**REPORT for OBJ1.TASK 12:**

**TREES CASE STUDIES**

**To: MPCA**

From: The Kestrel Design Group Team

Date: October 18, 2013

Re: Contract CR5332 Objective 1 Task 12

**SCOPE**

**Obj1.Task 12: Prepare 5-10 Urban Forest and Storm Water Management Case Studies:**

Prepare a report summarizing 5-10 case studies of existing urban forestry efforts and programs.  At least half of the case studies will be representative of cold climates.  Case studies will cover different aspects of trees in urban settings (e.g. different species, types of tree BMPs) and include information about urban forestry programs and green infrastructure tree practices.  The case studies will include life cycle cost information.

**CASE STUDIES**

**Maplewood Mall, Maplewood Minnesota**

As a part of the response to the Kohlman Lake TMDL (Total Maximum Daily Load) report, which calls for the reduction of phosphorus from both its watershed and the sediment in the lake bottom, the Maplewood Mall recently underwent a comprehensive redesign of its 35 acre parking lot. The four-phase construction process of this redesign took place between 2009 and 2012. This parking lot was designed by Barr Engineering Company on behalf of the Ramsey-Washington Metro Watershed District (who sponsored the project) and Simon Property Group (who owns Maplewood mall). This redesign was completed with the intent of capturing one inch of runoff from 90% of the parking lot area, while reducing at least 90% of the sediment load and 60% of the phosphorous load leaving the site.

To help meet the proposed stormwater goals, this project included 375 trees across the project site. Two hundred trees were placed in tree trenches and 175 trees were placed in rainwater gardens. This case study will focus on the planting methods for the trees planted within the tree trenches. Each tree placed in a tree trench was planted using a Stockholm Tree Trench Method for Stormwater.

The Stockholm Tree Trench Method uses angular granite rock to bear the load of the pavement profile and vehicular traffic above. The void space between the angular granite was filled with soil, which is washed into the angular granite and the soil does not need to be compacted to support loads. This non-compacted soil and remaining void space between the angular granite are then available for use by trees as both a growing medium and space for gaseous exchange to and from the roots.

Approximately 820 cubic feet of soil/angular granite and clear angular granite was provided per tree on average. The average installed cost per tree using this method was $18,000. This cost includes soil treatment and all other aspects of the tree trench installation such as storm sewers, asphalt pavement profile, concrete curb, tree grates, cages, etc. The trees received supplemental watering via 15 gallon capacity gator bags for the first two years of growth. Following the two-year establishment period, the trees will only receive water from above and below during rainfall events. At the time of the writing of this case study, October 2013, the planted trees are in good to excellent condition. When initially planted, the tree canopy covered less than 1% of the site, at 20 years growth, the trees are projected to cover 17% of the site with canopy.

The designer stated that in future work using similar planting techniques they would modify their maintenance protocol to include biannual fertilization at the tree root ball for the first two years of growth (per the advice from the street tree specialists in Stockholm, Sweden) and use larger capacity gator bags to better facilitate watering during the first two years of growth.

The stormwater goals of this project were as follows:

* Determine the effectiveness of the tree trench systems in reducing pollutant loading and volume
* Determine the effectiveness of the overall project in reducing pollutant loading and volume
* Monitor the use of the cistern during the first full season of its operation in order to determine water use and the frequency of cleaning required in the future.

In 2011 and 2012, Barr Engineering Company worked with the Ramsey-Washington Metro Watershed District to develop a monitoring plan and to create an XPSWMM model to determine the reduction in runoff volume as a result of this project.

The following monitoring was planned for 2013:

* Monitor rain gage levels
* Monitor the east and south locations for water quality and quantity from post-project conditions
* Record water levels in the entrance cistern while it is online.
* Monitor tree grove level loggers
* Model (using rain gage data) to determine the reduction in runoff volume due to project
* Analyze water quality data and tree grove level logging data, and
* Develop a monitoring report to assess the effectiveness of the project.

At the time of writing of this case study, the analysis of the data was still being completed and the monitoring report had not been released.

INSERT IMAGES 12.1-12.5

Figure 12.1: Maplewood Mall, Maplewood, MN, Image Courtesy of Barr Engineering Company

Description: This photo shows the excavated tree trench with the aggregate base and pipe system

Figure 12.2: Maplewood Mall, Maplewood, MN, Image Courtesy of Barr Engineering Company

Description: This photo shows the soil being washed into the angular granite rock

Figure 12.3: Maplewood Mall, Maplewood, MN, Image Courtesy of Barr Engineering Company

Description: This photo shows the completed project with installed trees

Figure 12.4: Maplewood Mall, Maplewood, MN, Image Courtesy of Barr Engineering Company

Description: This photo shows the detail of the tree protection and integrated educational signage

Figure 12.5: Maplewood Mall, Maplewood, MN, Image Courtesy of Barr Engineering Company

Description: This photo shows the completed project in use

**Project Summary:**

* **Owners:** Ramsey-Washington Metro Watershed District (who sponsored the project) and Simon Property Group (who owns Maplewood mall)
* **Designers:** Barr Engineering Company
* **Year of completion:** 2012
* **Tree Planting Method:** Stockholm Soil Trench Method
* **Tree Species Used in Planting Method:** Discovery Elm (*Ulmus davidiana 'Discovery'*), Skyline Honey Locust (*Gleditsia tricanthos var. inermis 'Skyline'*), Espresso Kentucky Coffeetree (*Gymnocladus dioicus 'Espresso'*), Common Hackberry (*Celtis occidentalis*), and Swamp White Oak (*Quercus bicolor*)
* **Number of trees in Planting Method**: 200
* **Approximate Installed Cost Per Tree:** $18,000
* **Stormwater Goals:** capturing one inch of runoff from 90% of the parking lot area, while reducing at least 90% of the sediment load and 60% of the phosphorous load leaving the site.
* **Is the Site Accessible:** Yes

**For more information, see:**

* Ramsey-Washington Metro Watershed District

<http://www.rwmwd.org/index.asp?Type=B_BASIC&SEC=%7BDB475310-069F-4230-9E97-01E92FD50527%7D>

* Retrofitting a Major Retail Mall for Stormwater Volume Reduction

<http://www.rwmwd.org/vertical/sites/%7BAB493DE7-F6CB-4A58-AFE0-56D80D38CD24%7D/uploads/Maplewood_Mall_Land_and_Water_Sept-Oct2012.pdf>

* Maplewood Mall Tree Trenches – Design and Impact on Stormwater, Erin Anderson Wenz, P.E., Barr Engineering Company

<http://www.rwmwd.org/vertical/sites/%7BAB493DE7-F6CB-4A58-AFE0-56D80D38CD24%7D/uploads/Tree_trench_summary_April_24_2012.pdf>

Maplewood Mall Rainwater Runoff Retrofit Project <http://www.rwmwd.org/vertical/sites/%7BAB493DE7-F6CB-4A58-AFE0-56D80D38CD24%7D/uploads/MaplewoodMall_ProjectFlyer.pdf>

**Central Corridor Green Line Integrated Tree Trench System, St. Paul and Minneapolis, Minnesota**

The Central Corridor LRT line is located within a highly-urbanized and heavily-paved corridor connecting downtown St. Paul and downtown Minneapolis. This corridor is made up of 111 acres of impervious surface. The stormwater runoff from the impervious surfaces ultimately drains to the Mississippi River via the municipal storm drain system and enters the Mississippi at fast speeds, carrying both sediment and pollutant loads. Portions of the river are impaired for turbidity, nutrients, and bacteria.

As this project is located within the jurisdiction of the Capitol Region Watershed District (CRWD), it was required to comply with the CRWDs rules for stormwater management. These rules require that the site capture and retain the first inch of rainfall on site, reducing the volume of stormwater.

Four different green infrastructure practices were used in conjunction to help meet the requirements outlined by CRWD, but this case study focus on the integrated tree trench systems. These systems stretch out along both sides of the corridor for over five miles of the LRT corridor. The tree trench systems are approximately 10 feet wide, with a 3 foot deep profile of CU structural soil and 1.5 feet of clear aggregate below that. These trenches provide approximately 792,000 cubic feet of CU structural soil in total for the project (approximately 634 cubic feet of CU structural soil per tree).

These tree trench systems are layered systems of trees, porous pavers, CU Structural Soil, drainage rock, and a 12" perforated PVC pipe that directs runoff from the street into the clear rock in the integrated tree trench systems. Where possible and appropriate, these systems are paired with existing soils with high infiltration rates. In addition to the structural components mentioned above, approximately 1,250 new trees have been planted within the integrated tree trenches. The total bid for the integrated tree trench system was $3.29 million (approximately $2,632 per tree). Please note that this bid was lump-sum and is likely low in regard to final costs. The engineer's estimate for the system was approximately $6.0 million (approximately $4,800 per tree).

The goals of the green infrastructure, including the integrated tree trench systems:

* Treating stormwater runoff to remove sediments and other pollutants
* Reducing the quantity and rate of stormwater runoff entering the Mississippi River
* Infiltrating a significant portions of the street and sidewalk runoff
* Increasing the amount of pervious surface in the right of way
* Providing non-irrigated water source to the proposed trees.
* Enhancing livability/beauty of the corridor with streetscape enhancements and plantings.

It is estimated that the green infrastructure practices will:

* Reduce runoff volume by 3 acre feet per storm event (which includes total storage volume within the tree trench systems, pavers, and CU Soils plus an estimated 0.15 inch reduction per square foot of canopy for a 20-year-old tree for each species)

Monitoring is taking place along the integrated tree trench systems, which includes the following:

* Water level and drawdown information with pressure transducer
* Temperature sensors at 1 and 2.5 feet below the pavers
* Watermark moisture sensors at .5. 1.5. 2.0. and 3.0 foot depth (electrical resistance granular matrix sensor)
* Watermark Monitor Data Logger

INSERT IMAGES 12.6-12.13

Figure 12.6, CC LRT, Minneapolis/St. Paul Minnesota, Image Courtesy of Capitol Region Watershed District

Description: This image shows a detail of the Integrated Tree Trench System

Figure 12.7, CC LRT, Minneapolis/St. Paul Minnesota, Image Courtesy of Capitol Region Watershed District

Description: This section shows how water flows into and out of the Integrated Tree Trench System

Figure 12.8, CC LRT, Minneapolis/St. Paul Minnesota, Image Courtesy of Capitol Region Watershed District

Description: This section shows how water flows into and out of the Integrated Tree Trench System

Figure 12.9, CC LRT, Minneapolis/St. Paul Minnesota, Image Courtesy of Capitol Region Watershed District

Description: This photo shows a close-up of CU Structural Soil

Figure 12.10, CC LRT, Minneapolis/St. Paul Minnesota, Image Courtesy of Capitol Region Watershed District

Description: This photo shows the CU Structural Soil being placed

Figure 12.11, CC LRT, Minneapolis/St. Paul Minnesota, Image Courtesy of Dwayne Stenlund

Description: This photo shows how stockpile covers were used over the CU Structural Soil for temporary sediment and erosion control

Figure 12.12, CC LRT, Minneapolis/St. Paul Minnesota, Image Courtesy of Capitol Region Watershed District

Description: This photo shows the finished porous pavement surface treatment

Figure 12.13, CC LRT, Minneapolis/St. Paul Minnesota, Image Courtesy of Capitol Region Watershed District

Description: This photo shows how trees were planted in the CU Structural Soil

Figure 12.14, CC LRT, Minneapolis/St. Paul Minnesota, Image Courtesy of Capitol Region Watershed District

Description: This photo shows an example of the completed installation

**Project Summary:**

* **Owners:** The Metropolitan Council
* **Designers:** AECOM, Kimley-Horn, HZ United
* **Year of completion:** 2013
* **Tree Planting Method:** Integrated tree trench system using CU structural soil and drainage rock.
* **Sample of Tree Species Used in Planting Method**: Armstrong Red Maple (*Acer Rubrum 'Armstrong'*), Autumn Spire Red Maple (*Acer Ruburm 'Autumn Spire'*), Sienna Glen Maple (*Acer fremanii 'Sienna'*), Sensation Maple (*Acer negundo 'Sensation'*), Skyline Honeylocust (*Gleditsia tricanthos var. inermis 'Skyline'*), Princeton Sentry Ginkgo (*Ginkgo biloba 'Princeton Sentry'*), Kentucky Coffee Tree (*Gymnocladus dioicus*), Spring Snow Crabapple (*Malus x 'Spring Snow'*), Swamp White Oak (*Quercus bicolor*), Ivory Silk Lilac (*Syringa reticulate 'Ivory Silk'*), Boulevard Linden (*Tilia americana 'Boulevard'*), Redmond Linden (Tilia americana'Redmond'), Cathedral Elm (*Ulmus 'Cathedral'*), Discovery Elm (*Ulmus davidiana 'Discovery'*), Valley Forge Elm (*Ulmus Americana 'Valley Forge'*), Princeton Elm (*Ulmus Americana 'Princeton'*), Accolade Elm (*Ulmus x 'Morton (Accolade)'*), Regal Prince Oak (*Quercus x robar 'Long'*).
* **Number of trees in Planting Method**: 1,250
* **Approximate Installed Cost Per Tree:** $2,632-$4,800, estimated
* **Stormwater Goals:** Retain the 1-inch rainfall on site
* **Is the Site Accessible:** Yes

**For more information, see:**

* Capitol Region Watershed District

http://www.capitolregionwd.org/

http://www.capitolregionwd.org/wp-content/uploads/2012/09/GreenLineBrochure2013-v9.pdf

http://www.capitolregionwd.org/our-work/watershed-planning/cclrt\_wq/

* The Metropolitan Council

http://www.metrocouncil.org/Transportation/Projects/Current-Projects/Central-Corridor.aspx

**Tryon Street Mall Trees, Charlotte, NC**

**Project Description**

Planted in 1985, the Tryon Street Mall Trees are some of the oldest trees planted using suspended pavement. The pavement around the trees is held slightly above the soil by 3 foot tall underground pillars so that the soil under the pavement is not compacted beyond root-limiting densities by the pavement loads. In 2013, the willow oaks planted had an average diameter at breast height of 18 inches and an average height of 71 feet (Smiley, 2013). In addition to growing big trees, the system modeled a 10% reduction in peak flows (peak storm event) to the City’s stormwater system (EPA, no publication year given). As of 2013, almost 30 years after planting, the trees are flourishing (see Figures 12.15 and 12.16).

INSERT IMAGES 12.15-12.16

Figure 12.15: Tryon Street Mall Trees in 2011, 26 years old (Image Courtesy of The Kestrel Design Group, Inc.)

Figure 12.16: Tryon Street Mall Trees in 2013, 28 years old (Image Courtesy of Thomas Smiley, Bartlett Tree Research Lab)

**Project Summary:**

* **Designers:** Don McSween and Tom Perry
* **Year of completion:** 1985
* **Tree Planting Method:** Suspended pavement
* **Tree Species Used in Planting Method:** Willow Oak (Quercus phellos)
* **Number of trees in Planting Method**: 154
* **Cubic feet of soil per tree:** 700 c.f. per tree, shared
* **Is the Site Publicly Accessible:** Yes

**MARQ2, Minneapolis, Minnesota**

The MARQ2 project (Marquette Ave and 2nd Ave Busways) originated in response to the Minneapolis Ten Year Transportation Plan, to improve transit service by redefining lanes, lane widths, and sidewalk zones and widths. Stakeholders requested that healthy trees be part of the project.

To maximize the trees’ health, lifespan, as well as maximize stormwater and other ecological services, the designers maximized rootable soil volume for each tree using Silva Cells, a proprietary soil cell system that supports suspended pavement.

It is estimated that the average urban tree only survives about 13 years (Skierra and Moll 1992), not nearly long enough to be able to provide the ecological and stormwater treatment services that they are able to provide at maturity. A primary reason for the shortened lifespan of urban trees is inadequate soil volume. Soil cells are modular structures that provide uncompacted soil volumes under paved surfaces and can support up to HS20 loading (US Standard Bridge Loading), making it possible to provide urban trees with large soil volumes even in urban areas with little open space. The uncompacted soil volume in soil cells can also be used for stormwater treatment, creating a bioretention system under paved surfaces. Using structural cells with bioretention soil, stormwater becomes an asset as a way to water the trees. The trees in turn will help cleanse and abstract storm water runoff.

The trees and soil cells in this project collect runoff from the sidewalks along 2 of Minneapolis’ main downtown streets (Marquette and 2nd Avenues) through pervious pavers that drain into the underlying structural cells. One of the soil cell groups also collects roof runoff from adjacent building scuppers.

While the amount of runoff treated per tree varies from block to block and from tree to tree, on average, each tree pit collects runoff from about a 300 square foot watershed. With 167 trees, this adds up to an estimated 50,118 s.f., or 1.15 acres of sidewalk runoff captured. The loam soil in the structural cells therefore has enough capacity to capture runoff from a 1” rain event from 5 times as much impervious surface as it currently captures. In other words, the soil in the structural cells has capacity to capture 1” of rain from 5.75 acres of impervious surface.

The City of Minneapolis is reserving this extra soil stormwater holding and infiltration capacity for future routing of street runoff to the cells.

As trees grow larger, they will also contribute more and more to stormwater capture through interception and evapotranspiration.

INSERT IMAGES 12.17-12.21

Figure 12.17: MARQ2 Sidewalk Plan at Opening For Tree Within Tree Trench, Plans by URS/SHE

Figure 12.18: Soil Cell Installation at MARQ2 project, City of Minneapolis Staff note that “The ease of placing new utility pipes, or working on existing pipes, is one of the major advantages of the Silva cell system over a structural soil system.” Image Courtesy of The Kestrel Design Group

Figure 12.19: Soil Installation at MARQ2 project, Image Courtesy of The Kestrel Design Group

Figure 12.20: Installation of soil cell decks at MARQ2 project, Image Courtesy of The Kestrel Design Group

Figure 12.21: Installation of trees at MARQ2 project, Image Courtesy of The Kestrel Design Group

**Project Summary:**

* **Owners:** City of Minneapolis
* **Designers:** Short Elliott Hendrickson Inc. and URS Corporation
* **Year of completion:** 2009
* **Tree Planting Method:** Suspended pavement with Silva Cells
* **Tree Species Used in Planting Method:** Autumn Blaze Maple (Acer x freemanii 'Jeffersred'), Crimson Spire Oak (Quercus alba x Q. robur 'Crimschmidt'), Emerald Lustre Maple (A. platanoides '*Emerald Lustre*'), Skyline Honeylocust (Gleditsia triacanthos 'Skycole'), Hophornbeam (Ostrya virginiana), Japanese Tree Lilac (Syringa reticulata), Greenspire Linden (Tilia americana 'Greenspire'), Swamp White Oak (Quercus bicolor)
* **Number of trees in Planting Method**: 167
* **Approximate Installed Cost Per Tree**: $8,038
* **Cubic feet of soil per tree:** average of 588 c.f. per tree
* **Stormwater Goals:** maximize stormwater benefits
* **Is the Site Publicly Accessible:** Yes, however only the pervious pavers are visible at the surface.  The Silva cells are not visible.

**Garrison Concourse Overlook Site Restoration and ADA Improvements, City of Garrison, Minnesota**

**Project Summary:**

This MnDOT overlook directs runoff from the access road to a center island/historic interpretive area through ADA curb cuts that also double up as stormwater curb cuts. Turf in the interpretive area is planted into an 80% sand/20% compost bioretention soil mix. Trees are planted into this area in MnDOT select topsoil borrow that extends to a 5 ft radius from each tree trunk. A 6” deep fine filter aggregate layer that spans under the bioretention soil and topsoil borrow provides for drainage to the underdrain, which is wrapped in coarse filter aggregate.

Project plans are attached, including a SWPPP plan, estimated quantities, and tree protection, and tree planting details.

**Project Summary:**

* **Designers:** MacDonald &Mack Architects
* **Year of completion:** In Progress
* **Tree Planting Method:** Trees are planted in turf open space. Each tree is planted in a 10’ diameter circle of MnDOT topsoil borrow, within bioretention areas of turf planted in an 80% sand/20% compost soil mix.
* **Tree Species Used in Planting Method:** Princeton Elm, Ulmus Americana ‘Princeton’
* **Number of trees in Planting Method**: 8
* **Is the Site Publicly Accessible:** Yes

**REFERENCES**

EPA. No publication year given. Stormwater to Street Trees: Engineering Urban Forests for Stormwater Management. EPA 841 B 13 001. Available October 2013 from <http://water.epa.gov/polwaste/green/upload/stormwater2streettrees.pdf>

Skiera, B.; Moll, G. (1992). The Sad State of City Trees. Am. Forests. March/April, 61-64.

Smiley, Thomas. 2013. Personal Communication. Bartlett Tree Research Lab.