Appendix E-3 – GSI Cost Literature Review

Objectives of GSI Cost Literature Review

The ALCOSAN Wet Weather Program Management (PM) team performed a literature review of recently published green stormwater infrastructure (GSI) construction costs for projects around the United States. The objectives of this review are:

- Identify published green stormwater infrastructure construction costs from other cities implementing GSI as part of their wet weather program; and
- Compare published unit costs for specific green infrastructure technologies with the planning level costs used in the ALCOSAN Alternatives Costing Tool (ACT), to see if any updates are warranted.

C.1 Literature Review Procedure

The intent of this literature review is to gather construction cost data from installed GSI projects which experience similar wet weather planning considerations as ALCOSAN and its customer municipalities. This review only considered larger, metropolitan cities and authorities which are coordinating multiple GSI installations as part of a combined sewer overflow (CSO) long term control program. In most cases the cities included in the review are implementing GSI within the context of a Federal Consent Decree.

The literature review focuses on sources which have been published since 2008, which represents the approximate time frame since the basis for the ALCOSAN Alternative Costing Tool (ACT) GSI unit costs was initially developed. Primarily, information was sought that was published by a city/authority, but the review also examined state and federal publications and information presented through wet weather industry conferences and journals. Academic journals were not included as a part of this report. The industry sources included in the review include:

- US Environmental Protection Agency
- Water Environment Federation (WEF)
- American Society of Civil Engineers Environmental and Water Resources Institute
- Wet Weather Partnership Conference Proceedings

Information was gathered from industry resources and also general internet research. This review was limited to collecting readily available information from public domain documents and no outside agencies were contacted for information included in this review. Given how installed cost information is not widely published or sometimes published without sufficient detail to understand the entire scope of costs, outside agencies can be contacted for additional information as a follow-up to this memo if desired.

A summary of some of the largest cities across the United States with programmatic commitments to GSI projects is included in Table C-1. Within this summary are the projects identified in this study to have published data for GSI costs. Actual construction costs were reported in some cities, however many cities are reporting anticipated planning level GSI cost estimates.

Published GSI construction cost data were found for the following municipalities/authorities:

- Onondaga County, New York, Department of Water Environment Protection
- Metropolitan Sewer District of Greater Cincinnati (MSDGC), Cincinnati, OH

Planning level GSI cost estimating data were found for Green Infrastructure Plans (GIP) in the following municipalities/authorities:

- Northeast Ohio Regional Sewer District (NEORSD), Cleveland, OH
- District of Columbia Water and Sewer Authority (DC Water), Washington DC
- Milwaukee Metropolitan Sewerage District (MMSD), Milwaukee, WI
- New York City Department of Environmental Protection

In addition, a 2013 3RWW study of conceptual GSI designs in three different neighborhoods within the City of Pittsburgh was reviewed and costs were compared to ACT GSI unit costs.

Note that GSI construction costs from the Philadelphia Water Department (PWD) were not included in this analysis as they served as the original basis of the ACT, and PWD has not yet published information regarding actual GSI construction costs for the more than 200 projects completed since 2008. PWD and ALCOSAN jointly developed the ACT and the resulting unit costs for GSI served as the basis of costs for PWD's 2009 Long Term Control Plan Update, currently the only cost data published by PWD.

The balance of the report summarizes background information on GSI costs in the ACT, the details of the cost data which has been published by the cites included in this review as well as some details of the ongoing or planned GSI program elements for these cities.

Table C-1 – Summary of Green Stormwater Infrastructure Commitments in Combined Sewer Cities

Region	Planned GSI Commitment	Published Source of GSI Costs (Since 2008)	Unit Costs Reported in Published Source
Cincinnati, OH	Have invested in GSI demonstrations throughout City, total has not been published. Funds committed to incorporating GSI into $192 Million Lick Run Stream Daylighting have not been published.	Ellwood, Nancy. "A Detailed Look at Costs Associated with Green Stormwater Controls." Conference Proceedings from Water Environment Federation Stormwater Symposium, 2012.	Construction Costs
Cleveland, OH	Required by CD to control 42 MG through $44 Million GSI investment, 2012 Plan outlines $102 Million in potential GSI projects.	Northeast Ohio Regional Sewer District. *Green Infrastructure Plan*, 2012.	Planning Level Unit Costs
Kansas City, MO	$28 Million to GSI pilot projects and $40 to distributed green storage	City of Kansas City (MO), *Overflow Control Plan Overview* 2009.	None
Lancaster, PA	Projecting up to $77 Million for 25-year GSI implementations	City of Lancaster (PA), *Green Infrastructure Plan*. 2011.	None
Louisville, KY	$47 Million in GSI demonstration projects	Louisville Metropolitan Sewer District, Integrated Overflow Abatement Plan Final CSO Long-Term Control Plan (2009)	None
Milwaukee, WI	Planning to spend $1.3 Billion through 2035, not under CD.	Milwaukee Metropolitan Sewerage District. *Regional Green Infrastructure Plan*, 2013.	Planning Level Unit Costs
New York City, NY	$192 Million in public funded GSI through 2015 prepared to spend $1.5 Billion through 2030.	New York City Department of Environmental Protection, *Green Infrastructure Plan*. 2010.	Planning Level Unit Costs

Table C-1 – Summary of Green Stormwater Infrastructure Commitments in Combined Sewer Cities

Region	**Planned GSI Commitment**	**Published Source of GSI Costs (Since 2008)**	**Unit Costs Reported in Published Source**
Philadelphia, PA	$1.67 – 2.09 Billion Capital + O&M Public Funded GSI Installed (25-year cost)	Philadelphia Water Department, *Amended Green City Clean Waters Program Summary*. 2011.	Planning Level Unit Costs
Portland, OR	$145 Million in constructed GSI and Source Controls	Ryan, William “Portland’s Completed CSO Program” Conference Proceedings from Wet Weather Partnership, 2013.	None
St. Louis, MO	$100 Million in GSI within Mississippi River Drainage areas.	Metropolitan St. Louis Sewer District, *CSO LTCP Update*, 2009.	None
San Francisco, CA	$57 Million on demonstration projects through 2016.	Mackenbach, Kari. “San Francisco Central Bayside Improvement Project Reducing CSO Overflows and Improving Reliability” Proceedings from Pittsburgh Water and Sewer Authority Green Infrastructure Charrette #1, 2013.	None
Syracuse, NY	$87 Million committed to GSI projects between 2010 – 2018.	Onondaga County, New York Department of Water Environment Protection. *Save the Rain Program 2010-2018 Green Infrastructure Plan*, 2012. http://savetherain.us/green-projects-3	Construction Costs
Washington DC	Large Scale GSI in Potomac River and Rock Creek Basins by 2023	Amendment 1 to CD, May 2015	None

C.2 ALCOSAN ACT Background Information

ALCOSAN, in a joint effort with the Philadelphia Water Department (PWD), developed an alternatives costing tool (ACT) for use in planning level screening and comparison of CSO control technologies. The ACT provides planning-level cost estimates to facilitate the evaluation and comparison of wet weather control strategies. GSI technologies are included in the ACT as “Land Based Stormwater Management” technologies, but will be referred to herein by the more common term GSI. GSI costs are estimated based on the tributary impervious area managed by a given GSI technology. The computed costs include construction costs, capital costs, operation and maintenance (O&M) costs, and total present worth. The cost estimates generated by the ACT are considered American Association of Cost Engineering (AACE) Class IV planning level cost estimates. For a Class IV estimate, the range of probable cost is +50%/-30% of the cost generated from the ACT[1].

The ACT includes construction and O&M unit costs for five GSI technologies:

- bioretention;
- green roofs;
- porous pavement;
- street trees; and
- subsurface infiltration.

With the exception of street trees, the ACT reflects the costs to capture the first 1-inch of runoff via a combination of infiltration, evapotranspiration, and storage with slow release over 24 hours. The street tree costs included within the ACT reflect simple tree pit installations in an urban setting with no provisions to capture stormwater runoff. Street trees are included in the ACT to address the common scenario of incorporating trees along with other GSI technologies when a street is retrofitted for GSI. All ACT costs are intended to reflect the complete cost of a GSI installation, including costs associated with modifying upstream storm inlets and other upstream improvements needed to convey flow to the GSI, and costs associated with constructing a slow release outlet pipe from the installation to the nearest sewer.

In the literature, GSI costs are reported with a variety of different unit costs depending in part on the particular technology installed. There are several reasons why the ACT is based on a unit volume (one acre-inch of runoff controlled) rather than a unit area (e.g. one square foot of pervious pavement) or a unit length (one linear foot of bioswale) for estimating planning level GSI costs as listed below.

- The unit volume relates more directly to the GSI performance objective of capturing the first inch of runoff from impervious area.
- Some GSI installations include significant costs that have no relationship to the area of GSI installed. Some examples are:

[1] As defined in the source document for the cost estimate classification system titled “AACE International Recommended Practice No. 18R-97.”

  - costs associated with modifying upstream storm inlets and other improvements needed to convey flow to the GSI;
  - costs associated with constructing a slow release outlet pipe from the installation to the nearest sewer; and
  - the depth of the installation: two GSI installations can have the same installed area, but one can control double the runoff with a deeper and more costly installation.
- It allows the use of a common unit that can be used for all GSI technologies and all locations.
- It more closely correlates to how GSI is represented in hydrologic models when evaluating widespread application of GSI in an area before specific project locations and tributary areas have been established.

Once a project is sited and a conceptual design is developed, it is recommended that site specific cost estimates be performed using actual material and labor estimates for the actual quantities of work involved.

C.3 ACT Unit Costs for Green Stormwater Infrastructure and Loading Ratio Assumption

The GSI loading ratio is defined herein as the ratio of the impervious area managed by a GSI installation to the area of the GSI installation. Based on available national data, most GSI installations for CSO control have loading ratios between 5:1 and 10:1, meaning each acre of installed GSI manages runoff from 5 to 10 acres of impervious area. A simple illustration of the loading ratio concept is shown in Figure C-1. Green roofs are an exception; the loading ratio for a green roof is always assumed to be 1:1.

Since many GSI installation costs in other cities are presented in terms of unit area rather than unit volumes, the loading ratio can be used to present the ACT costs in terms of unit area and unit volume, so as to facilitate comparison to costs in other cities. A rough approximation of the costs per square foot of a given GSI technology can be made by assuming a typical loading ratio. A summary of the ACT GSI unit costs is presented in Table C-2 for two different sets of units: $ per impervious acre managed (or acre-inch of volume managed); and the extrapolated cost per square foot of GSI installed, assuming loading ratios of 5:1 and 10:1.

Table C-2 displays the unit costs for construction and capital costs for each of the GSI technologies within the ACT. GSI technologies are also are categorized by retrofit or redevelopment installation. For the purposes of using the ACT, these categories are defined as:

- Redevelopment - The marginal construction cost (beyond the cost of traditional measures) to implement each GSI approach assuming that redevelopment is already taking place.
- Retrofit - The full construction cost required to implement each GSI approach by retrofitting traditional development on an existing site.
- Construction Costs – Construction costs are the raw costs of construction (i.e., the contractors' bid costs). Construction costs include: general conditions, overhead and profit, mobilization, demobilization, bonds and insurance, sub-contractor markups and a construction contingency.

- Capital Costs – Capital costs are the sum of the estimated construction costs plus all other costs associated with implementing the project including permitting, design and construction engineering, administrative, legal costs, geotechnical, surveying, public participation, and an overall project contingency.

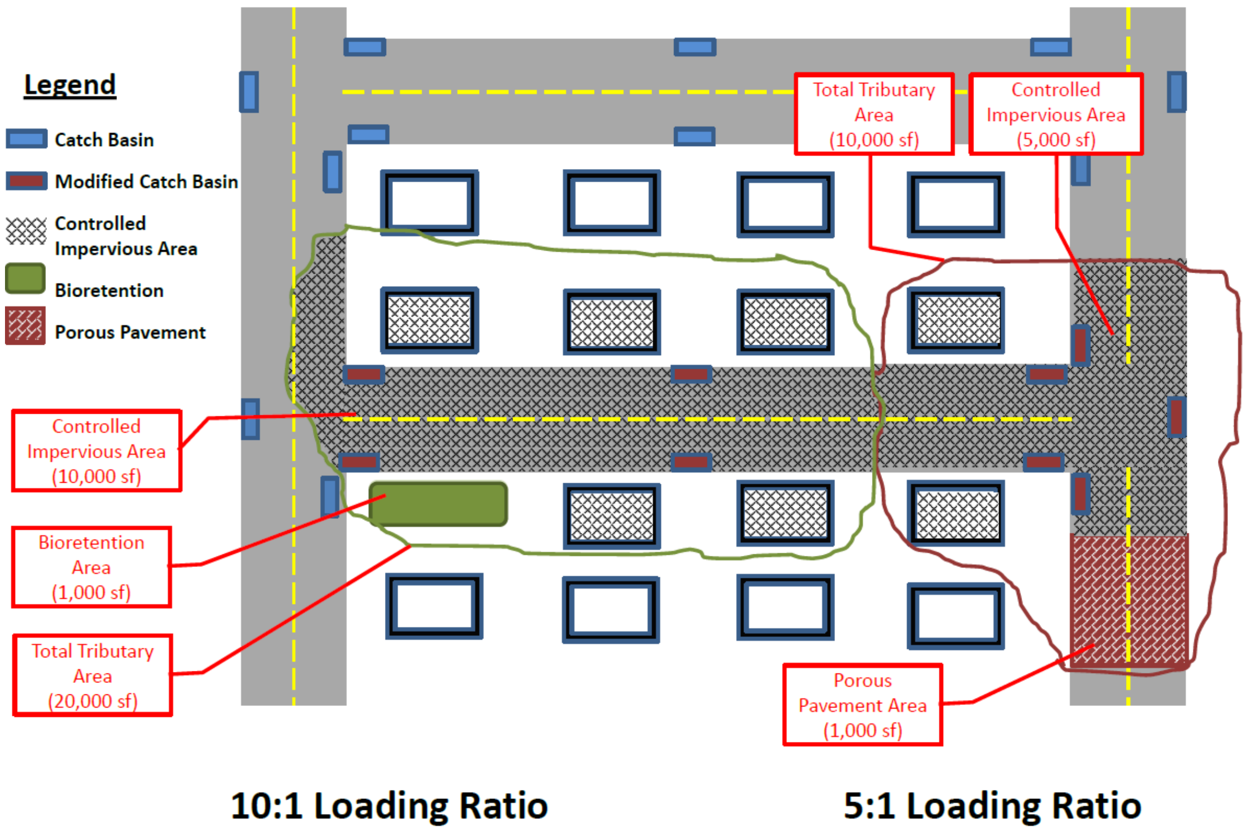

Figure C-1 – Green Stormwater Infrastructure Loading Ratio Conceptual Example (Not to Scale)

An example conversion from $/impervious acres managed to $/square foot of GSI using an assumed loading ratio is below:

$$\frac{\$}{\text{Impervious Acres Managed}} \times \frac{\text{Loading Ratio}}{43{,}560\ \text{ft}^2} = \frac{\$}{\text{Square foot of GSI}}$$

Example using ACT Bioretention Retrofit Base Year Probable Cost and 5:1 loading ratio:

$$\frac{\$199{,}000\ \text{construction cost}}{\text{impervious acre managed}} \times \frac{5\ \text{impervious acres managed}}{1\ \text{acre installed GSI}} \times \frac{1\ \text{acre}}{43{,}560\ \text{ft}^2} = \frac{\$23}{\text{ft}^2\ \text{of GSI}}$$

Table C-2 – Unit Costs of Green Stormwater Infrastructure in the ACT

Best Management Practice	Type[1]	$ / Impervious Acre Controlled		$/ Square Foot of GSI Assuming 5:1 Loading Ratio		$/ Square Foot of GSI Assuming 10:1 Loading Ratio	
		Construction Cost[1]	Capital Cost[2]	Construction Cost[1]	Capital Cost[2]	Construction Cost[1]	Capital Cost[2]
Bioretention, Subsurface Infiltration, Porous Pavement	Retrofit	$199,000	$287,000	$ 23	$ 33	$ 46	$ 66
	Redevelopment	$164,000	$226,000	$ 19	$ 26	$ 38	$ 52
Green Roof	Retrofit	$570,000	$821,000	N/A		N/A	
	Redevelopment	$299,000	$413,000				

All costs in 2010 Dollars: ENRCCI 8641; RS MEANS 99.6.

[1] Connections to collection system are assumed as 4 per impervious acre managed. Green roofs are assumed to have no connections to collection system. Construction costs include a 25% construction contingency.

[2] Capital costs include a 20% markup on construction costs for engineering and implementation. In addition retrofit projects are assumed to have a 20% project contingency and redevelopment projects are assumed to have a 15% project contingency

C.4 Summaries of Individual Cities

Onondaga County, New York

In accordance with an Amended Consent Judgment (ACJ) of 2009, Onondaga County must achieve approximately 247 million gallons (MG) of CSO reduction through GSI by 2018. As of the end of 2011 they have achieved 73 MG in CSO reduction through completed projects, or projects under construction. They have an additional 66 MG identified in candidate projects, leaving 108 MG of CSO reduction required by 2018. The Green Infrastructure Program is estimated to have a cumulative construction cost of $63M and total cost (adding engineering) of $87M by 2018. This equates to an average cost of $0.35 per gallon of CSO eliminated.

The Onondaga County GIP summarizes all public and private projects which will contribute to the CSO reduction goal to be built between 2010 and 2018. Approximately 54% of the CSO reduction goal will be achieved by public projects and 46% by private projects. These projects are categorized into 11 distinct program types based on the manner which the project will be applied. These programs vary from specific GSI applications integrated into streets or parking lots to institutional programs which will contribute to the CSO reduction goal such as ordinances or incentive programs. A summary of the construction costs for public GSI construction programs is shown in Table C-3.

Table C-3 – Summary of Onondaga County Unit Construction Cost per Gallon of CSO Reduction for GSI Projects in 2010-2018 Green Infrastructure Plan

Public Program Type	Cost per CSO Reduction, $/gal/yr		
	Average	Minimum	Maximum
Streets	0.39	0	1.43
Parks & Open Space	0.54	0.10	1.18
Parking	0.40	0.20	0.62
Public Facilities	0.48	0	4.32
Green Roofs	1.49	0	2.65

It is important to note two items regarding Table C-3. First, the projects which are reported include everything which has been built or is planned to be built at the time of the reporting for a construction period between 2010 and 2018. Thus, these costs represent constructed projects, projects in ongoing construction and design and conceptual phase projects. In addition, Onondaga County is only reporting costs which are allocated to their $87 Million GSI commitment. The GIP reports some projects with $0/gal CSO reduction unit costs, which represents CSO volume reductions through GSI technologies which are funded outside of the $87 Million GSI commitment. Thus, the unit costs reported account for both private and public sector sources, however they only appear to account for public sector costs.

Due to the two items noted above, the values reported in Table C-3 do not allow a direct correlation to ACT planning level cost estimation. In addition, the Onondaga report does not relate the unit costs to impervious area controlled or offer the basis of design for GSI installation. However, the plan also provided summaries of specific projects with additional data including area of GSI control feature, impervious area tributary to GSI control and construction cost. A sampling of 13 constructed projects was selected for data evaluation based on their similarities to the anticipated green technologies to be used in Pittsburgh. These projects were in the public right-of-way and designed to manage runoff from streets, sidewalks and other public spaces. Table C-4 provides a summary of these projects.

Onondaga continues to update the public on installed GSI projects through its website, http://savetherain.us/green-projects-3/. Onondaga includes project summaries of GSI projects and report costs and drainage areas, but there are not as many details of these projects as has been reported in the GIP. A summary of GSI ROW projects installed since the publication of the GIP is included in Table C-5. Onondaga did not include certain project details of the projects in Table C-5 such as impervious area managed and the GSI area footprint. For this reason, the projects listed in Table C-5 have been exempt from further analysis at this time.

Table C-4 – Summary of Selected Public Right-of-Way Projects Reported in Onondaga County Green Infrastructure Plan (January 2012)

Project	Technology	Year Completed	Construction Cost	Construction Cost Adjusted for ACT Index Values[1]	Impervious Area Managed (sq ft)	Installed GSI Area (sq ft)	Adjusted Cost per Impervious Area ($/Acre)	Adjusted Cost per GSI Area ($/SF)	Loading Ratio (Impervious Area: GSI Area)
1. Parking Lot 21	Bioretention & Infiltration-Trench	2010	$188,046	$190,602	26,252	5,000	$ 316,000	$38	5:1
2. Parking Lot	Infiltration-Trench	2010	$342,000	$346,648	53,940	3,800	$ 280,000	$90	14:1
3. CreekWalk	Pervious Pavement	2010	$47,000	$47,639	6,780	6,780	$ 306,000	$7	1:1
4. City Lot Pearl	Pervious Pavement	2010	$397,000	$402,396	73,172	25,300	$ 240,000	$16	3:1
5. Municipal Parking Garage*	Bioretention	2011	$246,985	$242,862	72,000	2,000	$ 147,000	$123	36:1
6. Sidewalk Planter*	Bioretention & Infiltration-Trench	2011	$119,166	$117,177	9,650	1,800	$ 529,000	$66	5:1
7. Towsend Median	Enhanced Street Trees & Pavement Demo	2011	$86,000	$84,564	18,000	13,785	$ 205,000	$6	1:1
8. OnCenter Lot	Pervious Pavement & Tree Trench	2011	$678,818	$667,486	134,000	28,000	$ 217,000	$24	5:1
9. Skiddy Park	Pervious Pavement-Basketball Court	2011	$164,674	$161,925	19,000	11,000	$ 371,000	$15	2:1
10. Concord Place	Subsurface Infiltration-Trench	2011	$78,900	$77,583	38,521	3,387	$ 88,000	$23	11:1
11. SunnyCrest Golf	Bioretention, Pavement Demo & Storage Bed	2011	$367,065	$360,937	38,000	15,000	$ 414,000	$24	3:1
12. Park Greening Avery Ave	Rain Garden	2011	$316,420	$311,138	30,402	5,228	$ 446,000	$61	6:1
13. Wilbur Ave Zoo	Pervious Pavement & Rain Garden	2011	$303,148	$298,087	39,000	12,000	$ 333,000	$25	3:1
* Bid Cost		**TOTAL**	**$3,335,000**	**$3,309,000**	**559,000**	**133,000**	-	-	-
		Averages	**$257,000**	**$255,000**	**42,978**	**10,237**	**$ 258,000**	**$25**	**4:1**

[1] Index Values of ENRCCI 8799 for 2010 and 9070 for 2011, Syracuse RS Means 96.5. Adjusted to ACT Default Index values for costs reported in WWP in 2010 dollars: ENRCCI 8641, RS Means 99.6

Table C-5 – Sampling of Onondaga GSI Projects Constructed in Public ROW since January 2012 release of Onondaga Green Infrastructure Plan

Project	Year Completed	Technology	Construction Cost	Total Tributary Area (sf)
Connective Corridor Phase 1 - Project 1	2011	Green Street	$948,717	326,000
Connective Corridor Phase 1 - Project 2	2011	Green Street	$50,000	6,800
Connective Corridor Phase 1 - Project 3	2011	Green Street	$621,870	142,000
Delaware Rain Garden	2011	Bioretention	$910,914	12,877
Downtown Streetscapes	2011	Enhanced Street Trees	$218,813	17,000
Geddes Street	2011	Bioretention	$278,196	29,700
Harrison Street	2011	Green Street	$109,920	10,000
OnCenter Parking Garage	2011	Bioretention	$246,985	72,500
Otisco Street Corridor	2011	Curb Extension & Rain Garden	$1,616,635	79,981
Vacant Lot Oswego St	2011	Infiltration Trench, Urban Garden	$99,714	15,000
Water Street Gateway	2011	Infiltration Trench, Porous Pavers	$986,937	53,000
City Lot #4	2012	Porous Pavement, Tree Trench, Bioretention	$381,000	71,000
Downtown Streetscapes 100 S State	2012	Enhanced Street Trees	$133,884	15,200
Downtown Streetscapes 200 Montgomery (East)	2012	Enhanced Street Trees	$92,317	10,000
S State St Reconstruction	2012	Underground Infiltration Trench	$291,044	133,000
Vacant Lot 109 Hartson	2012	Bioretention	$36,831	2,000
Vacant Lot 1344 W Onondaga	2012	Bioretention	$68,577	8,000
Vacant Lot 224 Putnam	2012	Bioretention	$43,787	6,000
West Fayette St	2013	Sewer Separation	$446,269	509,100
Westcott Street Green Corridor	2013	Green Street	$852,000	67,000
West Onondaga Green Corridor	2013	Green Street	$1,265,474	317,200
South Clinton Street Road Reconstruction	2013	Underground Infiltration Trench	$221,000	50,700
Richmond Ave Road Reconstruction	2013	Underground Infiltration Trench	$254,000	82,400
		TOTALS	**$10,174,884**	**2,036,458**

Cincinnati, Ohio

Cost data for GSI demonstration projects designed and installed under the Metropolitan Sewer District of Greater Cincinnati (MSDGC) wet weather program to address CSOs was reported at the 2012 WEF Stormwater Symposium. At the time of the report, "between 2008 and 2012, a total of approximately 260,000 square feet of bioinfiltration practices; 165,000 square feet of vegetative (green) roofs; 169,000 square feet of porous/pervious paving; 55,000 gallons of rainwater storage for reuse; 2,040 linear feet of storm sewer separation; and five large capacity stormwater dry wells were installed at 18 projects in the Greater Cincinnati area."

This report focused on the common design features and appropriate costs that are directly related to site preparation and restoration, construction, and functionality of the installed GSI controls. The unit costs include materials, equipment, labor, and overhead and profit. They do not include planning or design costs. Site specific costs that do not affect the functionality of the GSI control were not included. This included costs for items such as street painting, unique demolition items, signage, fencing materials and permitting the GSI locally, items which varied by location, project type and project size. The volume capture and other design criteria for the projects was not reported. Unit costs were developed using detailed cost estimates and actual construction costs, and presented in ranges as shown in Table C-6.

Table C-6 –Summary of Cincinnati Green Stormwater Infrastructure Unit Construction Costs Reported

Green Infrastructure Control Type and Units of Measure	Low End Unit Cost ($/unit)	High End Unit Cost ($/unit)	Average Unit Cost ($/unit)
Bioinfiltration Basin, SF	8	20	13
Retrofit Bioinfiltration Basin, SF	19	19	19
Bioswale, SF	7	17	13
Urban Planter – one project, SF	17	17	17
Green Roof – Extensive/Modular, SF	11	14	13
Green Roof – Extensive/Layered, SF	22	28	25
Green Roof – Intensive – one project, SF	35	35	35
Green Roof – Sloped – one project, SF	19	19	19
Permeable Pavers, SF	7	20	13
Porous Concrete, SF	2	15	8
Porous Asphalt – one project, SF	8	8	8
Aboveground Cistern – one project, gallons	2	2	2
Belowground Cistern – two projects, gallons	8	8	8

This paper indicated the wide range of bioinfiltration costs were tied to two factors – project size and labor costs. Small projects had higher unit cost due to labor costs and low end unit cost were a result of basins being combined with other green controls or site construction work. Green roof costs vary significantly based on type and design of roof. Sloped roofs are more expensive than flat roofs. Layered extensive roof are double the cost of modular systems due to higher labor costs.

This paper also compared grey costs to green costs. The cost for grey controls was reported to lie between $0.10 and $0.30 in cost per gallon of runoff captured on an annual basis which was assumed typical for traditional stormwater management practices. The sources of these gray unit costs were not identified in the paper, but did not appear to reflect the grey costs to achieve a specific level of CSO control in the project area. It was noted that all but four of the 18 green projects fell below, or within the gray control costs.

Northeast Ohio Regional Sewer District (NEORSD), Cleveland, Ohio

A Consent Decree (CD) was filed in July 2011 between the USEPA, the State of Ohio and the NEORSD that requires NEORSD to develop a plan to control an additional 44-MG of wet weather CSO volume through green infrastructure and spend at least $42M to build GSI projects within 8 years of CD entry (7/7/11).

The 2012 Green Infrastructure Plan lays out a program to perform 20 projects that will reduce CSO volume by 95.1 MG in the typical year at a total project cost of $101,681,000 (includes 55% markup for construction contingency, engineering and administrative services), or $1.07 per CSO gallon reduced. NEORSD did not specify the basis of design criteria for sizing GSI projects.

The unit capital costs were developed from detailed cost estimating performed for GSI controls based on assumed typical design for each GSI control method. Appendix F in the NEORSD Green Infrastructure Plan provides a detailed description of the cost estimating criteria for each GSI control. A condensed summary of unit cost development for each GSI control is included in Table C-7. NEORSD groups GSI into control measure groups, which are summarized below.

Legend (for Table C-7)

SST – Stormwater Storage and Treatment
SIT – Stormwater Infiltration and Treatment
SSR – Stormwater Source Reduction
SCC – Stormwater Capture and Conveyance

Note: Stormwater infiltration and treatment (SIT) unit cost development does not include any cost for conveyance to or from the GSI control.

Table C-7 – Summary of NEORSD Green Stormwater Infrastructure Planning Costs

GSI Type	Description	Capital Cost (Including 55% markup)	
		$	$/SF or $/LF where noted
SST-Dry Basin	Short term detention with controlled release • 15-20 acre drainage area • One acre footprint • 3FT deep	$168,000	$3.90/SF
SST-Wet Pond	Permanent pool of deep water and shallow ledges for aquatic plants (detention and treatment) • 15-20 acre drainage area • One acre footprint • 3FT deep	$281,000	$6.45/SF
SST-Constructed Wetland	• 15-20 acre drainage area • Plants and soils suitable for wet and dry conditions • One acre footprint • 3-3FT deep permanent water pools • Average 1.5FT deep pooling	$280,000	$6.40/SF
SST-Irrigation Pond	Similar to wet pond with irrigation pumping capability • One acre footprint • 3-3FT deep wet weather storage • 1-3.5FT deep permanent pool • Irrigation equipment (pump only)	$380,000	$8.70/SF
SIT - Infiltration Basin	Shallow impoundment for sandy soil infiltration • 5-50 acre drainage area • One acre footprint • One foot gravel media • Three foot deep water storage • One foot of stone filter	$297,000	$6.80/SF
SIT-Infiltration Trench	Long, narrow, collects sheet flow for infiltration • 0.1 – 0.25 acre drainage area • 100FT long x 10FT wide • Gravel media 4FT deep • 1000 SF footprint	$22,000	$22.00/SF
SIT-Bioretention Swale or Cell	Intercept runoff to slow and filter storm water through engineered soil and plants • 0.1-0.25 acre drainage area • 24-48 hours retention • 6"-9" ponding depth • 100FT long x 10FT wide • Min. 4FT deep bioswale soil media • 1000SF footprint	$25,000	$25.00/SF
SIT-Green Streets	Street ROW – bumpouts, bioswales, pervious pavements, pervious parking stalls/bike lanes		

Table C-7 – Summary of NEORSD Green Stormwater Infrastructure Planning Costs

GSI Type	Description	Capital Cost (Including 55% markup) $	Capital Cost (Including 55% markup) $/SF or $/LF where noted
Green Streets low level	Bump-ins/bump outs within street ROW • 30%-50% capture rate • 24FT wide Street – 300FT long • 2-20FT long x 6FT wide bioretention • $/LF of street reported	$14,000	$47/LF $15/SF
Green Streets Medium Level	Continuous narrow bioswale on both sides of street within tree lawn and two bump-ins or bumpouts • 50%-75% capture rate • 24FT wide street – 300FT long • 2-20Ft long x 6FT wide bioretention cells • 2-300FT long x 3FT wide bioswales • $/LF of street reported	$68,000	$227/LF $25/SF
Green Streets High Level	Same as medium level with the addition of 300LF of 24" storm sewer pipe • 50%-90% capture rate • $/LF of street reported	$138,000	$460/LF $50/SF
SSR-Pervious/ Porous Pavement	Stormwater filters through a drivable or walkable surface for infiltration or slow release to sewer system • 0.5 acre pavement • 18" gravel drainage layer • 4" underdrain pipe • 22,000 SF	$303,800	$14.00/SF
Low level vacant lot repurposing	Selective demolition of vacant residential area and conversion to grassed area • One house per acre removed • 200FT long x 24FT wide paving removed • Regrading to create depression • Seeding • One acre area	$30,000	$0.70/SF ($30,000/acre)
High level vacant lot repurposing	Similar to low level • Two house demolitions • 250FT long x 24FT paving removed • Regrading to create depression area • Seeding and tree liner plantings • One acre area	$37,000	$0.85/SF ($37,000/acre)
SSR-Impervious area removal	Removal of one acre of pavement removal and reforestation of the land.	$50,640	$1.16/SF ($50,640/acre)

Table C-7 – Summary of NEORSD Green Stormwater Infrastructure Planning Costs

GSI Type	Description	Capital Cost (Including 55% markup)	
		$	$/SF or $/LF where noted
SSR-Green roof	Vegetation and growing medium over a waterproofing membrane • 4"-6" green roof media • No full roof replacement • One acre area	$1,249,090	$28.70/SF
SCC-Storm sewer	In commercial areas, sewer separation to convey stormwater to a central GSI control • 300LF • 36" sewer buried at 7FT depth • Backfilled with exist. Material • Pavement removal and restoration • 2 catch basins replaced • $/LF of storm sewer	$84,000	$280/LF
SCC-Open Channel/ Swale	Drainage conveyance • 300FT long • 3FT deep • Seeding • $/LF of swale	$9,000	$30/LF
SCC-Overland Flow	Residential street with slope >2% • Closure of 2 catch basins • 300LF street length • Conveyance to downstream GI control • $/LF	$5,000	$17/LF

District of Columbia Water and Sewer Authority (DC Water)

Under a Consent Decree (CD) entered in March 2005, DC Water is required to implement projects for the capture and storage of CSOs during rain events that exceed the capacity of the combined sewer system. The CD requires control of CSOs in all three of the District's main waterways – Anacostia River, Potomac River and Rock Creek. The Anacostia River CSO controls must be in place by 2018 and the Potomac River and Rock Creek CSO controls must be in place by 2025. Currently, there are no numerical goals for CSO reduction through green infrastructure in the CD. In 2012, DC Water entered into an agreement with the USEPA to study potential for GSI for inclusion into their CSO control program which may require modification of the 2005 CD. DC Water is planning to implement a GSI demonstration program of $10 – $30M in capital cost.

DC Water uses unit costs for GSI practices (for construction and materials only) based on data from DC Department of the Environment (DDOE) RiverSmart Program, the Water Environment Research Foundation (WERF) and EPA. These costs are summarized in Table C-8. There were no further details on the development of these unit costs and no reference to a cost index.

To estimate capital cost for each subshed area a 35% contingency was added to the total extended construction costs. An additional 1.4 multiplier was then factored on top of the cost plus contingency to obtain total capital cost.

Table C-8 – Summary of DC Water GSI Technology Assumptions and Unit Costs

GSI Technology	Description/Design	Average Costs
Bioretention	Freestanding Cells: shallow vegetated depression, includes 6”-12” ponding area underlain with a permeable soil medium. Sidewalk Cells: below elevation of sidewalk, tree boxes, curb cut-outs and overflows. Bump-out Cells: constructed between sidewalk and roadway in parking lanes, curb cut-out inlets	$42 per SF
Bioswale	Shallow, linear, sometimes sinuous, vegetated swale underlain by a permeable substrate	$32.50 per SF
Vegetated Strips	Small bioretention areas flush with surrounding landscapes, no ponding depth, underlain with bioretention soil media, heavily vegetated, small drainage area	$10.00 per SF
Tree Box Filter	Small-scale bioretention system, adjacent to standard curb and gutter, concrete box filled with permeable soil medium.	$18 per CF
Green Roofs	Lightweight growing medium and vegetation on top of a roof, layered membrane or proprietary floating tray systems.	$27 per SF
Blue Roof	Series of tray filled with gravel ballast to capture rainfall.	$8.00 per SF
Downspout Disconnect	Redirect downspout to ground, or other detention or infiltration facility (i.e., rain barrel, cistern, or bioretention area)	$200 per downspout
Permeable Pavement	Permeable concrete, asphalt, or pavers that permit percolation of surface runoff into a gravel subgrade.	$30.00 per SF
Large Volume Underground	Detains water below grade in the void space of either a gravel bed or proprietary pipe, arch, or matrix system.	$20.00 per SF

Milwaukee Metropolitan Sewerage District (MMSD), Milwaukee, WI

The Milwaukee Metropolitan Sewerage District’s (MMSD) commitment to green infrastructure is one piece of their plan in order to meet the 2035 vision for zero basement backups, zero overflows, and improved water quality. Approved in July 2013, MMSD’s Regional Green Infrastructure plan documents how to meet the 2035 vision of capturing the first one-half (0.5) inch of rainfall on impervious surfaces. This capture is equivalent to 740 million gallons of storm water storage at an estimated capital cost of $1.3 billion for full implementation, or approximately $59 million per year. MMSD estimates incremental annual operation and maintenance costs at $10.4 million. The level of green infrastructure commitment was made without a consent decree or state order. MMSD estimates costs will roughly be split in half between the public and private sectors.

The MMSD Regional Green Infrastructure Plan included a summary of unit costs from other sources without specific details on what the costs included (Table C-9). These stand-alone costs refer to individual retrofit projects, such as installing a green roof on an existing building or replacing conventional pavement with porous pavement. MMSD also developed incremental costs which represent the difference between GSI construction alone and general construction projects that incorporate green infrastructure components.

Table C-9 – Summary of Stand Alone GSI Costs for Milwaukee Metropolitan Sewer District

Green Infrastructure Strategy	Stand Alone Cost ($/SF)	Loading Ratio
Bioretention/Bioswale	$24	12.0
Porous Pavement	$10	4.0
Green Roof	$12	1.0

New York City Department of Environmental Protection (NYCDEP)

New York City is prepared to invest $1.5 Billion in public green infrastructure through 2030 and is also developing an institutional framework for an anticipated additional $900 Million in private green infrastructure investment. The planned total of $2.4 Billion of GSI is intended to capture the first inch of runoff from 10% of the total impervious area within combined sewersheds throughout New York City. The first phase of GSI investment commits $192 Million of public funds through 2015, intended to capture 1.5% of the impervious area of combined sewersheds City-wide.

For publicly funded GSI projects constructed in the public right-of-way, NYCDEP estimates a unit cost of $720,000 to control one inch of runoff from one impervious acre. The basis of this unit cost is a typical sidewalk swale with costs and sizing based on actual demonstration projects that have been built or bid out by NYCDEP. This technology has the design capacity to capture one inch of impervious runoff without consideration of infiltration. Details of a loading ratio of impervious area to GSI control area were not provided, but the reported ratio of total drainage area (pervious and impervious area) to GSI area is approximately 11:1, so the loading ratio would be less than 11:1. NYC DEP estimates that 1,606 acres of ROW construction will be implemented at a capital cost of $1.155B of NYC DEP's funds.

For stormwater control outside the public right-of way, NYCDEP offered three examples of practices for basis of cost estimation. The lower end of cost would be blue roof detention of stormwater, a mid-range are subsurface infiltration/detention techniques such as gravel beds and perforated pipe, and at the high end are bioinfiltration and green roof GSI applications. NYCDEP chose to use the mid-range of costs for a subsurface infiltration/detention perforated pipes with material and labor costs typical of New York City. To estimate costs for on-site retention of one inch of runoff (on both public and private land), NYCDEP estimates a unit cost value of $200,000 per impervious acre. The design capacity is set to achieve a release rate of 0.25 cfs for an acre of property with a 0.9 runoff coefficient, and does not assume infiltration. NYC DEP estimates that 2,019 acres of Public on-site retention will be implemented at a capital cost of $404 Million of NYCDEP's funds.

City of Pittsburgh, Conceptual Green Infrastructure Designs

In May 2013, Three Rivers Wet Weather (3RWW) completed a draft report titled Conceptual Green Infrastructure Design in the Point Breeze Neighborhood, City of Pittsburgh. Additional conceptual GSI design reports were released in October 2013 by 3RWW for the Swisshelm Park and Brookline neighborhoods in the City of Pittsburgh. These studies are included for ACT comparison in the Literature Review because the conceptual costs estimates are similar in scope to what is proposed for projects being identified in the ALCOSAN Source Control Study. The 3RWW conceptual projects are the only local projects included in this literature review, but additional projects can be added in the future if sufficient data on the projects are available.

Conceptual designs and construction cost estimates included in these 3RWW reports are summarized in Table C-10, and unit costs per square foot of GSI installed were calculated for comparison purposes. These projects are designed to capture one inch of runoff, the same performance criteria as used for ACT planning level cost assumptions. The estimated Point Breeze unit costs for construction vary between $9 and $179 per square foot of installed GSI. The cumulative total of all 3RWW conceptual project construction costs ($1,637,036) divided by the cumulative GSI footprint (37,545 SF) is $44/SF.

The 3RWW conceptual project costs cannot be compared directly to the ACT since the total impervious area controlled by these projects is not reported. A rough comparison can be made by using the total GSI footprint of 3RWW conceptual projects (0.86 acres) and assuming a loading ratio between 5:1 and 10:1. Using this loading ratio assumption, the impervious area captured would be between 4.3 and 8.6 acres. Inputting these assumed impervious areas into the ACT, and adjusting for inflation, the construction cost for the 5:1 loading ratio assumption is $27/SF, and for the 10:1 loading ratio the construction cost is $54/SF of GSI installed. The cumulative GSI costs for the 3RWW conceptual projects of $44/SF falls within this range.

Table C-10 – 3RWW Conceptual Design Construction Costs for GSI within City of Pittsburgh

Site	Technology	GSI Area (SF)	Projected Construction Cost (2013 Dollars)	Calculated Unit Cost ($/SF GSI Area)
Point Breeze Neighborhood				
Frick Museum Parking Lot	Bioretention planter box	750	$ 37,433	$ 50
	Permeable pavement parking stalls (interlocking pavers)	3,600	$ 145,406	$ 40
S. Homewood Avenue	Curb-extension bioretention w/ underdrain	240	$ 13,676	$ 58
	Traffic island bioretention w/ underdrain	1,600	$ 53,031	$ 33
Le Roi Road	Center median bioretention w/ underdrain	400	$ 8,775	$ 22
	Permeable paving parking stalls (interlocking pavers)	1,920	$ 94,462	$ 49
Osage Lane	Permeable alley (porous concrete w/ underdrain)	5,550	$ 158,331	$ 29
Roycrest Place	Permeable pavement parking strips (interlocking pavers)	3,600	$ 150,934	$ 42
Card Lane	Permeable pavement parking strips (interlocking pavers)	2,350	$ 123,036	$ 53
Lang Court	Permeable pavement parking strips (interlocking pavers)	1,740	$ 89,600	$ 55
Windermere Drive 1300 Block	Permeable pavement parking strips (interlocking pavers)	5,100	$ 236,504	$ 46
Swisshelm Park Neighborhood				
Windermere Drive 1300 Block	Traffic island bioretention w/ underdrain	1,125	$ 23,650	$ 21
Windermere Drive 1200 Block	Curb-extension bioretention w/ underdrain	120	$ 21,500	$ 179
Windermere Drive 1200 Block	Curb-extension bioretention w/ underdrain	120	$ 21,500	$ 179
Windermere Drive 1200 Block	Curb-extension bioretention w/ underdrain	120	$ 21,500	$ 179
Windermere Drive 1100 Block	Permeable pavement parking strips (interlocking pavers)	6,840	$ 405,025	$ 59
Brookline Neighborhood				
Sussex Avenue North	Bioretention w/ underdrain	870	$ 10,350	$ 9
Sussex Avenue South	Bioretention w/ underdrain	1,500	$ 22,323	$ 11
	City-Wide TOTAL	**37,545**	**$ 1,637,036**	**$ 44**

C.5 Comparison of ALCOSAN ACT Generated Costs to Other Cities

The six sets of cost data found in the literature review indicate a variety of methods in which GSI costs are reported. Table C-11 provides a summary of unit costs reported in or converted to dollars per impervious acre managed. Table C-12 provides a summary of the unit costs reported in terms of $/SF. All values in these two tables are based on reported costs without adjustments.

Table C-11 – Summary of Recently Published GSI Capital Costs in $ Per Impervious Acre Controlled

GSI Location	Onondaga County, New York	New York City Department of Environmental Protection	ALCOSAN ACT
Public Right of Way	$257,000 (for 13 selected ROW projects)	$720,000 (swale, retrofit)	$287,000 (retrofit) $226,000 (redevelopment)
Private Parcels	Not calculated	$200,000 (subsurface infiltration/detention)	

In comparing costs between projects or comparing project costs to those in the ACT, the following differences between reported costs must be considered:

- Actual implementation costs versus estimated cost of proposed projects
- Estimates for widespread implementation of GSI that has yet to be sited versus individual projects which have been sited and include a conceptual design
- Construction costs versus capital costs
- Retrofit projects versus redevelopment projects
- $/SF or $/impervious acres managed
- All project costs versus GSI related aspect only
- Differences in GSI basis of design (e.g. 0.5" or 1" capture; storage and slow release only versus storage and slow release plus infiltration)
- Projects within the public right-of-way versus on parcels
- Geographic differences in the cost of construction

To make a common baseline comparison among all reported data and the ACT, all unit costs were extrapolated to $/SF of GSI control and adjusted to the ACT index values. The ACT unit cost was developed using the planning assumption of a 5:1 to 10:1 loading ratio range. As shown in Table C-13, there is a wide variation in costs compared amongst GSI programs and also the ACT due in part to the many differences noted above. Individual city comparisons to the ACT are detailed below.

Onondaga County, New York

Construction costs for the selected projects in the Onondaga County 2012 Plan that are considered similar to those anticipated in Pittsburgh exhibit a wider and higher range of construction cost compared to other cities' planning level cost estimating criteria. The wide range of project cost appears to be influenced by non-GSI components of the projects, such as street paving and parking lot improvements that are part of the overall project. Note, Onondaga did not report unit costs per square foot of GSI controlled, these statistics were calculated based on the individual project details provided in the report. The calculated average GSI construction cost for all 13 projects was approximately $25/SF of installed GSI control which compared to the $19/SF used in the ACT, based on the cumulative Onondaga loading ratio of 4.2:1. This is within the +50%/-30% range expected for ACT planning level cost estimates.

The Onondaga costs can also be compared more directly to the ACT in dollars per acre impervious surface managed. Per Table C-4, the index adjusted average cost of $255,000 per acre impervious surface managed is approximately 28% higher than the ACT costs for retrofit ($199,000/impervious acre).

Onondaga's extensive GSI installations and the detail to which they are already sharing construction costs make them a candidate city to contact for further information about actual GSI construction costs.

Cincinnati, Ohio

The Cincinnati paper reported actual construction costs that were stripped down to GSI materials and labor components only, and unit costs are significantly lower than unit costs in the ACT. The publication did not discuss a quantitative value per square foot of GSI of the non-GSI construction costs which are lumped into the total cost for a project. Without this cost inclusion, and without offering a basis of GSI design, the total project construction costs are not equivalent comparisons to the ACT assumptions. An assumed cost multiplier could be applied to the Cincinnati unit costs if bid details of these projects were obtained.

Given the amount of actual construction projects installed by MSDGC, Cincinnati is a candidate city to contact for further information about actual GSI construction costs.

Cleveland, Ohio

The NEORSD Green Infrastructure Plan developed a construction cost estimating method based on typical designs for each green technology to establish an average unit cost per square foot. The methodology resulted in relatively low unit cost ranges, including capital costs, when compared to the ACT. An understanding of the NEORSD GSI basis of design criteria is needed to understand the relative difference between NEORSD and ACT unit costs.

NEORSD has gone through a process similar to what ALCOSAN is currently developing for the Regional Evaluation of Green Stormwater Infrastructure and Other Source Controls. Although NEORSD is not yet constructing its Green Infrastructure Plan, the work that authority produced could serve as an example of ways for ALCOSAN and its customer municipalities to consider GSI.

As NEORSD advances its plan and completes multiple projects, it could be a candidate to contact for better understanding of actual GSI construction costs.

Washington DC

The DC Water cost estimating unit cost criteria are similar to the ACT, except with more categories and greater variations among the specific technologies. An understanding of the basis of design is needed to understand the relative difference between DC Water and ACT unit costs. Since the Green Infrastructure Projects Plan was recently completed there are no published costs on completed projects, but as DC Water advances their study on GSI and completes demonstration projects, they could be a candidate for contacting to understand more about GSI construction costs.

Milwaukee, Wisconsin

The MMSD green infrastructure planning level cost estimating criteria include significantly lower unit construction costs than the ACT. One potential reason for this is that the costs developed by MMSD are assumed for 0.5 inches of capture of runoff. This would have a significant effect of higher costs if scaled up to 1 inch, but without a detailed description of the development of unit costs in the Regional Green Infrastructure Plan, it is not possible to further investigate the difference. Given these limitations and that MMSD is not operating under a Consent Decree to implement their Plan, it is not recommended that MMSD be contacted further to gain an understanding of their costs.

New York City

New York City provided unit cost estimates for two applications, one a sidewalk bioswale and the other a perforated pipe on-site retention application. The sidewalk bioswale unit cost for construction index values is significantly higher than the ACT planning level estimate in part due to the large percentage attributed to labor. Furthermore, NYCDEP's selected design criteria do not assume the effects of infiltration into the sizing of the GSI. Based on this important design consideration, and unknowns of NYCDEP assumptions of labor required, it is not recommended that this unit cost be considered for comparison to the ACT unit costs.

Given that the ALCOSAN and its customer municipalities are focused on GSI applications within the public right-of-way the NYCDEP on-site retention application does not have an analogous technology for comparison using the ACT and was not included in the comparison.

C.6 Conclusions

This literature review confirms that there is a wide variation of actual construction and planning level cost opinions among agencies that are implementing green stormwater infrastructure as part of a CSO program. Onondaga County, New York is experiencing actual construction costs that are higher than those estimated by the ALCOSAN ACT, but within the expected range for a planning level estimate. The other source of actual construction costs, Cincinnati, offered results that were inconclusive due to the lack of details of complete project costs and basis of design.

While actual construction cost data would be the primary reason to update the ACT, planning level estimates from other cities offered little additional insight as to whether the ACT would need to be adjusted due to the lack of details offered on the basis of GSI designs. DC Water is also using cost estimating criteria of similar magnitude to the ACT, except for green roofs which are significantly higher. Cleveland is using planning level estimates below the assumed accuracy range for the ACT, except for green roofs which are at the high end of the ACT range. Milwaukee is also using estimates below the ACT accuracy range, which is expected given the lesser basis of design (0.5" rainfall capture). Finally, New York is using guidelines above the ACT accuracy range.

The results of the 3RWW report on conceptual GSI projects in the Point Breeze, Swisshelm Park and Brookline neighborhoods is an indicator that the ACT planning level cost estimates yields reasonable results when compared to detailed cost estimates of conceptual design projects. Using assumed loading ratios these Pittsburgh conceptual cost estimates displayed a wide range of unit costs on an individual project basis, but when cumulatively assessed the unit costs are comparable to the accuracy range anticipated for the ACT. This comparison could be refined if the total impervious area controlled by these projects could be obtained.

It is evident that GSI projects when actually implemented typically include certain non-GSI functional components to address temporary construction measures, desired community benefits, the needs of the surrounding area, and the concerns of abutting property owners. Since the ACT is in reasonable agreement with actual project costs that include these factors, it is reasonable to continue to use the ACT for the preliminary screening of GSI projects in the ALCOSAN service area. As specific projects are identified and conceptual designs are developed, site specific cost estimates should be developed as they would for any other project, using actual materials and labor estimates for the actual quantities of work involved.

As mentioned earlier in the report, this study focused on public domain data and did not contact outside agencies. Outside agencies can be contacted as a follow-up to this report if desired to see if they are willing to share additional data on actual construction costs and project details. The programs with the largest number of constructed GSI projects with most relevance to ALCOSAN would be:

- Philadelphia Water Department;
- Onondaga County Department of Water Environment Protection;
- Metropolitan Sewer District of Greater Cincinnati;

- Portland Oregon Bureau of Environmental Services;
- Seattle Public Utilities and King County; and
- Kansas City (MO) Water Services Department.

The ACT can be updated in the future if additional data can be obtained on actual construction costs for GSI projects from other cites, or preferably local demonstration projects.

Table C-12 - Summary of Recently Published GSI Unit Costs in Square Feet

Best Management Practice / Other Parameters	**Northeast Ohio Regional Sewer District (Cleveland)[1]**		**Cincinnati Metropolitan Sewer District[2]**		**Milwaukee Metropolitan Sewer District[3]**	**District of Columbia Water and Sanitation Authority[4]**	**ALCOSAN ACT Extrapolation** (range is based on retrofit costs with 5:1 to 10:1 loading ratio where applicable)	
	Low	**High**	**Low**	**High**			**Construction**	**Capital**
Bioretention	$25		-	-	$24	$42	$23 - $46	$46 - $66
Porous Pavement	$14		$2	$20	$10	$30	$23 - $46	$46 - $66
Green Roof	$29		$11	$35	$12	$27	$13	$19
Bioinfiltration	$7	$22	$8	$20	-	-	$23 - $46	$46 - $66
Bioswale	$25		$7	$17	$24	$33	$23 - $46	$46 - $66
Type of Cost	Capital		Construction, but some costs are excluded.		Not Reported	Construction – direct cost plus OH&P – no contingency	Construction	Capital
Targeted Capture	Not Reported		Not Reported		First 0.5" of rainfall	Not Reported	First 1" of stormwater runoff	
Loading Ratio	Bioretention Cell/Swale - 5:1 to 10:1. No others listed		Not Reported		Green Roofs 1:1 Rain Gardens 12:1 Stormwater Trees 0.5:1 Soil Amendments 12:1 Porous Pavement 4:1	Not Reported	Costs assume 5:1 to 10:1 for all technologies except green roofs, which is 1:1.	
Slow Release Connections	Infiltration Trench: 1 connection per 0.1 - 0.25 acre impervious, $6,600 per connection Bioretention swale or cell: 1 connection per 0.1 - 0.25 acres impervious, $4,300 per connection Pervious pavement: 1 connection per 0.5 acres of pavement, $18,000		Not Reported		Not Reported	Not Reported	Assumes 1 connection per each 1/4 acre of impervious, $10,000 per connection	
Contingencies Included	Includes a 55% markup for construction contingency, design and construction administration.		Not Reported		Not Reported	Add 35% contingency on top of base construction cost for total construction cost, then multiply by 1.4 to get total capital cost	Construction Contingency: 25% Project Contingency: 20% for retrofit	
Other Notes					Costs reported are intended for stand-alone projects or retrofits. MMSD also published "incremental costs," or the cost difference between conventional construction and construction that incorporates green infrastructure.		Costs reported are for retrofit projects	

Note: All Costs above are as reported in their published source, unadjusted to show the variation in how different CSO programs interpret GSI costing.

1. Northeast Ohio Regional Sewer District. *Green Infrastructure Plan*, 2012
2. Ellwood, Nancy. "A Detailed Look at Costs Associated with Green Stormwater Controls." Proceedings from Water Environment Federation Stormwater Symposium, 2012.
3. Milwaukee Metropolitan Sewerage District. *Regional Green Infrastructure Plan*, 2013.
4. District of Columbia Water and Sewer Authority. Technical Memorandum No. 3: Green Infrastructure Plan, Revision No. 1, 2012.

Table C-13 - Adjusted Unit Cost Per Square Foot of Green Stormwater Infrastructure Installation

(Adjusted for Time and Location with ALCOSAN ACT Index values to compare to ACT Costs)

Best Management Practice / Other Parameters	Constructed GSI Projects Calculated Unit Costs				Planning Level GSI Unit Costs						
	Cincinnati		Onondaga Co.[1]		Cleveland		Milwaukee	New York City	DC Water[2]	ALCOSAN ACT Extrapolation[3]	
	Low	High	Low	High	Low	High				Construction	Capital
Bioretention	-		$6	$121	$24		$21	-	$39	$23 - $46	$46 - $66
Porous Pavement	$2	$20	$7	$16	$13		$9	-	$28	$23 - $46	$46 - $66
Green Roof	$11	$36	--	--	$27		$10	-	$25	$13	$19
Bioinfiltration	$8	$20	$23	$91	$7	$21	-	-	-	$23 - $46	$46 - $66
Bioswale	$7	$17	-		-		$21	$108	$30	$23 - $46	$46 - $66
Type of Cost	Construction, but some costs excluded		Construction		Capital		Not Reported	Capital	Not Reported	Construction / Capital	
ENRCCI	9268		2010 - 8799 2011 - 9070		9172		9542	8799	9324	8641	
ENRCCI Date	March 2012		Annual averages of 2010 and 2011		December 2011		June 2013	2010 Annual Average	June 2012	December 2009	
RS Means Location Adjustment	91.1		96.5		99.0		103.2	133.2	98.8	99.6	

Notes:

1. Based on 13 selected Onondaga County projects considered similar to anticipated public projects in Pittsburgh.
2. Unit costs shown are based on direct construction costs plus 35% construction contingency
3. Range is based on retrofit costs with 5:1 to 10:1 loading ratio where applicable