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Great Lakes Chapter

Toronto and Region Conservation for The Living City

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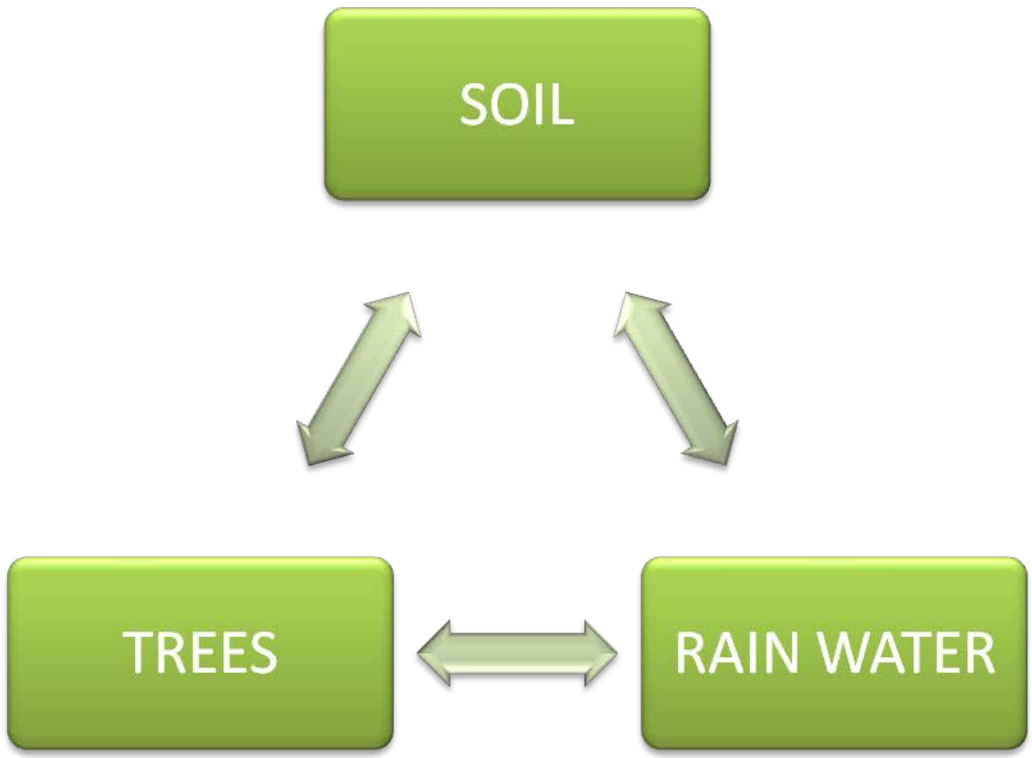

The Foundations of Green Infrastructure


"LUTHIEN" by Ted Nasmith
Scanned by Eriol

"Nothing is invention
Everything is written in nature"

Antoni Gaudi

deeproot

Courtesy Jim Urban

Green Infrastructure

To Mitigate The Urban Heat Island, Pollution & Storm water

Large Deciduous Trees

"A 76cm (30 inch) DBH tree provides **70 times** the ecological services of a 8cm (3 inch) DBH tree"

(Tree USFS, SE Section, 1999)

51cm (20") Trunk Diameter Tree

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BLOOR ST.
TORONTO, ON

13cm (5") diameter in 30 years

This tree is a potted plant

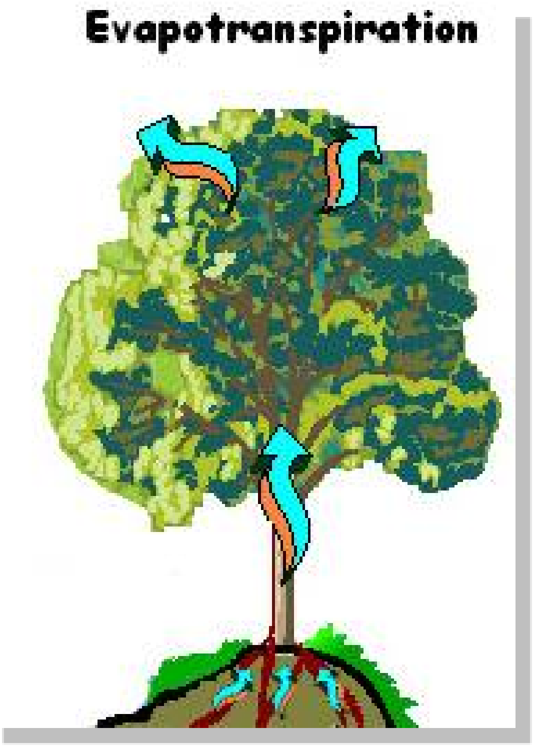
Evapotranspiration and Storm Water

- Another way trees and vegetation cool the air is by absorbing water through their roots and evaporating it through the leaf's stomata's (pores).

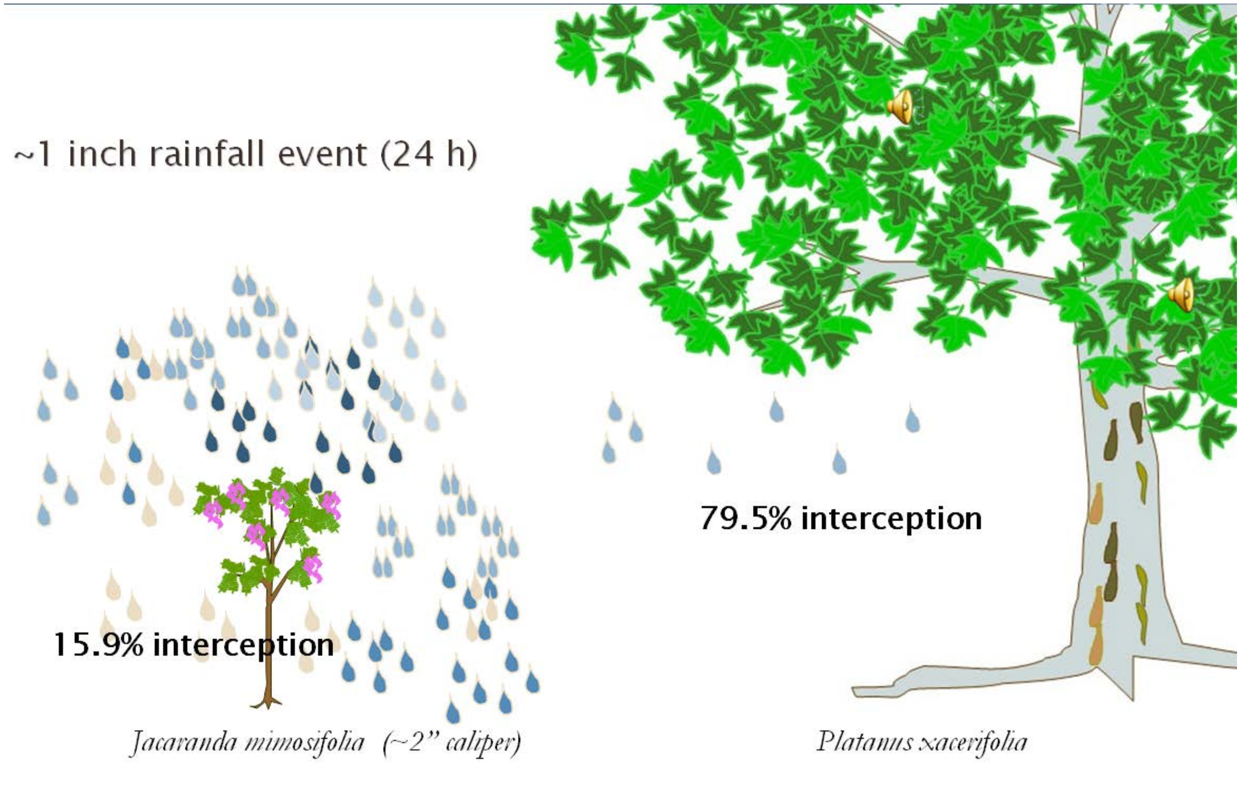
- A mature tree with a 30-foot crown transpires approximately 40 gallons of water per day.

- Evapotranspiration alone can result in peak summer temperature reductions of 2 to 9° F (1° to 5° C).

Source: US – EPA and USFS



2” Caliper Jacaranda versus 22” DBH Plane Tree



Xiao Q., and E.G. McPherson. 2003. Rainfall interception by Santa Monica's municipal urban forest. Urban Ecosystems

Stormwater Interception Volumes

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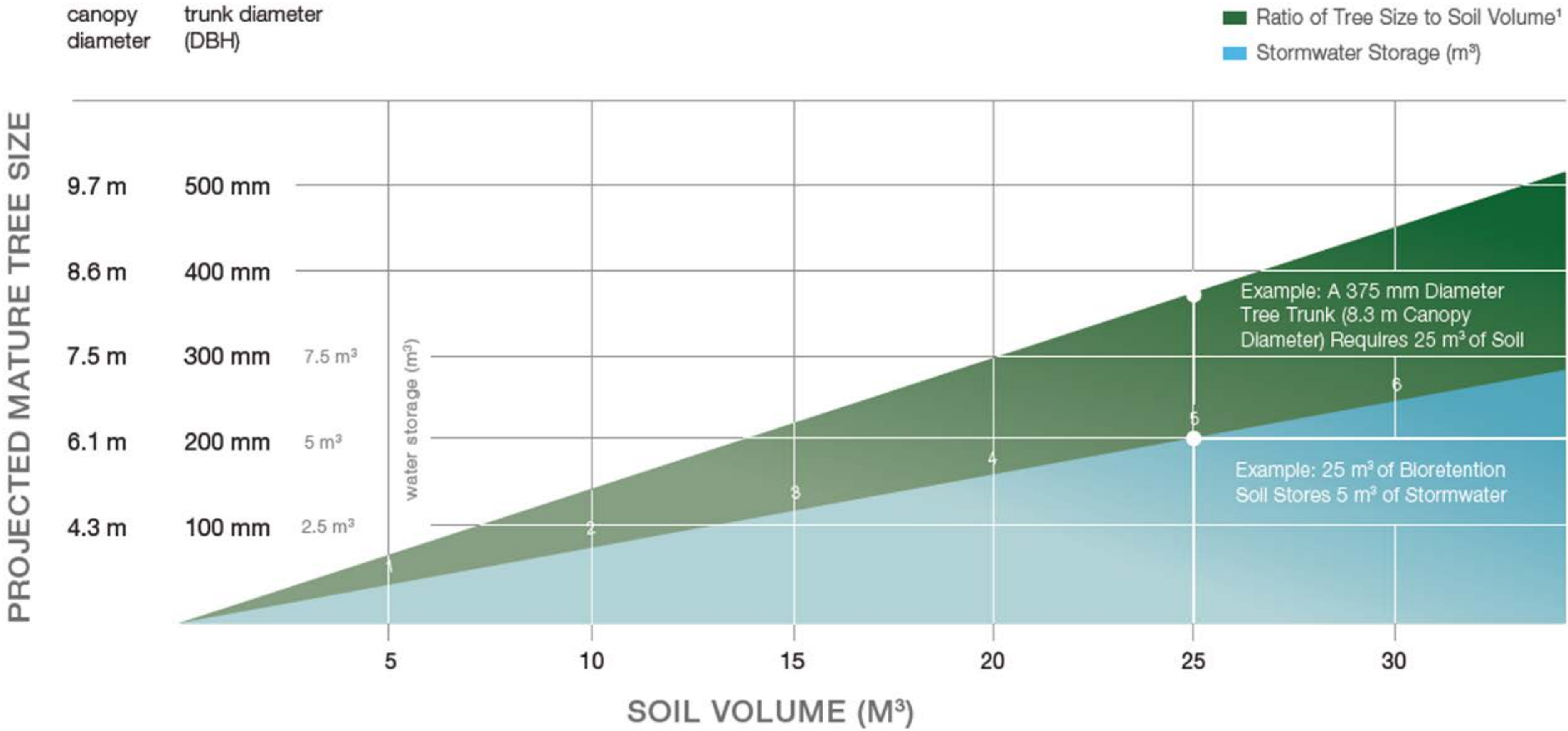
Large Mature Trees provide financially measurable value to a municipality

How are we going to grow large mature trees in an urban environment?

HOW MUCH SOIL TO GROW A BIG TREE?



Ratio: 2.2m2 of canopy to 1m3 of soil

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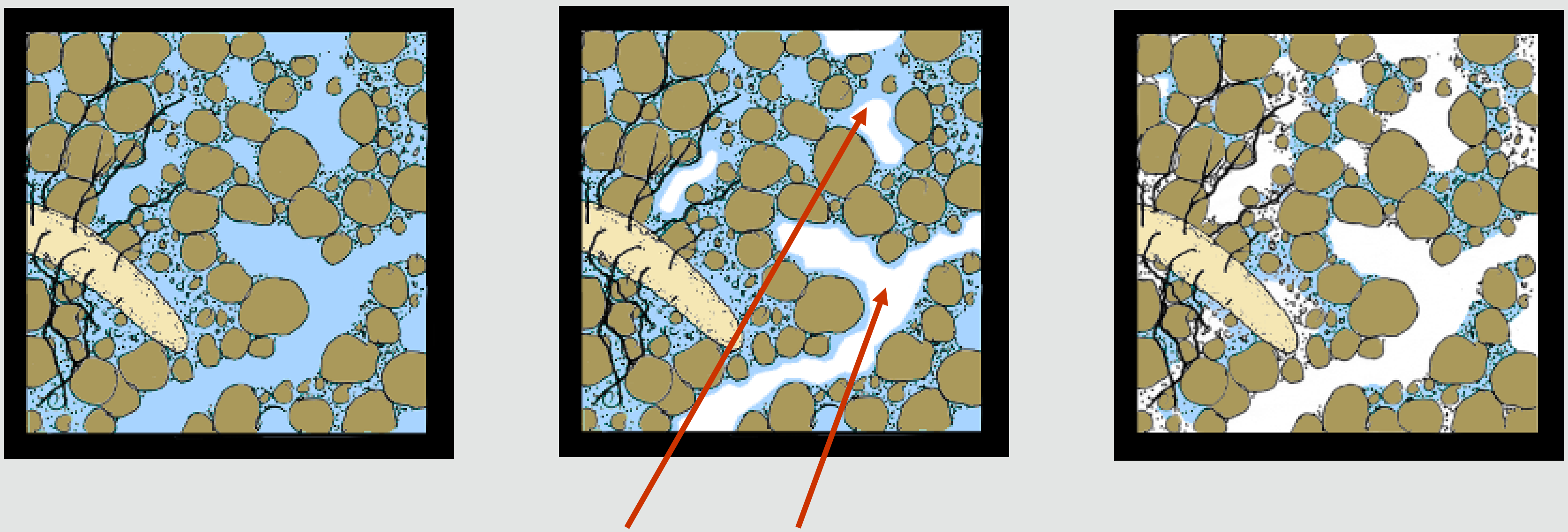
Uncompacted Soils: Walk Through compaction / 80 Proctor

80 Proctor compacted soils have a 20% holding capacity for water

Saturation Point

Field Capacity

Wilt Point



Micro-pores *Macro*-pores

Water movement is highly dependent on soil structure and soil ped retention

(Urban, 2008, Up By Roots)

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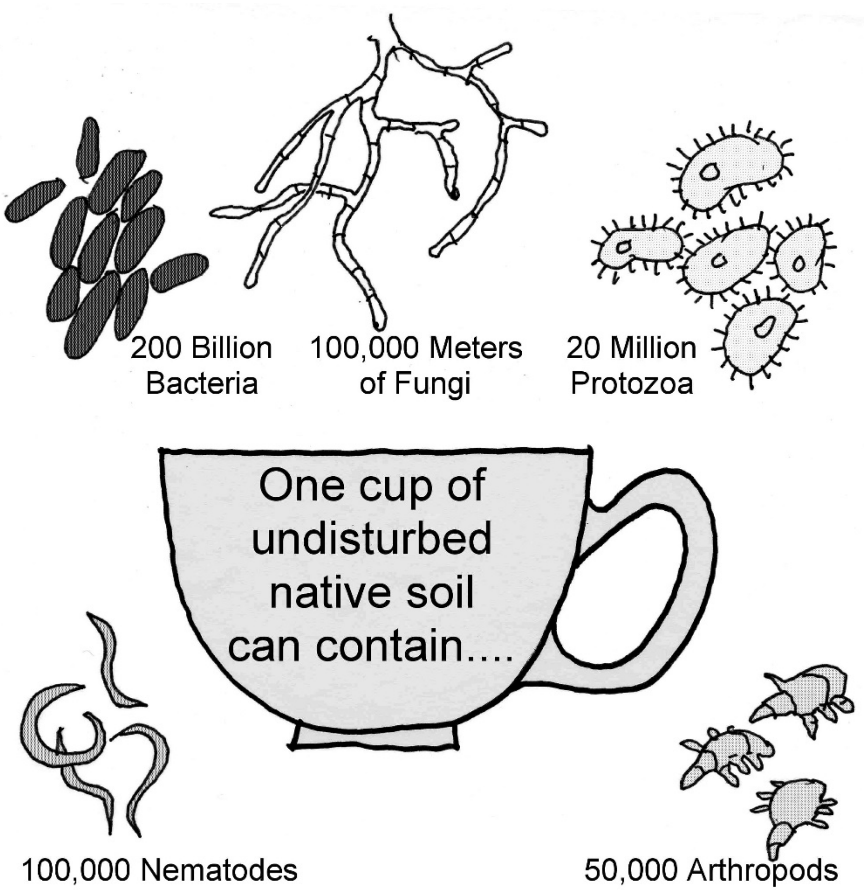
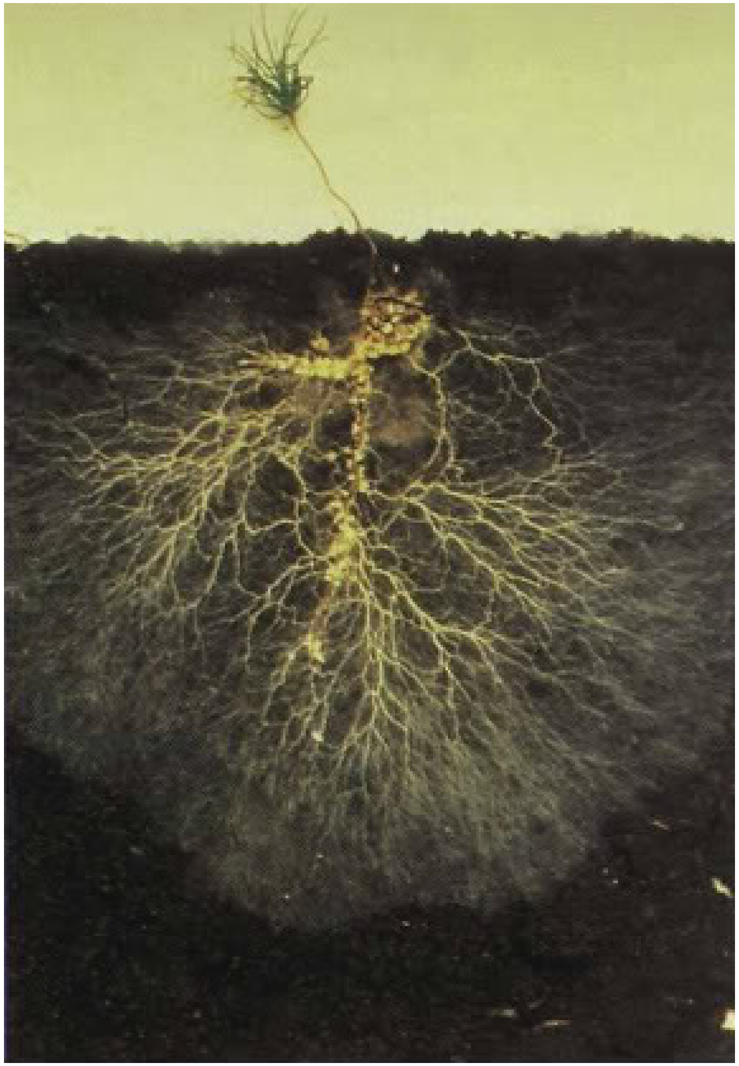
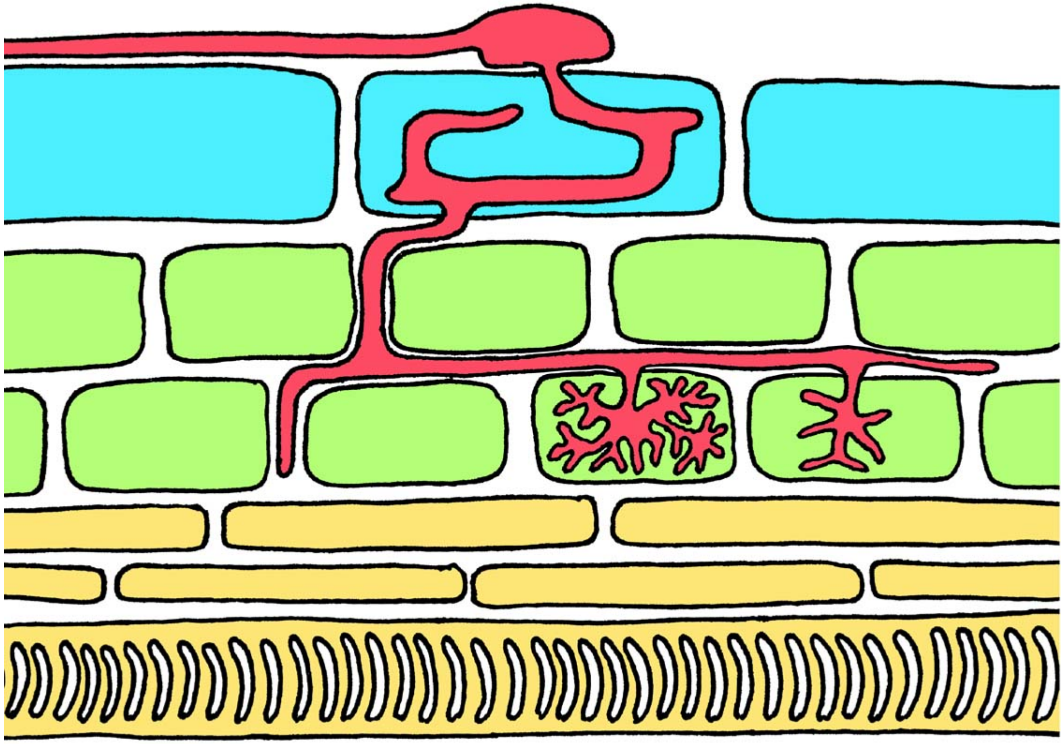
Glomus Intraradices



To this day most tree roots, in of themselves, cannot support a large canopy. Most of the oxygen, water, nutrient absorption that the successful tree harvests is via other organisms - fungi, bacteria, etc.

Tree roots have not had to become super efficient at harvesting water, oxygen, and nutrients, because the soil organisms have been doing this so well for so long.





Reach

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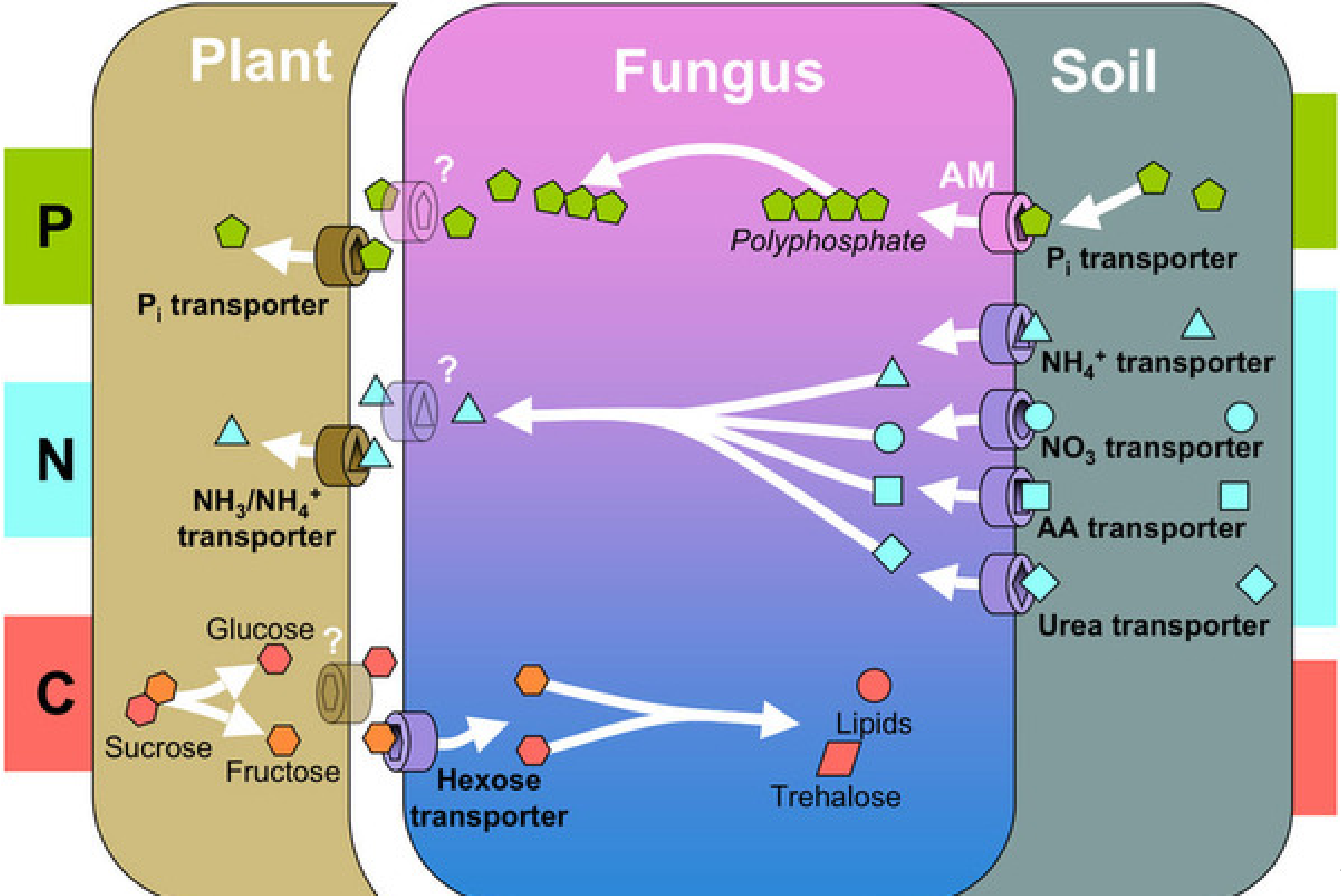
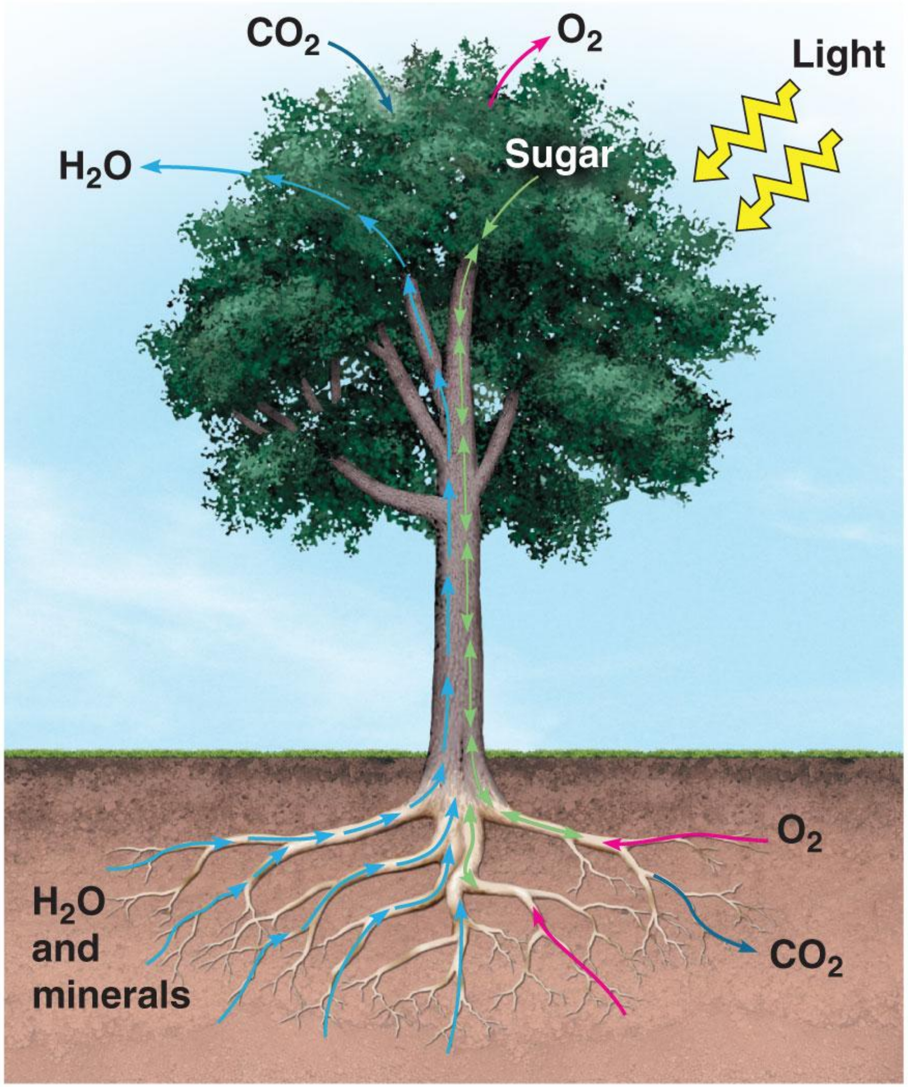
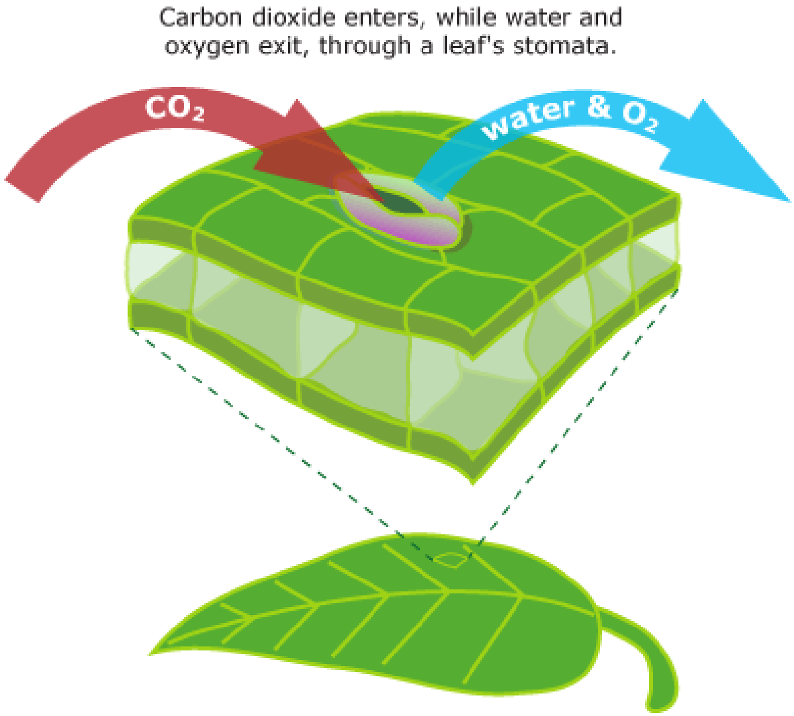
Symbiotic relationship







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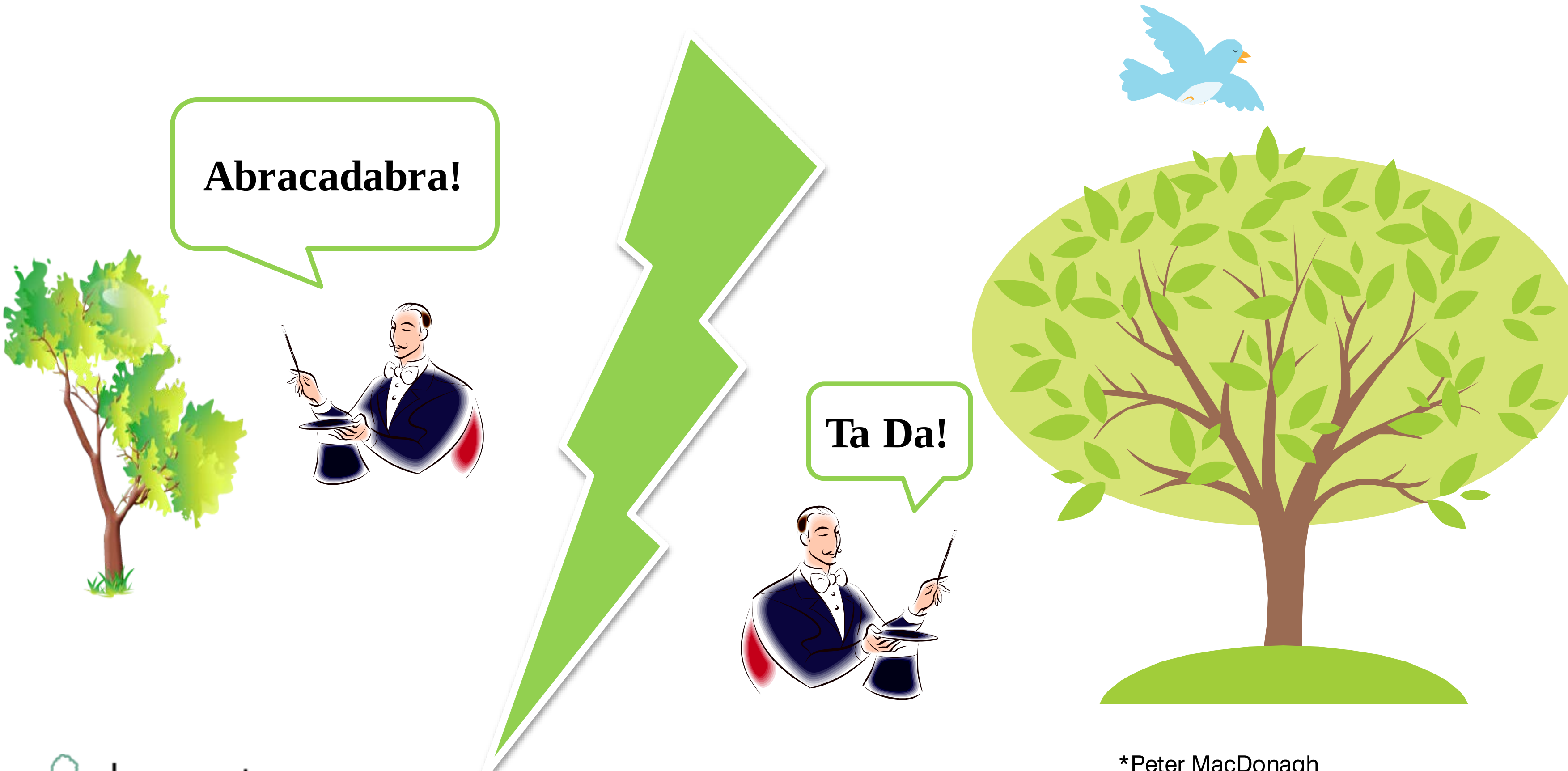
Water - Transport

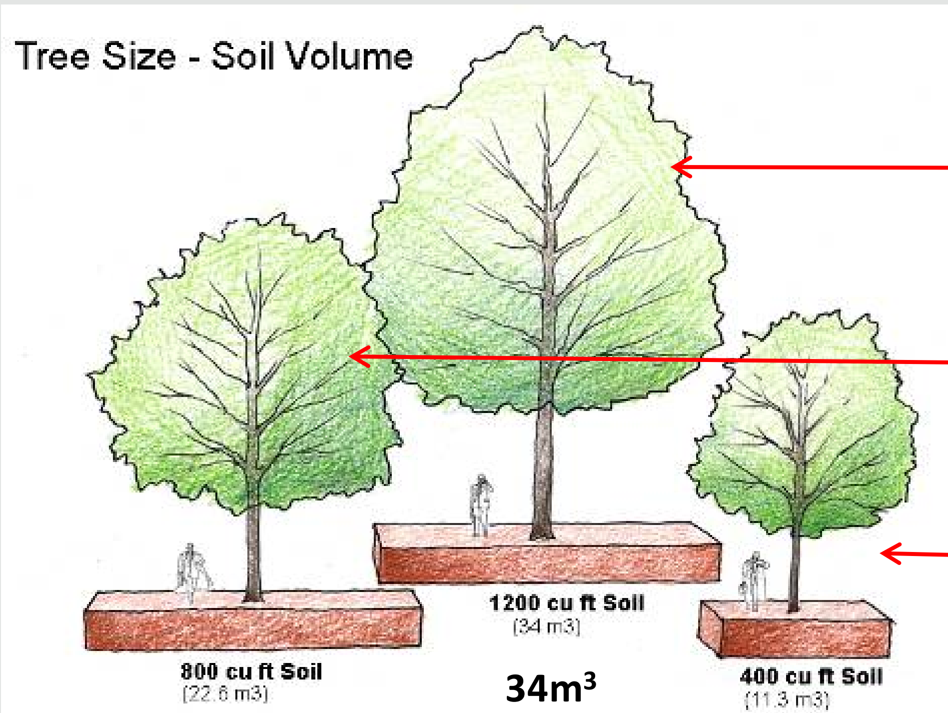
The End of Magical Thinking About Trees



*Peter MacDonagh
The Kestrel Design Group

How do we grow big trees?

5.6 m^3 of Soil will Grow a Shrub - But NOT a TREE



6.8m^3 Rain water
395m^2 Drainage area (2cm rain)

4.5m^3 Rain water
265m^2 Drainage area (2cm rain)

2.3m^3 Rain water
132m^2 Drainage area (2cm rain)

22.5m^3

11.3m^3

(Urban, MacDonagh et al, 2008)

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Municipal Soil Volume Standards

Municipalities need soil volume specifications for street tree plantings (shop drawing for trees)

Toronto
(Standard)

Winnipeg
(Downtown)

Markham
(Standard)

Whistler
BCSLA/BCNTA standards

Vancouver
(SEFC Development Area)

Langley
(Standard)

Kitchener
(Standard)

Oakville
(Standard)

North Vancouver
(Standard for Lower Lonsdale Development Area)

Calgary
(Residential)

Burnaby
(Standard for Metro Town Development Area)

York Region
(Viva-Next design standard)

Brampton
(Joint Sustainability Matrix)

Vaughan

Richmond Hill

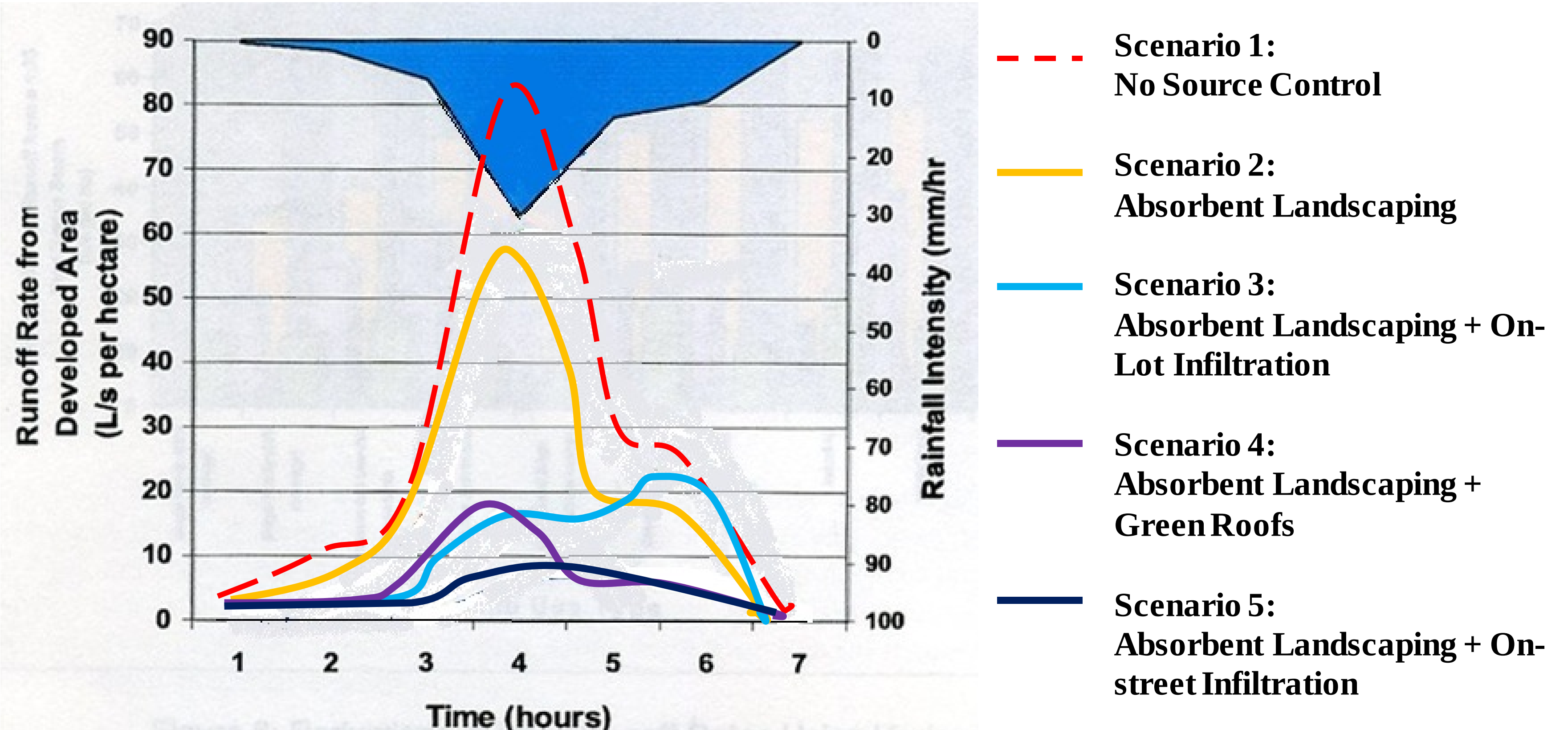
Connects Canopy Targets in the Official Plan to Land Use

Storm Water Management

…the other advantage of Soil Volume Standards

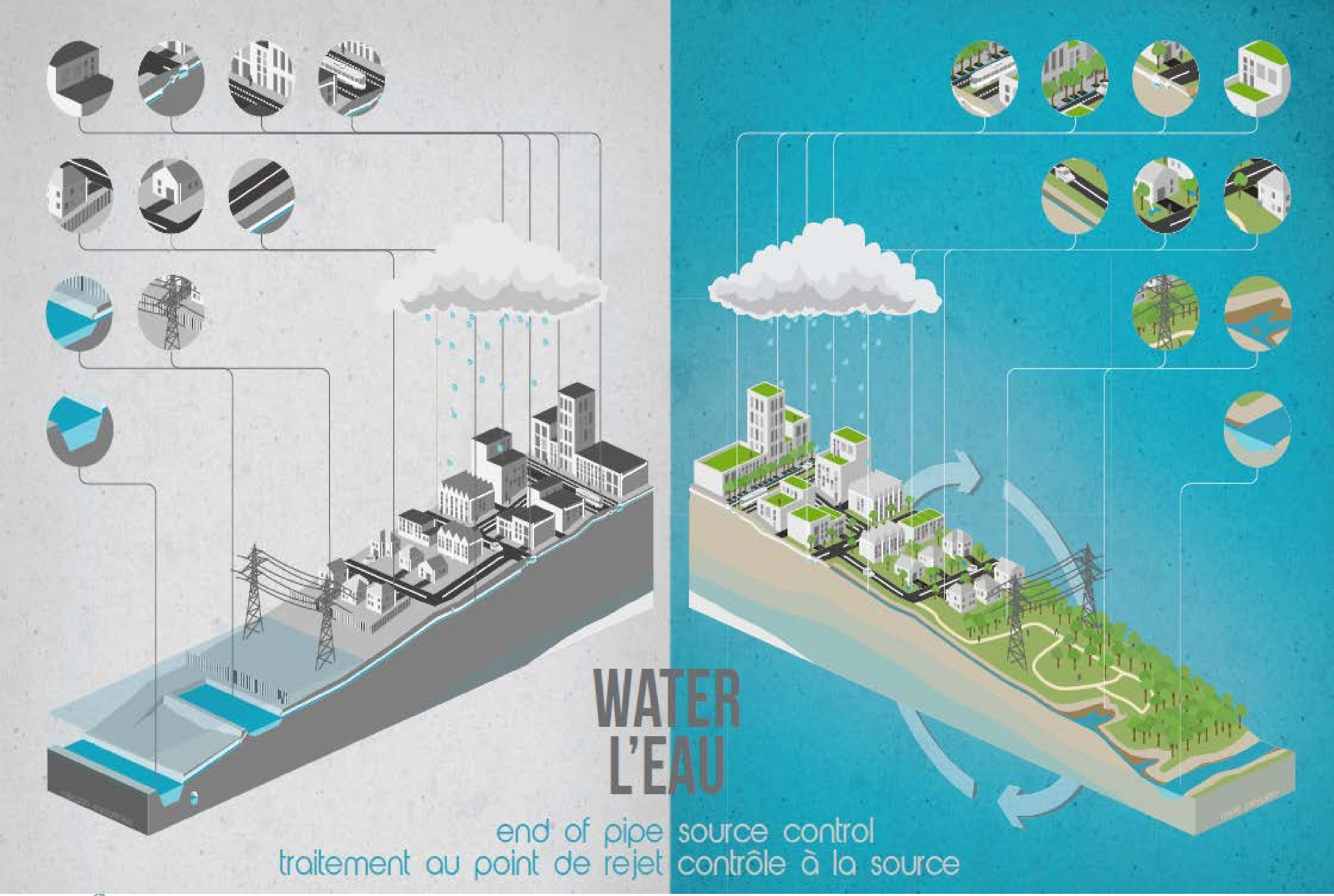
Effectiveness of Source Controls at Reducing Peak Runoff From an Intense Cloudburst

Multi-family neighbourhood (72% coverage on lots, no surface parking, 11m wide roads)
Poor Soils (hydraulic conductivity of 2.5 mm/hr)



Source: Patrick Graham, Marian Kim. Evaluating the Stormwater Management Benefits of Green Roofs Through Water Balance Modeling, 2003.

Figure 7:
Comparison of Neighbourhood Retrofit Scenarios During a High Intensity Cloudburst



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With permission from Megan Esopenko and Matt Perotto

Cost Comparisons Between Conventional Pipes Only and LID Approaches

Project [a]	Conventional Development Cost	LID Cost	Cost Difference[b]	Percent Differnce[b]
2nd Avenue SEA Street	$868,803	$651,548	$217,255	25%
Auburn Hills	$2,360,385	$1,598,989	$761,396	32%
Bellingham City Hall	$27,600	$5,600	$22,000	80%
Bellingham Bloedel Donovan Park	$52,800	$12,800	$40,000	76%
Gap Creek	$4,620,600	$3,942,100	$678,500	15%
Garden Valley	$324,400	$260,700	$63,700	20%
Kensington Estates	$765,700	$1,502,900	-$737,200	-96%
Laurel Springs	$1,654,021	$1,149,552	$504,469	30%
Mill Creek[c]	$12,510	$9,099	$3,411	27%
Prairie Glen	$1,004,848	$599,536	$405,312	40%
Somerset	$2,456,843	$1,671,461	$785,382	32%
Tellabs Corporate Campus	$3,162,160	$2,700,650	$461,510	15%

Total capital cost savings ranged from 15 to 80 percent when LID methods were used, with a few exceptions in which LID project costs were higher than conventional storm water management costs (source: Fact Sheet: Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices, downloaded from http://www.epa.gov/owow/NPS/lid/costs07/factsheet.html

Case Study Portland, OR
Taggard D combined sewer basin CSO Tunnel

Table 1. Comparison of pipe-only versus a mixture of pipe and sustainable stormwater solutions

Solution	Capital Cost	Annual O&M Cost	100-year Life Cycle Cost
2000 Pre-design Solution: • Stormwater Pipe System • Combined Sewer Pipe • Large Stormwater Treatment Facility	$144,100,000	$44,000	$165,000,000
2006 Pre-design Solution: • Green Street Facilities • Private Property Stormwater Retrofits • Combined Sewer Pipe • Street Trees	$80,500,000 **Savings:** **64 million**	$252,000	$111,000,000 **Savings:** **54 million**

Pipe reduced from 28ft diameter to 22ft diameter

TagD_Predesign_PipevsGreen_Comparison_Aug2013.doc 8/5/2013

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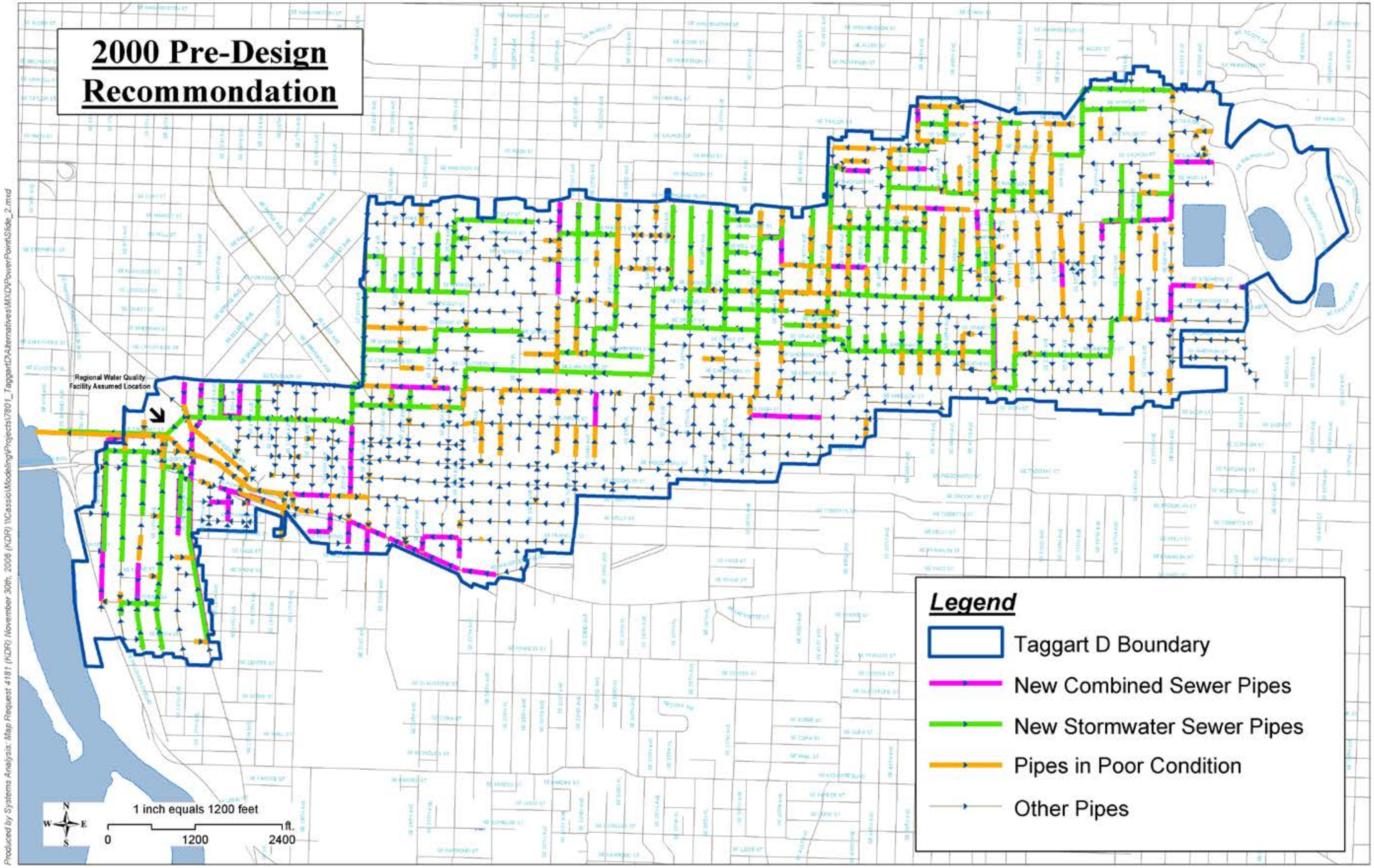
caption



Case Study Portland, OR
Taggert D combined sewer basin CSO Tunnel

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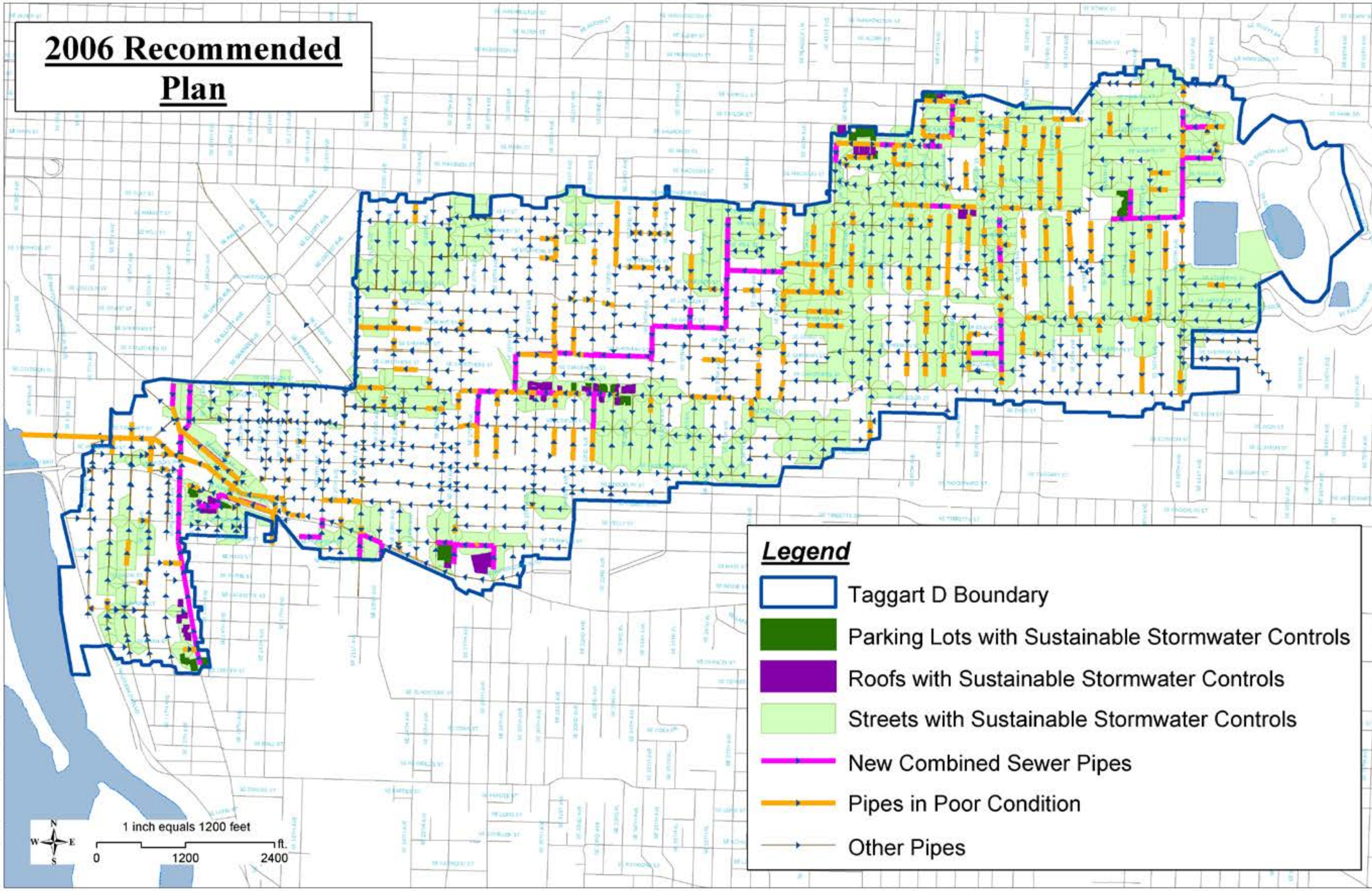

Case Study Portland, OR
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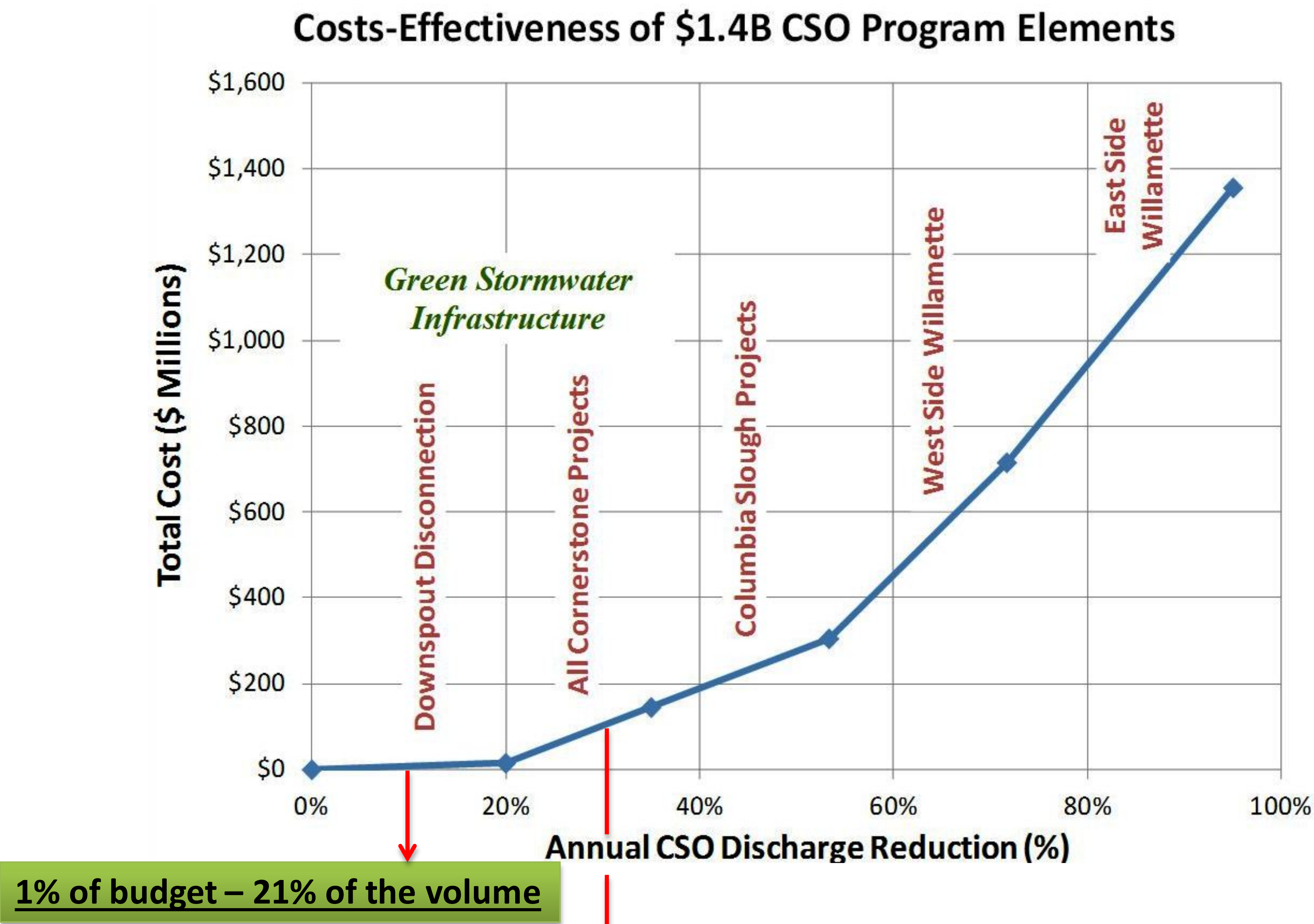

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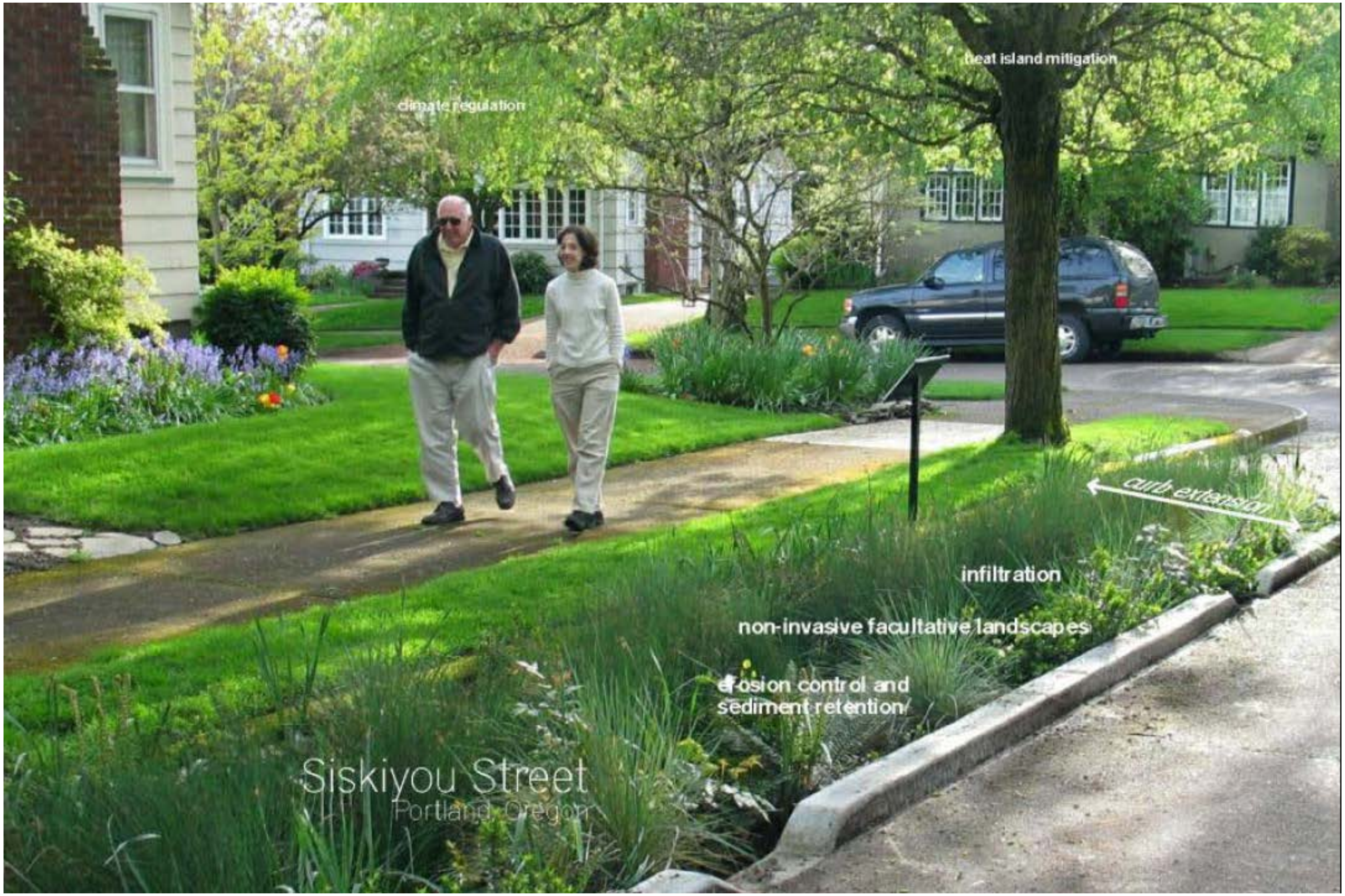
TagD_Predesign_PipevsGreen_Comparison_Aug2013.doc 8/5/2013

Rain Garden/Bio-Retention

Portland, OR



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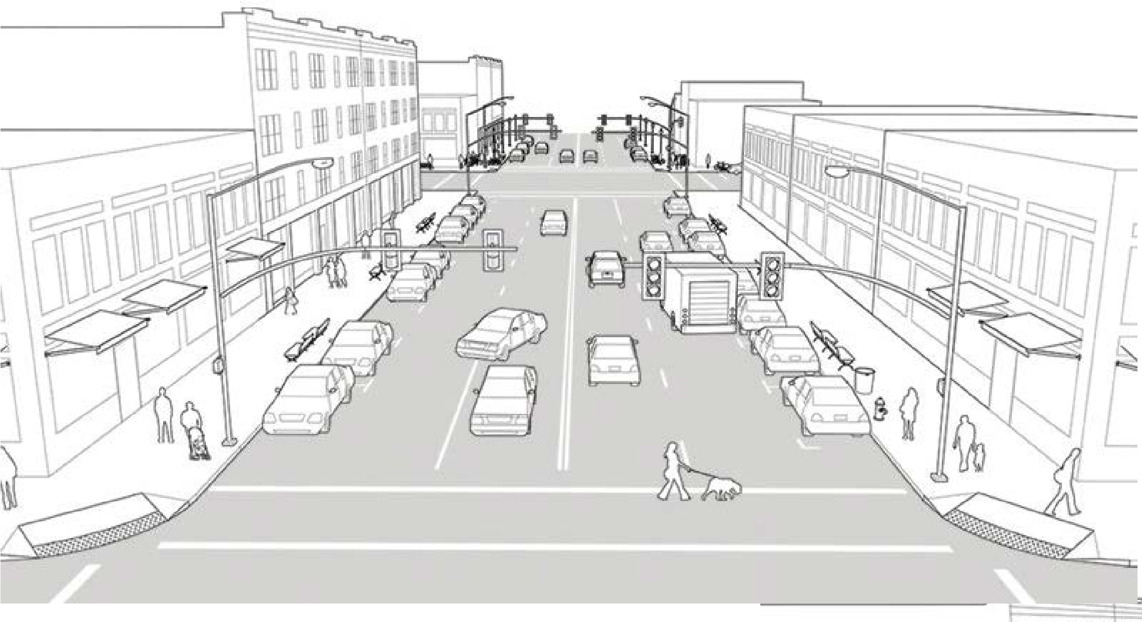


- •Land is expensive
- •Collect garbage
- •High Maintenance cost
    - TSS removal
    - Invasive species
    - Weeding / Replanting
- •Liability
- •Retail push back
    - Loss of Parking
- •Fewer Drive Lanes

Portland Approach

- Maintenance 3/per year
- Clean out Forebays-same contract as CB contractor
- Replanting schedule

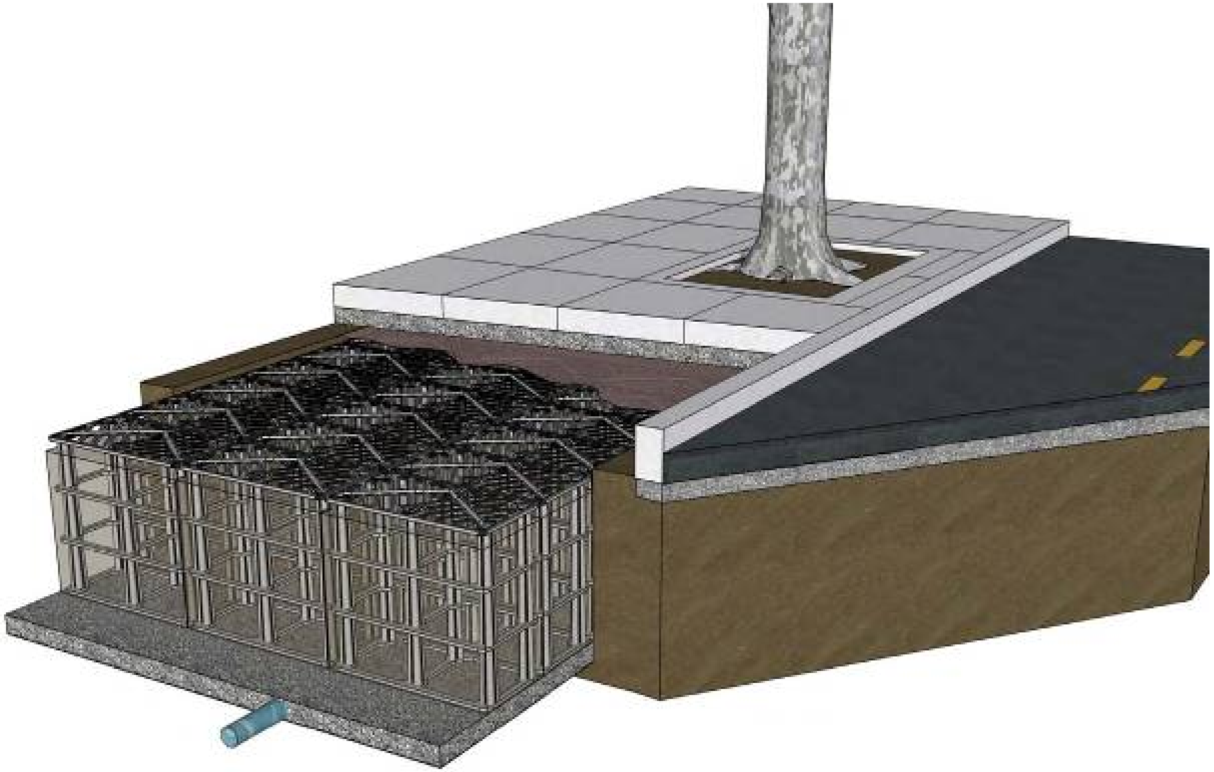
Council wrote their Commitment to O&M into the ordinance.

Jim Ryan – Chief Engineer BES

caption

Suspended Pavement Systems:

Soil Cells



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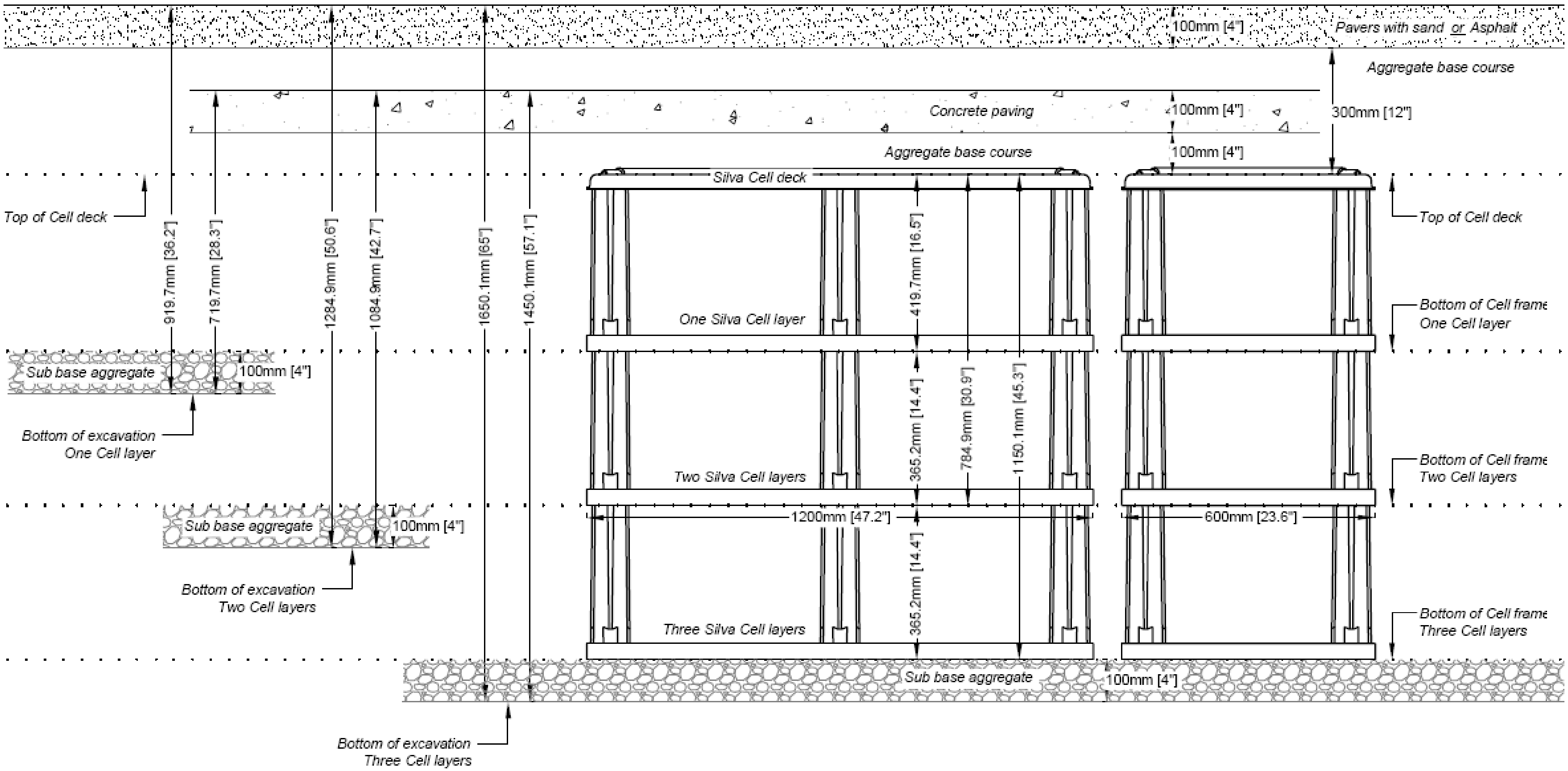
Bring The Functionality of the Forest to the City

The Silva Cell

+

=

Construction Depths for Silva Cells



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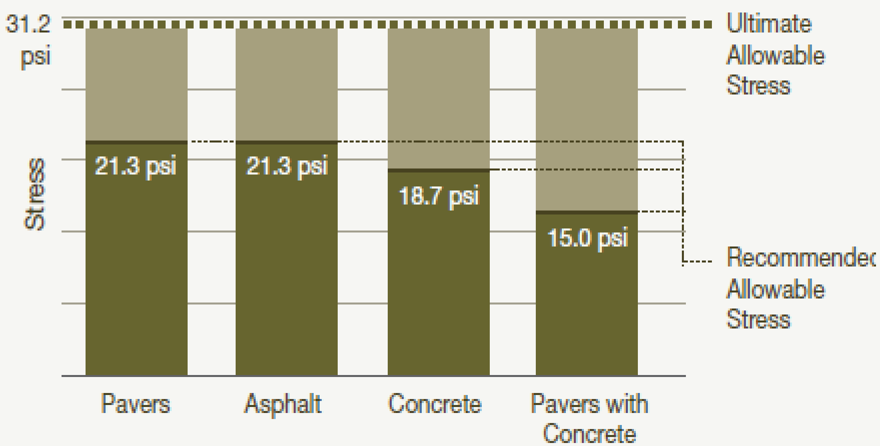
H-20 Loading Specifications

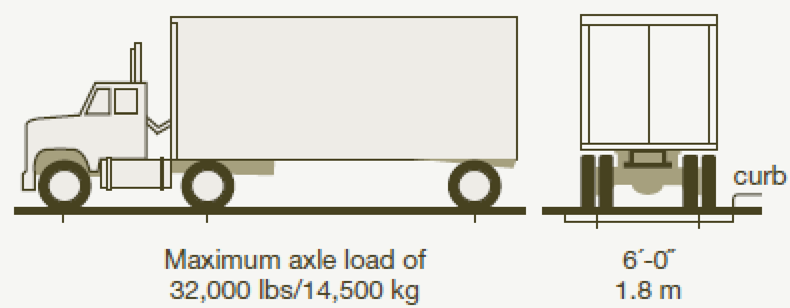
Summary of top deck stresses under H-20 loading conditions (32,000 lbs./14,500 kg)

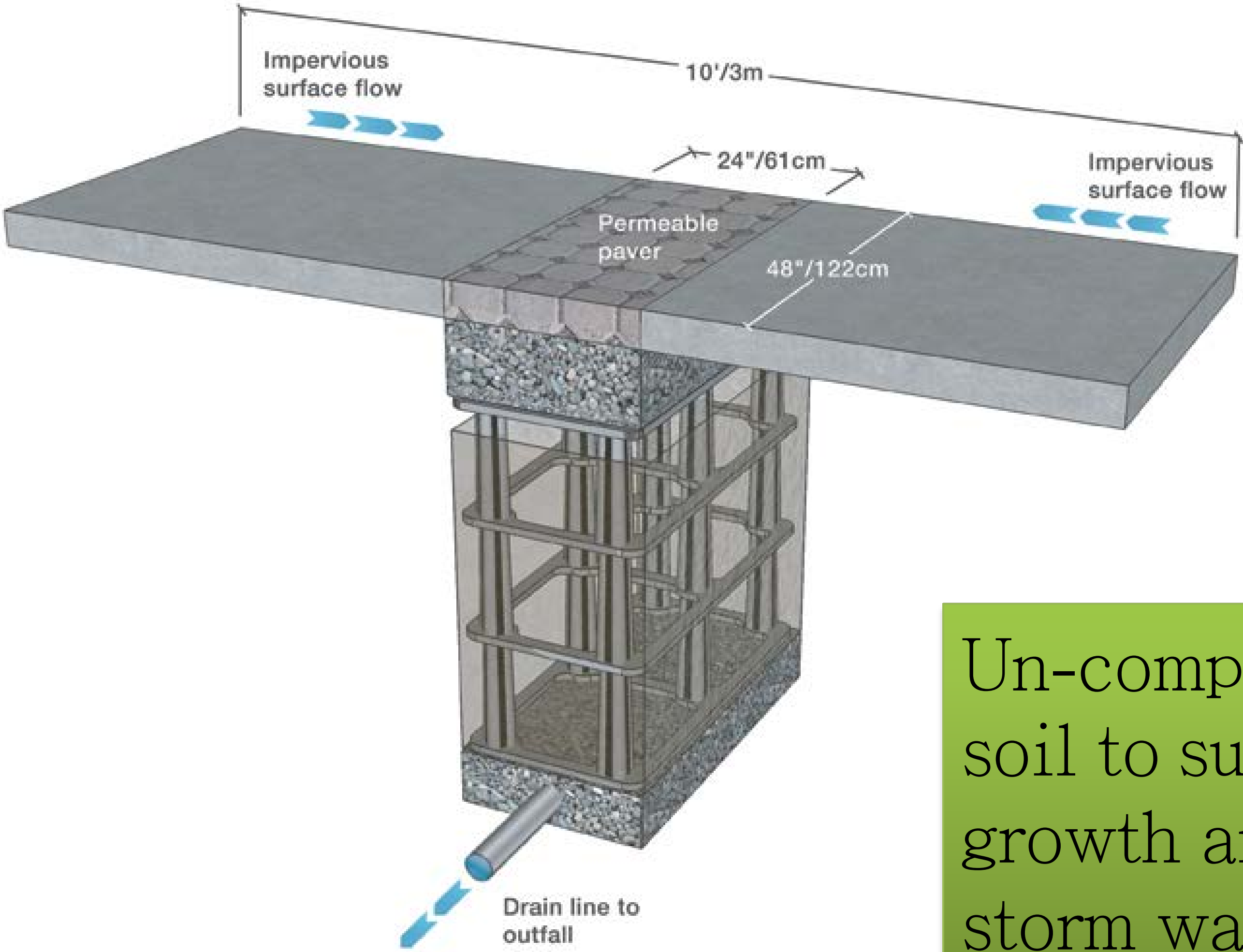


—— is the recommended allowable stress that can be applied to the deck and represents a minimum safety factor of 1.45 when compared to the ultimate allowable stress value

■ Factor of Safety

Typical H-20 Axle Loading at the Pavement Surface





Un-compacted living soil to support tree root growth and manage storm water as a source control.

The Queensway

The Sustainable Sidewalk Project

Toronto, ON, Canada

Silva Cells and Rainwater Management

Oct. 2008

Design Guideline: Manage the 38mm (1.5”) rain event


MOYNES AVE
BERL AVE
THE QUEENSWAY
Rainwater catchment area for the Silva Cells
Parking Bay Silva Cell trenches

Perforated drain line is installed at the bottom of the 1st layer of Silva Cells and connected to the storm water catch basin

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Silva Cells are filled with Bioretention Soil

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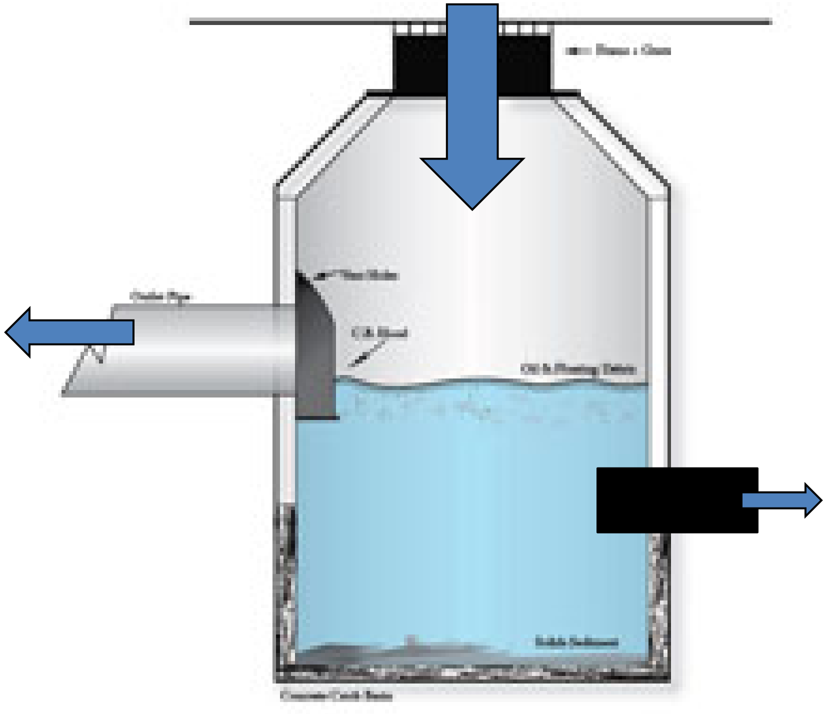
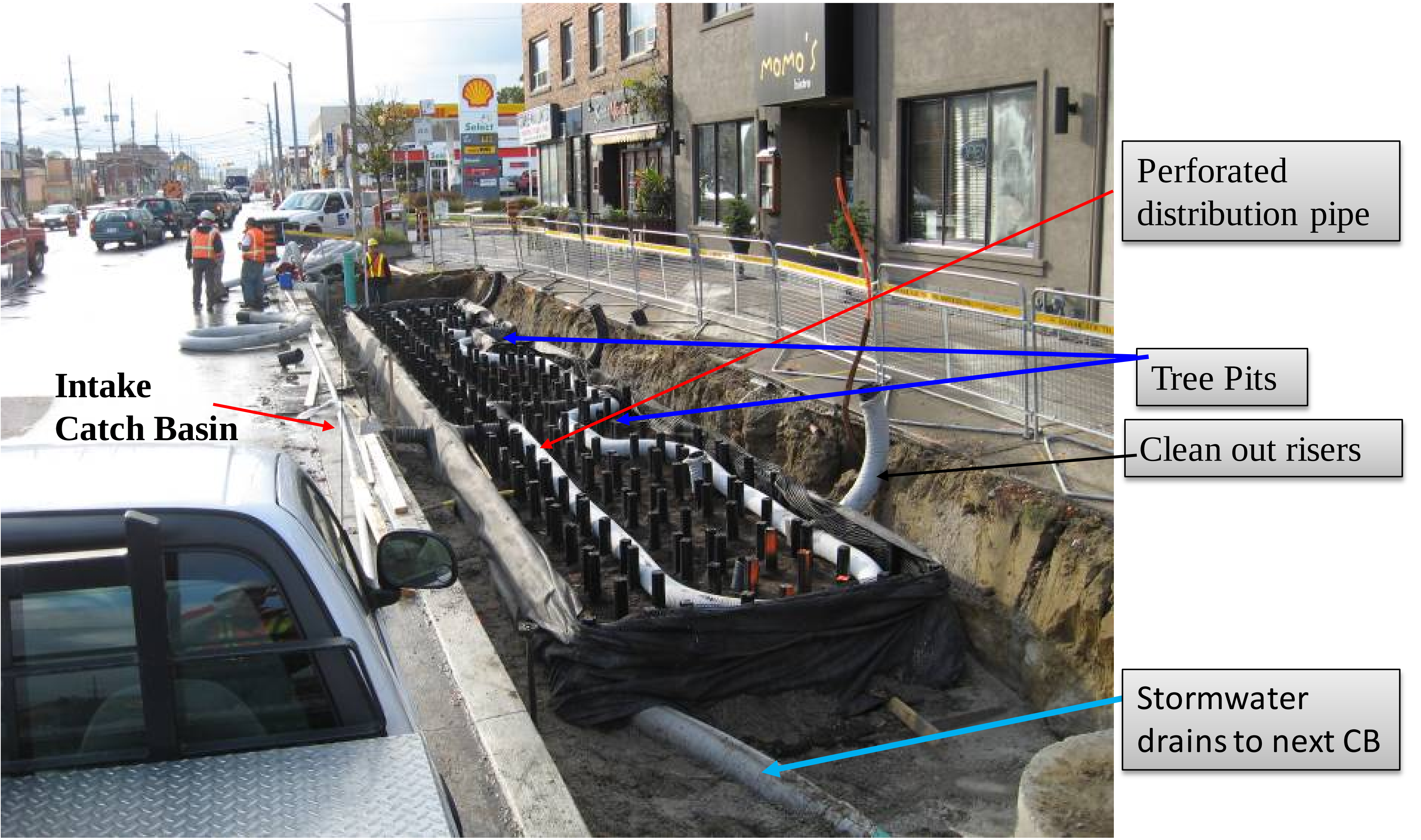
Intake Catch Basin

Overflow



To Silva Cells (1st Flush)



Perforated distribution pipe
Tree Pits
Clean out risers
Intake Catch Basin
Stormwater drains to next CB

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Decks on
Tree Pits
CB
Michael IGNATIEFF, M.P. Constituency Office

Trees planted

Oct. 09

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Silva Cells and Soil Filtering Capabilities

Cumulative Percent Removal by Depth						
Laboratory/Field Summary						
Soil Depth	**Cells Deep**	**Cu** copper	**Pb** lead	**Zn** zinc	**P** phosphorus	**TKN** Keldahl nitrogen
12”	1	90	93	87	0	37
24”	2	93	99	98	73	60
36”	3	93	99	99	81	68

Data on bio-retention removal rates of pollutants such as ammonium and total nitrogen is variable, so has not been included here.

Adapted from Prince George’s County Bio-retention Manual

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July 2010

Trees are 1.5 years old

Sept. 2012

3.5 years old

deeproot

July 2013

July 2013

Suspended Pavement Systems

Maintenance

Yes:

- Clean out CB / Forebays / Porous Pavers - on existing maintenance cycle
- Clean outs on all distribution and drain pipes - flushed on existing maintenance cycle
- Efficient use of space

No:

- Invasive species
- Weeding
- Soil replacement due to TSS matting
- Loss of parking spaces/ driving lanes / sidewalks

Silva Cell Stormwater Management System:

48 Blocks of Downtown Minneapolis - 2009

Water in:

- Porous Pavers
- Roof Leaders disconnected and run into the Silva Cells

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48 Blocks of Downtown Minneapolis

Installation Summary

Total bioretention soil per tree: 670 ft3

Number of Silva Cells: Over 10,800 frames

Installation date: Spring-Summer 2009

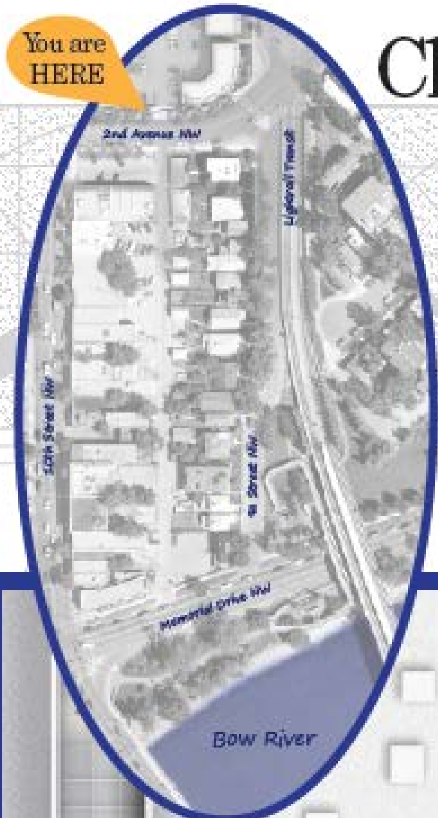
Installation type: Large trees and stormwater management

Water volume treated: 24,000 ft3 (662 m3, or 180,000 gallons)

Project designers: Short Elliott Hendrickson Inc. (SEH) and URS Corporation

Owner: City of Minneapolis and Metro Transit

Clean Water for the Bow River



What is the blue ribbon beneath your feet?

Most of the water that flows in the streets of Calgary makes its way directly to the Bow River. As this water flows, it picks up dirt, pollutants and heat on paved surfaces, carried and deposited in the river. The blue ribbon of concrete represents the goal of a **cleaner Bow River** which this site is helping to achieve by taking care of storm water **at its source**.

Why here?

This site is the first of its kind in Calgary. Beneath your feet, an underground soil system was installed to help clean water and grow large trees. Instead of water flowing down the street and into the storm sewer, the water is **captured, cleaned** and **recycled**, to irrigate the trees you stand beneath.

What does that mean to me?

Imagine the BMO Centre corral floor flooded with 4.7 meters (15.4 feet) of water. That is the amount of water that this small site captures (525m3) each year. Within this infrastructure, the 100-year rain event can be captured, **reducing flooding** downstream. The soil system also cleans the water, helping to provide **safer water** for recreation, drinking and plant and animal communities.

for more information about this system, go to deeproot.com

2nd Ave, Calgary AB

Before

After

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Wilmington Stormwater Treatment Performance Monitoring

L. Peter MacDonagh, ASLA, ISA, RHS, LEED AP
Director of Science & Design, Kestrel Design Group, Inc.
Adj. Faculty Arch. & Land. Arch., Univ. of Minnesota

June 6, 2013

NC State University
A&T State University
COOPERATIVE EXTENSION
Empowering People · Providing Solutions

NCDENR

KestrelDesignGroup

CITY OF WILMINGTON NORTH CAROLINA

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Wilmington Silva Cell Catchment Areas

Figure 2: Orange Street and Ann Street retrofit sites with contributing drainage areas in Wilmington, NC

Average Annual precipitation: 57.61 inches

Mean Temperature: 64.0 degrees F

Data from NOAA; Period used to compute averages and normals: 1981-2010

Aerial view of Silva Cell Retrofit Sites in Wilmington (adapted from Jonathan Page, Ryan Winston and William Hunt, Bio & Ag Engineering, North Carolina State University)

Stormwater Treatment Performance Study Underway

Two Silva Cell Sites Being Monitored in Wilmington, NC

North Carolina State University

Dr. William Hunt's lab
in Raleigh, NC,

Ryan Winston,
Jonathan Page
Bill Hunt

Control Monitoring Equipment

The monitored parameters for this study are:

- Inflow and outflow volumes and rates
- nitrate-nitrite nitrogen ($NO_{2\text{-}3}$-N)
- total ammoniacal nitrogen (TAN)
- total Kjeldahl nitrogen (TKN)
- total nitrogen (TN)
- Orthophosphate
- total phosphorus (TP)
- total suspended solids (TSS)
- the heavy metals zinc (Zn), copper
- (Cu), and lead (PB)

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Table 1: Contributing drainage area summary

Parameter	Orange Street	Ann Street
Drainage Area	486 m^2 (5231 ft^2)	526 m^2 (5663 ft^2)
Imperviousness	100%	100%
Average Slope	2.5%	1.8%
Underlying Soil Class	PSA: Sand (95% - 98%)	
Receiving Water Body	Burnt Mill Creek: 303 (d) List	

Table Courtesy of Jonathan Page, Ryan Winston and William Hunt, Bio & Ag Engineering, North Carolina State University

Note: If trees were 30' o.c. and street was 22' from crown to curb, watershed would be 660 s.f. per tree, almost 1/10 of what it is in Wilmington

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Parameter	Orange Street	Ann Street
Silva Cell™ Units	68	
Surface Area	26.8 m² (288 ft²)	
Soil Volume	21.7 m³ (766 ft³)	
Tree	Crape Myrtle (*Lagerstroemia*)	
Loading Ratio (DA:SA)	18:1	19.5:1

Table Courtesy of Jonathan Page, Ryan Winston and William Hunt, Bio & Ag Engineering, North Carolina State University

Note: Typical bio-retention drainage area: surface area ratio is max 10:1

Wilmington Silva Cell Monitoring Results

Two tree/soil/Silva Cell systems installed with **1 variable – the soil**:

- The main differences between the 2 soil mixes are that the standard tree planting medium has more organic matter and fine particles.

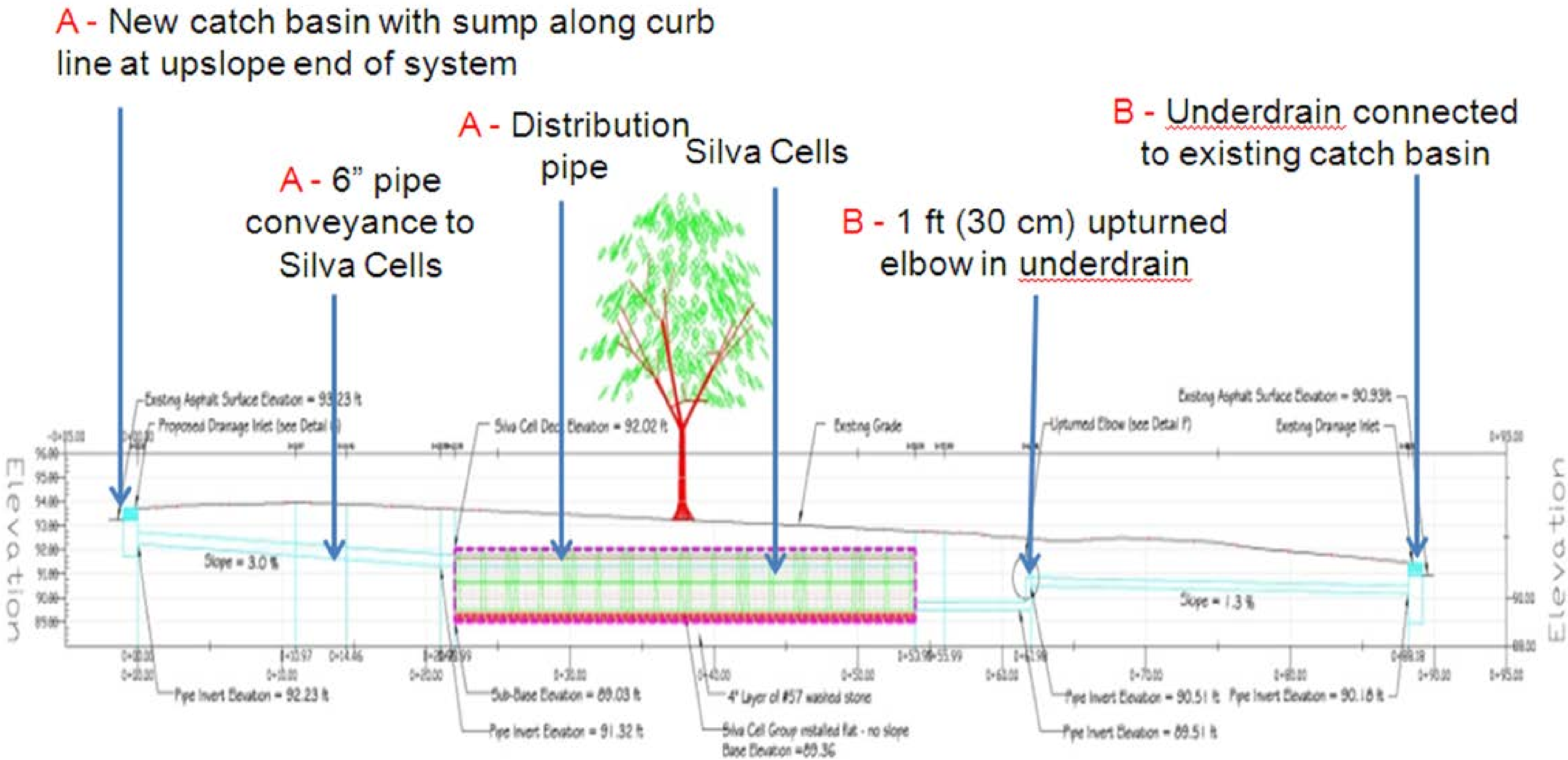
Orange Street: North Carolina Bioretention Media:

*85-88% sand, 4.5% gravel, **8% clay and silt** by volume, **3% organic matter** by weight*

Ann Street: Tree Planting Media:

*85-88% sand, 0% gravel, and **13% clay and silt** by volume, **6% organic matter** by weight*

Stormwater Routing Cross Section



www.bae.ncsu.edu/stormwater

NC STATE UNIVERSITY Bio&Ag ENGINEERING

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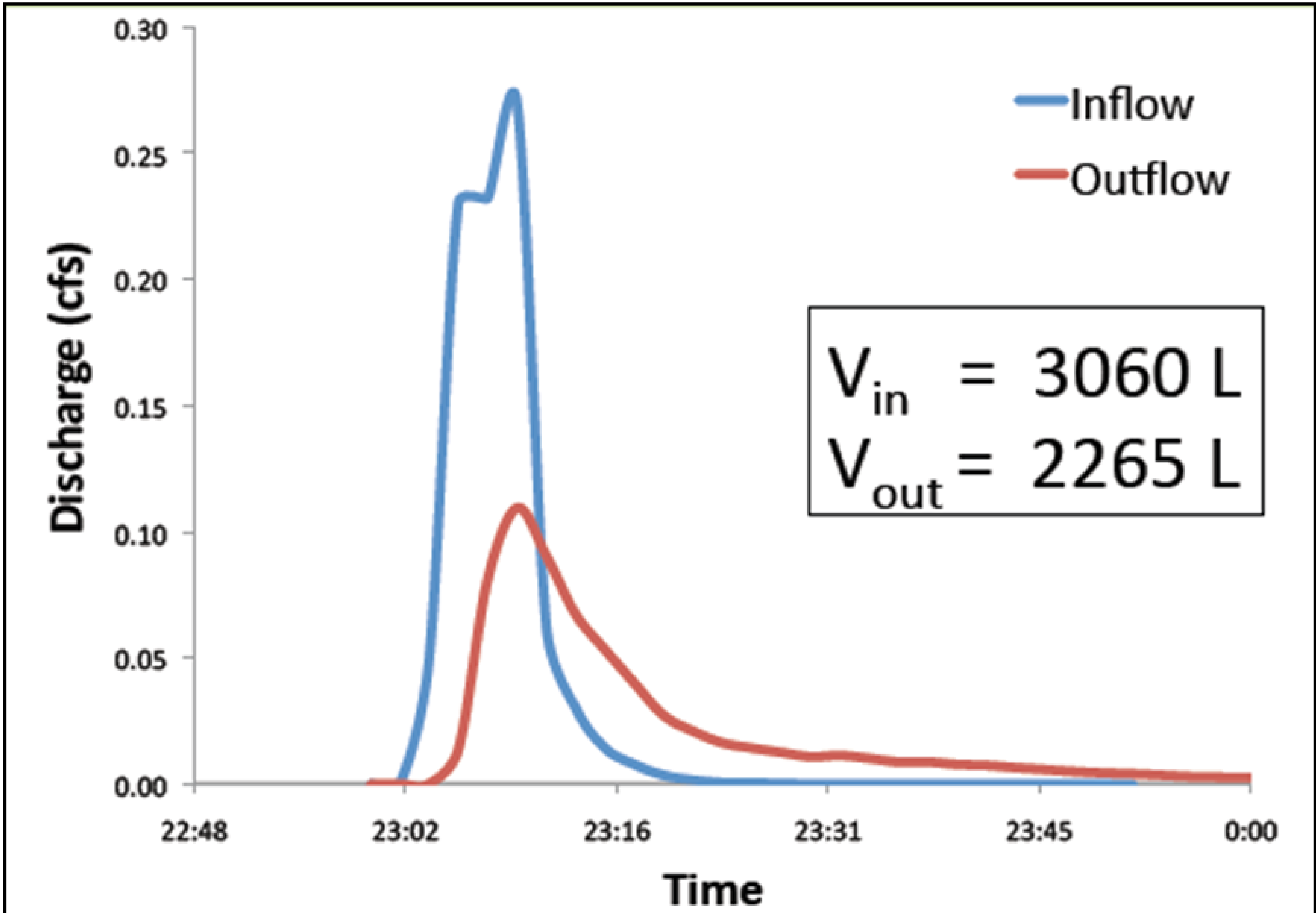
Hydrograph: 12.7 mm (0.5 in) storm on 9/6/12, Ann Street (typical street tree soil),



(Courtesy of Jonathan Page, Ryan Winston and William Hunt, Bio & Ag Engineering, North Carolina State University)

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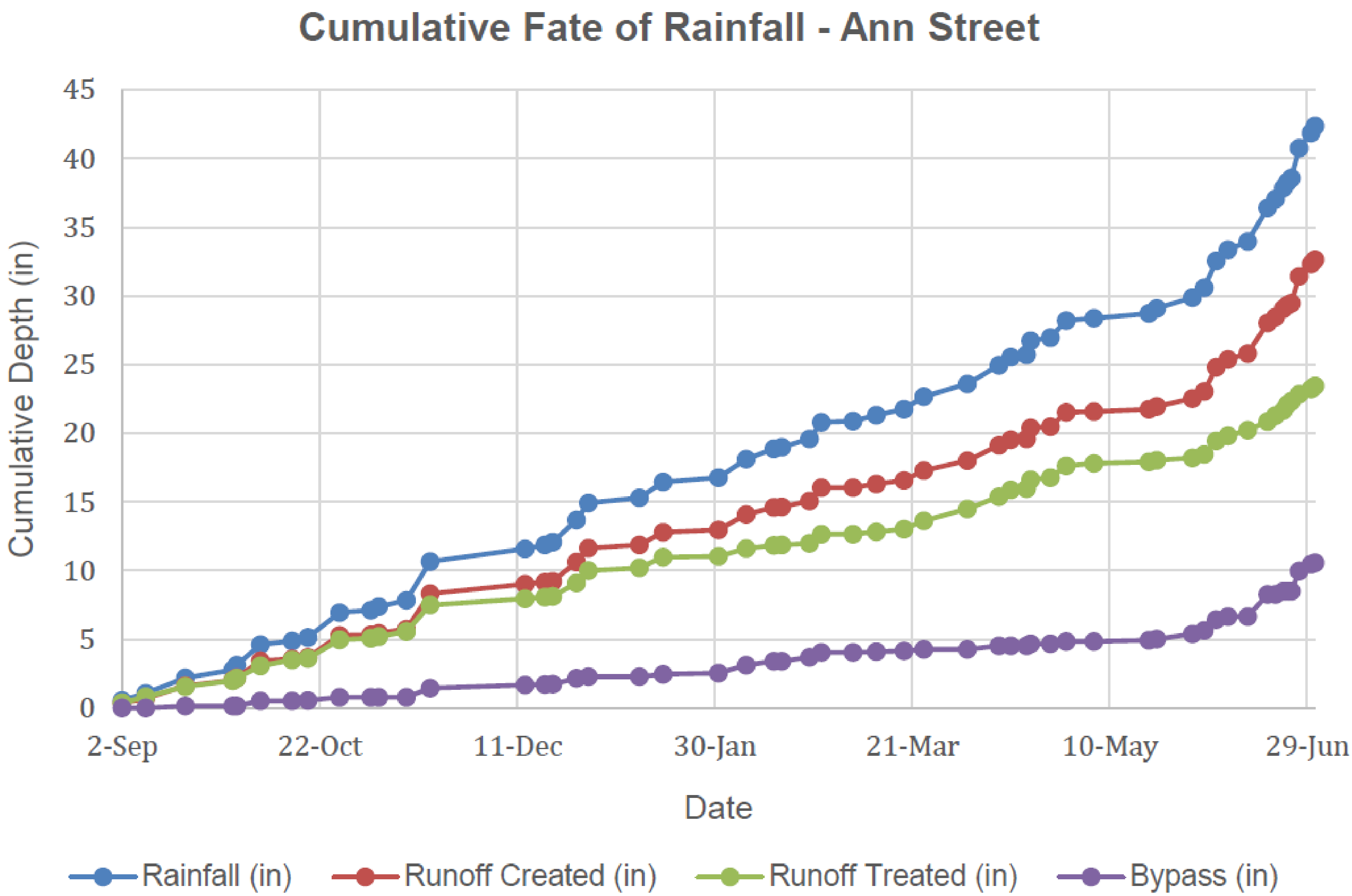

Cumulative Fate of Rainfall - Ann Street
Cumulative Depth (in)
45
40
35
30
25
20
15
10
5
0
2-Sep
22-Oct
11-Dec
30-Jan
21-Mar
10-May
29-Jun
Date
Rainfall (in)
Runoff Created (in)
Runoff Treated (in)
Bypass (in)

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Pollutant	Ann Street				Orange Street				PQL[b]	Bioretention Systems in Peer Reviewed Literature[c]
	n	IN (mg	OUT	Change in Concen-tration	n	IN	OUT	Change in Concentra -tion		Change in Concen-tration
TKN	21	0.75	0.22	-71%T*	18	1.99	0.33	-84% T*	0.38	-9
NO2,3-N	21	0.08	0.05	-35%T*	18	0.17	0.07	-60% T*	0.006	+14
TAN	21	0.11	0.03	-73% T*	18	0.33	0.08	-76% T*	0.006	-79
TN	21	0.82	0.27	-66% T*	18	2.17	0.40	-82% T*	NA	
$O\text{-}PO_4^{-3}$	20	0.03	0.01	-70% T*	19	0.18	0.03	-82% T*	0.006	NA
TP	21	0.12	0.03	-72% T*	18	0.41	0.11	-74% T*	0.01	+70
TSS	21	45	6	-86% S*	19	101	8	-92% T*	5-10	-79
Cu[a]	21	14.3	2.1	-85% T*	19	10	1.4	-86% T*	2	-28
Pb[a]	21	9.8	1.0	-90% S*	19	16	1.0	-94% T*	2	-29
Zn[a]	21	64	11	-83% T*	19	82	11	-76% T*	10	-78

Blue: Below detection limits

Green: Silva Cells performed better than mean for bio-retention in peer reviewed literature per Page et al 2013

Yellow: No comparison from peer reviewed literature provided in Page et al 2013

Conclusion

Silva Cell systems performed better or about the same as the mean for bioretention systems in peer reviewed literature for:

- **Total suspended solids** (TSS)
- **Heavy Metal** (Cu,Pb,Tn)
- **Pollutants** (TKN,NO2,3-N,TAN,TN,O-PO3-,TP)

"Unlike some bioretention systems, which leach nutrients, these two tree/soil/Silva Cell systems also provided nutrient removal."

"Tree/soil/Silva Cell systems have now been shown to be a viable option to provide sustainable storm water management in ultra urban areas, by providing tree rooting volume under paved areas with loads up to HS20 loading, where space does not allow for traditional bioretention systems."

University of North Carolina

J. L. Page[1], R. J. Winston[2], W. F. Hunt III[3]

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
PO Box 47600 • Olympia, WA 98504-7600 • 360-407-6000
711 for Washington Relay Service • Persons with a speech disability can call 877-833-6341

May 14, 2013

Brenda Guglielmina
DeepRoot Partners
530 Washington Street
San Francisco, CA 94111

RE: Silva Cells for Stormwater Runoff Filtration

Dear Ms. Guglielmina:

The Washington State Department of Ecology (Ecology) finds the Silva Cells functionally equivalent to a bioretention facility. The media specifications for Silva Cells must adhere to the guidelines for Bioretention areas, found in Appendix C, Volume III, in the 2005 Stormwater Management Manual for Western Washington (SWMMWW); or BMP T7.30 in the 2012 SWMMWW. The sizing procedure must also adhere to the procedure outlined in the Bioretention area of the manuals mentioned above or the procedure DeepRoot submitted to Ecology for design of the Silva Cells using WWHM dated March 2013.

Contractors may use the Silva Cells BMP at project sites without seeking additional Ecology approval though Ecology cannot endorse this product or its manufacturer. Manufacturer installation recommendations must be followed.

For more information, contact Doug Howie at douglas.howie@ecy.wa.gov, or (360) 407-6444.

Sincerely

Douglas C. Howie, P.E.
Stormwater Engineer
Program Development Services
Water Quality Program

cc: Kathleen Emmett, Ecology
Ed O'Brien, Ecology

"The Washington State Department of Ecology finds the Silva Cells treatment system functionally equivalent to a bio-retention facility."

"Contractors may use the Silva Cells BMP at project sites without seeking additional Ecology approval…"

Using the Western Washington Hydrology Model (Version 4.0) to Size Silva Cells for Runoff Treatment and Flow Control

March 2013

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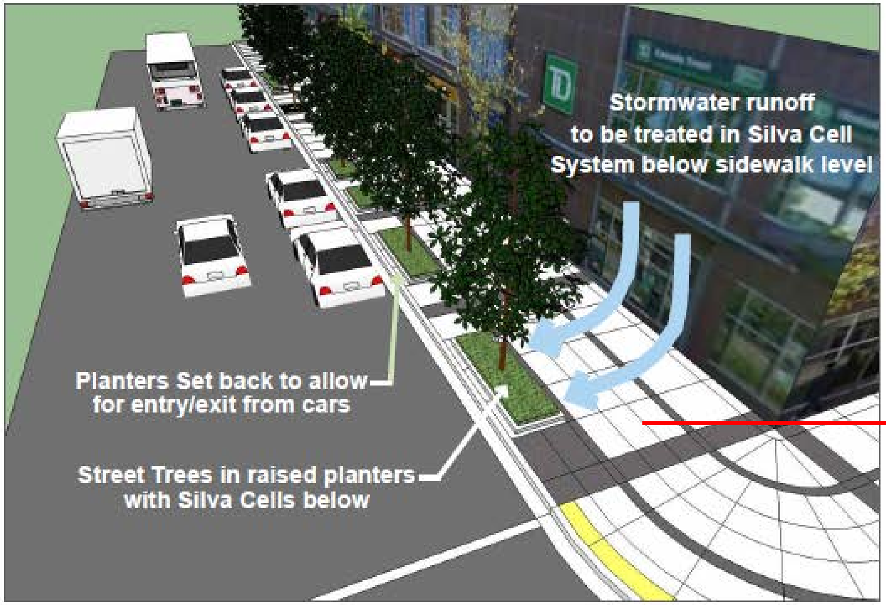
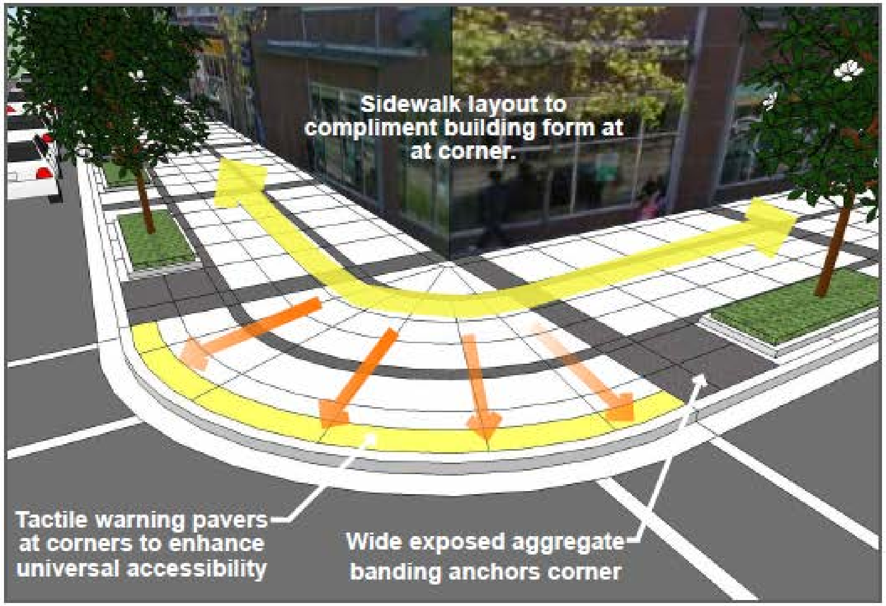
DeepRoot HDR

Lonsdale Streetscape Guidelines





Note: Universally accessible pedestrian drops not shown, but will be installed per MMCD standards.

Stormwater Trifecta

Peak flow reduction

Increase in Quality

Storage

- Evapotranspiration
- Interception
- Ground Re-Charge

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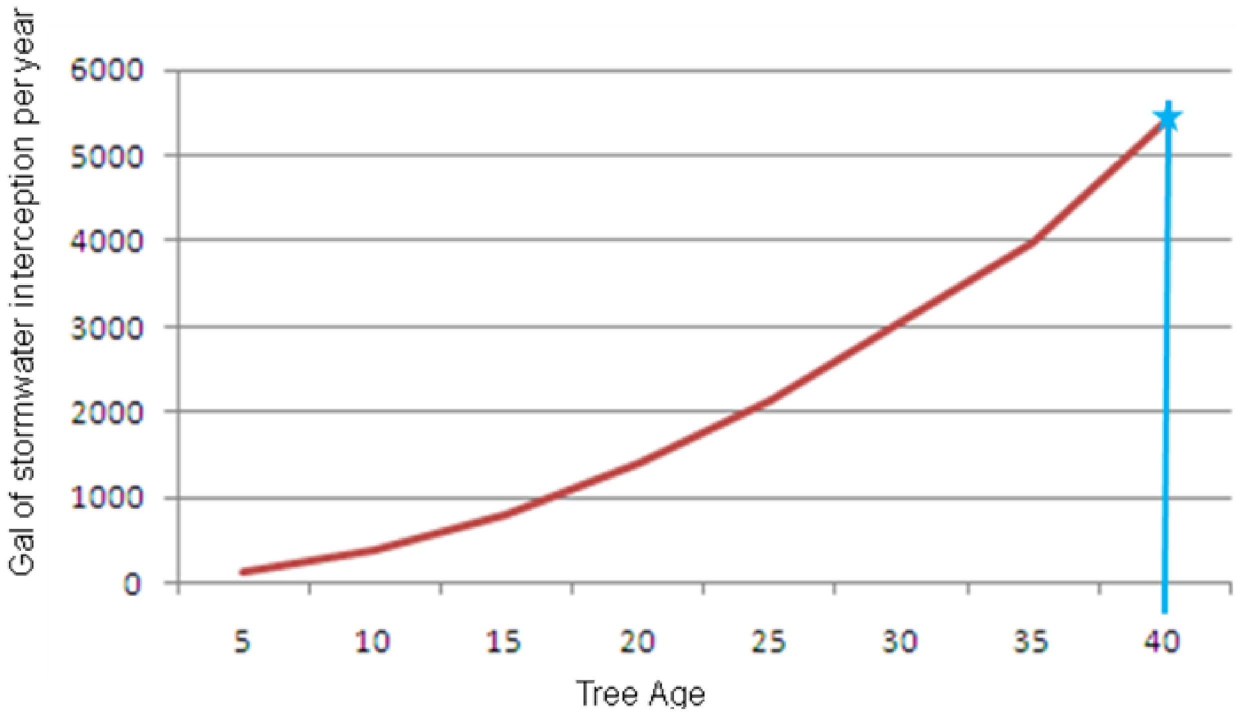
Interception

A model of a hackberry tree in the Midwest estimates that interception will increase as follows with tree age (see Figure 13.2):

- a 5 year old hackberry intercepts 0.5 m3 (133 GAL) rainfall per year
- a 20 year old hackberry intercepts 5.3 m3 (1,394 GAL) rainfall per year
- a 40 year old hackberry intercepts 20.4 m3 (5,387 GAL) rainfall per year



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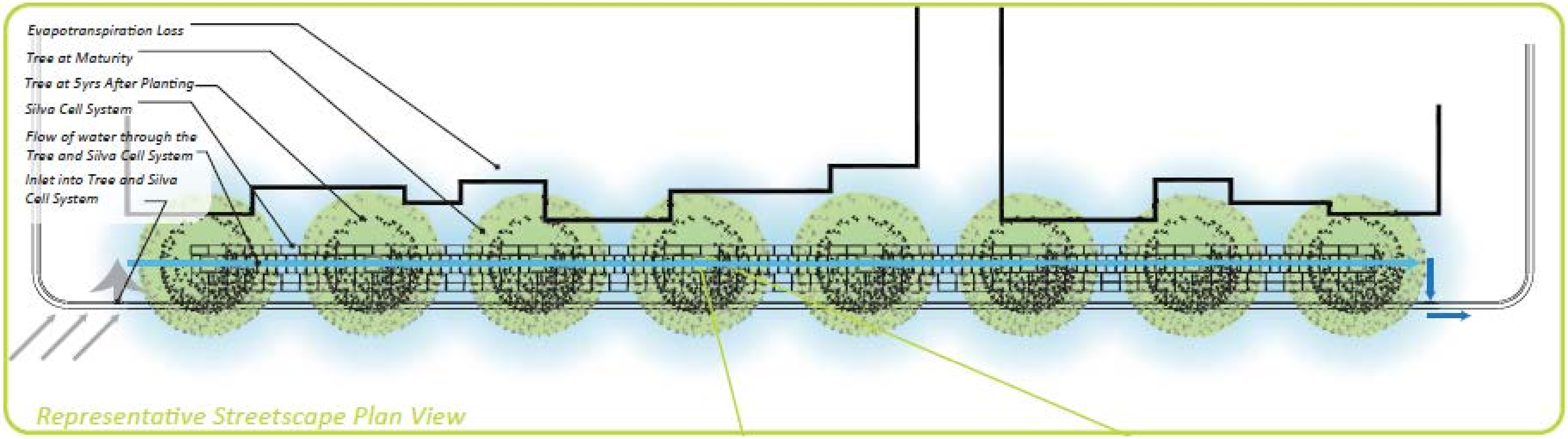
(McPherson et al, 2006).

Evapotranspiration Model for City of Toronto

Sample Streetscape Assumptions

- 90m (295ft) length of street draining into 1 catch basin in Toronto, Ontario, Canada
- 0.066ha (0.16ac) of impervious surfaces draining into the catch basin, runoff coefficient is 0.9
- 0.024ha (0.06ac) of pervious surfaces draining into the catch basin, runoff coefficient is 0.25
- Total runoff generated per catch basin from a 5mm (0.2in) storm is 3.27m3 (115ft3)
- Total runoff generated per catch basin from a 13mm (0.5in) storm is 8.5m3 (300ft3)
- Three days between rain events
- Eight Swamp White Oak *(Quercus bicolor)* were used in the calculations
- Each tree was provided with 33m3 (1,165ft3) of soil volume



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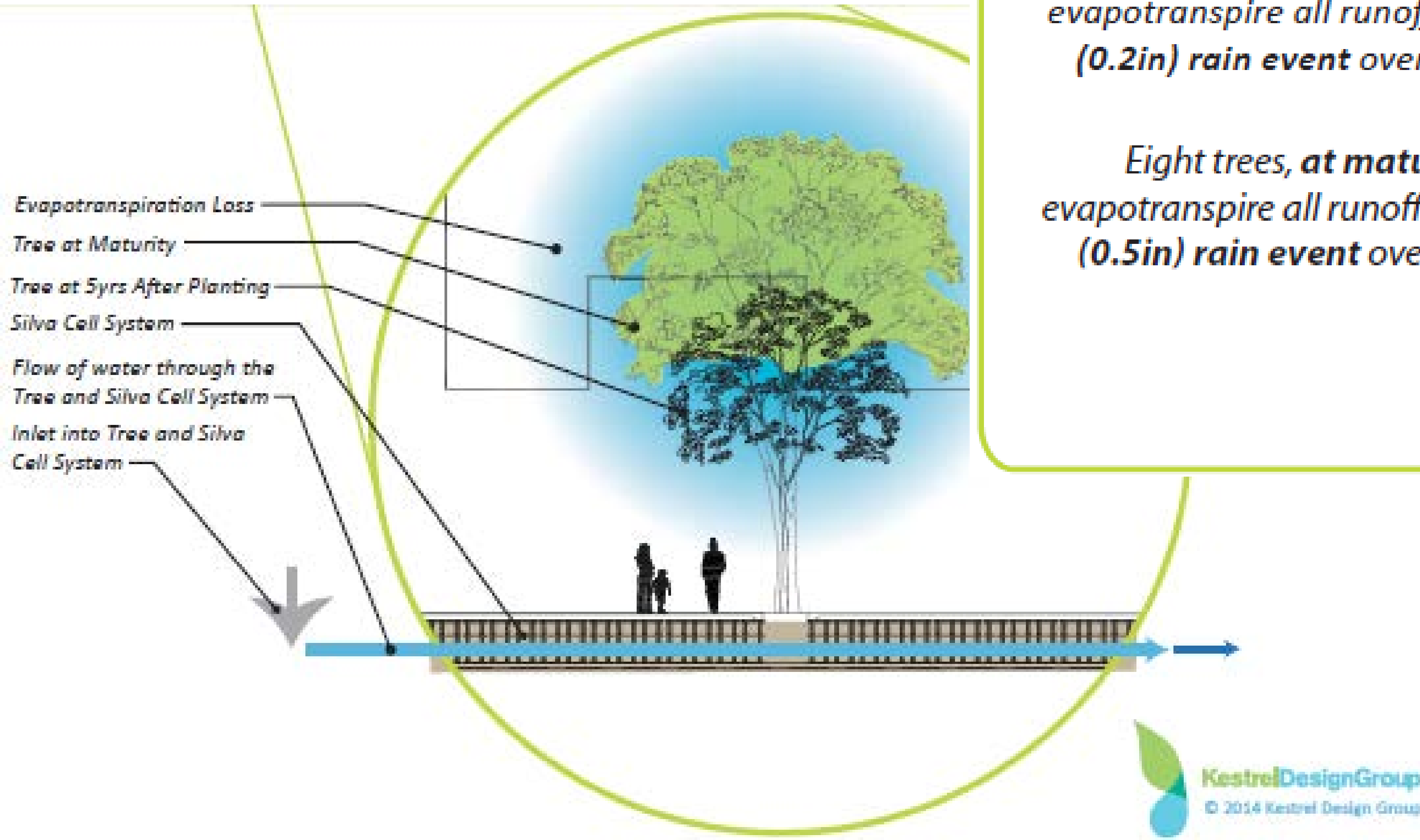
Evapotranspiration Model for City of Toronto

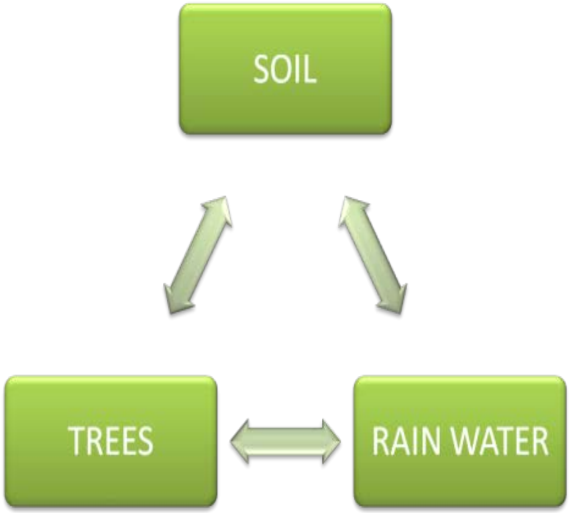


*Eight trees, **five years after planting,** can evapotranspire all runoff from a **5mm (0.2in) rain event** over three days.*

Eight trees, **at maturity,** can evapotranspire all runoff from a **13mm (0.5in) rain event** over three days.

“Nearly all of the associated problems result from one underlying cause: loss of the water-retaining and evapotranspiration functions of the soil and vegetation in the urban landscape.”

EPA Report: Urban Stormwater Management in the US



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Charlotte NC

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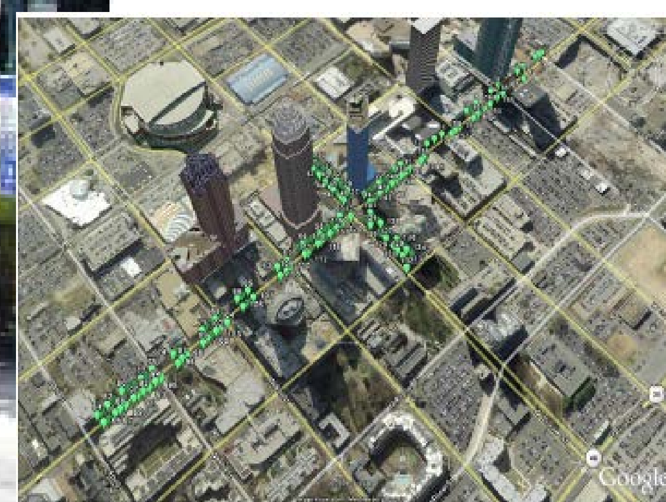
W. TRADE
U-HAUL
U-HAUL

Suspended Pavement Vaults

Charlotte, NC – 1985
Tyron St. (25 years)

<u>Willow Oaks:</u>
40cm (16”) DBH
13.5m (44ft) High
$19m^3$ ($700ft^3$) of soil / tree

98% survival rate



National Geographic Headquarters
Washington, D.C.

Soil Trenches

- 11.3 cubic meters
- (400 cubic feet) at year 12
- 200mm (8”) diameter DBH

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Jim Urban, LA

400 cubic feet
At year 16

400 cubic feet
At year 25

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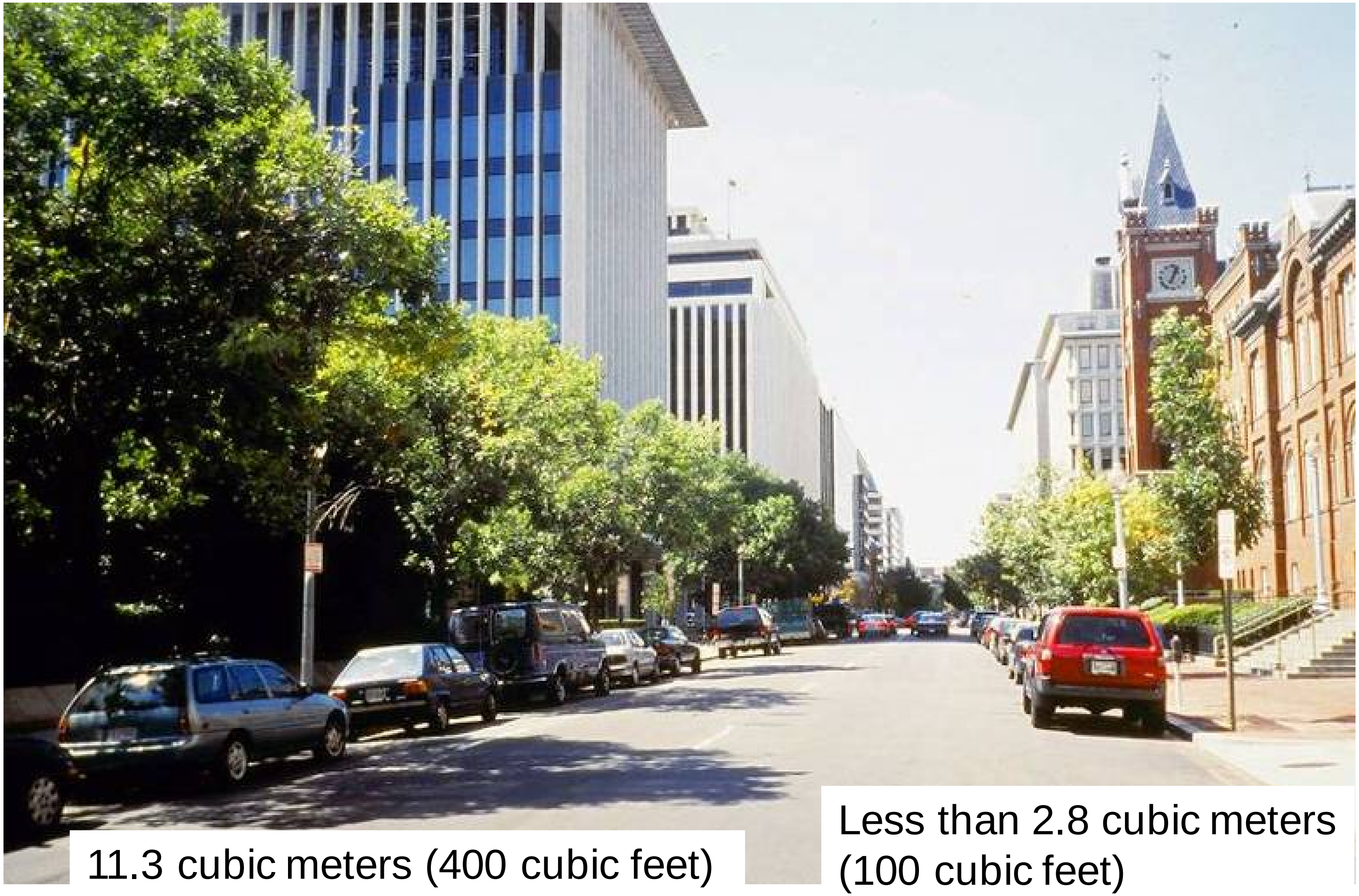
Value for Money



11.3 cubic meters (400 cubic feet)
At year 16

Less than 2.8 cubic meters
(100 cubic feet)
At year 16
Third replacement

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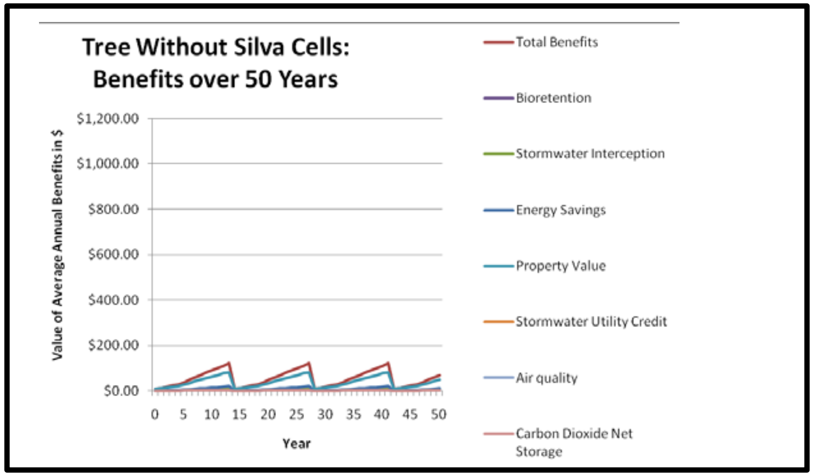
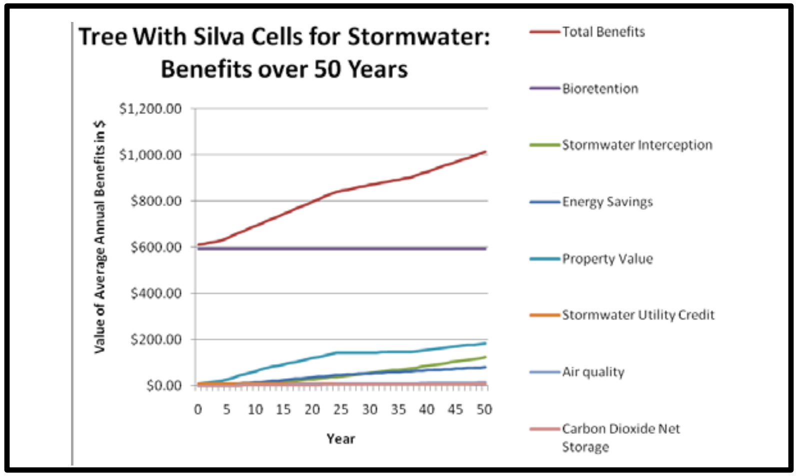
Value of Urban Tree Benefits Over 50 Years

Avg. tree in compacted soil lifespan: 13 years; Estimated Silva Cell lifespan: 50 years





Total Benefits over 50 years: $2,717.66
Total Costs over 50 years (installation & maintenance): $5,811.95
Net Lifecycle COST over 50 years: $3,094.29

Total Benefits over 50 years: $41,769
Total Costs over 50 years (installation & maintenance): $16,341.75
Net Lifecycle BENEFITS over 50 years: $25,427.22

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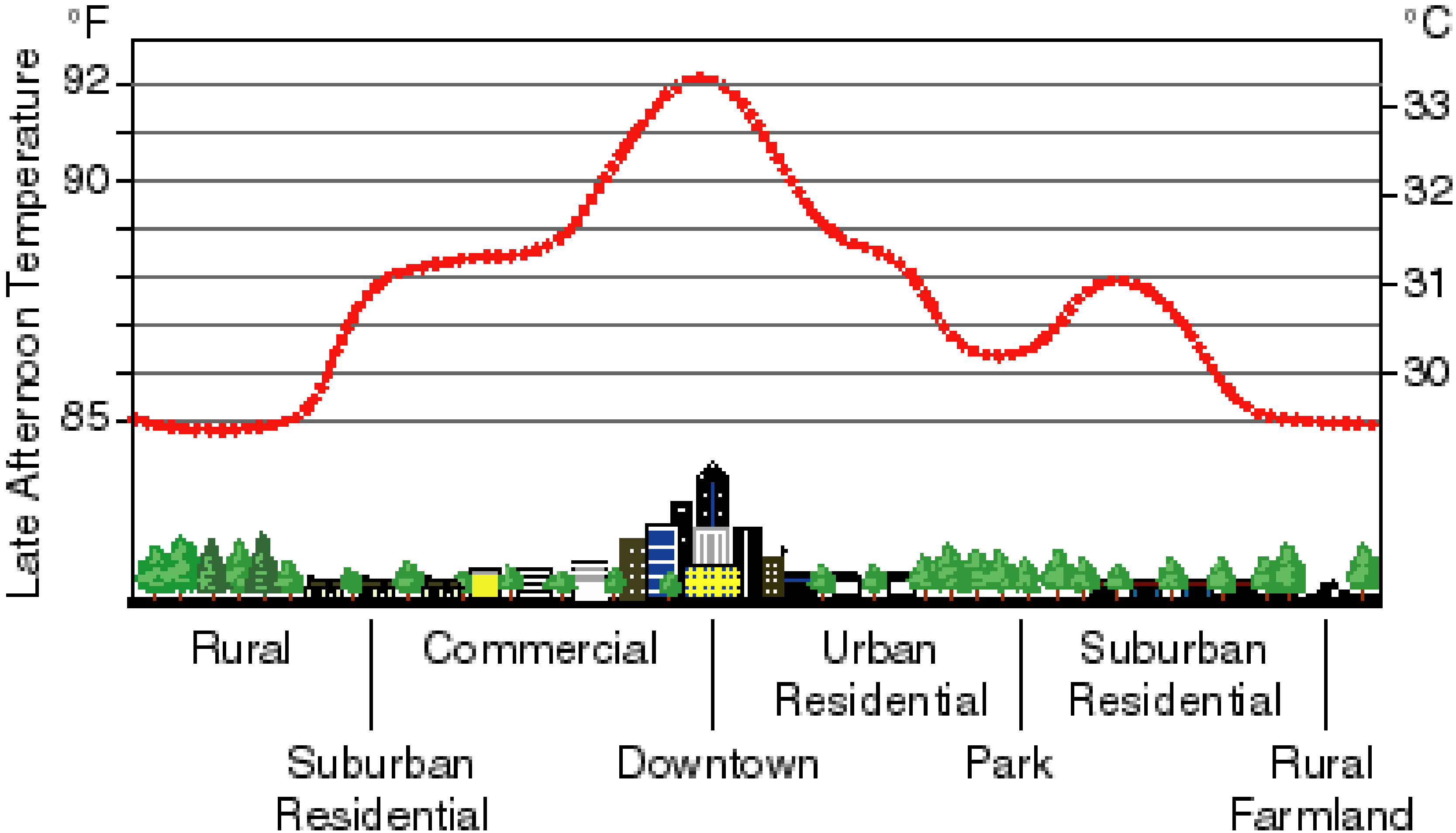
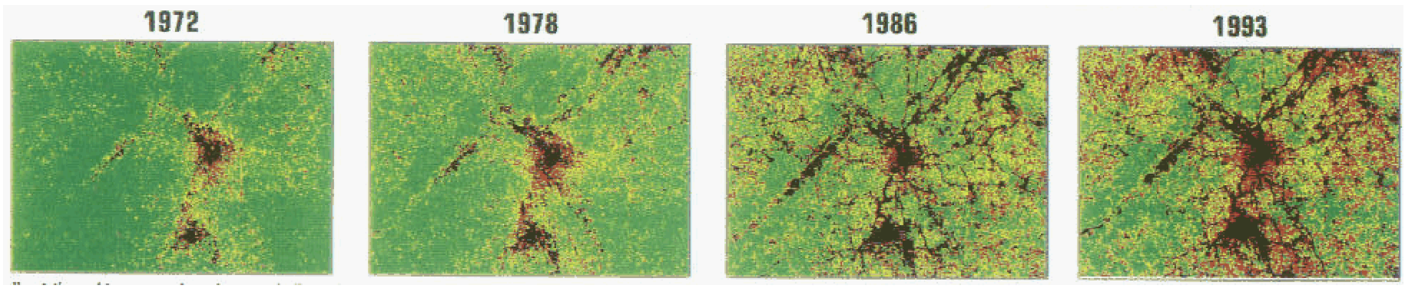
Sketch of an Urban Heat-Island Profile

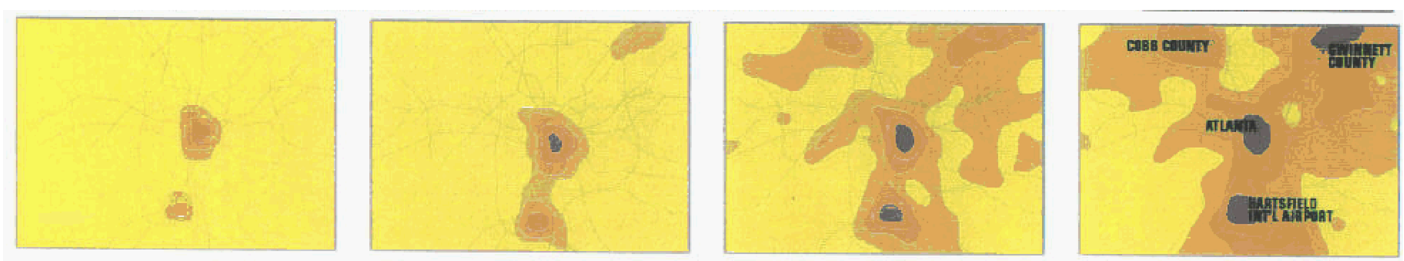


Source: Heat Island Group, LBNL, http://EETD.LBL.gov/HeatIsland

Vegetation and Heat-Island Trends in Metro Atlanta Area

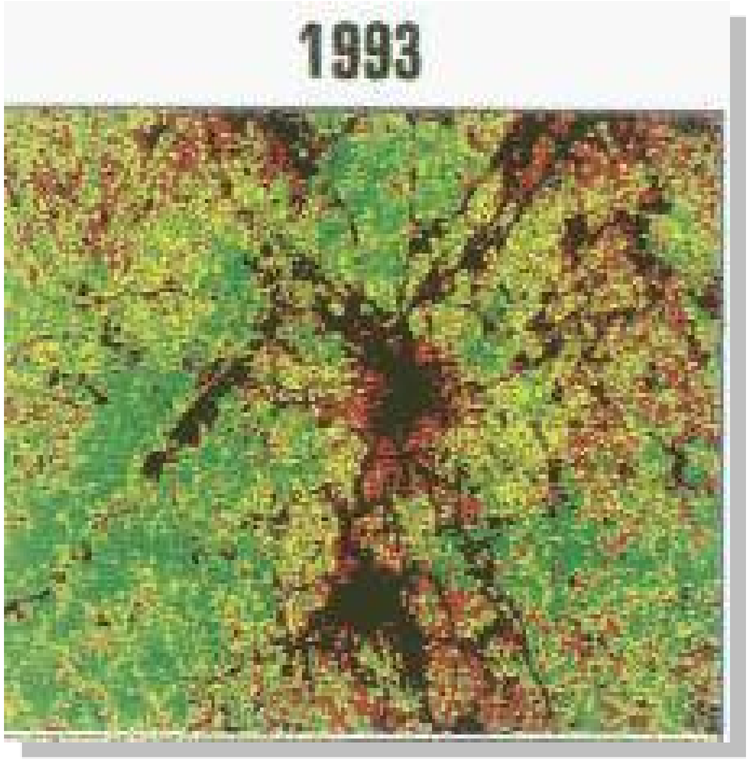


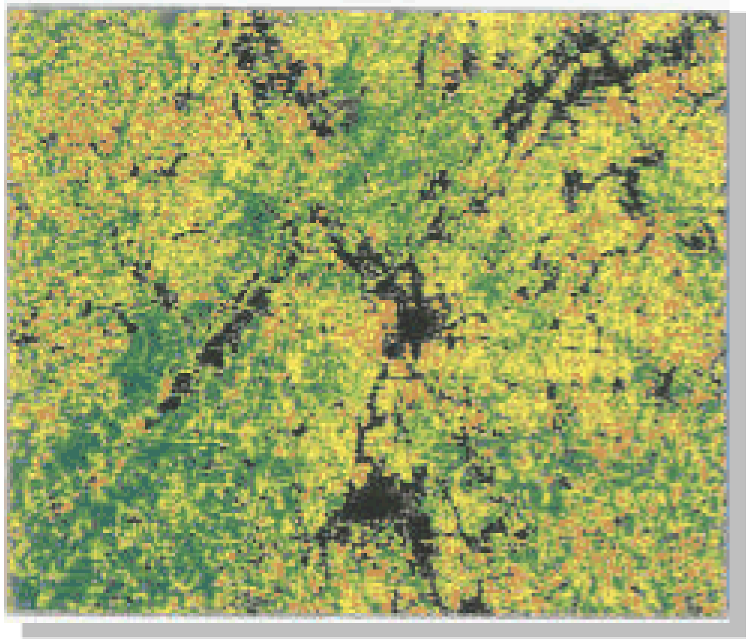
Vegetation and tree cover, shown in green, decline as build-up urban areas, in black, grow. Red and yellow areas area mixture of the two.



The growing urban heat island corresponds to the changing land cover. The hottest areas appear in black and expand from downtown Atlanta and Hartsfield International Airport.

Courtesy of Trees Atlanta





The map above is a projection of the area with a 20 percent increase in tree canopy from 1993 levels.

•Heat

•Hydrology

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Courtesy of Trees Atlanta

Current storm water problems and why GI is uniquely suited to solve these problems

Old problem and solution

Huge Pipe

=

Flood Control

New problem and solution

+

=

Flood Control
Volume
Rate
Water Quality

Medium Pipe

Source Controls

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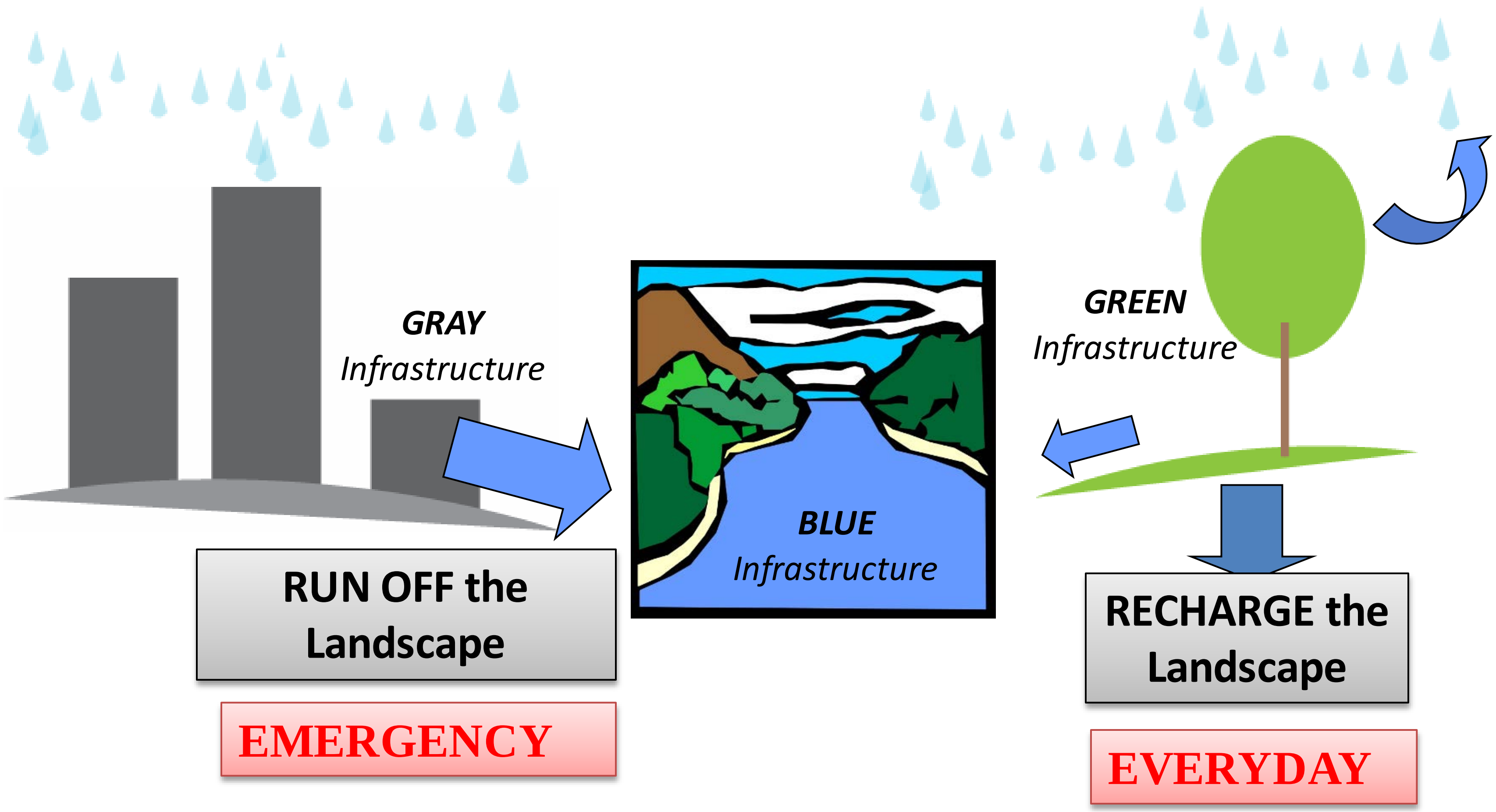
Green Infrastructure

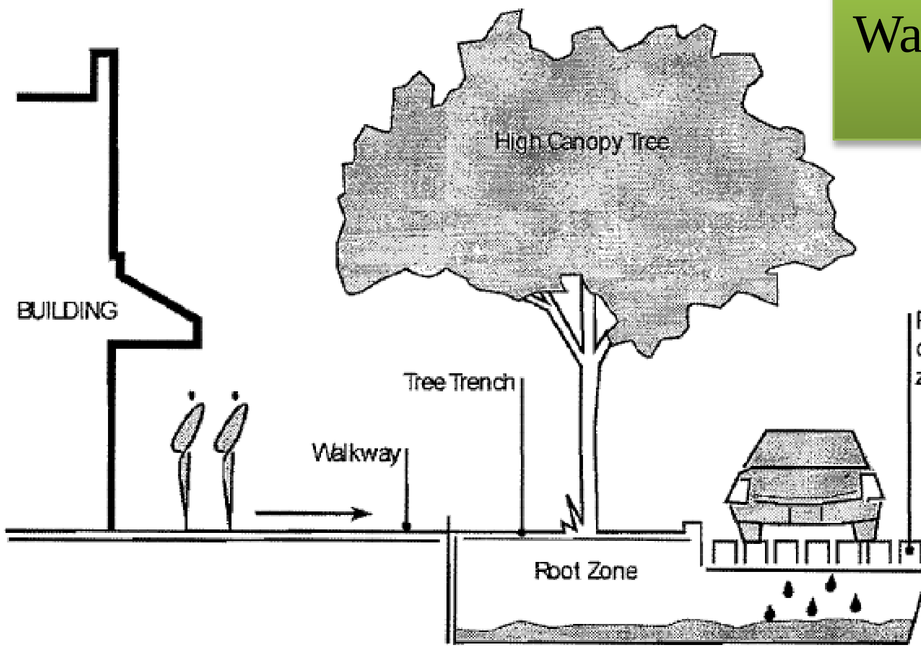
Avoided Gray Infrastructure Costs

Green Infrastructure to Reduce Gray Stressors and Improve Blue Quality



*Note: Water falling on paved surfaces is addressed by the Vancouver Building By-law and may require an Alternative Solution Application. Contact a professional or City of Vancouver Licenses and Inspections for further information how a design can meet the requirements of the By-law.

City of Vancouver
Water Wise Landscape Guidelines
2009

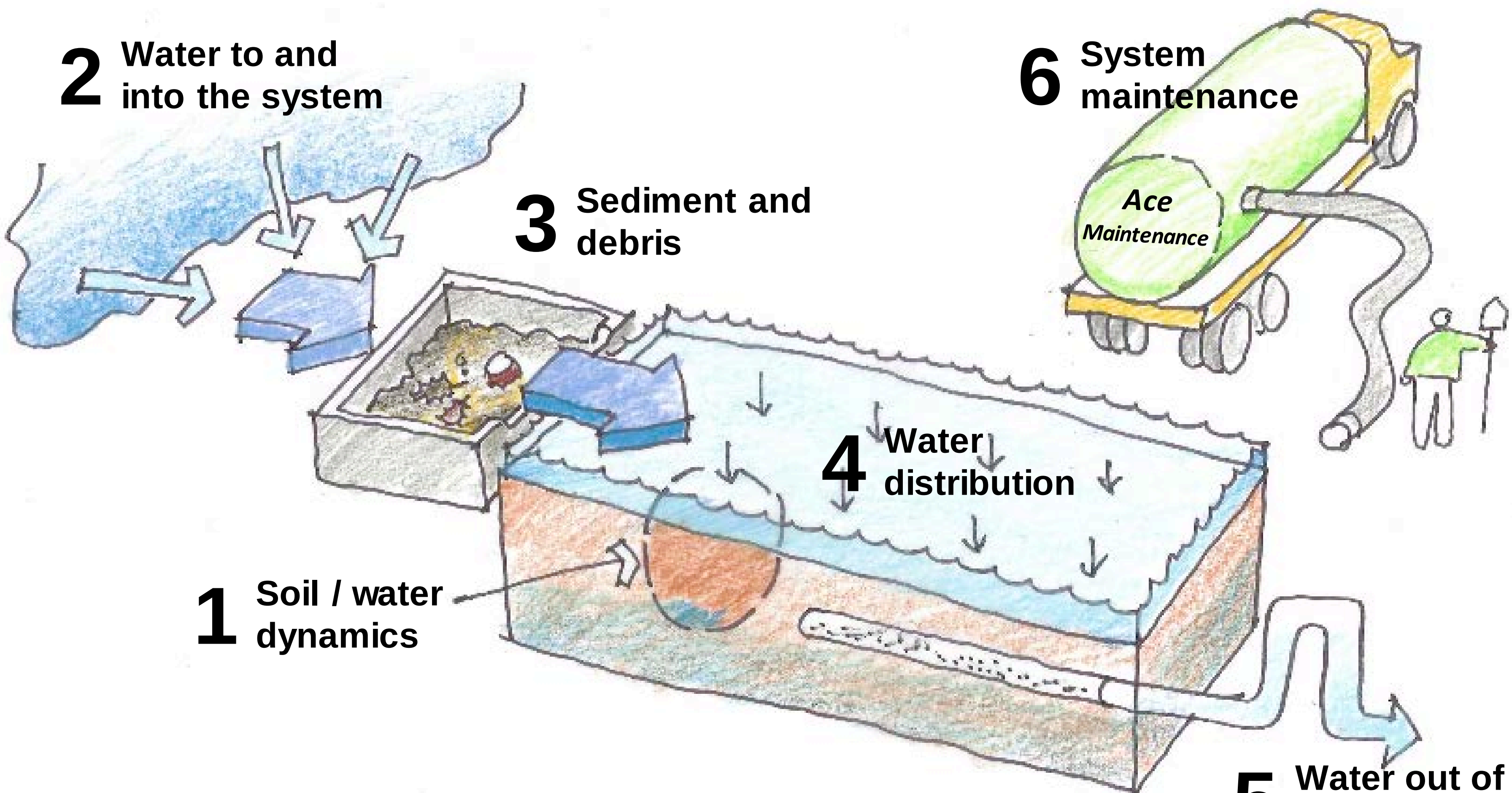


Permeable parking strips over clear crush structural rooting zone (eg: Structural Cells)

Figure 5. Permeable Paving

Through integrated design, permeable paving can be incorporated in a variety of urban settings. Refer to Metro Vancouver's Stormwater Source Control Design and Guidelines

Webinar: Using trees and soils in urban stormwater management



Urban Storm Water Systems

First principles

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James Urban

https://www.youtube.com/watch?v=-OMnKnCYVAg