The State of the Science & Practice using Urban Trees as a Stormwater Control Measure

PRESENTED BY:
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October 14, 2015
SENY Stormwater Conference

8.1”/Type 2

INTRODUCTION

VOLUMIZE & COOL HAND LUKE

So You Want an Urban Forest that Cleans Water?

DO This……

- Codify Minimum LOAM Soil VOLUMES FIRST >1000cf
- DIVERSIFY Species
- No Single Tree Genus >5%
- Set Minimum CANOPY TARGET >25% West of the Mississippi River with Deadline
- FIND & FILL GAPS with Trees
- Plant Lots of SMALL TREES with LARGE SOIL Volumes
- Monitor & Apply Responsive O&M

Don't Do This…..

- Plant Trees in Small PITS
- Plant Trees in COMPACTED SOIL or SAND or STRUCTURAL SOIL
- Plant Lots of A FEW Species
- Plant Trees Only After COMPLAINTS
- Plant Tree Root Packages LOW
- Plant Trees As BEFORE
- Announce a MILLION Tree Planting Program Applying Above Steps
- Respond to Merchants Complaining about Trees BLOCKING Their SIGNS by Removing Trees

5 KEYS to a SUCCESSFUL URBAN FOREST
Become Part of Stormwater System

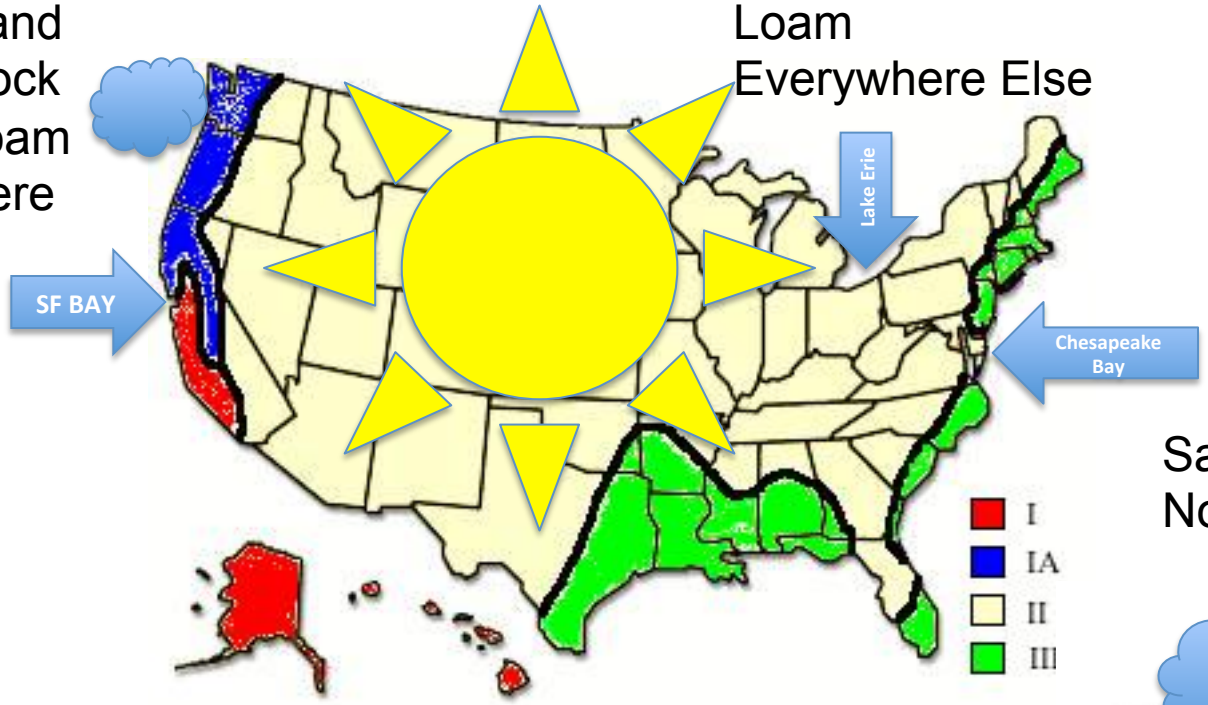
1. REQUIRE LARGE (2:1/>1,000 cf) SOIL VOLUMES
2. SPECIES DIVERSITY (UTC <5% GENUS)
3. DIRECT STORMWATER to TREES
4. SHOW STORMWATER VALUE of TREES
5. CALCULATE STORMWATER CREDITS for TREES

Trees Require Portion of Stormwater Budget

Does it Rain? or Storm? Loam? Sand? Rock?

Sand
Rock
Loam
Here

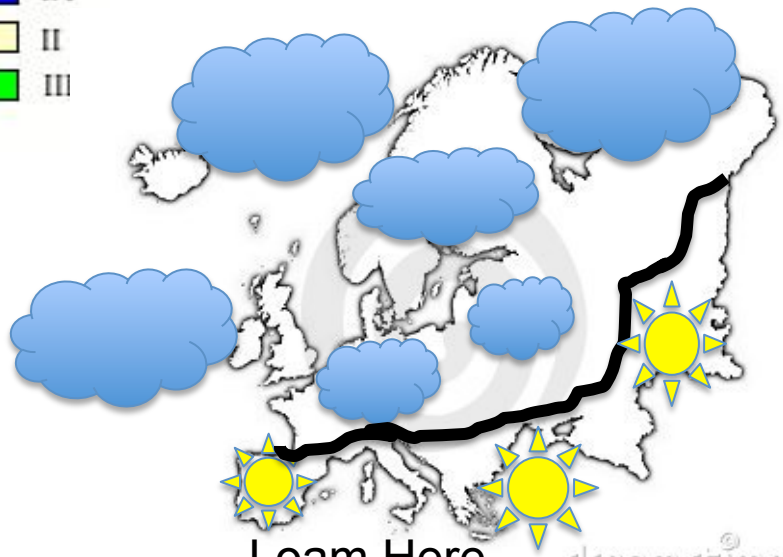
Loam
Everywhere Else



USA Mainly Storms
Type II

Europe
Mainly Rain
Type 1A

Sand, Rock, Loam
North of the Alps & Pyrenees



Loam Here

What's So Great About Big Trees?

Stormwater Interception by Hackberries versus Age of Tree

150 Gal.
Year 5

5000 Gal.
Year 40

Images from http://www.tankwatersolutions.com.au/rainwater_tanks.php


550—TREE BEGAN GROWING
570—MOHAMMED BORN
640—ALEXANDRIAN LIBRARY BURNED
732—SARACENS DEFEATED AT TOURS
800—CHARLEMAGNE CROWNED
896—ALFRED THE GREAT FRAMES LAWS
1000—LEIF ERICSON LANDS ON AMERICAN COAST
1066—BATTLE OF HASTINGS
1147—THE SECOND CRUSADE
1215—MAGNA CARTA SIGNED
1302—MARINER'S COMPASS IN EUROPE
1429—JOAN OF ARC
1492—AMERICA DISCOVERED
1588—SPANISH ARMADA DESTROYED
1620—LANDING OF PILGRIMS
1750—FRANKLIN'S DISCOVERIES IN ELECTRICITY
1776—DECLARATION OF INDEPENDENCE
1815—BATTLE OF WATERLOO
1861—CIVIL WAR
1891—TREE CUT DOWN

Soil Volume and Canopy Size?

Germany

Pride & Joy

A "Special Tree….."

Spilled Diesel?
Hours of Idling Machines?
Concrete & Sheetrock Soil Amendments?
String Trimmer Bark Treatments?
Deep Trunk Immersion?
Once Yearly Watering?
Salt Spray Foliar Feedings?
&
Ran out of Money?

Actual conditions: Average street tree has access to **between 0.9 m^3 (32 ft^3) to 1.8 m^3 (64 ft^3) of soil.**

MSP MN: Honeylocust (Gleditsia triacanthos)
Zone 4; Type II Storms; 31" Annual Precipitation

Let’s End Magical Thinking about Trees*

*Peter MacDonagh
The Kestrel Design Group

KEY #1: LARGE (>1,000 CF) ROOT SOIL VOLUME = 95% GOOD TREES

Walt Disney World Orlando FL

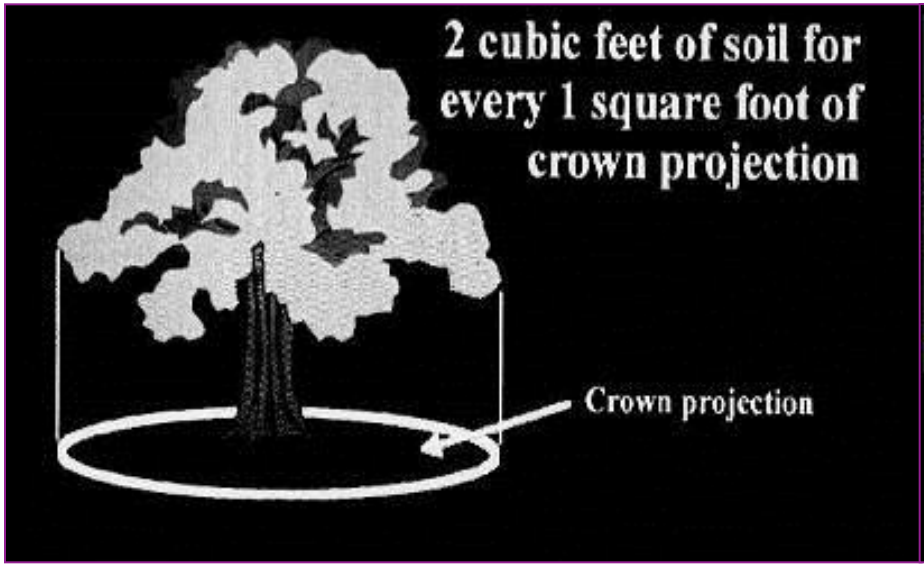
USDA Zone 9; Type III Storms; 51" Annual Precipitation

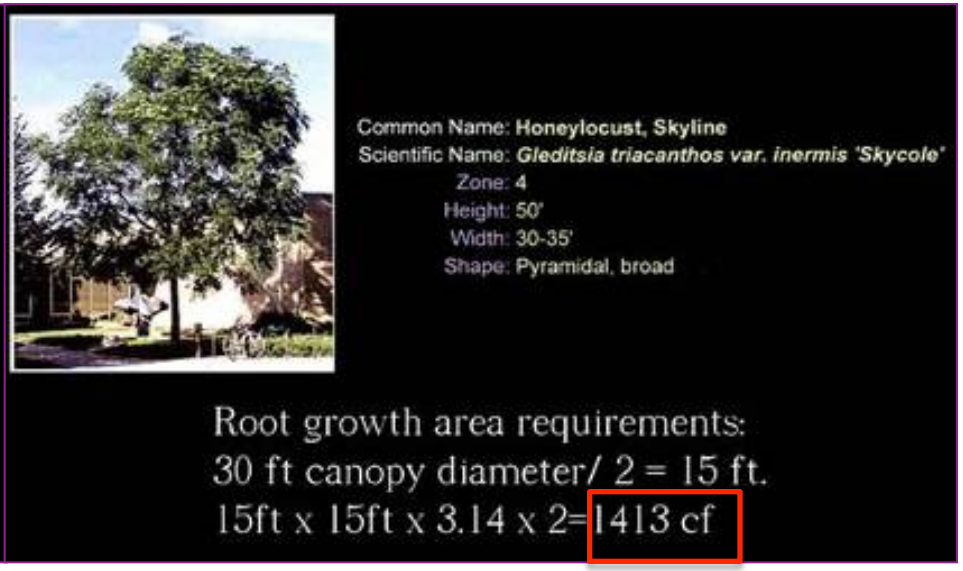
- **Evaluated 1,127 Parking Lot Trees: 1-30 Years Old; 21 Spp.**
  - **Define Tree Success: Good, Fair, Poor, Dead**
  - **Relationships: Soil Vol & Tree Condition**
  - **Test Applicability: Soil Vol Recommendations**
- **GOOD CONDITION**
  - **100% of Trees in 1,500 CF (Cubic Feet)**
  - **95% of Trees in 1,000 CF**
  - **84% of Trees in 500 CF**
  - **65% of trees in 100 CF**

What do Trees Need to Get Big? Will We Ever Know? YES We Know

Trees Need Large Volumes of Oxygenated Soil

"Ideal" Conditions

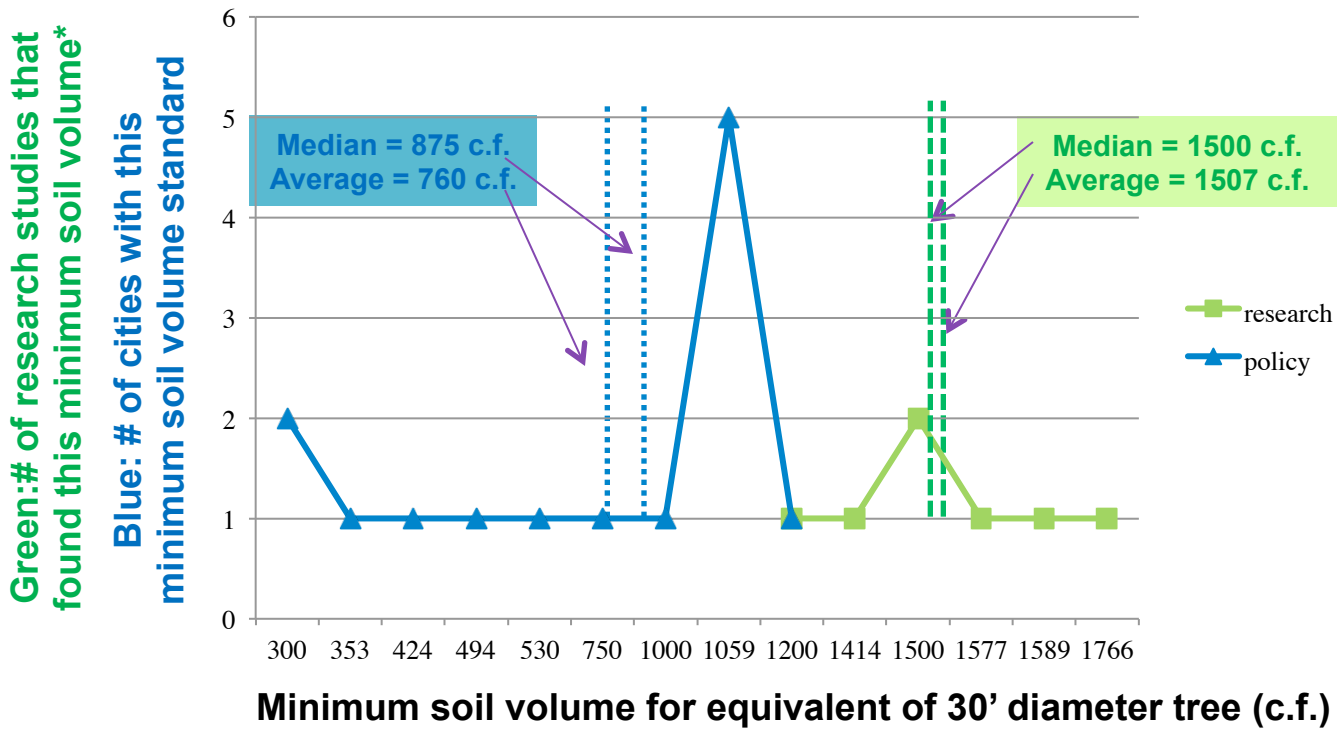




Grabosky, Trowbridge and Bassuk (2002)

1 in the AIR 2 in the GROUND
1,000 CF Per Tree

Minimum Soil Volume Standards Research vs. Adopted



METASTUDY: RESEARCH RESULTS - Minimum Rootable Tree Soil Volumes based on Field Studies or Water or Nutrient Requirements vs ADOPTED POLICY STANDARDS - Minimum Tree Rootable Soil Volume Standards in North American Municipalities

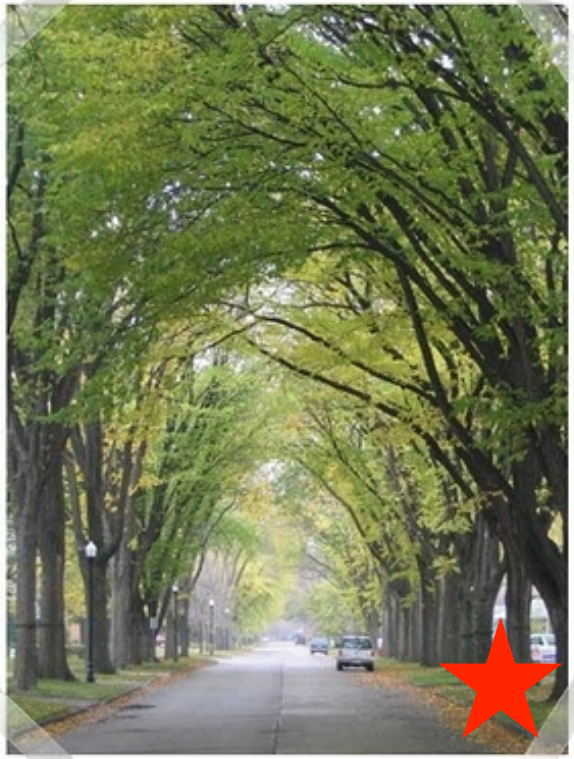
Studies included: Bakker. J.W., 1983; Lindsey, P. and N. Bassuk, 1991; Kopinga, J., 1991; Kent, D., S. et al 2006; Schoenfeld, P.H. 1975; Helliwell, D.R. 1986; Schoenfeld, P.H. and J. van den Burg, 1984

KEY #2: SPECIES DIVERSITY (<5% UTC per GENUS)

What We Had & Lost

SuperTrees that Can Grow Anywhere?
BUT Can't survive monocultures

American Chestnut:
Chestnut Blight



American
Elms: Dutch Elm Disease

American Ash:
Emerald Ash Borer

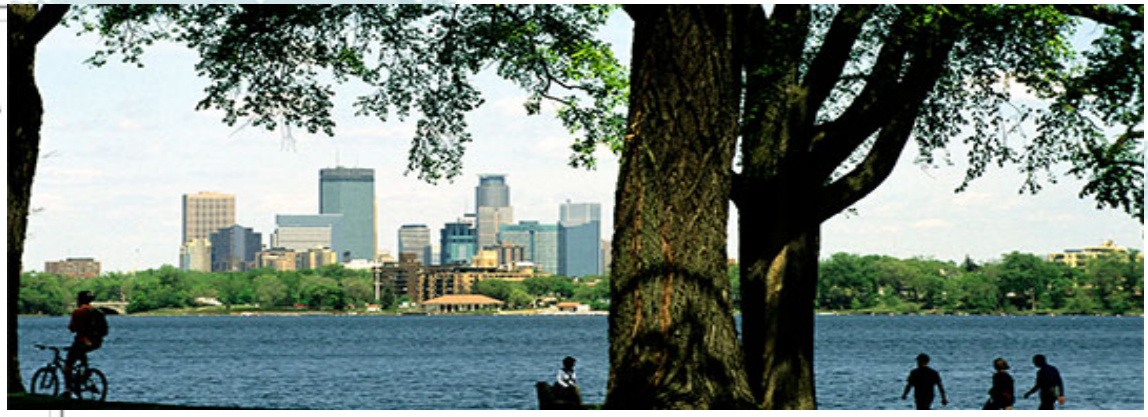
Image to the right from the Forest History Society, Inc. at http://www.appalachianwoods.com/appalachianwoods/history_of_the_american_chestnut.htm

In the Late 1800s, American Elm made up 90% of the boulevard trees in Minneapolis

- 1963: First Dutch Elm Disease Detected in Trees
- **1977: 31,000 Elm Trees Removed**
- **1978: 20,000 Elm Trees Removed**
- 2004: 10,000 Elm Trees Removed
- 2005-2015: 2,700 Elm Trees Removed Annually

the entire City, with an average DBH of >30 inches.

Since 1977, 63,700 Elm trees have been removed in the boulevards of Minneapolis



Minneapolis Chain of Lakes

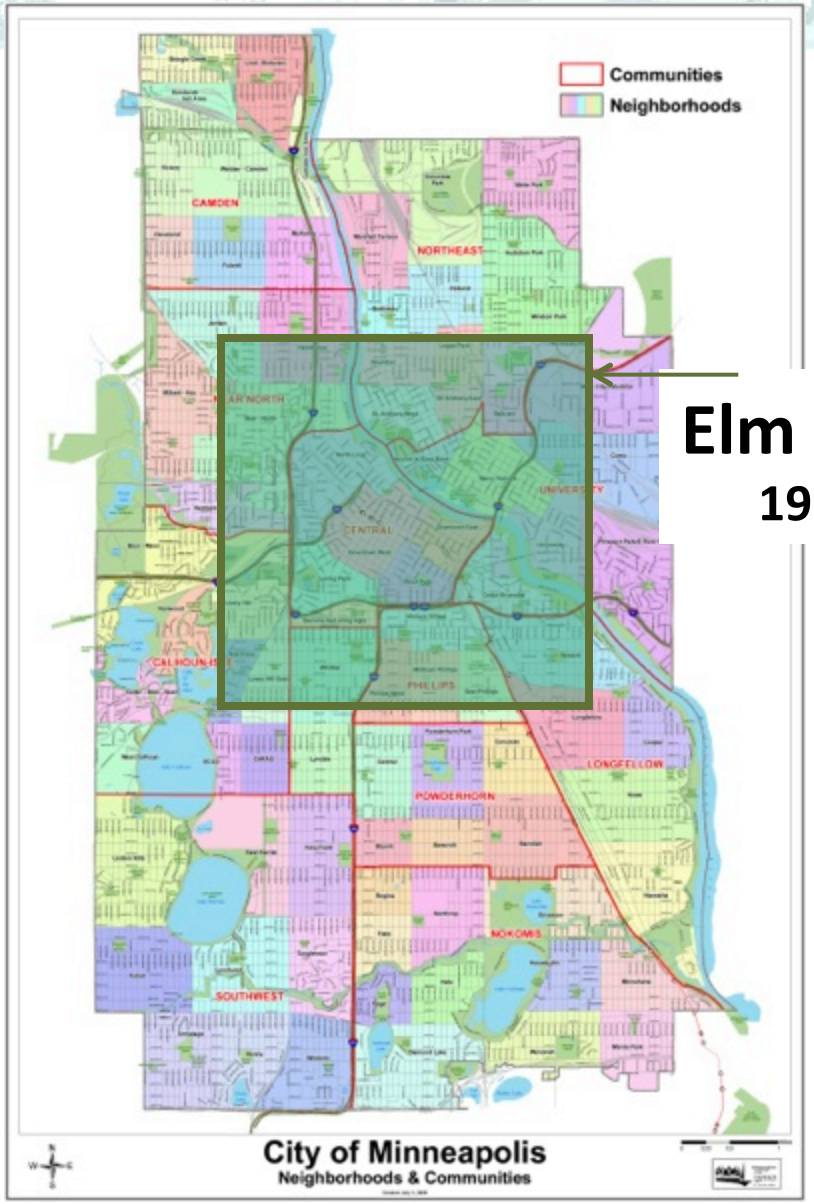
Correlative Study

MacDonagh 2014: Unpublished

53 Square Miles

Relationship of Tree Species Diversity and Water Quality

Dutch Elm Disease

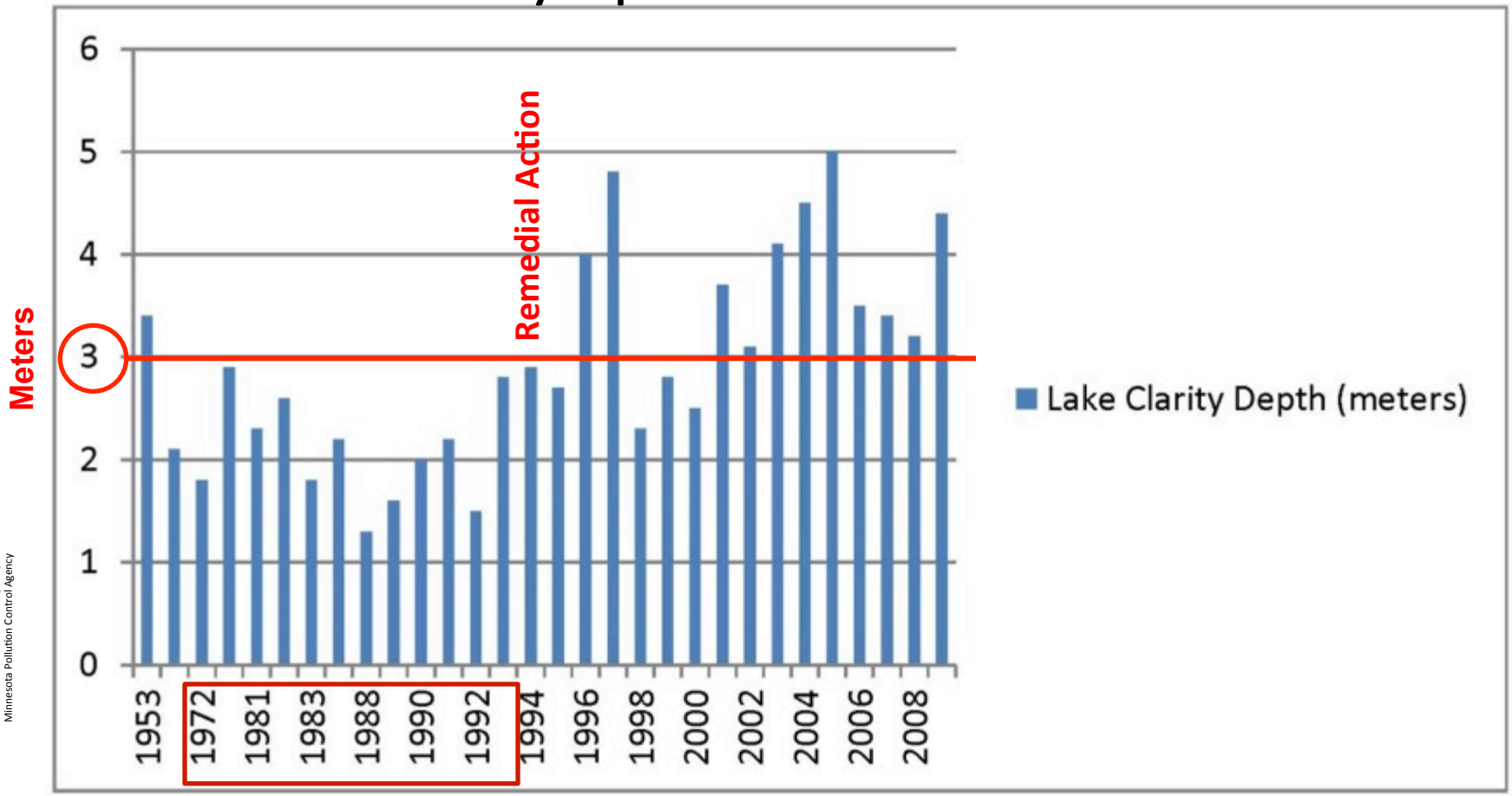


Elm Canopy Loss

19 Square Miles

Relationship of Tree Species Diversity and Water Quality

Lake Calhoun Lake Clarity Depth Over Time in METERS



Data Collected from the Citizen Lake Monitoring Program for Lake Calhoun, Minnesota Pollution Control Agency

There is a correlation to loss of tree canopy and water clarity

Following the removal of Elm trees (during the late 1970s and early 1990s), there was a marked decrease in water clarity depth in the Chain of Lakes, yet building development stopped in 1953 throughout the contributing sub-watershed around Lake Calhoun.

MINNEAPOLIS GREEN & BLUE INFRASTRUCTURE

1. Wildlife Skyscrapers (Cormorant Platforms) at Lake Harriet Micropool Mirror Minneapolis Skyscrapers

2. Minnehaha Creek Streambank Soil Bioengineering Stabilization approach to enhancing wildlife, recreation, and surface water infrastructure

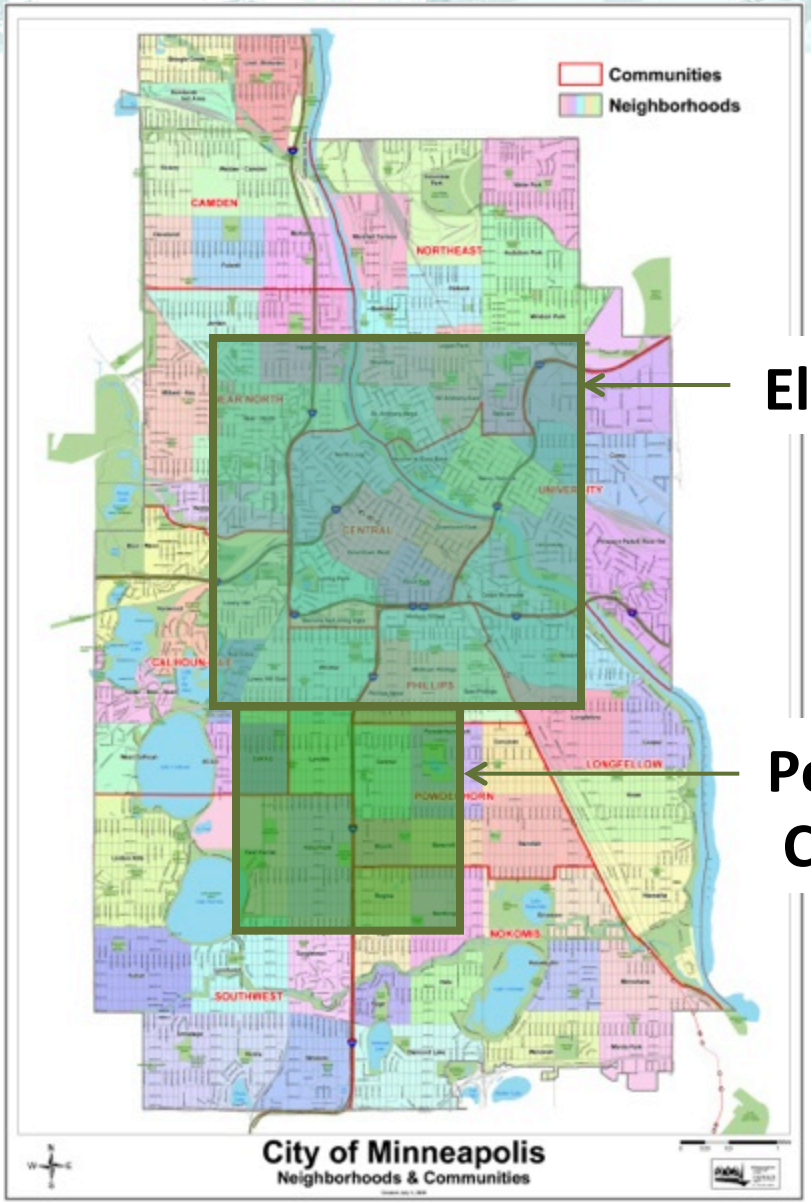
3. Marcy-Holmes Neighborhood Rain Gardens aregreen infrastructure that collect stormwater runoff from adjacent roofs and parking lot

4. Green roof at the Phillips Eco-Enterprise Center: creating stormwater & wildlife infrastructure

5. Lake Nokomis Stormwater Wetlands: Pre-settlement landscape informing stormwater and wildlife infrastructure design

Relationship of Tree Species Diversity and Water Quality

Dutch Elm Disease & Emerald Ash Borer

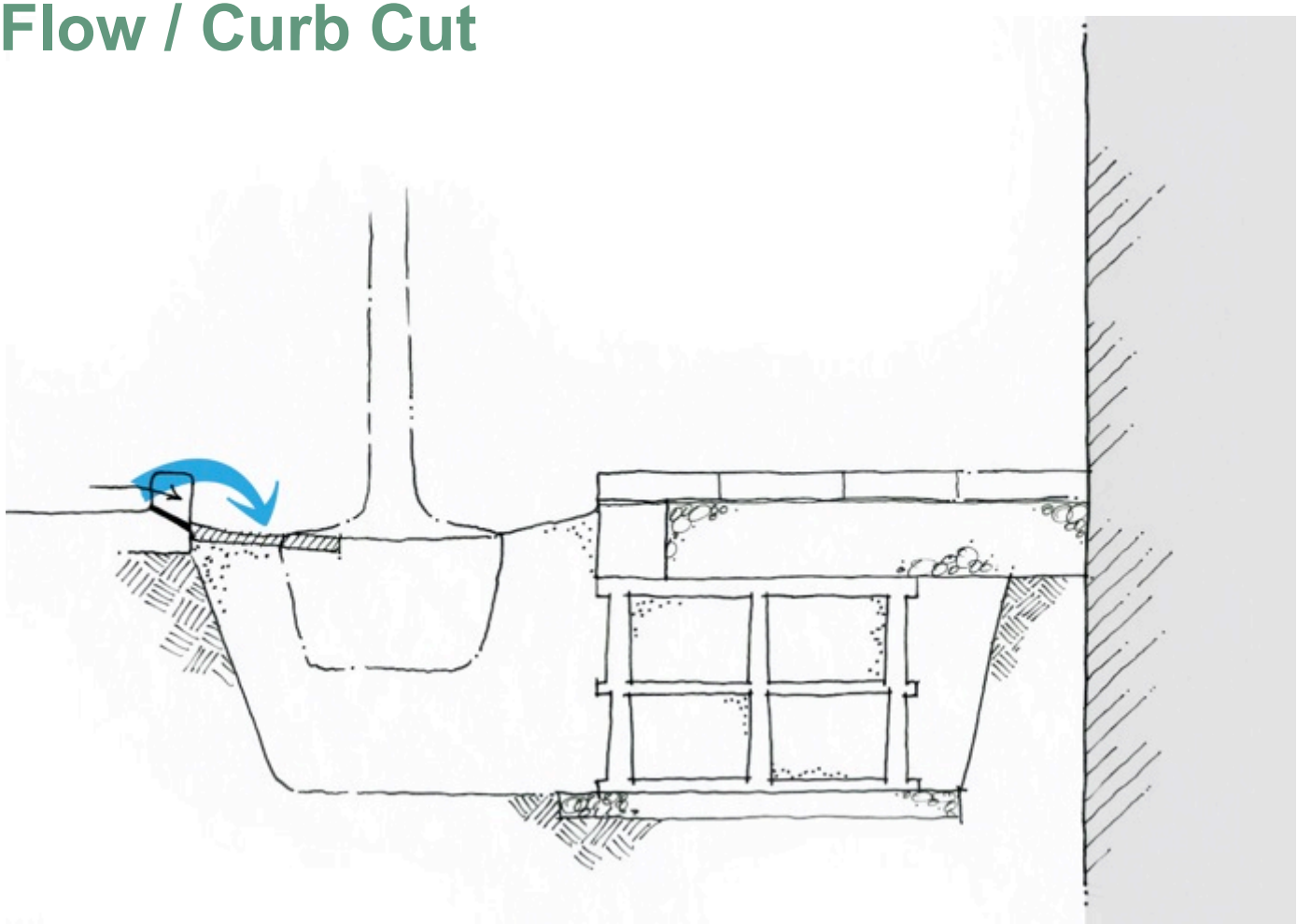


Elm Canopy Loss

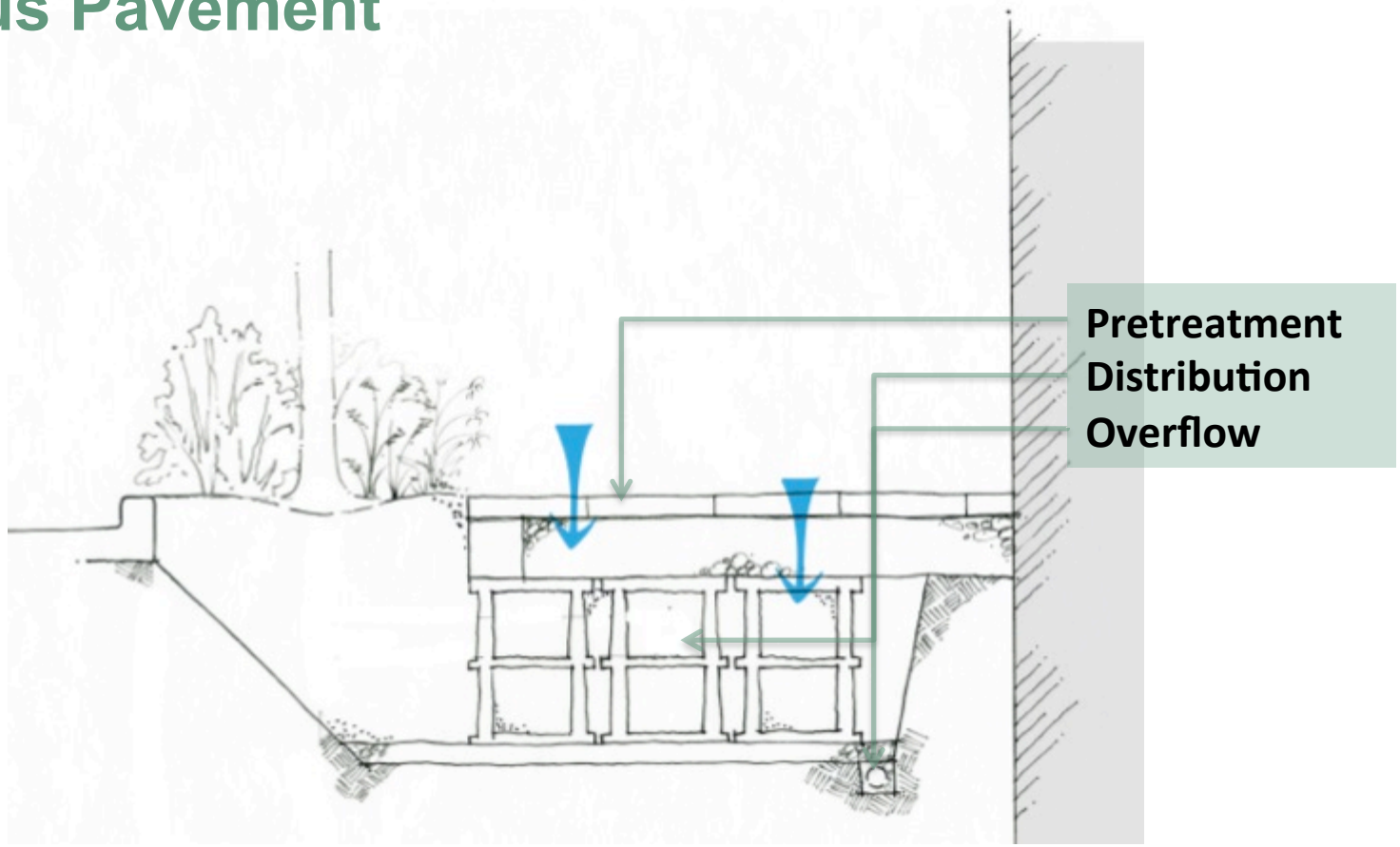
Potential Ash Canopy Loss

KEY #3: DIRECT STORMWATER TOWARDS TREES

Sheet Flow / Curb Cut

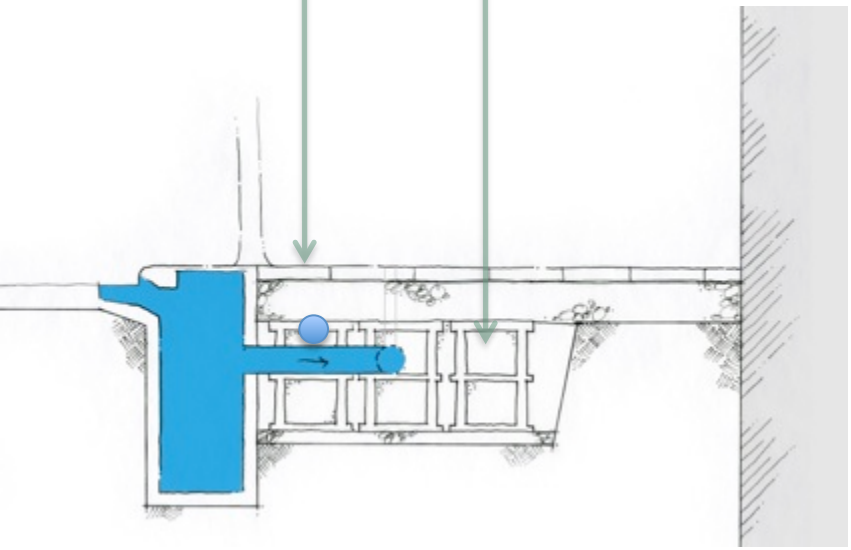


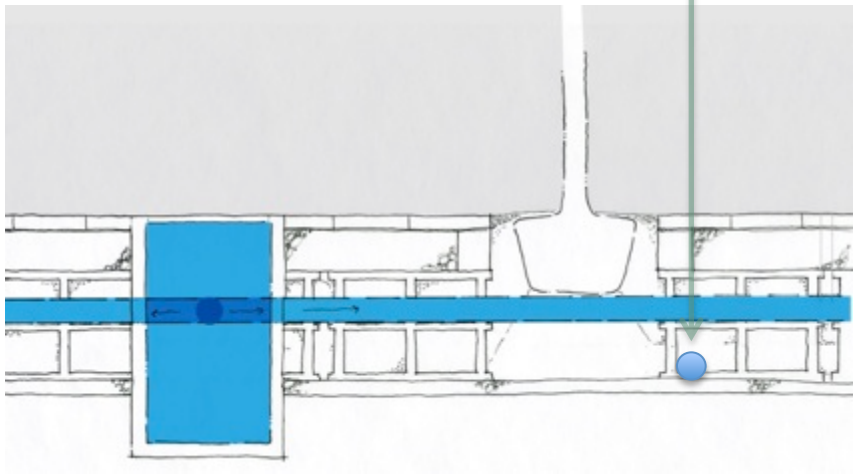
Porous Pavement



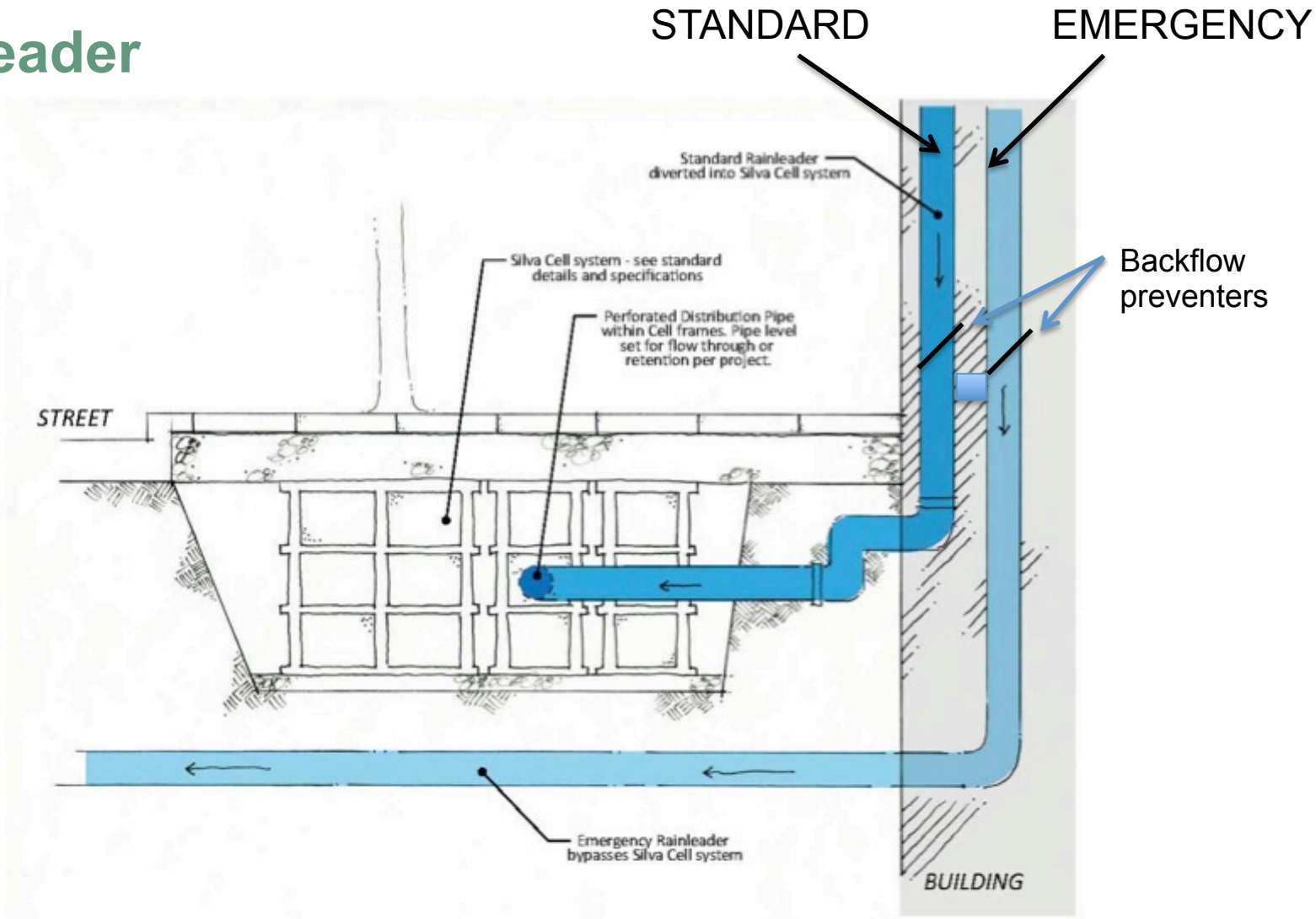
Catch Basin

Pretreatment
Distribution
Overflow





Rain Leader

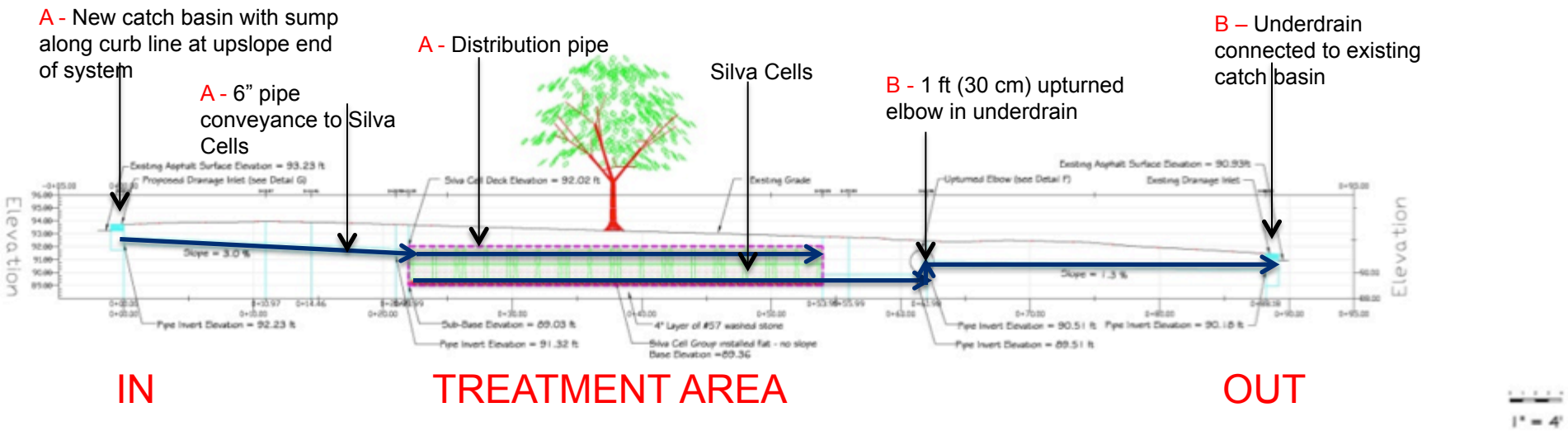

STANDARD
EMERGENCY
Standard Rainleader diverted into Silva Cell system
Silva Cell system - see standard details and specifications
Perforated Distribution Pipe within Cell frames. Pipe level set for flow through or retention per project.
Backflow preventers
STREET
Emergency Rainleader bypasses Silva Cell system
BUILDING

KEY #4: SHOW STORMWATER VALUE of TREES

Directly Connected Impervious Drainage Area (DCIA)

NCSU Research

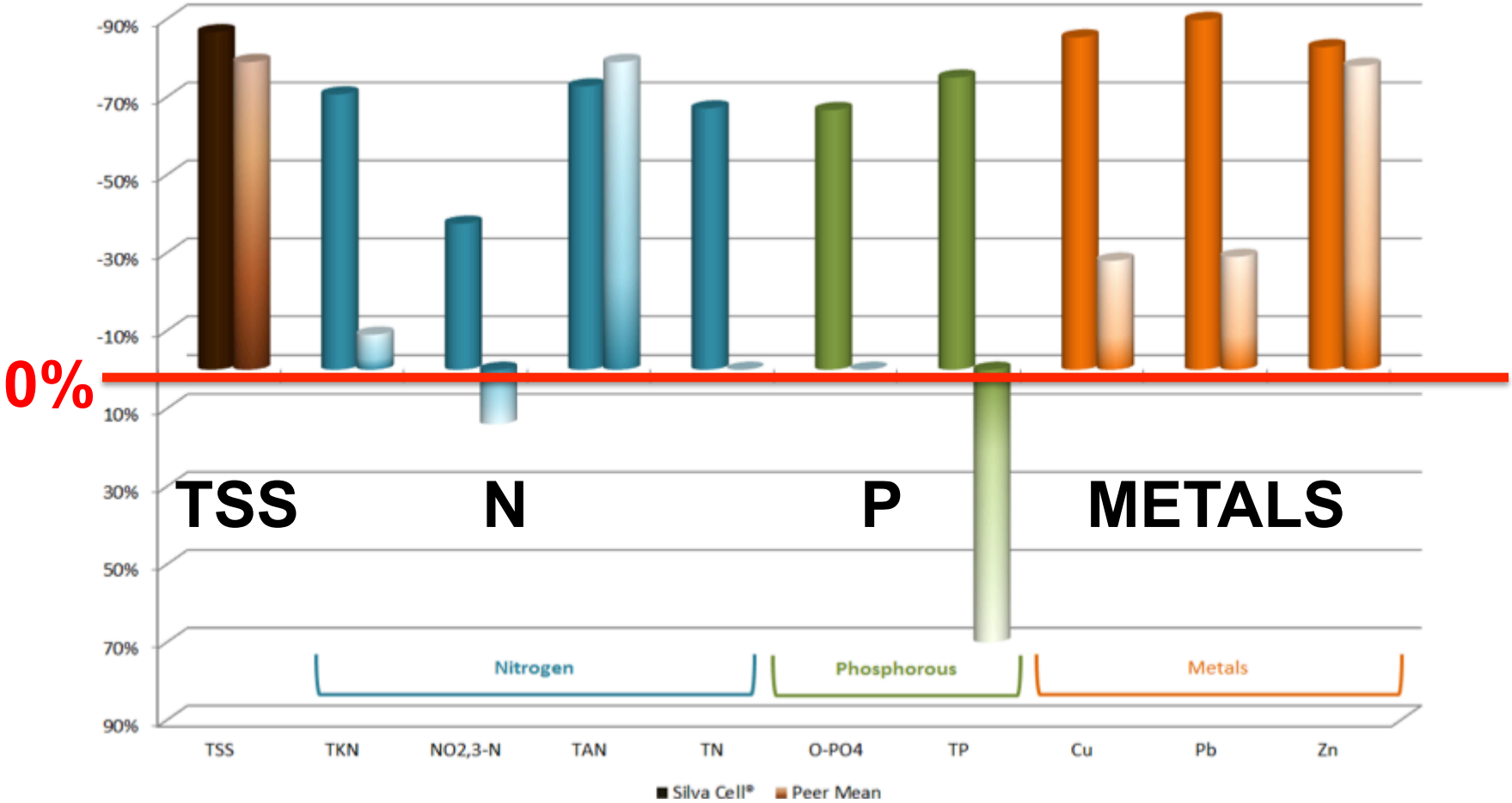
- Pond liner
- Runoff from street directed via a catch basin & sump into distribution pipe into the Silva Cells (see A)
- Underdrains with upturned elbows slow water, denitrify, then direct runoff into the Wilmington's MS4 (see B)
- Profile by Jonathan Page, NCSU Biological and Agricultural Engineering



NCSU Research

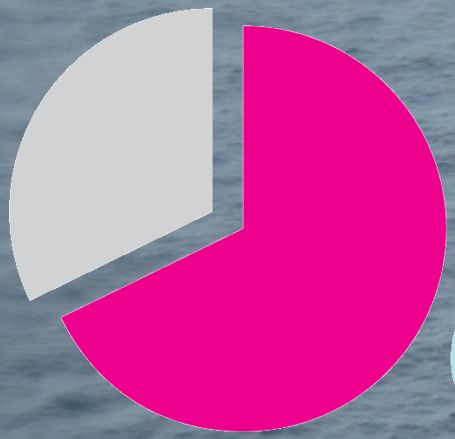
Water Quality Results

Silva Cells at Wilmington DARKER vs.
Mean Traditional Bioretention Results From Peer Reviewed Literature LIGHTER



NCSU Research

Percent of Runoff Treated



68% of the runoff was treated by the Ann St Silva Cell system

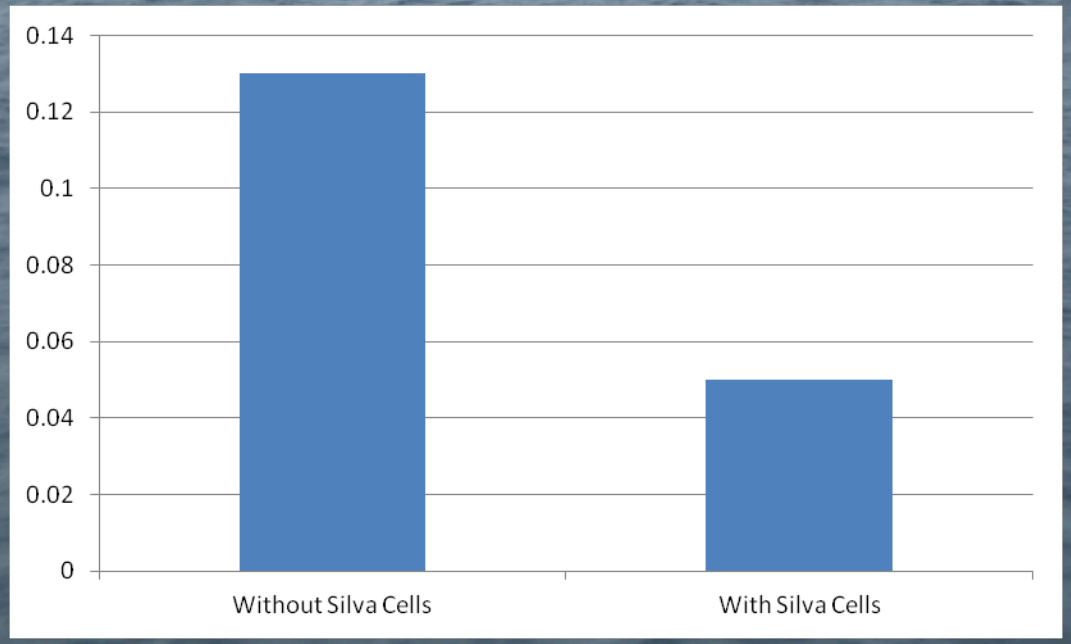
Significantly less bypass is expected at typical Silva Cell installations because:

1) Pond liner was used so no exfiltration was possible – for typical Silva Cell installations pond liner is NOT so exfiltration is possible.
2) Drainage area to these Silva Cell systems (1 tree per 0.1 acre) was significantly greater than typical installations

NCSU Research

62% Peak Flow Reduction

Despite pond liner and large drainage area,
mean peak flow decreased 62% from 0.13 cfs to 0.05 cfs



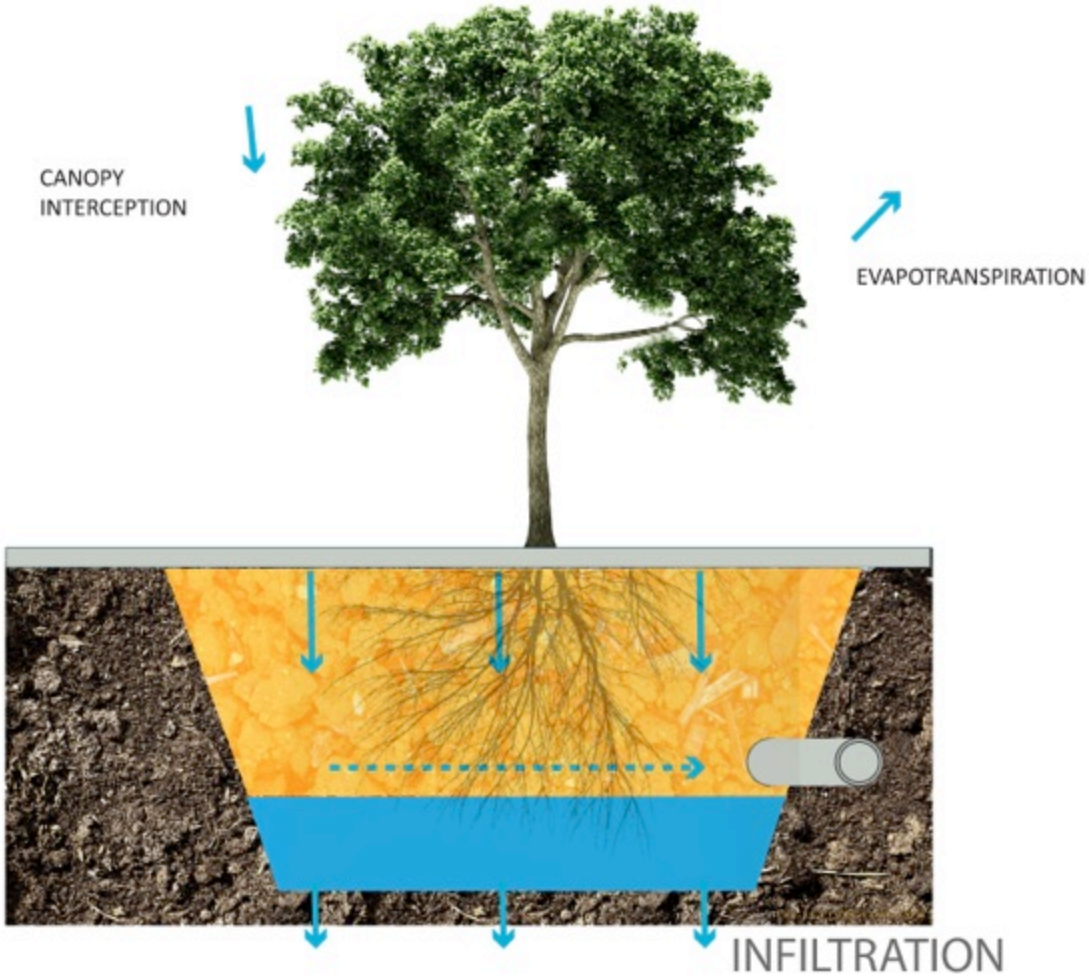
KEY #5: CALCULATE STORMWATER CREDIT FOR TREES

Minnesota Stormwater Manual: Tree Chapter

http://stormwater.pca.state.mn.us/index.php/Trees

- Tree quality and planting
- Soil quality
- Minimum soil volume
- Techniques available to provide rootable soil under load bearing surfaces.
- Species list for tree SCMs
- Maintenance
- Inspection form
- Monitoring

Full ET credit for a mature tree is given IF 2 c.f. of soil is provided per 1 s.f. of canopy at Planting

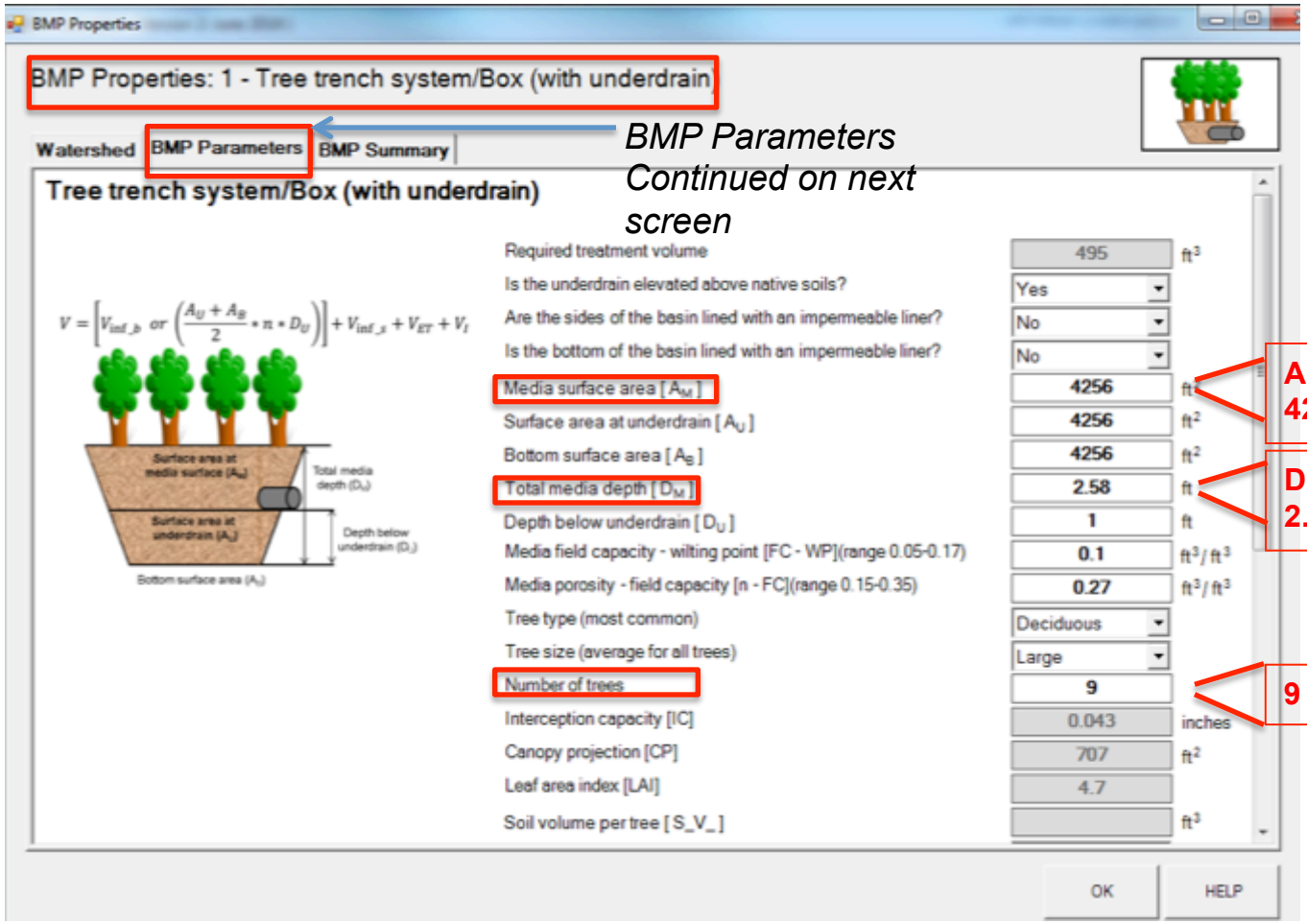


Minnesota Stormwater Manual: Tree Chapter

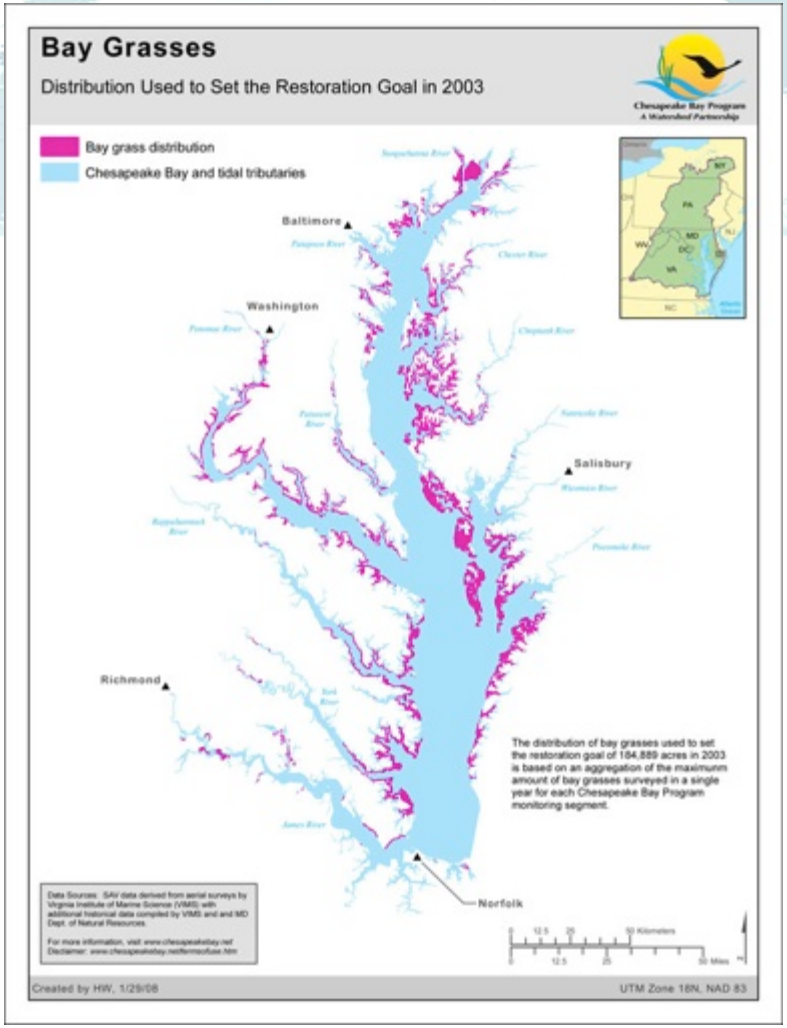
Example Tree Credit Calculation Sample Scenario

http://stormwater.pca.state.mn.us/index.php/Trees

- Watershed: 270’ long x 20’ wide sidewalk (0.12396 acres)
- Tree SCM: 266’ long x 16’ wide x 2.58’ deep
- Silva Cells with 9 large trees, 30’ oc



b3mn.org



MINNESOTA B3 GUIDELINES

Chesapeake Bay Tree Canopy SW Credits: 2016

Upland Forest Conservation;
Individual Tree Planting;
Existing Tree Rescue

B3 (Minnesota Sustainable Building Guidelines)

2003; 2014
S.3 Soil Management
Minimum Soil Volumes for Trees: Sm, Med, L

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Trees Require Portion of Stormwater Budget

Vancouver Canada 2007

SEFC: the site of the 2010 Olympic Village

40.5”/Type 1A

Vancouver Canada 2008

Jan.2008

2012

2014

Case Study:
Marquette & 2nd Avenues (MARQ2) Busway Minneapolis, Minnesota

Stormwater Trees with Sidewalk Runoff to Pervious Pavers

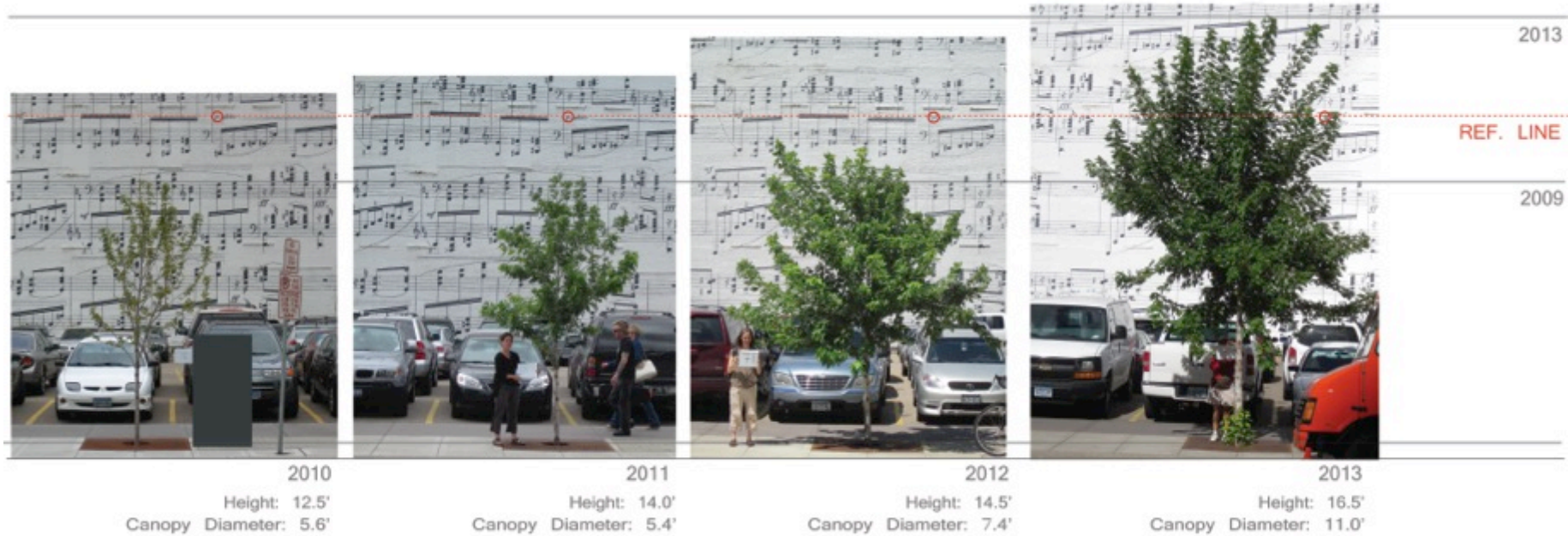
- Average soil volume per tree: 650 ft3
- Catchment: 5.15 acres
- 167 Trees
- Total Silva Cells: 4,909 decks, 9,818 frames
- Installation: 2008-2009
- USDA Zone 4
- Type II Storms
- No Dry Season
- 13 Days >90F, 11 Days <0F
- Cloud Cover 52% - 92%
- Project Designer: SEH and URS
- Technical Consultant: Kestrel Design Group

29.3”/Type 2

Photo taken summer 2012, Kestrel Design Group

Case Study: MARQ2 Busway, Minneapolis, Minnesota

Stormwater Trees with Sidewalk Runoff to Pervious Pavers



Overview of Yearly Growth:
2010-2013: 4' taller, 5.4' wider

Marq2 Silva Cell Installation, tree monitoring images by Kestrel Design Group

Case Study: 2nd Avenue Streetscape, Calgary, Alberta; 2013

Stormwater Trees with Streetwater Runoff to Curb Cuts into Raingardens

Plan by Kestrel Design Group

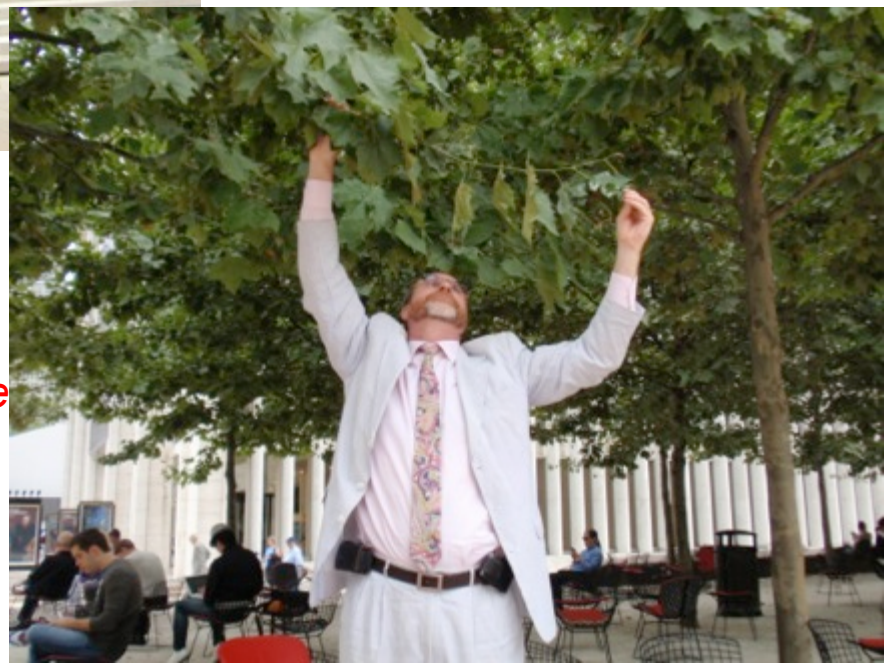
Case Study: 2nd Avenue Streetscape, Calgary, Alberta

Stormwater Trees with Streetwater Runoff to Curb Cuts into Raingardens

- USDA Zone 3
- Type II Storms
- Annual Precipitation: 16.5” (422 mm)
- Dry Season
- 5 Days >90F, 17 Days <0F
- Cloud Cover 61% - 83%

- Average soil volume per tree: 19m3 (671 ft3)
- Catchment : 1,235 m2 (0.3 acres)
- 7 Trees
- Total Silva Cells: 470 frames, 270 decks
- Installation: June 2013
- Project Design Team: Kestrel Design Group, DeepRoot, Calgary WR, Larson Engineering

46.3”/Type 3



Manhattan NYC Lincoln Center: 2009

Trees in Loam Under Suspended Pavement…….

2.5 Years Old: 6” Caliper *Average 600 cf loam per tree*

No transplant shock

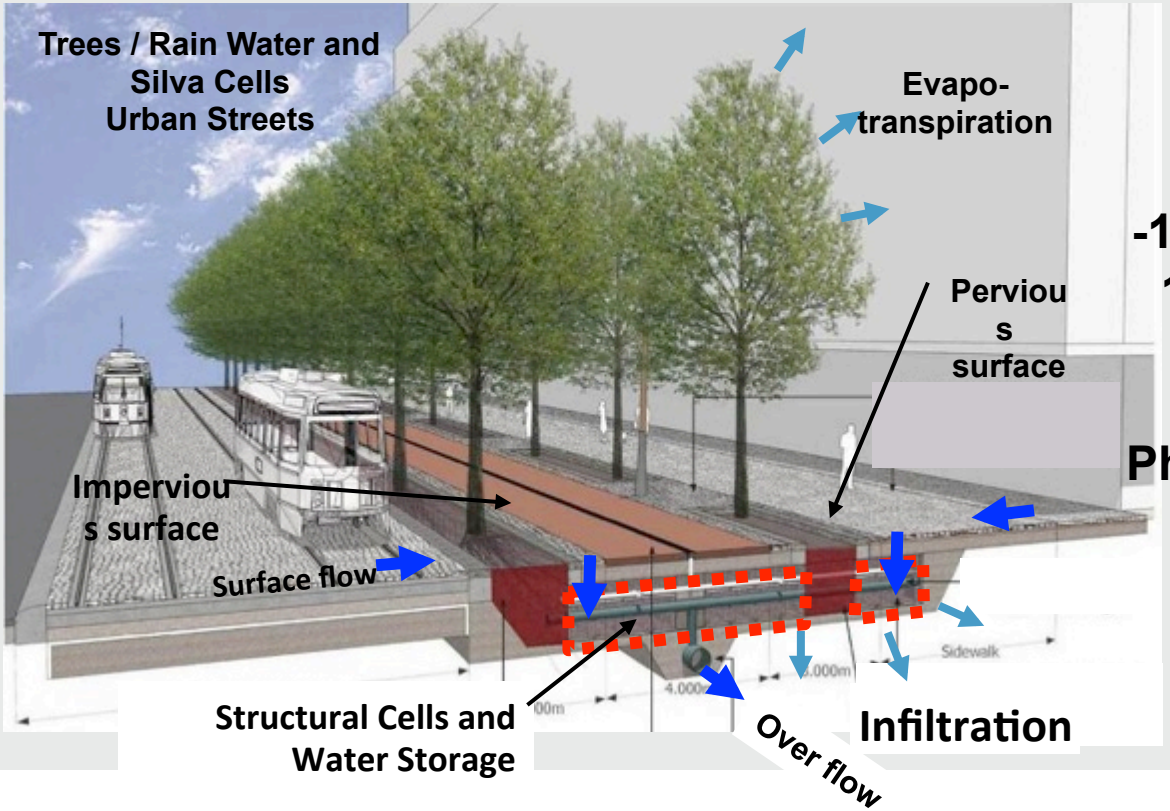
>8”/mm twig extension in 1st Season (2009)

>30”/762mm twig extension in 2nd Season

>35”/mm twig extension in 3rd Season

Trees Managing Stormwater at Scale

Let's Make Livable Cities: Waterfront Toronto: 2100 Acres On Lake Ontario: 2009
Largest Waterfront Project in the World



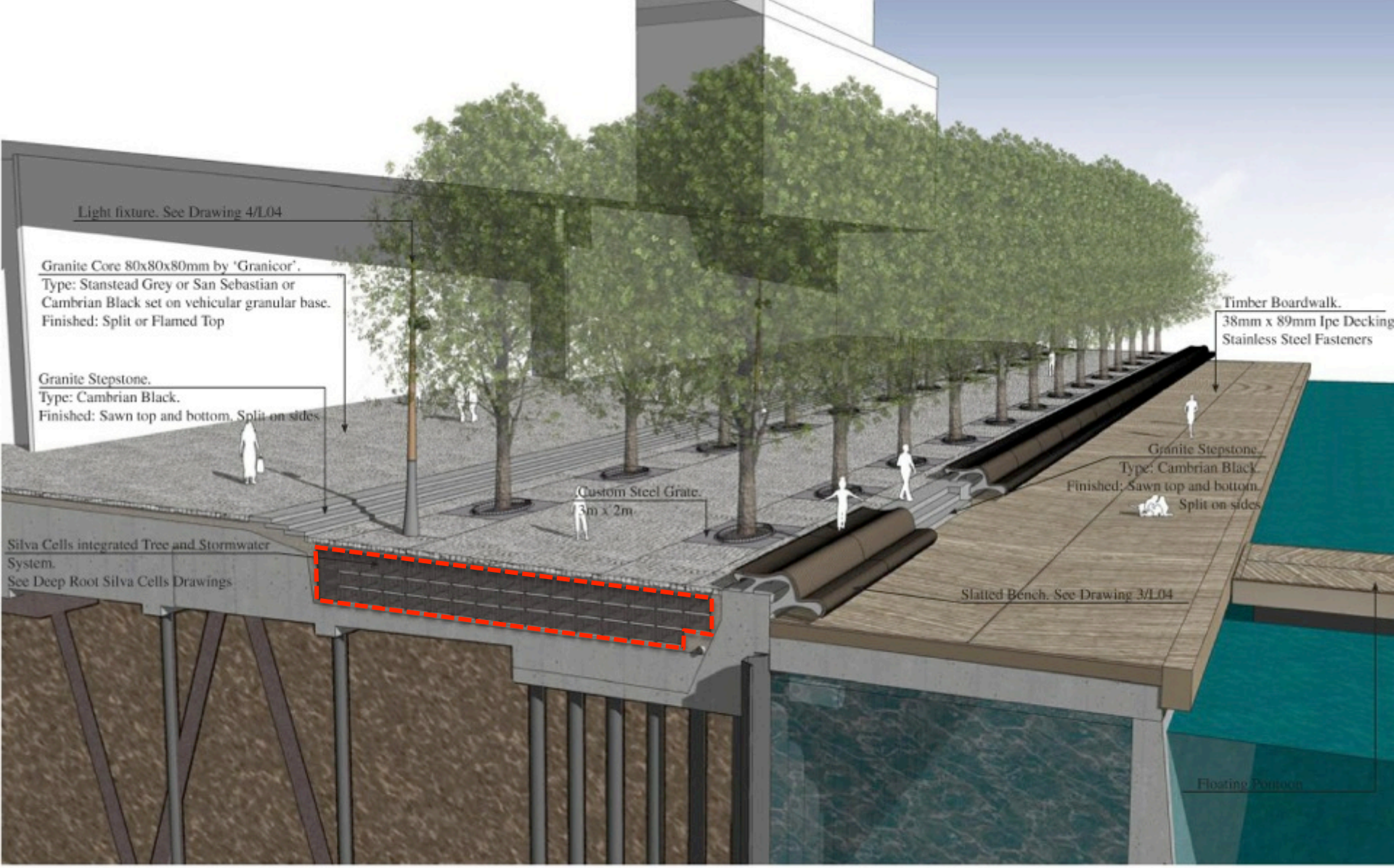
16 trees per acre capture
-1"/24 hour storm in: Soil

-16 trees @ 22" DBH capture
1.8"/24 hour storm in: Soil
& Interception

Phase 1 Installed: 1,300 trees
All Phases: 16,800 trees

32.7"/Type 2

Courtesy: West 8 + DTAH



Waterfront Toronto

PERSPECTIVE/SECTION. WATER PROMENADE

Courtesy: West 8 + DTAH

Waterfront Toronto: Sugar Beach: 2009

29 Year Old Trees in Suspended Pavement

41.6”/Type 3

Bartlett Tree Labs; Tom Smiley 2014

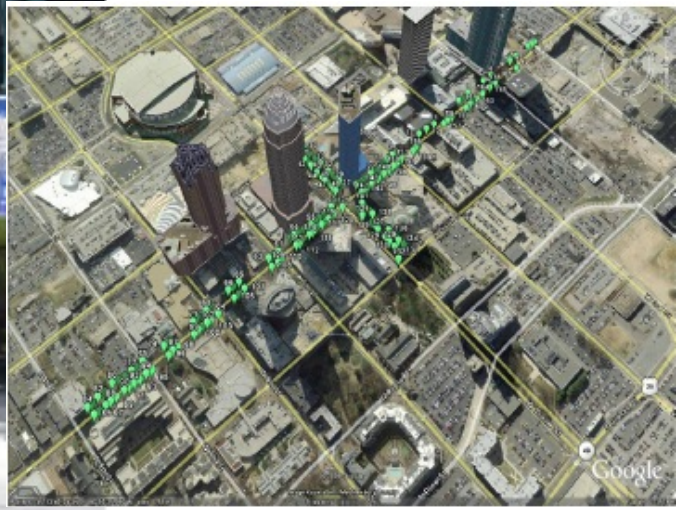
Suspended Pavement

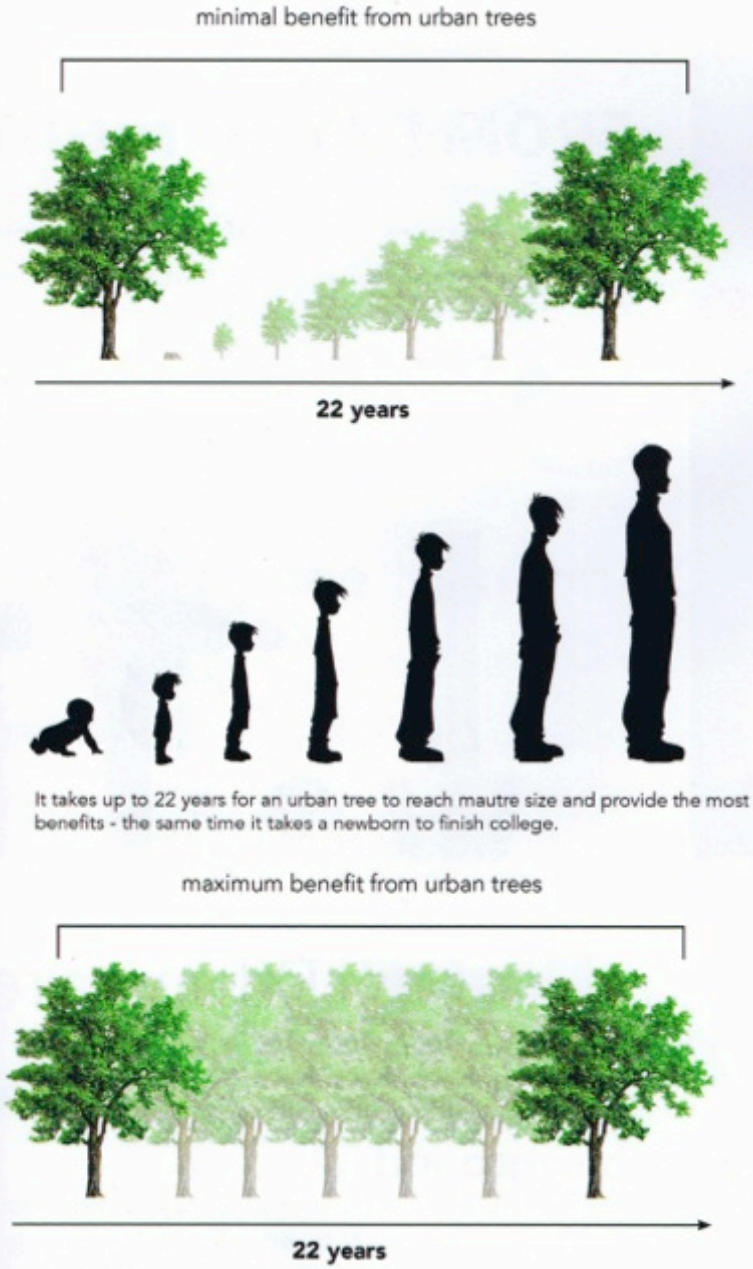
Charlotte, NC – 1985
Tyron St. (29 years)

<u>Willow Oaks:</u>
40mm (19 inch) DBH
21.7m (91 feet) Tall
19m³ (700ft³) of loam soil / tree

98% survival rate (167/170)

Designed by McSween





Badon, Thomas, 2013, Surviving in the Urban Environment, ASLA, _Scape, Issue #17: 9-11.

47 Year Old Trees Loam under Suspended Pavement
Christian Science Center, Boston, MA

Little Leaf Lindens
700 c.f. of loam per tree average
100% Success Rate
Sasaki & Assoc. 1967

43.8”/Type 3

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Trees Require Portion of Stormwater Budget

Love Tunnel Railway, Klevan, Ukraine
Case studies:

http://www.deeproot.com/products/silva-cell/case-studies

Urban Trees MN Manual:
http://stormwater.pca.state.mn.us/index.php/Trees

G….H……..? Q & A

Contact Information:
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References

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