produced per gallon gasoline burned (US Dept of Energy)
  - Gallons burned * emissions per gal = **Total CO_2 emissions**
    - 16 gallons gas * 19.64 lbs/CO_2 = **314.24 lbs/CO_2** per mowing
    - 7.2 gallons gas * 19.64 lbs/CO_2 = **141.4 lbs/CO_2** per mowing

Fescue, a cool season grass hardy to N.C. Piedmont conditions, is the primary lawn grass at NCMA. The N.C. Agricultural Extension Agency recommends mowing twice a week during the peak growing season when temperatures range from 60°F to 75°F and once a week when weekly temperature averages exceed 80°F and no mowing when weekly temperature averages are below 55°F. According to the City of Raleigh annual temperature averages, there are 4 months per year when mowing is required twice a week, five months a year when mowing is required once a week and three months per year when no mowing is required.

- Number of mowings per year = **52**
    - Twice a week for months April, May, October, and November
        - 2 * 16 = **32 mowings**
    - Once a week for months March, June, July, August, and September
        - 1 * 10 = **20 mowings**
- Difference in annual CO_2 emissions= **8,996 lbs CO_2 emissions avoided**
    - Pre-renovation: 314.2lbs * 52 mowings = 16,338.4 lbs annual CO_2 emissions
    - Post-renovation: 141.2lbs * 52 mowings = 7,342.4 lbs annual CO_2 emissions
- Difference in annual mow hours = **192 hours, 24 minutes saved post-renovation**
    - 6.7 x 52 = 348.4
    - 3 x 52 = 156
- Difference in annual fuel consumption = **457.6 gallons fuel saved with renovation**
    - 7.2 gallons per mowing x 52 mowings = 374.4 gallons
    - 16 gallons per mowing x 52 mowings = 832 gallons
- Estimated social costs of carbon:
    - $40 per metric ton (US EPA)
    - 40 * (8,996/2,240) = $160
- Life-cycle increase:
    - 50-year minimum functional life of a project supported with State of North Carolina funds (per Thagard 2015)
    - $160 * 50 = $8,000

Limitations:

Many variables could impact estimated mowing time, such as the frequency the mower blades are sharpened, the type of mower being used (i.e., if it is a tractor-pulled or a zero-turn mower), mower horsepower, etc. Because actual mowing records were not available, estimates of mow time and frequency were based on consultation with a local landscape maintenance professional and of known averages.

Resources:

Correspondence with Connie Joyce, Landscape contractor, Southern Garden, Inc. on July 14, 2015.

Polomski, Bob. (2015). *Tall Fescue*. Clemson University. Available at http://www.clemson.edu/extension/hgic/plants/landscape/lawns/hgic1210.html

Correspondence with Leonard Thagard, PE. Engineer and Life-Cycle Assessment Specialist, North Carolina State Construction Office on August 6, 2015.

Thompson, J. William, and Sorvig, Kim. (2007). *Sustainable Landscape Construction: A Guide to Green Building Outdoors (2nd Edition)*. Washington, DC, USA: Island Press.

US Department of Energy. (2015). *Energy Information Administration* available at http://www.eia.gov/tools/faqs/faq.cfm?id=307&t=11

US Environmental Protection Agency. (2015). *The Social Cost of Carbon* available at http://www.epa.gov/climatechange/EPAactivities/economics/scc.html

Social Performance Benefits

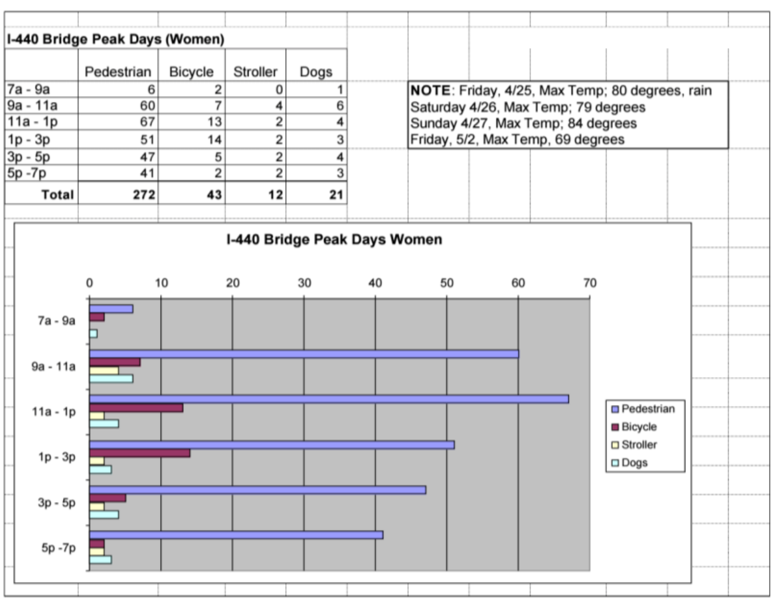
- *Attracts an average of 11,877 monthly park visitors, and a total of 143,528 visitors accessed the site via the local greenway system from October 2013 to September 2014.*

Method:
Used the *2013-2014 NCMA Arrival Count Study* to generate totals. In addition, used the *Health Impact Assessment* (Gibson et. al 2014) to illustrate known health concerns of the Blue Ridge Corridor, in which the site is located, to describe the value of physical activities supported by the site. Also used the usage/behavior counts reported in the Cizek/Turner study (2012) to show both the number of users and behaviors.

Data:

	Park Visitors via Greenway
Oct, 2013	10,924
Nov, 2013	5,948
Dec, 2013	10,752
Jan, 2014	7,256
Feb, 2014	14,792
Mar, 2014	12,516
Apr, 2014	11,960
May, 2014	16,120
June, 2014	11,932
July, 2014	11,884
Aug, 2014	14,272
Sept, 2014	14,172
Year Total	**142,525**

Figure 6: Record of monthly visitation via the interconnected Capital Area Greenway



I-440 Bridge Peak Days (Women)

	Pedestrian	Bicycle	Stroller	Dogs
7a - 9a	6	2	0	1
9a - 11a	60	7	4	6
11a - 1p	67	13	2	4
1p - 3p	51	14	2	3
3p - 5p	47	5	2	4
5p -7p	41	2	2	3
Total	**272**	**43**	**12**	**21**

Figure 7: Sample Report from the *NCMA Arrival Count Study*

Limitations:
Additional visitations and observations were not conducted as a part of this case study process.

References:

Jacqueline MacDonald Gibson, Daniel Rodriguez, Taylor Dennerlein, Jill Mead, and Steve Bevington. (2014). *Health Impact Assessment: Predicting Effects of Urban Design on Public Health, A Case Study in Raleigh, North Carolina.* University of North Carolina, Chapel Hill.

NCMA Arrival Count Study. (October 2013 - September 2014).

Cizek, Adrienne and Jesse Turner. (2012). *Case Study Investigation of the North Carolina Museum or Art.*

Economic Performance Benefits

- *Contributed to a 14.6% increase in recorded annual membership revenue since the museum expansion was completed.*

Method:
Membership was averaged for the reported years pre- and post-expansion. The percent change was then calculated on the difference between the two values.

Data:
Best available data provided by the project owner (Figure 8).

	Year	Individual Memberships
	2005	$1,315,558
	2008	$1,622,868
NCMA Expansion completed, 2010	2009	$1,458,495
	2011	$1,581,229
	2014	$1,692,362
	2015	$1,873,478

Figure 8: NCMA annual membership records

- Average pre-construction membership:
  1,315,558+1,622,868+1,458,495 = $4,396,921
- Average post-construction membership:
  1,581,229+1,692,362+1,873,478 = $5,147,069
- Difference and Average:
  $5,147,069 - $4,396,921 = $750,148
  750,148 / 5,147,069 = .1457 (14.6% increase)

Limitations:
No data was available for 2006, 2007, 2010, 2012, or 2013. The museum staff cannot say with certainty what affects the rise and fall of membership numbers, including correlating the construction of the new museum expansion with increased membership, because revenues are most often exhibition driven. NCMA staff stated, "A rule of thumb in memberships: the higher the mountain, the lower the valley. In other words, the peaking that happens around a blockbuster is robust, and many of those new members do not renew (there are many reasons why—primarily the original purchase is emotion-based and the renewal is much less emotional.) This happens in most blockbuster membership situations. So to say that the West building helped membership is quite true, but the press and opening were unprecedented."

References:
Correspondence with Lindsey M. Dougherty, Administrative Coordinator, NCMA, on June 2, 2015.

Cost Comparison:
The NCMA stormwater complex includes a 55,757-sf wet pond, 44,867-sf wetland, and 32,670 sf of terraced bioretention trays. The estimated construction cost of a traditional stormwater retention basin and wetland complex of this size is $940,972. The actual construction cost of the NCMA stormwater pond and associated wetland was $3 million, a budget $2,059,027 more than a project using standardized devices of equal size. Although the NCMA's construction costs were substantially more than those estimated for standard solutions, an additional $1.5 million was acquired through a North Carolina Clean Water Management Trust Fund Grant (see Grant Funding Tab) which reduced the total net project cost increase to $559,027.70. This grant could not have been applied to a conventional stormwater pond and wetland.

The function of the site's upper stormwater BMPs had additional cost impacts. The combined function of these devices and strategies reduced peak flow, which translated into smaller pipe sizes around the amphitheater. A 15 in HDPE pipe with an installed price of $37 per linear ft was used instead of a 24 in HDPE pipe with an installed price of $50 per linear ft, thereby downsizing 620 linear ft of pipe at a savings of $13 per linear foot (installed), or $8,060. Additionally, the existing pipe that would move stormwater to the pond was deep and large. The bifurcated solution to divert a portion of the runoff to the pond terraces and convey a portion over land to downstream areas was both a cost reduction and a scheduling advantage. The project team estimated that this approach saved $250,000 and months of schedule delay because it avoided deep channel excavation, dewatering, and disruption to art.

Standard stormwater BMP cost calculations:

- Wet pond and stormwater wetland cost estimates were calculated using the equation for estimating standard wet ponds ($C=13{,}909X^{0.672}$), standard wetland costs ($C=3{,}852X^{0.484}$), and bioretention in clay soils ($C=10{,}162X^{1.088}$), where C = cost in dollars and X = size of watershed in acres (Wossink and Hunt 2003). These methods of determining cost curves is considered reliable for the purposes of this assessment because the equations were developed using construction costs from "more than 40 stormwater BMPs, principally from North Carolina" (Wossink and Hunt pg. 4).

	Wet ponds	*Stormwater wetlands*	*Sand filters*	*Bioretention in clay soils*	*Bioretention in sandy soils*
Construction cost	$C=13{,}909X^{0.672}$	$C=3{,}852X^{0.484}$	$C=47{,}888X^{0.882}$	$C=10{,}162X^{1.088}$	$C=2{,}861X^{0.438}$
20-year maintenance cost	$C=9{,}202X^{0.269}$	$C=4{,}502X^{0.153}$	$C=10{,}556X^{0.534}$	$C=3{,}437X^{0.152}$	$C=3{,}437X^{0.152}$
Required surface area of BMP in acres					
Residential development					
• Piedmont (CN 80-90)	SA=0.015X	SA=0.02X		SA=0.025X	SA=0.025X
• Coastal Plain (CN 65-75)	SA=0.0075X	SA=0.01X		SA=0.015X	SA=0.015X
Highly impervious area with CN 80	SA=0.02X	SA=0.03		SA=0.03X	SA=0.03X
100% impervious areas (CN 100)	SA=0.05X	SA=0.065X	SA=0.017X	SA=0.07X	SA=0.07X

C=cost in $; X=size of watershed in acres; SA=surface area of BMP in acres *Source: Wossink and Hunt (2003)*

Figure 11: Stormwater BMP cost equation chart (Source: Wossink and Hunt 2003)

- Estimated standard wet pond cost:
  - Equation: $C = 13{,}909X^{0.672}$
  - $42^{0.672} = 12.33$
  - 11.52*13,909 = 160,231.68
  - C = **$171,497.97**
- Estimated standard stormwater wetland costs:
  - Equation: $C = 3{,}852X^{0.484}$
  - $42^{0.484} = 6.10$
  - 6.10*3,852 = 22,418.64
  - C = **$23,497.20**
- Estimated standard bioretention costs (in clay soils):
  - Equation: $C = 10{,}162X^{1.088}$
  - $42^{1.088} = 58.36$
  - 58.36*10,162 = 593,054.32
  - C = **$593,054.32**
- Total estimated cost for standard stormwater wet pond, wetland, and bioretention BMPs:
  - 171,497.97 + 23,497.20 + 593,054.32 = **$788,049.49** (in 2003 dollars)
- Calculating for Inflation:
  - The Wossink and Hunt study cited above was published in 2003, therefore the estimated costs need to be adjusted for 6 years of inflation. The Consumer Price Index (CPI) escalation rate of 3% (.03) is used to adjust for annual increases.
  - The formula used for compounding the inflation factor is $Pn = P(1+i)^n$, where:

    Pn = Total Inflated Estimated Cost

    P = Base estimated Cost (**$788,049.49**)

    i = Inflation Rate (**.03**)

    n = Difference between Base Year and Selected Year (2009 - 2003 = **6**)

    (1+i)n = Inflation Factor

    - $788{,}049.49(1+.03)^6 = 940{,}972.30$
  - Adjusted estimated costs of construction = **$940,972.30**
- Cost differential calculation:
  - Net differential: 3,000,000.00 - $940,972.30 = **$2,059,027.70**
  - Grant adjusted differential = $2,059,027.70 - 1,500,000.00 = **$559,027.70**

HDPE pipe cost calculations:

- 15 in HDPE, installed:
    - 620lf*$37 = $22,940
- 24 in HDPE, installed
    - 620lf*$50 = $31,000
- Cost Difference:
    - $31,000 - $22,940 = $8,060, or
    - $50-$37 = $13*620lf = $8,060

Resources:

Artifex Environmental Design, Inc. (2012). *NCMA Pond Water Quality Improvement Project*.

Surface678. (2015). *NCMA Pond Water Quality Improvement Project Description*.

Wossink, Ada and Bill Hunt. (2003). *An Evaluation of Cost and Benefits of Structural Stormwater Best Management Practices in North Carolina*. North Carolina Cooperative Extension Service. Raleigh, NC.