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Civil Engineering
Landscape Architecture
Environmental Restoration
Planning

Green Factor Workshop

Rain Gardens & Permeable Paving Systems

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Topics to Cover

- Rain Gardens
  - Overview
  - Stormwater Planters
  - Bioretention
  - Examples
- Porous Pavement Examples
  - Types of Pervious Pavement
  - Applications
  - Design Considerations Overview
  - Pre-planning & Construction Issues
  - Post Construction
  - Maintenance
  - Lessons Learned
- Q & A
- Resources

Swales – What are they? A non- technical view

Swale	Graded Depression
Ditch	Deep- cut steep side slopes
Conveyance Swale	Purpose to move water
Bioswale	Regulated/engineered to clean water
Bioretention Swale	Generally –planted and soil retains water
Natural Drainage Swale	Generally – engineered system of swales
Raingarden	Generally- organic shaped depression with modified soil and plants to soak up and retain water. Typically has overflow.
Stormwater planter	Generally- more structural to complement building- functions as retention to reduce stormwater discharge. Planted
Furrow	Small conveyance swale
Dispersal or Infiltration Trench	Underground washed rock or gravel

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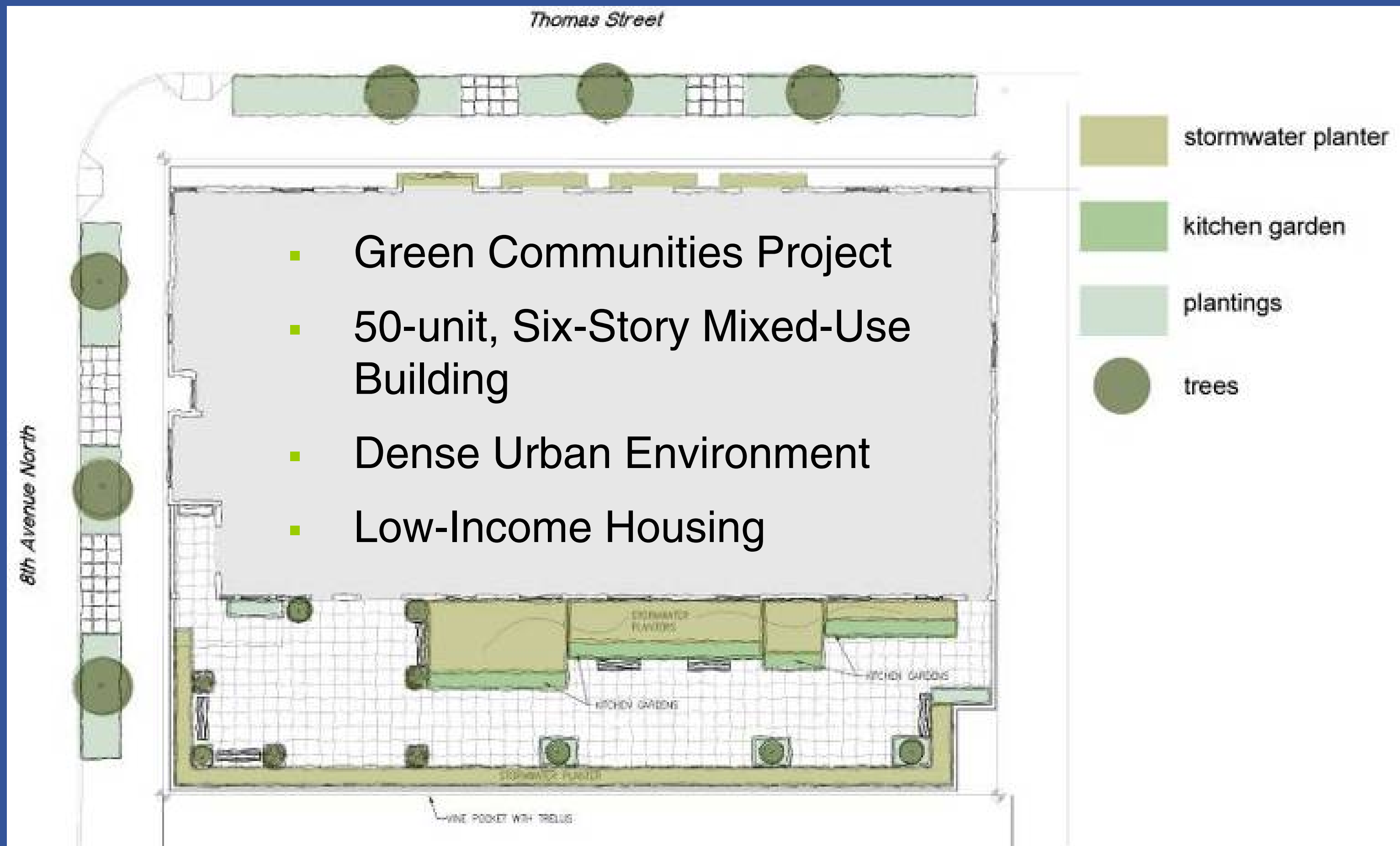
Raingardens

- Garden-Style Treatment of Runoff
- Depression
- Plant Choices
- Placement
  - Planters (Multi-story buildings)
  - Yards / Sites
  - Street Right of Way

Raingardens - Malmo, Sweden

- Advanced Applications
- What Makes the Difference?
  - Planning
  - Permitting
  - City advocacy
- ADA Issues
- Regional Sustainability Study Tour of Sweden-Denmark (June 2-8, 2007)

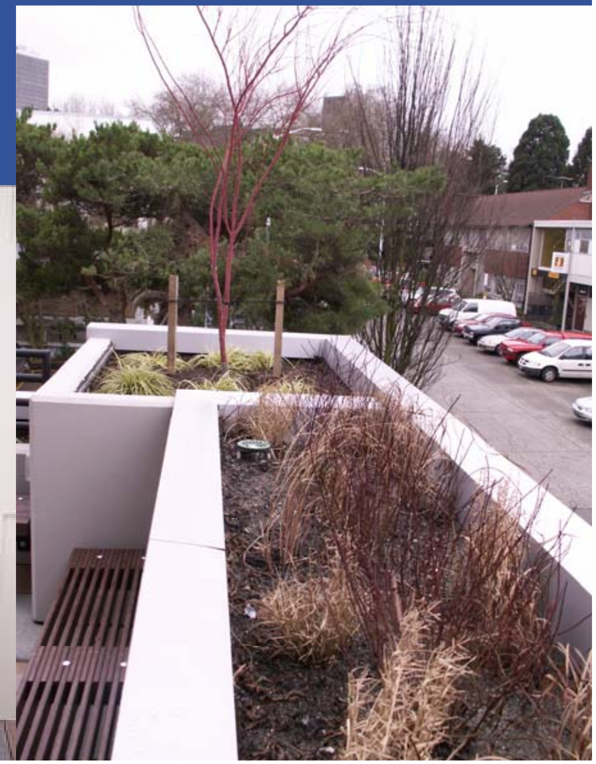
Denny Park Apartments

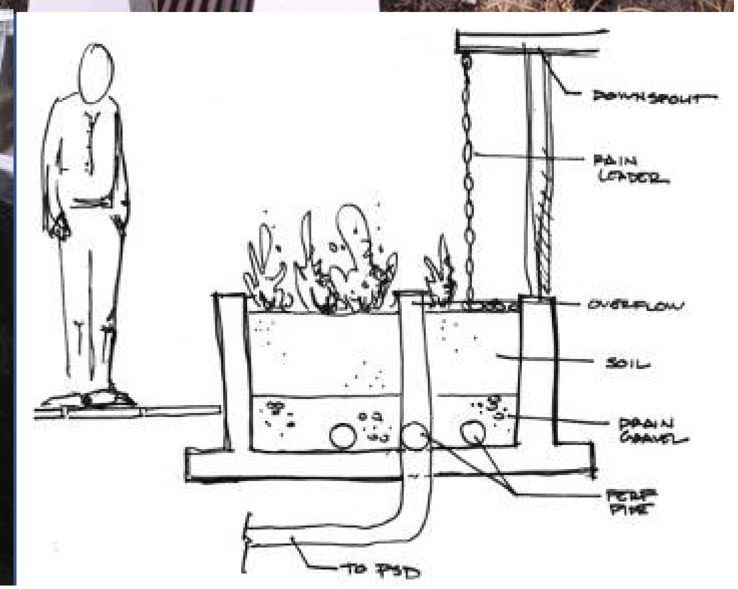


- Green Communities Project
- 50-unit, Six-Story Mixed-Use Building
- Dense Urban Environment
- Low-Income Housing

Denny Park Apartments

- Collection and Conservation of stormwater
- Irrigation of Landscaping
- Low-Maintenance Landscaping
- Drought-Resistant Plantings





High Point Public Natural Drainage Systems

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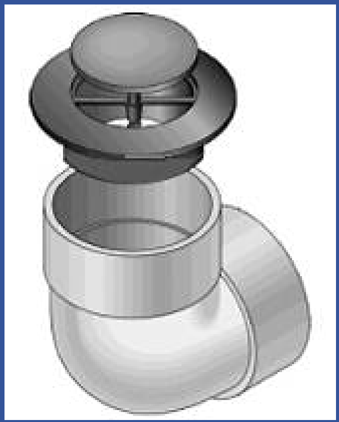
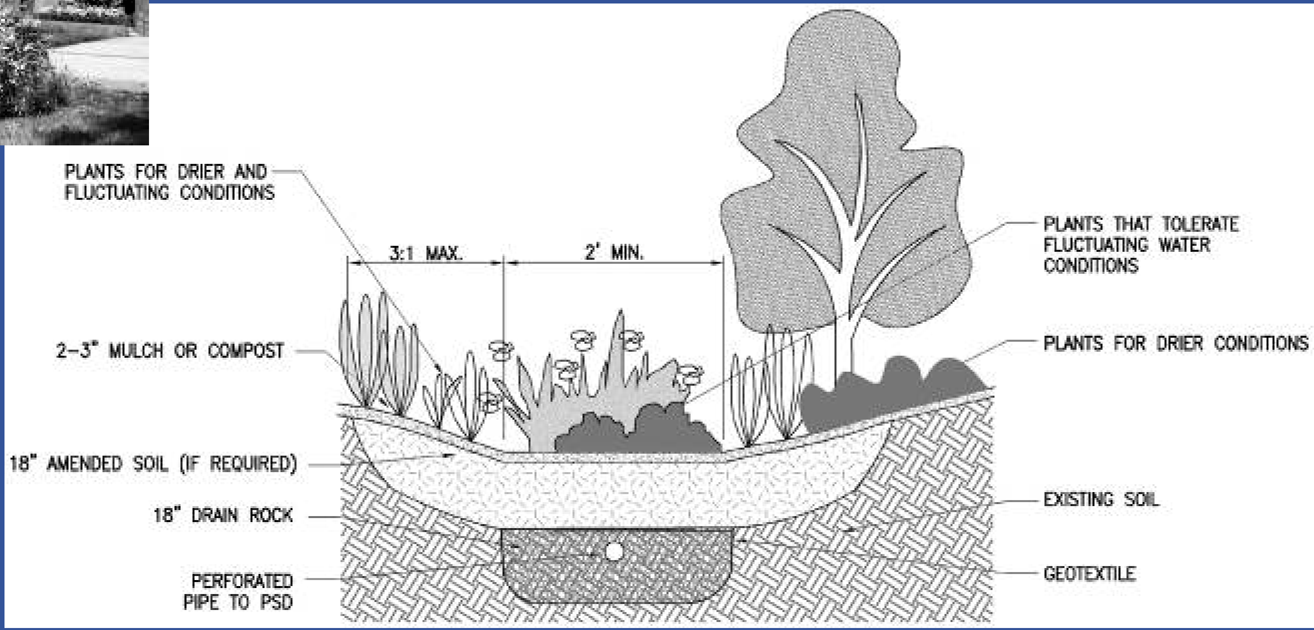
High Point Rain Gardens and Pop-up Emitters

- Small storm detention
- Overflows over land or through grate to NDS





- Releases flow away from building

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High Point Raingarden

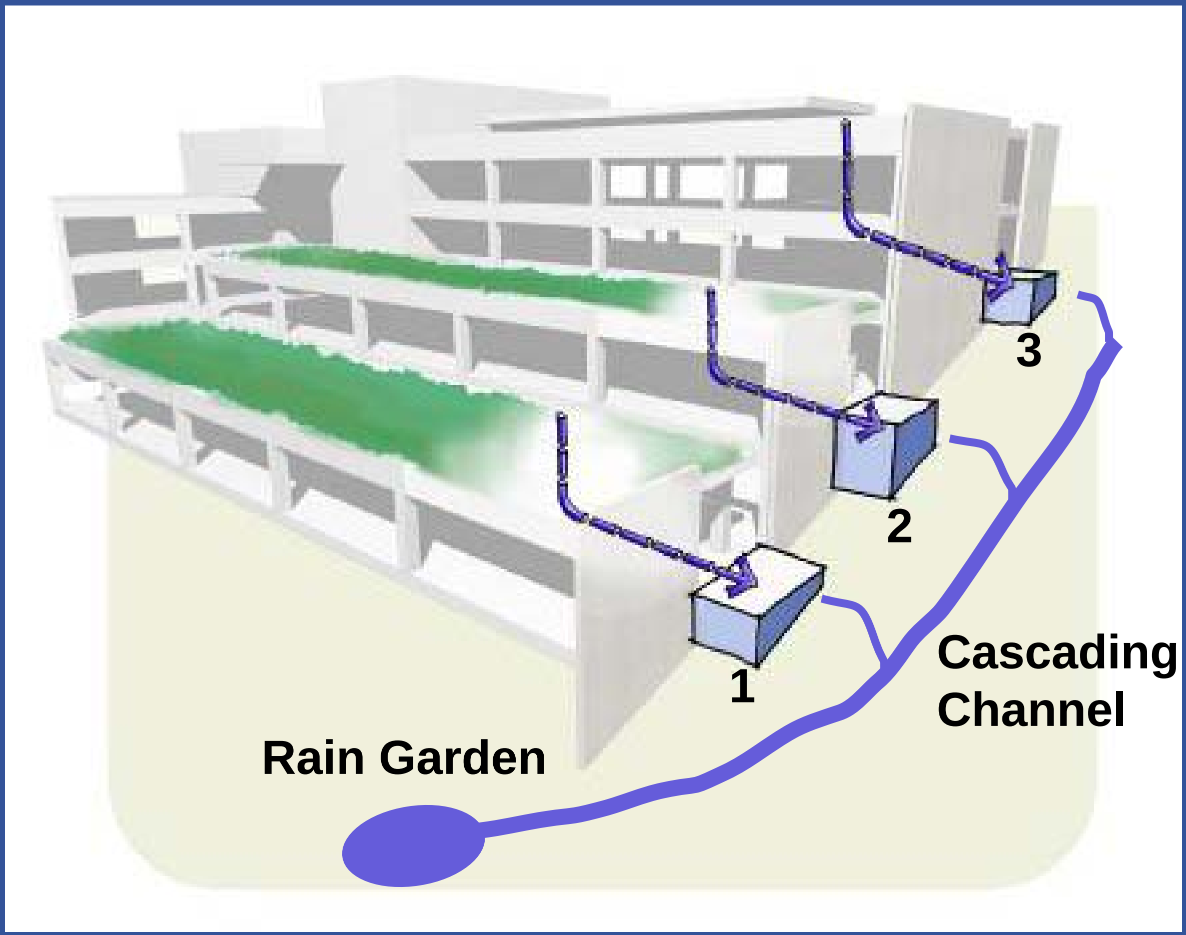
- Built into Yards
- Maintaned by Owners
- Roof-Top Runoff
- Vegetation
  - Grasses
  - Small Shrubs

Seattle Public Utilities Rain Catchers

- Different Palettes

Maryland Housing Retrofit

Kitsap County Administration Building



- Prime: Miller-Hull
- Urban Redevelopment
- Green roofs for runoff control
- Cisterns
- Rainwater harvesting for raingarden irrigation
- Integrating Disciplines

Kitsap County Administration Building

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Tregaron, Washington, DC

- Historic Site
- Restore Site to 1911 – 1941 Character
- Improve Habitat, Vegetation, Water Quality
- Issues
  - Compact dimensions
  - A/E community reservations

Euclid Street, St. Louis, MO

- Options Evaluated / Included
  - Porous Pavements
  - Rain Gardens
  - Rainwater Harvesting
  - Habitat Patches

Euclid Street, St. Louis, MO

- Challenges
  - Icy lanes
  - Rain garden maintenance
  - Salt-tolerant plant materials
  - Character Issues

Buckman Heights Apartments

- Portland
- Integrated into Building Character
- Rain Garden in Plaza for Roof
- Plant Palette Reflects Building Character
- Rhododendrons

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Liberty Parking Garage, Portland

- Receives runoff the parking garage roof
- Rain garden adjacent to parking garage
- Improve the Urban Environment
- Integration of Trees

Oregon Museum of Science and Industry (OMSI), Portland

- Rain Garden receives runoff from parking lot
- Landscape Features
- Softens the Site

People's Food Coop, Portland

- Has it all
- Green Roof
- Pavers in plaza
- Rain Garden along street & in plaza
- Retail Integration Works Very Well
- Dramatic Site Work Can Assist with Rain Garden Aesthetic
- Be Bold





Permeable Pavements

- Pervious Material Types
  - Porous Portland Cement Concrete
  - Porous Asphalt Concrete
  - Pavers
  - Grass Pave
  - Open-Celled Paving Grids
- Design
- Construction
- Maintenance
- Lessons Learned





Benefits of Porous Pavements & Pavers

- Water Quality Treatment
- Flow Control
- Eliminates or minimizes the treatment facilities
- Optimizes Space within ROW utilities
- Reduces Temperature of Runoff to Streams
- Reduces Heat Island Affect
- Benefits Trees and Landscaping
- Paved Surface

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Porous Portland Cement Concrete Pavement

- Mix with no fine aggregates
- Voids in pavement allow water to flow through section
- First installed in 1852 in the UK
- Used in the United States since 1970’s for paving applications, mainly in the Southeast Regions but has spread across U.S.
- Low-volume residential streets

32nd Avenue SW, Seattle, WA

Parking Lot

Applications of Porous Portland Cement Concrete Pavement

- Public walkways
- Parks
- Plazas and Patios
- Greenhouse Floors
- Surface Course for Tennis Courts
- Basketball Courts
- Noise barriers / walls

Public Sidewalk

Ernst Park

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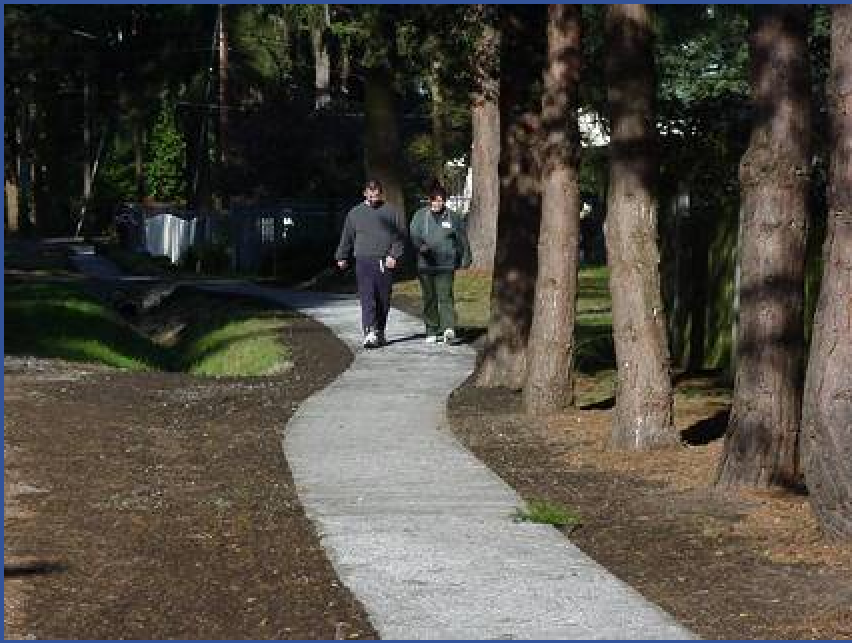
Examples of Porous Portland Cement Concrete Sidewalks

- Benefits Trees
- Reduces uplift of pavement from roots



Serene Way Sidewalk

Photo and Projects Courtesy of Randy Sleight, PE, Snohomish County from Fall 2006 APWA Conference presentation

Portland's Porous Portland Cement Concrete Roadways

- Constructed in Fall 2005
- N. Gay Avenue
- 10" Porous Concrete over 6" Subbase
- Full Street Section w/porous cement concrete (PPCC)
- One Street with PPCC in parking lanes only
- Reused existing curb and drain collection structures

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Seattle's 32nd Ave SW Porous Cement Concrete Pavement in Snow

- Studies underway in colder climates
- Been installed in cold climates such as Iowa, Pennsylvania, Colorado

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Safeway Parking Lot
Denver, CO – Next AM Following 12” Snow

Sites directly across street

Photos: 5 min. differential max

Pervious Concrete

Conventional Asphalt

Photos courtesy of National Ready Mixed Concrete Association and Slide courtesy of Center for Portland Cement Concrete Pavement Technology, 2005 via John Kevern at National Concrete Pavement Techology, Iowa State University

Fremont Library/Ernst Park, Seattle, WA

- Porous Cement Concrete Sidewalk
- Hillside Location
- Curvilinear layout

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Snoqualmie Gourmet Ice Cream Parking Lot Paving

Photo and Projects Courtesy of Randy Sleight, PE, Snohomish County from Fall 2006 APWA Conference presentation

City of Portland Porous Asphalt Concrete Pavement

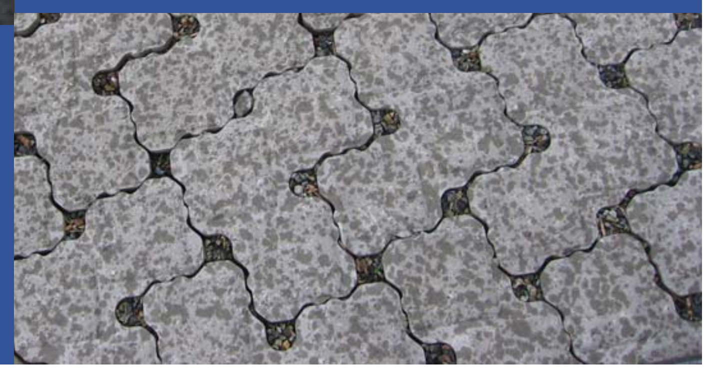
- N. Gay Avenue
- 8” Porous Asphalt over 6” granular base
- Reused existing curbs and drain collection structures
- Open graded asphalt (no fines)

Geocells - GravelPave² System for Parking Stalls

- Invisible Structures, Inc.
- Ring and Grid structures over Gravel Base
- Other: GrassPave² for Lawn finish

Permeable Pavers

- Developer: Lyle Homes
- Prime: Mithun
- Private Residential Drive
- Pavers through Mutual Materials
- Pavers over 3” Bedding Course and 10” Base Course for this installation
- Quick Installation 4’x4’ Grids
- Gap at joints



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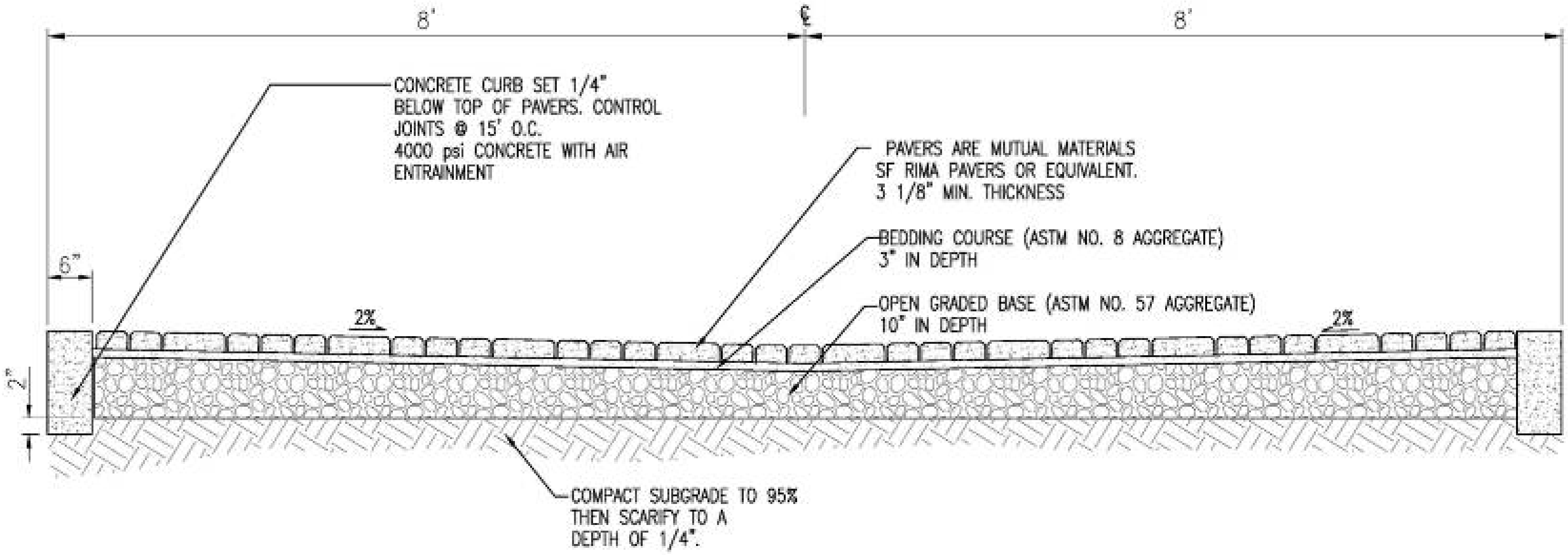
Example Section for Permeable Pavers



NOTES:

1. NO. 8 AND NO. 57 AGGREGATE SHALL BE OPEN GRADED, CRUSHED STONE. DO NOT USE ROUNDED GRAVEL OR STONE.
2. AGGREGATE BASE GRADATION PER PAVER MANUFACTURER'S STANDARDS FOR POROUS INSTALLATION.

NTS

Private Porous Drive Cross-Section

Open-Celled Paving Grids

- Parking lot
- Fire/Emergency Access Lanes
- Continues Green Planter Strip
- Grid units over bedding sand and base

Salty’s on Alki Overflow Parking

Design Considerations for Porous Pavements

- Determine your Design Goals
  - Reduce runoff flow rates? What storm event?
  - Water quality treatment?
  - Reduce impervious area?
  - Aesthetics?
  - Traffic loading?
- Design Conservatively – porous concrete
- Location
- Stabilization of adjacent areas
- Infiltration Rate through Porous Cement Concrete & Asphalt Pavement Section not limiting factor.
  - Seattle's porous cement concrete pavement street at High Point: 200 in/hr and greater.
  - Intensity of 100 year 24 hour storm event in Seattle: 2.3 in/hr (over 10 min interval)

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Design Considerations for Porous Pavements Continued

- Subgrade Soil Characteristics Control Infiltration Rate
  – Existing subgrade soils testing
  – Infiltration rate after construction
  – 0.5in/hr minimum percolation rate of subgrade (NRMCA)

- Subgrade Slope and Storage
  – Ideal 0% to maximize storage but can increase excavation
  – Sloped conditions (1% to 5%) reduces the amount of useable storage space but decreases amount of excavation. Use periodic impermeable check dams, or gravel trenches or other measures to allow water to backup & infiltrate/direct away.

- Overflow/Back-up System (various opinions yea or nay)

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Example: Seattle's First Public Porous Pavement Street
Existing 32nd Avenue SW

- Project: Seattle Housing Authority's High Point Redevelopment
- Longitudinal Slope 3% +/-
- Drainage basin 4.6 acres
- Existing developed basin with 8 dwelling units per acre
- Road 32' wide
- Sidewalk on one side of street
- Parking on grass areas
- 40% impervious
- 60% pervious

Example: Design Goals for 32nd Ave SW

- Pilot Porous Pavement Street for City of Seattle
- Infiltrate the 6-month Storm Event for the Roadway Section only
- Reduce the Existing Developed Peak Flow Rate up to the 2-year Storm Event
- Integration of Redevelopment into Existing Neighborhood
- Traffic Calming
- Provide Service for Residential Street Loading Condition

Example: Design Parameters for Seattle's First Public Porous Cement Concrete Pavement Residential Street

- 8" Compacted Thickness for Road over 18" Gravel Subbase
  - Designed for Residential Street Loading
- Cement Content (Two Mix designs 564 & 582 lbs/cy were chosen for comparison based on test panel results)
- Mix Aggregate: AASHTO No. 8* (3/8" to No 16) or No. 89 (3/8" to 50)
- Mix Design Non-Proprietary
- Water Cement Ratio 0.27 to 0.35*
- Voids 15% to 21%
- Field Infiltration Rate 200 in/hr through Pavement
- Design Flexural Strength 450 psi
- No Dowels (Corrode with Water in Pavement)
- Joints every 15-feet (Depth1/3 Pavement Thickness)

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Example: Design Assumptions/Parameters for 32nd Ave SW Subbase and Subgrade

- 20% Voids for Gravel Storage Subbase ¾” to 1 ½” Washed Crushed Aggregate for Road Subbase
- 3/8” to ¾” Washed Crushed Aggregate for Sidewalk Subbase
- Compaction 92% for Roadway Subbase
- Scarify Existing Subgrade to Prevent Sealing of Subgrade
- Geotextile between Existing Subgrade and Gravel Subbase
- Maximum Ponding Depth within Gravel Storage Subbase 1-foot
- Gravel Storage Subbase below Freeze/Thaw Depth (10” to 12”)
- Existing Subgrade Design Infiltration Rate 0.25 in/hr (silty fine sand to fine sandy silts) per Geotechnical Review.

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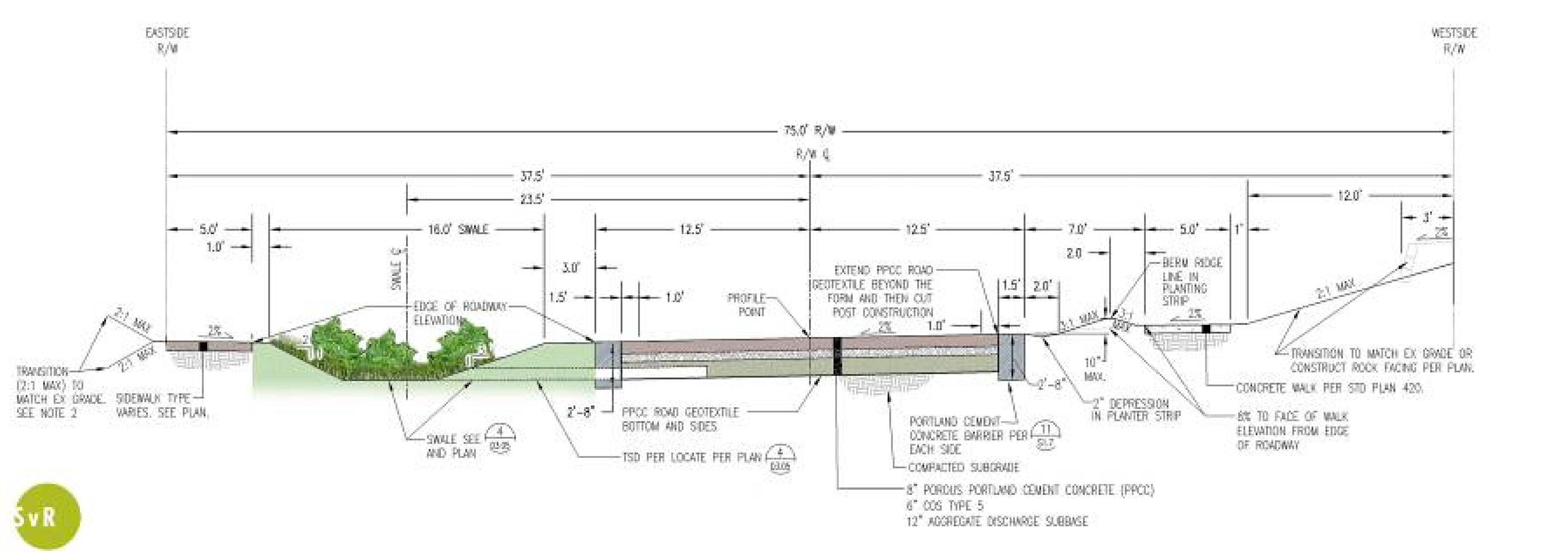
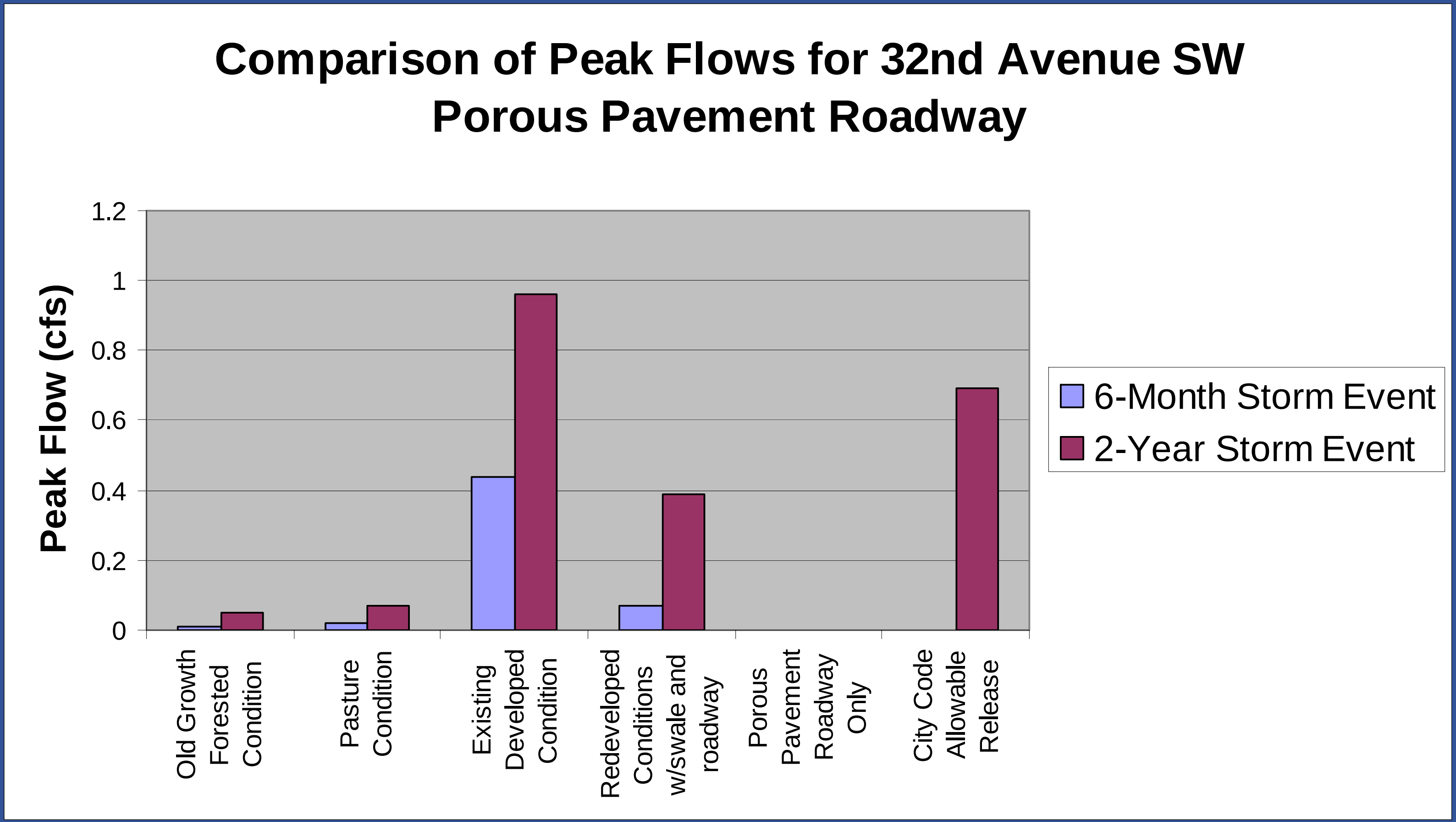
Example: Cross-Section for 32nd Ave SW



- Sloped Subgrade with Roadway Longitudinal Slope to Minimize Amount of Excavation
- Impermeable Check Dams across Roadway for Every One-Foot Drop in Elevation/Gravel Storage
- Gravel Storage Subbase Set above other Underground Utilities
- Back-Up System (CB and Swale) for Overflow during Large Storms
- Depression on Upslope Side for Collection of Fines
- Coordination with other New Underground Utilities

Example: Modeling Results for 32nd Ave SW



- In comparison, with impervious roadway, to meet same goal for developed basin during 6-month storm event approx. 533 ft of 36" detention pipe would have been required plus water quality treatment.

Preconstruction & Planning

- Installer Prequalifications
- NRMCA Pervious Concrete "Technician" Certification
  - 21 and counting have been certified in Washington since start of program in Summer 2006
- Install Test Panel(s)
- Preplanning Meetings between Supplier, Installers, Concrete Mixer Drivers, Inspectors, Designers
- Install Sediment and Erosion Control Measures to Redirect Water away from Construction Area Prior to Excavation of Pavement Section.
- Preplanning for Construction Sequencing and Truck Deliveries during Placement of Mix.

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Construction Issues for Porous Cement Concrete Pavement

- Method for Installation Varies
- Place from Chute, Wheeled or by Conveyor.
- No Trowels or Floats.
- Cover Immediately after placement – Voids enhance drying
- No Dowels
- Joint spacing (follow standard but under review)

Example of Placement of Porous Cement Concrete Sidewalk

Photos by Randy Sleight, Snohomish County, presented at 2006 Fall APWA Conference.

Construction of 32nd Ave SW

Before

Side Barriers

Installing Dams for Cells

Fabric at Subgrade

Gravel Storage Subbase

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Example of Placement of Porous Cement Concrete for Roadway – 32nd Ave SW

Moisten Subbase, Place Mix & Strikeoff

Cut in joints

Roller for compaction

Protect & cover

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Example: Seattle's First Public Porous Pavement Street Developed 32nd Avenue SW

- Designed 2003-04 Constructed 2005
- Drainage Basin 4.6 ac (Road and Housing)
- 25' Wide Road with Sidewalks on both Sides and No Curbs
- Westside Landscape Treatment to Encourage On-Street Parking
- New Utilities
- 30% Impervious
- 60% Pervious
- 10% Porous Paving

Post Construction for Permeable Pavements

- Maintain Stabilization of Adjacent Areas
- Post Construction Testing
  - Infiltration Test
  - Pavement Thickness
- Porous Asphalt & Cement Concrete – check for unraveling and sealing

Maintain Erosion Control BEFORE and **AFTER** construction. Permanently stabilize adjacent areas.

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Industry Trends for Porous Cement Concrete Pavement

- Industry is developing Standard Testing Specifications.
- Equipment is being developed to make it more automated for placement and installation.
- NRMCA Certification for Technicians and Installers
- Mix Design - Smaller aggregate for walkways as opposed to roads?
- Costs expected to go down as Quantity & Experience goes up
- Standard Specifications for public works are being developed by Cities & Counties for implementation in 2007.

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Maintenance for Pervious Pavements

- Depends on Type of Material
- Follow Manufacturer recommendations for Proprietary Products
- Porous Cement Concrete Pavements and Porous Asphalt - Use Vacuum, Pressure Washer, or combination
- Continuously inform maintenance staff
- Develop protection guidelines for future work in area
- Patch with same material

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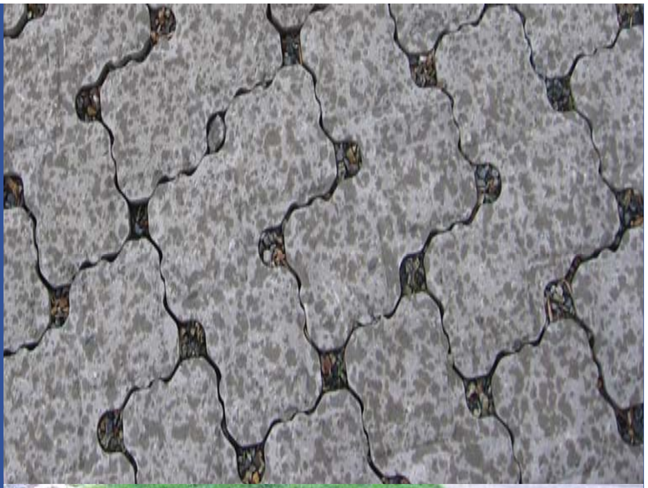
Lessons Learned

- Adjacent site erosion and flow control is critical.
- Inform users of protection of pavement
- Inform staff (Installers to Inspectors) of expectations and design intent.
- For right of way projects select locations that will not require vehicular access to adjacent properties during construction. This allows flexibility with the installation due to sequencing, weather and stabilization.
- Require Test Panel or Examples of Installation
- Require Porous/Pervious Concrete Installers haveNRMCA Certification
- Paving around utility vaults should allow for 6 inches minimum. The porous concrete sidewalks seems to have a tendency to crack if less than this width.
- Typical practice of maintenance along sidewalk edges (to prevent grass and groundcover intrusion for Porous Asphalt and Cement Concrete)
- Determine monitoring requirements during design.



Acknowledgments

Puget Sound Concrete Specifications Council
National Ready Mixed Concrete Association
American Concrete Institute

Seattle Housing Authority
City of Seattle
Washington State Department of Ecology
US Department of HUD
Examples from Other Jurisdictions

For more information:
www.svrdesign.com and
www.seattle.gov/util/naturalsystems

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Questions? Answers and Next

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END Presentation

Examples of Porous Cement Concrete Pavement Thickness*

- Design Conservatively
- Same Approach as Conventional Concrete Design Software
- Residential Street, 10 Trucks/day, 30 year design life, Soil California Bearing Ratio = 2 (Silt/Clay)
- Flexural Strength = 350 (fc' = 1250 to 1500 psi)*
  - 6.5 inches for expected life of 35 years
  - 7.0 inches for expected life of 73 years
- Flexural Strength = 375 (fc'=1400 to 1800 psi)*
  - 6.0 inches for expected life of 13 years
  - 6.5 inches for expected life of 46 years
  - 7.0 inches for expected life of 115 years
- Expected Life Estimated to Increase Significantly with Small Increases in Pavement Depth.

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*Example provided by Andy Marks, Puget Sound Concrete Specifications Council, at 2006 APWA Fall Conference

Resources (1 of 2)

- American Concrete Institute 522R-06 on Pervious Concrete May 2006 http://www.aci-int.org/PUBS/newpubs/522.htm
- National Ready Mixed Concrete Association Pervious Concrete Publications www.nrmca.org
- “Freeze Thaw Resistance of Pervious Concrete,” National Ready Mixed Concrete Association, May 2004. www.nrmca.org
- “Pervious Concrete Contractor Certification,” National Ready Mixed Concrete Association, August 2005. www.nrmca.org
- City of Seattle Department of Planning and Development Client Assistance Memo #515. http://www.ci.seattle.wa.us/dclu/Publications/cam/CAM515.pdf
- LID Technical Guidance Manual for Puget Sound, http://www.psat.wa.gov/Publications/LID_tech_manual05/lid_index.htm
- Jim Powell from Northwest Chapter from American Concrete Pavement Association, 360-956-7080.
- Local Suppliers: Greg McKinnon at Stoneway provided consultation for High Point, 425-226-1000. Glacier Northwest, 206-764-3000, www.glaciernw.com.
- “Porous Pavements,” by Bruce K. Ferguson, Taylor & Francis Group, 2005.
- Sample specifications from Florida, Tennessee and Georgia Concrete and Products Associations
- Andrew Marks from Puget Sound Concrete Specifications Council, andrew.marks@comcast.net
- Bruce Chattin from Washington Aggregates and Concrete Association, http://www.washingtonconcrete.org

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Resources (2 of 2)

- “Pervious Concrete Pavement” by Paul D. Tennis, Michael L. Leming and David J. Akers and Portland Cement Association and National Ready Mixed Concrete Association, 2004.
- “Villanova Urban Stormwater Partnership: Porous Concrete” By Robert Traver, Andrea Welker, Clay Emerson, Michael Kwiatkowski, Tyler Ladd, and Leo Kob in Stormwater magazine July/August 2004, pages 30-45.
- Charger Enterprises, http://www.chargerconcrete.com/SPECIFICATION.pdf
- Brett Kesterson from City of Portland
- “NC State University Permeable Pavement Research: Water Quality, Water Quantity, and Clogging,” Eban Z. Bean, EL, PhD Candidate and William F. Hunt, PhD, PE, NWQEP Notes, North Carolina State University, Number 119, November 2005.
- “Long-Term Stormwater Quantity and Quality Performance of Permeable Pavement Systems,” by Benjamin O. Brattebo and Derek B. Booth, July 1, 2003, Center for Water and Watershed Studies, Department of Civil and Environmental Engineering, University of Washington at http://depts.washington.edu/cwws/Research/Reports/permeableparking.pdf
- Pervious pavement in cold climates: http://www.perviouspavement.org/asphalt%20vs.concrete.htm
- SvR Design Company www.svrdesign.com

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