City of Chattanooga

Resource: Rain
Low Impact Development
Design Challenge

Cherokee Boulevard

Team No. 14357

June 20, 2014

City of Chattanooga, c/o Don Green
Water Quality Program, Development Resource Center
1250 Market Street, Suite 2100, Chattanooga, TN 37204

Chattanooga resource: RAIN Design Challenge

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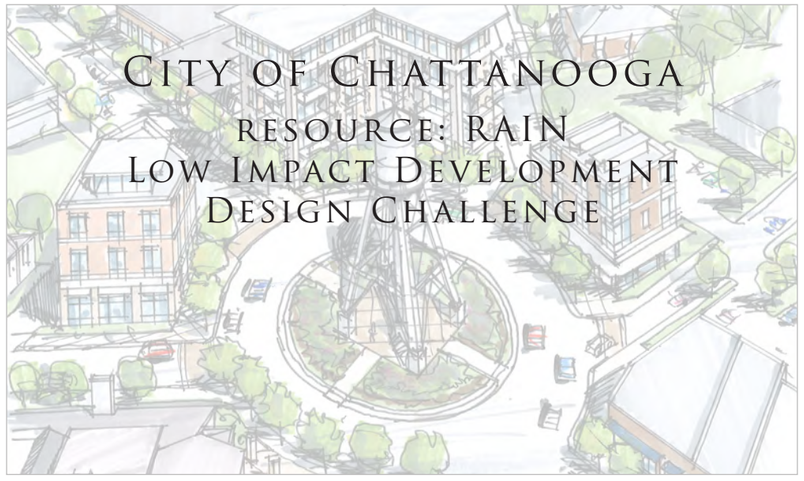
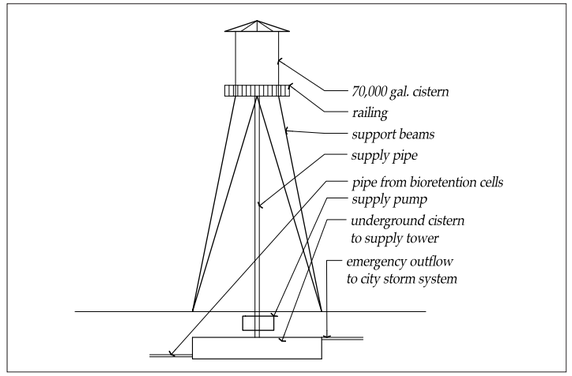
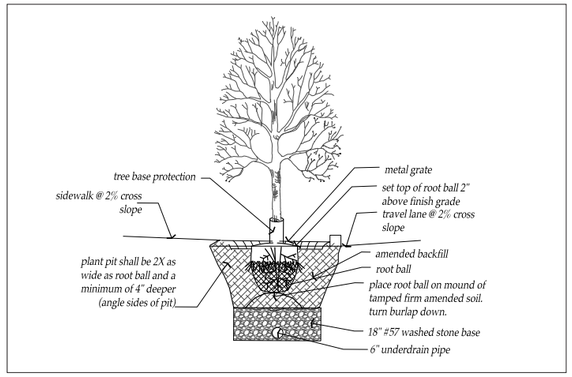


Section A
Concept Overview



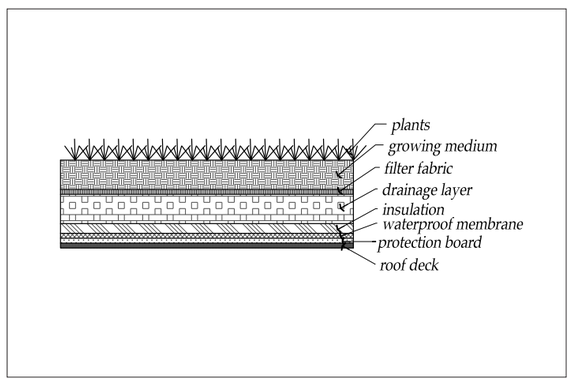
Cistern

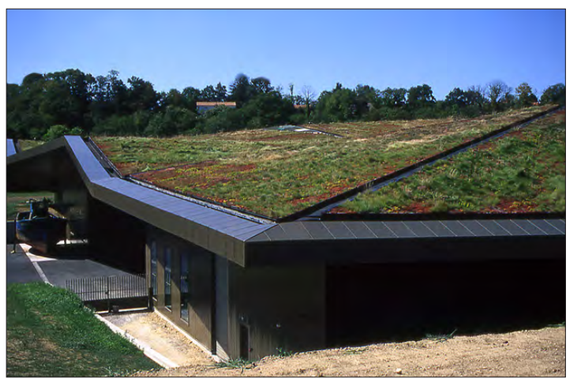
A cistern is a structure that captures and stores runoff. The collected water can be used for landscape irrigation and some interior uses, such as toilets and washing machines. Cisterns will be utilized on Cherokee Boulevard inside the proposed roundabout. A large, industrial style water tower will anchor the roundabout with a large underground cistern to supply the tower with water. Excess runoff from the bioretention cells will flow downhill and be piped into the underground cistern that will feed the water tower to supply the surrounding areas with grey water for irrigation, toilets, and fire protection.



Tree Wells

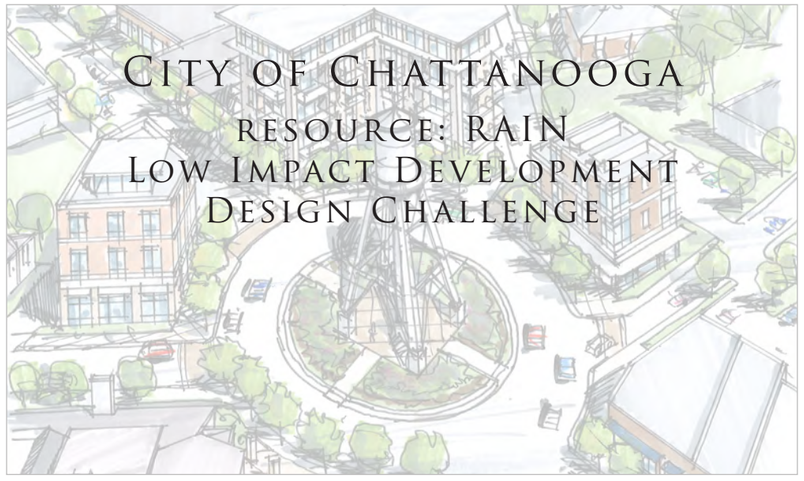
Tree wells are mini bioretention areas installed beneath trees. The system consists of a container filled with a soil mixture, a mulch layer, under-drain system and a shrub or tree. Stormwater runoff drains directly from impervious surfaces through a filter media. Treated water flows out of the system through an under drain connected to a storm drainpipe / inlet or into the surrounding soil. Tree wells will be utilized between the permeable sidewalk and travel lane on Cherokee Boulevard between W. Manning St. and N. Market St.





Green Roof

Green roofs are vegetated layers that sit on top of the conventional waterproofed roof surfaces of a building. They are constructed of a lightweight soil media, underlain by a drainage layer, and a high quality impermeable membrane that protects the building structure. The soil is planted with a specialized mix of plants that can thrive in the harsh, dry, high temperature conditions of the roof and tolerate short periods of inundation from storm events. Green roofs will be utilized on Cherokee Boulevard for all new construction that occurs within the project boundary.



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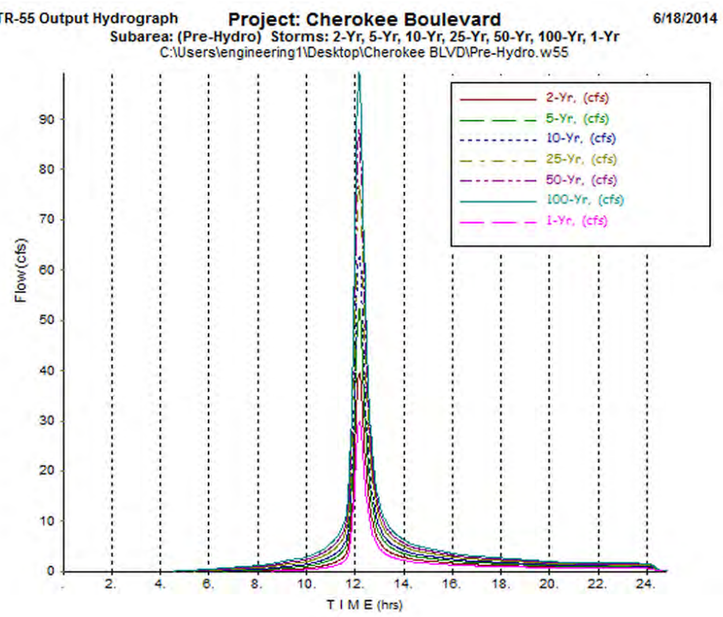
Section C

Hydrologic Calculations

Name Cherokee Boulevard
Resource Rain LID Design Competetion
Hamilton NOAA_8 County, Tennessee

Hydrograph Peak/Peak Time Table

Sub-Area or Reach Identifier	Peak Flow and Peak Time (hr) by Rainfall Return Period 2-Yr (cfs)	(hr)	5-Yr (cfs)	(hr)	10-Yr (cfs)	(hr)	25-Yr (cfs)	(hr)	50-Yr (cfs)	(hr)	100-Yr (cfs)	(hr)	1-Yr (cfs)	(hr)
SUBAREAS														
Pre-Hydro	39.48	12.18	52.36	12.18	62.55	12.18	76.71	12.17	87.97	12.17	99.44	12.16	29.94	12.18
REACHES														
OUTLET	39.48		52.36		62.55		76.71		87.97		99.44		29.94	

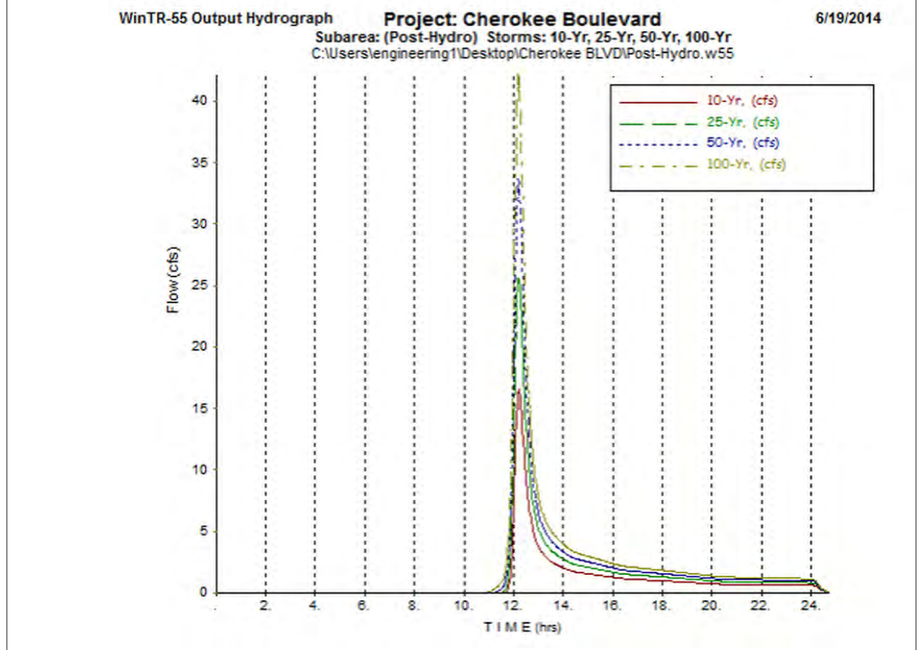


Pre-Development Hydrograph

Name Cherokee Boulevard
Resource Rain LID Design Competetion
Hamilton NOAA_8 County, Tennessee

Hydrograph Peak/Peak Time Table

Sub-Area or Reach Identifier	Peak Flow and Peak Time (hr) by Rainfall Return Period 10-Yr (cfs)	(hr)	25-Yr (cfs)	(hr)	50-Yr (cfs)	(hr)	100-Yr (cfs)	(hr)
SUBAREAS								
Post-Hydro	16.57	12.21	25.66	12.19	33.63	12.19	42.21	12.18
REACHES								
OUTLET	16.57		25.66		33.63		42.21	



Post-Development Hydrograph

Hydrographs

Two tools were used to determine the benefit of the conceptual LID design for the Cherokee Boulevard site. These tools included the USDA's TR-55 Small Watershed Hydrology Model and the Resource Rain LID Calculation Tool. For the purpose of determining the effect of the LID design, all calculations were based on data situated within the project boundary as provided by the City of Chattanooga. This site encompasses a total area of approximately 20.05 acres with 15.6 acres determined to be impervious surface.

To determine current conditions, the TR-55 model was used to create a pre-hydrograph for the site. This model is based on storm data presented in Chapter 7 of the Resource Rain guide, a weighted curve number of 85, and a calculated concentration time of .485 hours.

Project Name: Cherokee BLVD
Date Prepared: 6.18.14
Prepared by: NAME

WORKSHEET 1: SOV and BMP AREA

=> Denotes input by user

SOV DESIGN RAINFALL = 1 in.

TARGET LOADING RATIO = 10 (See Ch. 5 for details)

Concept Design

Total Parcel Area =	873,378	ft.²	or	20.05 ac
Total Proposed Impervious Area =	679,536	ft.²	or	15.60 ac
Protected Areas				0.00 ac
5.2.1 Area of Protected Undisturbed and Healthy Soils		ft.²	or	0.00 ac
5.2.1.1 Area of Minimized Land Disturbance	0	ft.²	or	0.00 ac
5.2.1.2 Area of Protected Soils/Steep Slopes	0	ft.²	or	0.00 ac
5.2.2 Area of Protected Natural Flow Paths	0	ft.²	or	0.00 ac
5.2.3 Area of Protected/Enhanced Riparian Corridors	0	ft.²	or	0.00 ac
5.2.4 Area of Protected/Preserved Vegetation	0	ft.²	or	0.00 ac
Total Protected Area	0	ft.²	or	0.00 ac
Total Disturbed Area	873,378	ft.²	or	20.05 ac
				0.00 ac
Total Impervious Area	679,536	ft.²	or	15.60 ac
Total Pervious Area	193842	ft.²	or	4.45 ac
Concept Level BMP Area (Based on Proposed Impervious Area)	67,954	ft.²	or	1.56 ac

Disturbed Area Requiring Stormwater Management = 873,378 ft² (A)
= 20.05 ac

Runoff Coefficients, Rv for Design Rainfall

Land Use Type	Surface Condition		0.5	0.6	0.7	0.8
-	-	-	-	-	-	-
Clayey Soils	Pervious		0.19	0.194	0.198	0.202
Flat Roof	Impervious		0.79	0.802	0.814	0.826
Large Impervious	Impervious		0.97	0.972	0.974	0.976
Pitched Roof	Impervious		0.95	0.954	0.958	0.962
Sandy Soils	Pervious		0.02	0.022	0.024	0.026
Small Impervious	Impervious		0.64	0.652	0.664	0.676
Typical Urban Soils	Pervious		0.10	0.104	0.108	0.112

- Large impervious includes parking lots with curbs, roads with curbs, highways, etc.
- Small impervious includes roads without curbs, small parking lots without curbs, and sidewalks.

Preliminary Design

INITIAL TARGET BMP AREA = 68,006 ft²

Sub-Drainage ID per BMP (numbers and lowercase letters only)	Land Use Type	Surface Condition	Disturbed Land Area (ft²)	Disturbed Land Area (ac)	Rv Value, from Table	Stay on Volume (ft³)
1a	Large Impervious	Impervious	548,102	12.58	0.98	44,762
1b	Small Impervious	Impervious	131,955	3.03	0.70	7,697
2	Typical Urban Soils	Pervious	193,842	4.45	0.12	1,938
		#N/A		0.00	-	-
		#N/A		0.00	-	-
		#N/A		0.00	-	-
		#N/A		0.00	-	-
		#N/A		0.00	-	-
		#N/A		0.00	-	-
		#N/A		0.00	-	-
		#N/A		0.00	-	-
		#N/A		0.00	-	-
		#N/A		0.00	-	-
		#N/A		0.00	-	-
		#N/A		0.00	-	-
		#N/A		0.00	-	-
		#N/A		0.00	-	-
		#N/A		0.00	-	-
		#N/A		0.00	-	-
		#N/A		0.00	-	-
		#N/A		0.00	-	-
		#N/A		0.00	-	-
		#N/A		0.00	-	-
		#N/A		0.00	-	-
		#N/A		0.00	-	-
	-	-		0.00	-	-
	-	-		0.00	-	-
	-	-		0.00	-	-
	-	-		0.00	-	-
	-	-		0.00	-	-
	-	-		0.00	-	-
	-	-		0.00	-	-
	-	-		0.00	-	-
	-	-		0.00	-	-
	-	-		0.00	-	-
	-	-		0.00	-	-
Documented Disturbed Land Areas (from above) =			873,899 ft²			(B)
=			20.06 ac			
Total SOV Capture Volume =			54397.46 ft³			

Lines (A) and (B) should equal if all Disturbed Land Areas have been entered correctly
Note: Runoff Volume based on Small Storm Hydrology Method, where Rv is the ratio of runoff to rainfall volume.

WORKSHEET 1: SOV & BMP AREA

SOV & BMP Area

The LID calculation tool was then used to determine the required Stay on Volume (SOV) to capture the first inch of rainfall. As can be seen in the LID Calculation Tool Worksheet 1, this resulted in a required SOV storage volume of 54,397.46 cubic feet. To achieve this SOV, multiple features were utilized in the design. These include bio-retention, pervious pavement, deciduous trees, green roof structures, and an elevated storage tank.

Project Name: Cherokee BLVD
Date Prepared: 6.18.14
Prepared by: NAME

WORKSHEET 2: Restorative Credits

=> Denotes input by user

Restorative Volume Credit Worksheet							
Sub-Drainage ID	Sub-Drainage SOV (ft^3)	Restorative Practice Credit Type	Area (ft^2)	# of Trees	Volume Credit (ft^3)	Total Volume Credit (limit to maximum of 25% of SOV) (ft^3)	Net Drainage Area SOV (ft^3)
1	52,459				0	0	52,459
					0		
					0		
2	1,938	Tree Planting - Deciduous		368	2,208	485	1,454
					0		
					0		

WORKSHEET 2: RESTORATIVE CREDITS

Project Name: Cherokee BLVD
Date Prepared: 6.18.14
Prepared by: NAME

WORKSHEET 3: BMP SIZING

=> Denotes input by user

Sub-Drainage ID	BMP Type	Infiltration Rate (in./hr)	Runoff Storage Type	Mid-height Area (ft^2)	Depth of Storage (ft)	Storage Capacity (%)	Storage Volume (ft^3)	BMP Surface Area (ft^2)	BMP Capture Volume (ft^3)	Net Drainage Area SOV (ft^3)	Drawdown Time (hrs)	Loading Ratio
1	Pervious Pavement	0.40	Surface	108,827	0.333	100%	36,239	0	36,239	52459	10	N/A
			Soil			0%	0					
			Stone			0%	0					
2	Bioretention	0.40	Surface	77,472	1	100%	77,472	77,472	108,461	1454	42	0
			Soil	77,472	1	20%	15,494					
			Stone	77,472	0.5	40%	15,494					
3	NONE	0.00	Surface	9,425	1	100%	9,425	0	9,425	0	-	N/A
	Water Storage Tank		Soil			0%	0					
			Stone			0%	0					
4	NONE	0.40	Surface			0%	0	0	0	0	0	N/A
			Soil			0%	0					
			Stone			0%	0					

WORKSHEET 3: BMP SIZING

Restorative Credits & BMP Sizing

Worksheet's 2 and 3 from the LID calculation tool were used to calculate the SOV achieved as a result of this design. All of the features except green roof structures were incorporated into this calculation. While these structures do provide hydraulic benefits to the site, they are not designed to provide substantial "storage" and therefore are not included in the SOV calculations. This design achieves an estimated 154,125 cubic feet of storage for SOV on this site, surpassing the 1" SOV requirement.

Project Name: Cherokee BLVD
Date Prepared: 6.18.14
Prepared by: NAME

WORKSHEET 4: CN Adjustment

=> Denotes input by user

Outfall #	Area (ft²)	Weighted CN	Storm Frequency	Rainfall (in)	S	Q (in)	BMP Capture Volume (ft³)	Infiltration Volume (12 hrs) (ft³)	Total BMP Volume Reduction (ft³)	Q minus Total Volume Reduction (in)	Adjusted CN
1	873,378	85	2	3.70		2.19				-0.95	#NUM!
			5	4.50		2.91				-0.23	#NUM!
			10	5.10	1.76	3.46	154,125	74,520	228,645	0.32	42
			25	6.00		4.30				1.16	50
			100	7.40		5.64				2.49	56
			2	3.70		3.70				3.70	100
			5	4.50		4.50				4.50	100
			10	5.10	0.00	5.10			0	5.10	100
			25	6.00		6.00				6.00	100
			100	7.40		7.40				7.40	100
			2	3.70		3.70				3.70	100
			5	4.50		4.50				4.50	100
			10	5.10	0.00	5.10			0	5.10	100
			25	6.00		6.00				6.00	100
			100	7.40		7.40				7.40	100
			2	3.70		3.70				3.70	100
			5	4.50		4.50				4.50	100
			10	5.10	0.00	5.10			0	5.10	100
			25	6.00		6.00				6.00	100
			100	7.40		7.40				7.40	100
			2	3.70		3.70				3.70	100
			5	4.50		4.50				4.50	100
			10	5.10	0.00	5.10			0	5.10	100
			25	6.00		6.00				6.00	100
			100	7.40		7.40				7.40	100
			2	3.70		3.70				3.70	100
			5	4.50		4.50				4.50	100
			10	5.10	0.00	5.10			0	5.10	100
			25	6.00		6.00				6.00	100
			100	7.40		7.40				7.40	100

Worksheet 4: CN Adjustment

Project Summary								
Sub-Drainage ID	Total Disturbed Area (ft²)	Total Disturbed Impervious Area (ft²)	Sub-Drainage Area SOV (ft³)	Volume Credit (ft³)	Net Sub-Drainage Area SOV (ft³)	Loading Ratio	BMP Capture Volume (ft³)	Capture > SOV?
1	680,057	680,057	52,459	0	52,459	N/A	36,239	NO
2	193,842	0	1,938	485	1,454	0	108,461	YES
3	0	0	0	0	0	N/A	9,425	N/A
4	0	0	0	0	0	N/A	0	N/A
5	0	0	0	0	0	N/A	0	N/A
6	0	0	0	0	0	N/A	0	N/A
7	0	0	0	0	0	N/A	0	N/A
8	0	0	0	0	0	N/A	0	N/A
9	0	0	0	0	0	N/A	0	N/A
10	0	0	0	0	0	N/A	0	N/A
11	0	0	0	0	0	N/A	0	N/A
12	0	0	0	0	0	N/A	0	N/A
13	0	0	0	0	0	N/A	0	N/A
14	0	0	0	0	0	N/A	0	N/A
15	0	0	0	0	0	N/A	0	N/A
16	0	0	0	0	0	N/A	0	N/A
17	0	0	0	0	0	N/A	0	N/A
18	0	0	0	0	0	N/A	0	N/A
19	0	0	0	0	0	N/A	0	N/A
20	0	0	0	0	0	N/A	0	N/A
Totals	873,899	680,057	54,397	485	53,913		154,125	YES

Project Summary

CN Adjustment & Project Summary

To further explore the benefits of the design, Worksheet 4 of the LID Calculation tool was used to calculate an adjusted curve number for the site. The achieved SOV is sufficient to handle rainfall estimates for the 2 and 5 year storm event, leaving only the 10-100 year events for calculation in the post-hydrograph. The adjusted curve number used for the post-hydrograph is 56, which is calculated for the 100 year storm event, providing a conservative estimate for the 10, 25, and 100 year events.

In addition to surpassing the 1" SOV requirement, comparison of the pre and post hydrographs show the benefits of the LID design. As previously mentioned, the SOV from this design will contain sufficient volume to surpass the 5-year event estimates. In addition, runoff from the 10, 25, and 100 year events are reduced. The 10 year event is reduced from 62.55cfs to only 16.57cfs. These benefits are evident throughout the 100 year mark with this storm runoff reduced from 99.44cfs to 42.41cfs.

This design and supporting calculations clearly show the benefits of utilizing LID design methods. In addition to aesthetics, these features provide positive long term effects by enhancing water quality and providing flood control on the site and throughout the surrounding area. The figures in this section provide supporting data from both the TR-55 and LID Calculation tools.

City of Chattanooga

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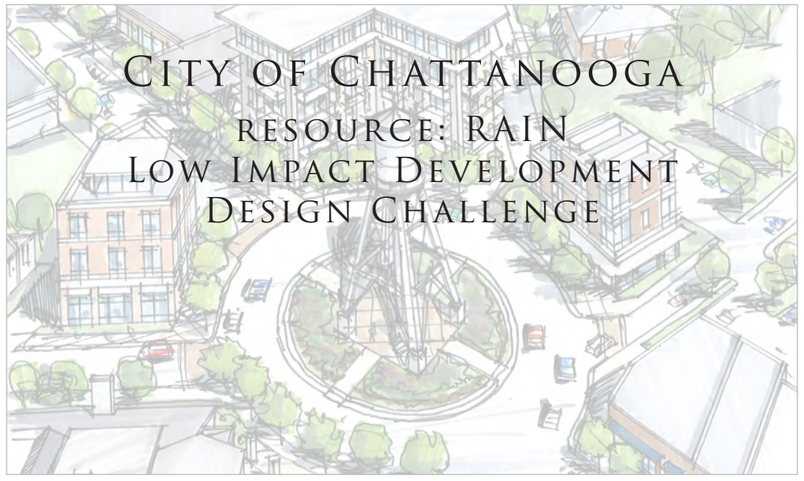

Section D
Cost Analysis

Volume Control

Required Volume Capture from .74927" over Whole Site (ft^3)	54,397
Volume Captured by current BMPs (ft^3)	144,731
Tree Box Filter (ft^3)	8,243
Swales (ft^3)	11,461
Roadside Swales (ft^3)	112,642
Permeable Pavement on Parking (ft^3)	9,130
Permeable Pavement on Sidewalks (ft^3)	3,255
Percentage of Required Volume Captured by current BMPs (%)	266
Decrease in Impervious Area (%)	50

Estimates Calculated Using the National Storm Water Management Calculator

Coefficients and Runoff

	Predevelopment	Conventional	Green	Predevelopment to Conventional Difference (%)	Conventional to Green Difference (%)
Average Annual Rainfall					
Total Runoff (in)	36.22	35.68	33.84	-1%	-5%
Total Runoff Volume (ft^3)	2,629,299	2,590,570	2,457,121	-1%	-5%
Cumulative Abstractions (in)		0.65	2.16		233.97
85% Storm					
Total Runoff (in)	0.76	0.47	0.09	-38%	-80%
Total Runoff Volume (ft^3)	55,311	34,123	6,763	-38%	-80%
Cumulative Abstractions (in)		0.37	0.42		13.44
CN	98	94	81		
Initial Abstractions (in)		0.13	0.46		248.94

Estimates Calculated Using the National Storm Water Management Calculator

COST ANALYSIS

An evaluation of project costs for Low Impact Development (LID) standards requires analysis beyond a simple cost comparison or a life-cycle cost analysis. Cost comparisons are easier to undertake and life-cycle cost analysis are a bit more comprehensive. However, both methods exclude economic benefits and the opportunities for effective implementation. The planning team for this proposal has chosen to undertake a cost benefit analysis using the National Storm Water Management Calculator. The preliminary planning calculator allows for efficient analysis and benefits of green infrastructure projects in comparison to conventional construction practices. The team's evaluation takes into account the environmental, economic and social equity of the projects intent

Volume Control:

The methodology and hydrologic modeling chosen for this entry are described in the hydraulic calculations section of this document. The runoff numbers and volume captured by proposed BMP's is illustrated below. The Stay on Volume (SOV) required to manage the first inch of rainfall for the 20 acre site is 54,397 cubic feet. The table below demonstrates the volume captured by all proposed BMP's as well as an evaluation of individual BMP's. The volume control calculations do not evaluate the green roof structures or the elevated storage cistern located in the roundabout at the intersection of Manning Street and Cherokee Boulevard.

Coefficients and Runoff:

The coefficients and runoff calculations note the average expected rainfall as well as a comparison of predevelopment runoff to conventional development and development using the proposed green infrastructure BMP's. The percentage difference between conventional and green infrastructure proposed within the teams concept is an 80% in runoff volume from conventional to LID practices.

Land Use

	Conventional Area (ft^2)	Green (Using BMPs) Area (ft^2)
Conventional Roof	68,266	68,266
Green Roof	0	0
Parking Lot	195,337	60,174
Permeable Parking Lot	0	54,782
Swales in Parking Lot	0	6,782
Streets	352,765	168,394
Reduced Street Width	0	126,995
Roadside Swales	0	57,375
Driveway and Alleys	4,514	4,514
Permeable Driveway and Alleys	0	0
Sidewalks	59,174	39,647
Permeable Sidewalks	0	19,527
Lawn	191,144	318,139
with Amended Soil	0	0
Native Vegetation	0	0
Rain Garden	0	0
Filter Strips	0	0
Planter Boxes	0	0
Trees	0	0
Total Impervious	**680,056**	**340,995**
Total Pervious	191,144	530,205

Estimates Calculated Using the National Storm Water Management Calculator

Land Use:
The existing land use in comparison to the proposed green infrastructure standards is shown in the chart below. The Land Use chart compares the proposed permeable and impermeable surfaces. There are 352,765 impermeable street surfaces within the project area. The LID proposal reduces this amount to 168,394 sq. feet of impermeable streets which are surrounded by permeable parking areas as well as Roadside Bioretention areas.

Costs

	Construction Cost ($)				Annual Maintenance Cost ($)				Life Cycle Cost ($, NPV)			
	Conventional	Green	Difference	%	Conventional	Green	Difference	%	Conventional	Green	Difference	%
Concrete Sidewalk	$307,113	$205,766	($101,347)	-33%	$1,716	$1,150	($566)	-33%	$351,783	$235,695	($116,088)	-33%
Concrete Driveway	$23,429	$23,429	$0	0%	$131	$131	$0	0%	$26,837	$26,837	$0	0%
Curbs and Gutters	$10,245	($118,457)	($128,702)	-1256%	$89	($1,030)	($1,119)	-1256%	$12,565	($145,270)	($157,835)	-1256%
Street	$1,527,471	$729,147	($798,324)	-52%	$19,402	$9,262	($10,140)	-52%	$2,032,526	$970,238	($1,062,288)	-52%
Parking Lot	$1,076,307	$331,558	($744,749)	-69%	$29,301	$9,026	($20,274)	-69%	$1,839,030	$566,516	($1,272,514)	-69%
Conventional Stormwater Storage	$628,285	$0	($628,285)	-100%	$1,632	$0	($1,632)	-100%	$670,766	$0	($670,766)	-100%
Standard Roof	$511,998	$511,998	$0	0%	$3,413	$3,413	$0	0%	$600,850	$600,850	$0	0%
Permeable Pavement-Pavers	$0	$527,595	$527,595	0%	$0	$2,675	$2,675	0%	$0	$597,231	$597,231	0%
Turf	$40,140	$66,809	$26,669	66%	$17,203	$28,632	$11,430	66%	$487,949	$812,141	$324,192	66%
Trees	$0	$101,200	$101,200	0%	$0	$7,360	$7,360	0%	$0	$292,788	$292,788	0%
Tree Box Filters	$0	$1,308,431	$1,308,431	0%	$0	$51,167	$51,167	0%	$0	$2,640,351	$2,640,351	0%
Swales in Parking Lot	$0	$101,723	$101,723	0%	$0	$814	$814	0%	$0	$122,906	$122,906	0%
Roadside Swales	$0	$860,626	$860,626	0%	$0	$6,885	$6,885	0%	$0	$1,039,850	$1,039,850	0%
Additional Aggregate	$0	$1,486,182	$1,486,182	0%	$0	$1,139	$1,139	0%	$0	$1,515,842	$1,515,842	0%
Additional Soil	$0	$647,680	$647,680	0%	$0	$497	$497	0%	$0	$660,606	$660,606	0%
Total	**$4,124,989**	**$6,783,687**	**$2,658,698**	**64%**	**$72,887**	**$121,121**	**$48,234**	**66%**	**$6,022,304**	**$9,936,579**	**$3,914,275**	**65%**

Estimates Calculated Using the National Storm Water Management Calculator

Cost Analysis:

In order to understand the costs and benefits in implementing the proposed LID standards an evaluation of construction costs, annual maintenance costs and a life cycle costs has been completed. The cost evaluation carries assumptions related to construction practices and costs that are beyond the control of the planning team. However, the analysis offers a reasonable estimate of the costs associated with planning, designing and constructing the the teams concept. The cost analysis indicates higher costs for undertaking green infrastructure interventions in comparison to conventional stormwater management strategies. Furthermore, the life cycle costs for the green infrastructure project would be considerably higher. However, the ecological and quality of life benefits gained by the implementation of these LID principles will make up for the additional costs, as seen on the following page.

Benefits

	Annual Benefits ($) Green Benefits	Life Cycle Benefits ($, NPV) Green Benefits
Reduced Air Pollutants	67	1,734
Carbon Dioxide Sequestration	44	1,150
Compensatory Value of Trees	101,200	2,634,334
Groundwater Replenishment	165	4,307
Reduced Energy Use	0	0
Reduced Treatment benefits	92	2,388
Total	**101,568**	**2,643,913**

Estimates Calculated Using the National Storm Water Management Calculator

Benefits:
The full benefits of using the recommended BMP's for the Cherokee Boulevard site are outlined in the Benefits table. The annual benefit of the green infrastructure project is estimated to exceed $101,568.00 annually. The Life Cycle benefit is estimated to reach $2,643,913.00 through reduced air pollutants, carbon dioxide sequestration and the compensatory value of the 368 street trees.