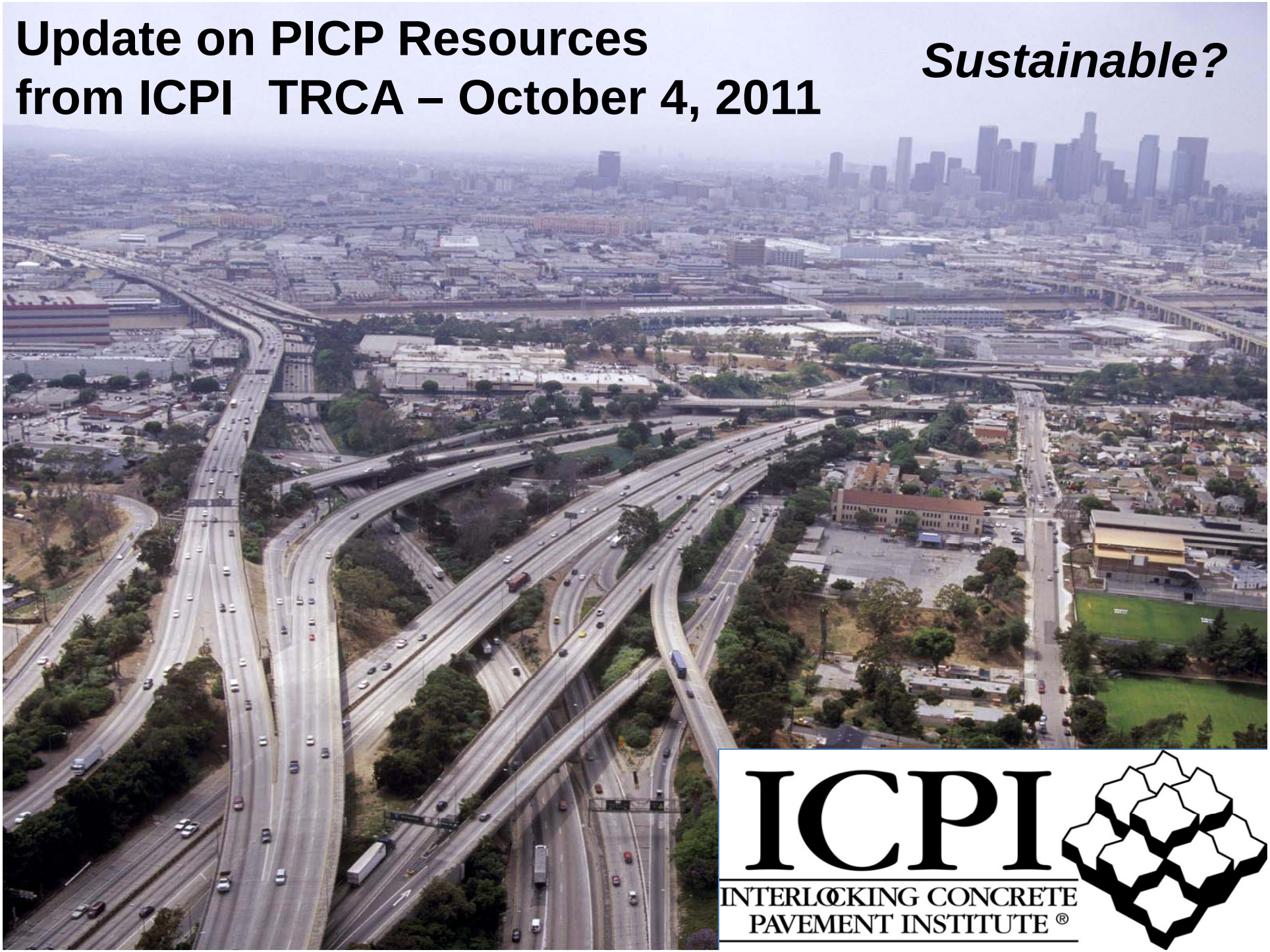
Update on PICP Resources from ICPI TRCA – October 4, 2011

Sustainable?



ICPI
INTERLOCKING CONCRETE PAVEMENT INSTITUTE ®

Some History…

First Edition 2000
Third Edition 2006

60 pages
~20,000 copies distributed
Out of print

Sometimes called….

“The White Album”

Permeable Interlocking Concrete Pavements

Selection • Design • Construction • Maintenance

David R. Smith

Third Edition

ICPI
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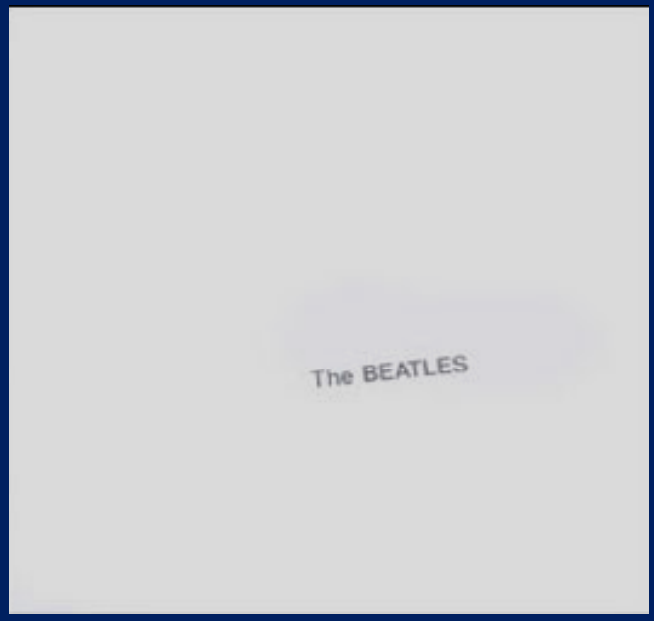
Beatles White Album
Issued 1968
Millions sold
iTunes available….



Back in the U.S.S.R.
Dear Prudence
Glass Onion
Ob-La-Di, Ob-La-Da
Wild Honey Pie
The Continuing Story of Bungalow Bill
While My Guitar Gently Weeps
Happiness Is a Warm Gun
Martha My Dear
I'm So Tired
Blackbird
Piggies
Rocky Raccoon
Don't Pass Me By
Why Don't We Do It in the Road?
I Will
Julia
Birthday
Yer Blues
Mother Nature's Son
Everybody's Got Something to Hide
Sexy Sadie
Helter Skelter
Long, Long, Long
Revolution 1
Honey Pie
Savoy Truffle
Cry Baby Cry
Revolution 9
Good Night

4th Edition PICP Manual

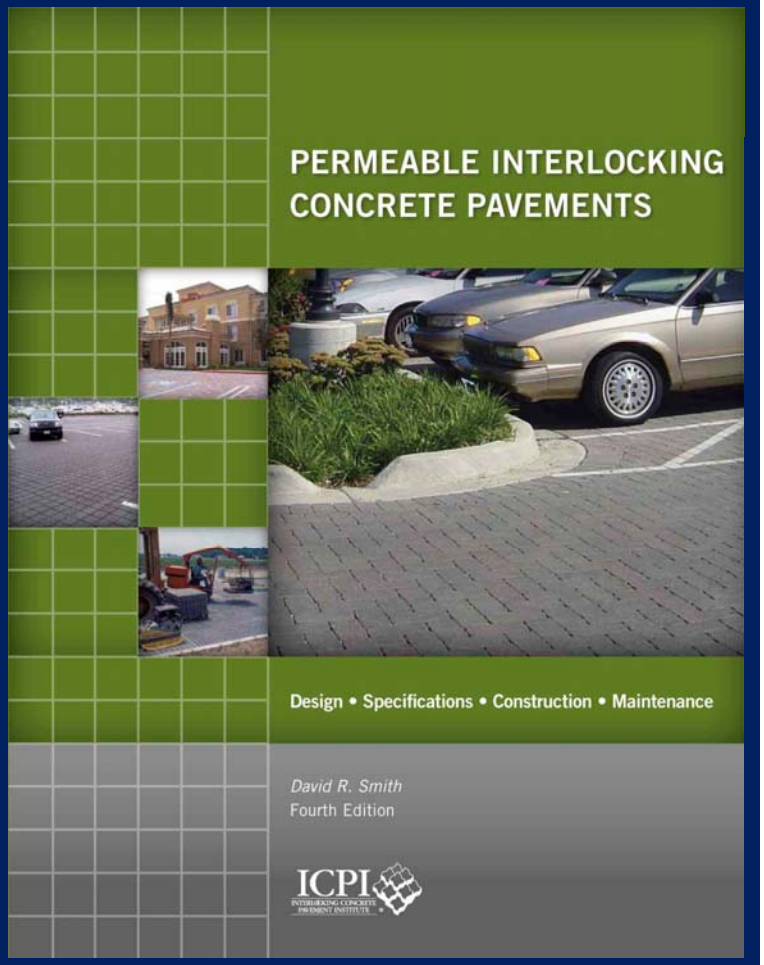
Released October 2011
100+ pages, 60+ figures
Industry consensus
1 Overview
- **Benefits/LEED credits/LCA**

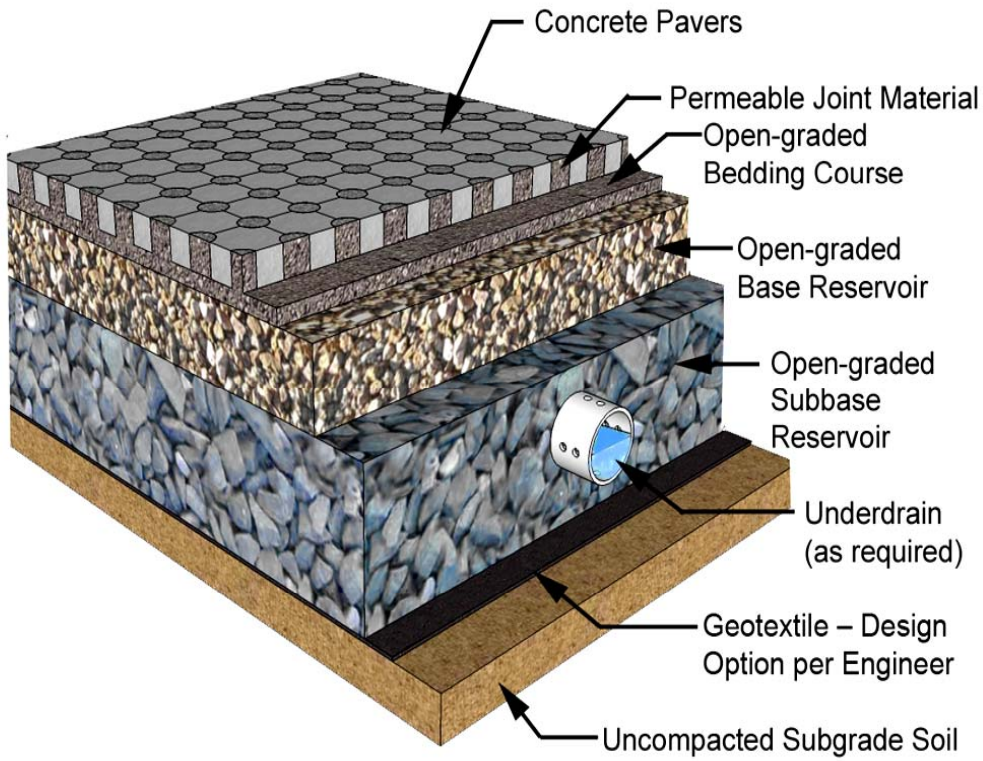
2 Design contexts
3 Hydrologic & structural design
- **Follows Permeable Design Pro software**

4 Construction & guide specs
- **Promotes using contractors with ICPI PICP course certificate**

5 Maintenance
80+ references & glossary

US$36….order on www.icpi.org





Permeable Interlocking Concrete Pavement PICP

Pervious concrete
Porous asphalt
Permeable ICP

Typical bedding, base & subbase
ASTM / AASHTO stone sizes

PICP Stormwater Benefits

- **Immediate cost savings**
  - Reduce/eliminate detention ponds
  - Fewer drainage pipes, inlets & appurtenances
- **Reduced runoff volumes & peak flows**
  - Manage 85th percentile storms or higher
  - Reduce downstream erosion, minor flooding
  - Help reduce property damage
- **Reduced nutrients, metals, oils**
  - Meet WQ volume capture/max. load requirements
  - Protect lake/river/beach recreation & fishing
- **Reduced impervious cover**
  - Recharge groundwater
  - Reduce sewer overflows & CSOs
  - Reduce/credit stormwater utility fees
  - Increase site utilization or conservation
  - Reduced temps to protect fish habitats

Water Pollutant Reductions

Concentrations, compared to impervious pavement

Application	Location	TSS	Metals	Nutrients
Driveways	Waterford, CT	67%	Cu: 67% Pb: 67% Zn: 71%	TP: 34% NO_3-N: 67% NH_3-N: 72%
Parking Lot	Goldsboro, NC	71%	Zn: 88%	TP: 65% TN: 35%
Parking Lot	Renton, WA	---	Cu: 79% Zn: 83%	---
Parking Lot	Toronto, ON	81%	Cu: 13% Zn: 72%	TP: 53% TKN:53%

Clausen and Gilbert, University of Connecticut 2006
Bean, et al. NC State University 2004
Brattebo and Booth, University of Washington 2003
Van Seters/Toronto & Region Conservation Authority 2007

Other PICP Environmental Benefits

- Stable base when frozen & thawing
- Meets ADA design guidelines
- Supports trees – cooler microclimates
- Harvest water for irrigation & gray use
- Reduce UHI with light colors
- Reduce air pollution with TiO_2 surfaces
- Reduce building energy with horizontal GSHP
- Earns LEED® points
  - Sustainable sites (Stormwater & UHI)
  - Water efficiency
  - Materials & resources

LEED 2012 & Life Cycle Assessment (LCA)

- **UHI, water efficiency, M & R credits unchanged**
- **New: Capture, retain, infiltrate, reuse**
  95^{th} percentile storm (2 points)
  (increase from managing pre/post 2-yr 24 hr storm)
- **Achieve above + capture & manage to**
  pre-development runoff levels (3 points)

LCA…

- **Manufacturer declared LCA**
- **Third-party certified environmental product**
  declaration (EPD)
- **November 2012 implementation**

PICP Limitations

An infiltration & detention facility that supports vehicles

Dual function means…

- **Greater site & soil evaluation and design effort**
- **Higher construction skills**
  - **ICPI PICP Installer Technician Certificate Course**
- **Maintenance**
  - **Regular vacuuming required**
- **Generally < 5% surface slope**

Design Basics: Exfiltration Options

Full* - *exfiltration

- **Sandy soils**
- **No perforated drain pipes**

Partial* – *detention & exfiltration

- **Silt/some clays**
- **Perforated pipes at or near bottom of base**

None* – *detention only

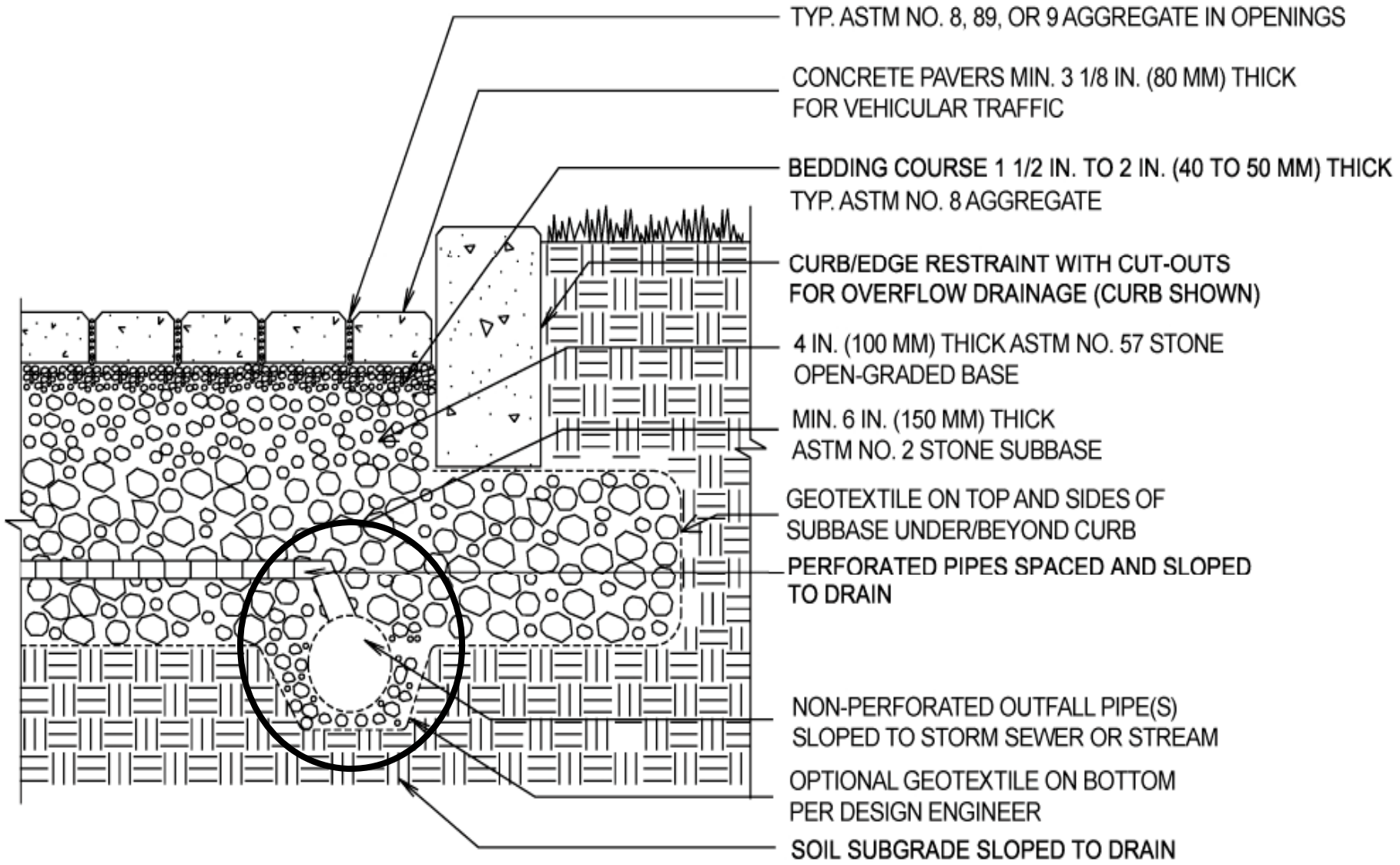
- **High rock, water table, poor soils**

Full exfiltration subbase construction
(with & without geotextiles)

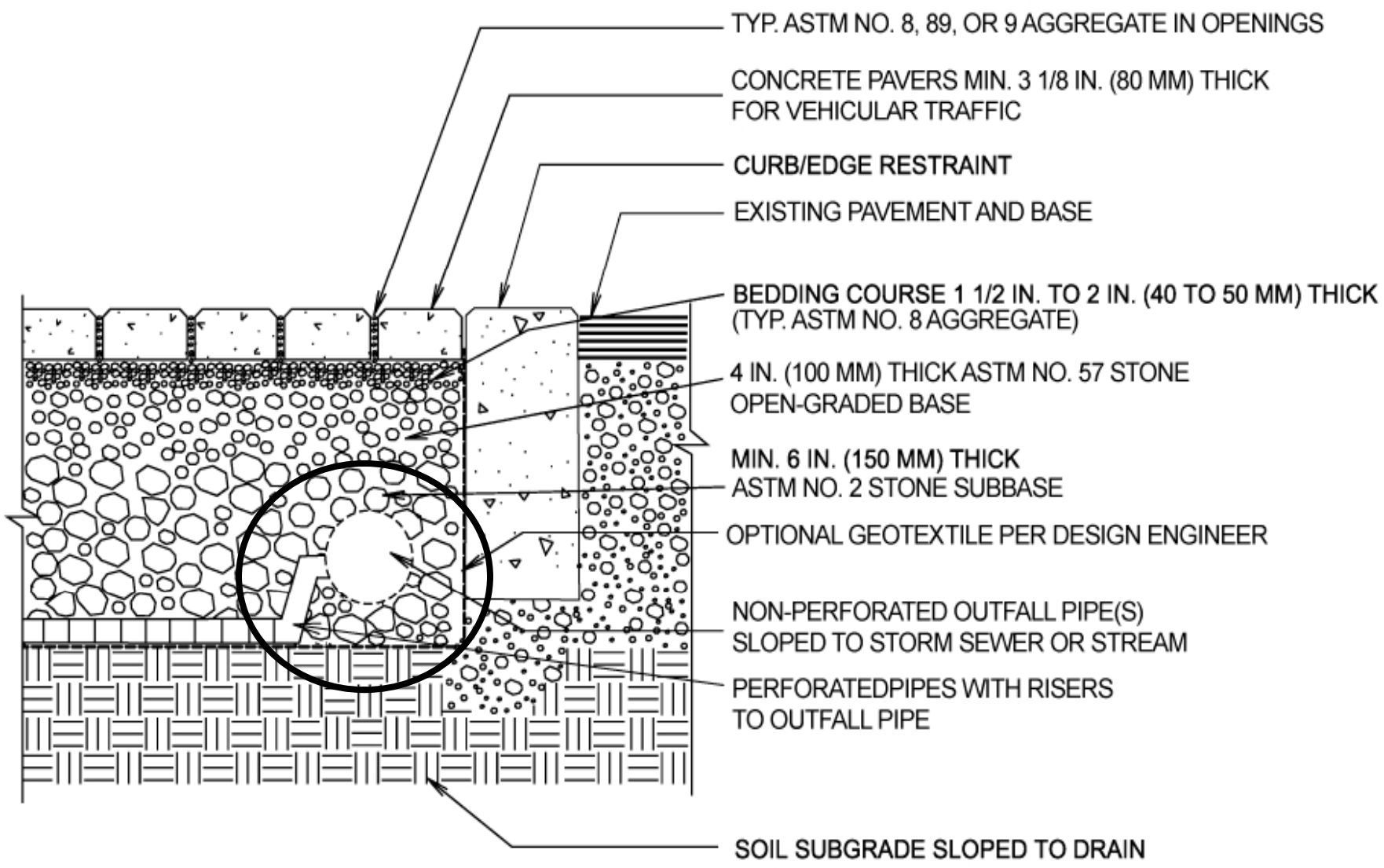

Full exfiltration: no subsurface drain pipes
Elmhurst College
Elmhurst, IL
Overflow drains to bioswale


Partial Exfiltration

Partial Exfiltration – Raised Perforated Drainpipe(s)



Partial Exfiltration – Raised Drainpipe(s)



Woven geotextile protects liner

No exfiltration

Possible water harvesting

Private/Public Project Examples

- Sidewalks & Plazas
- Parking Lots
- Green Alleys
- Roads


Stone Mountain, Georgia

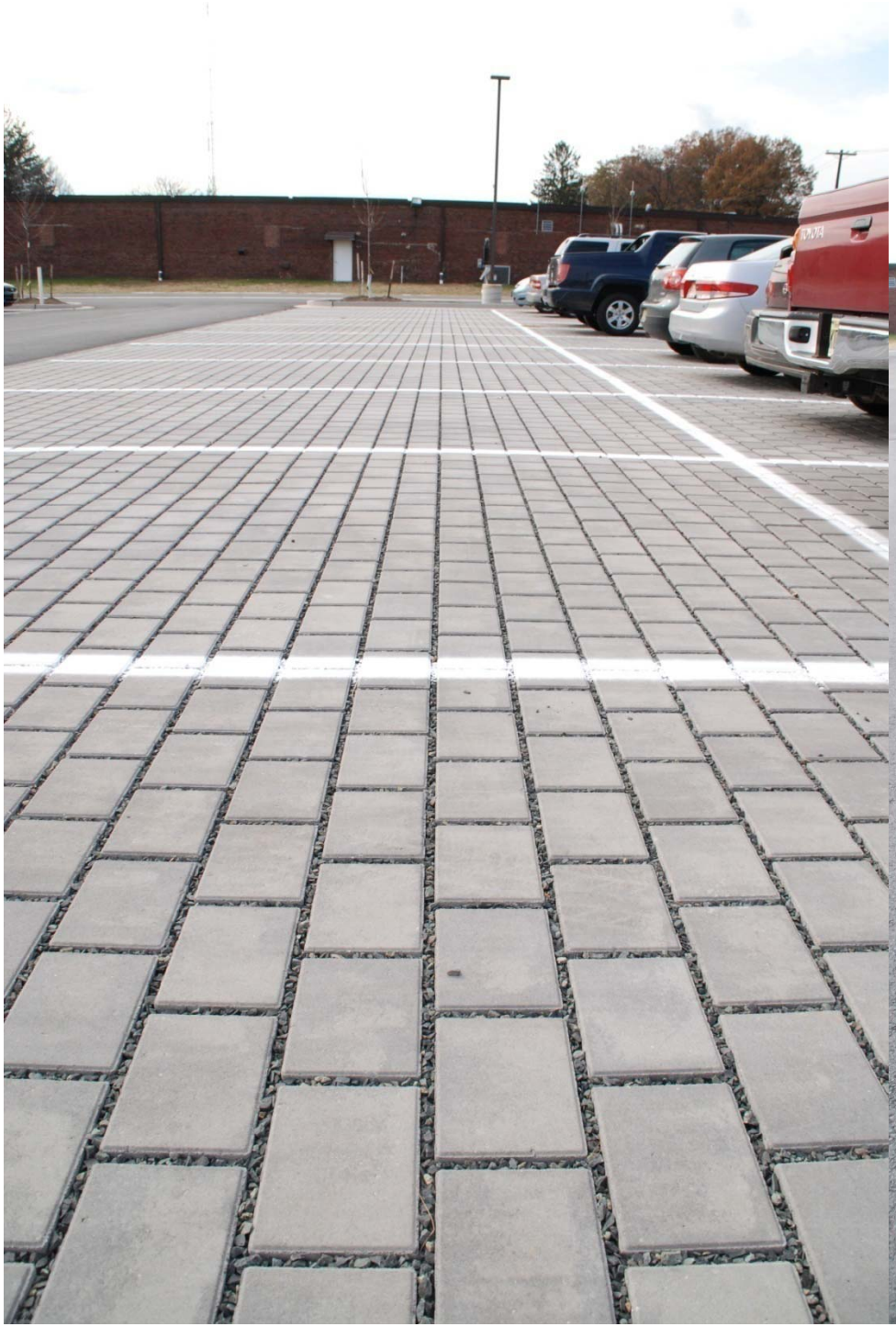

NDON DRUGS®
Computers · Audio·Video · Cosmetics
STOP
Marine Market Way
Burnaby, BC
350,000 sf
PICP receives roof runoff

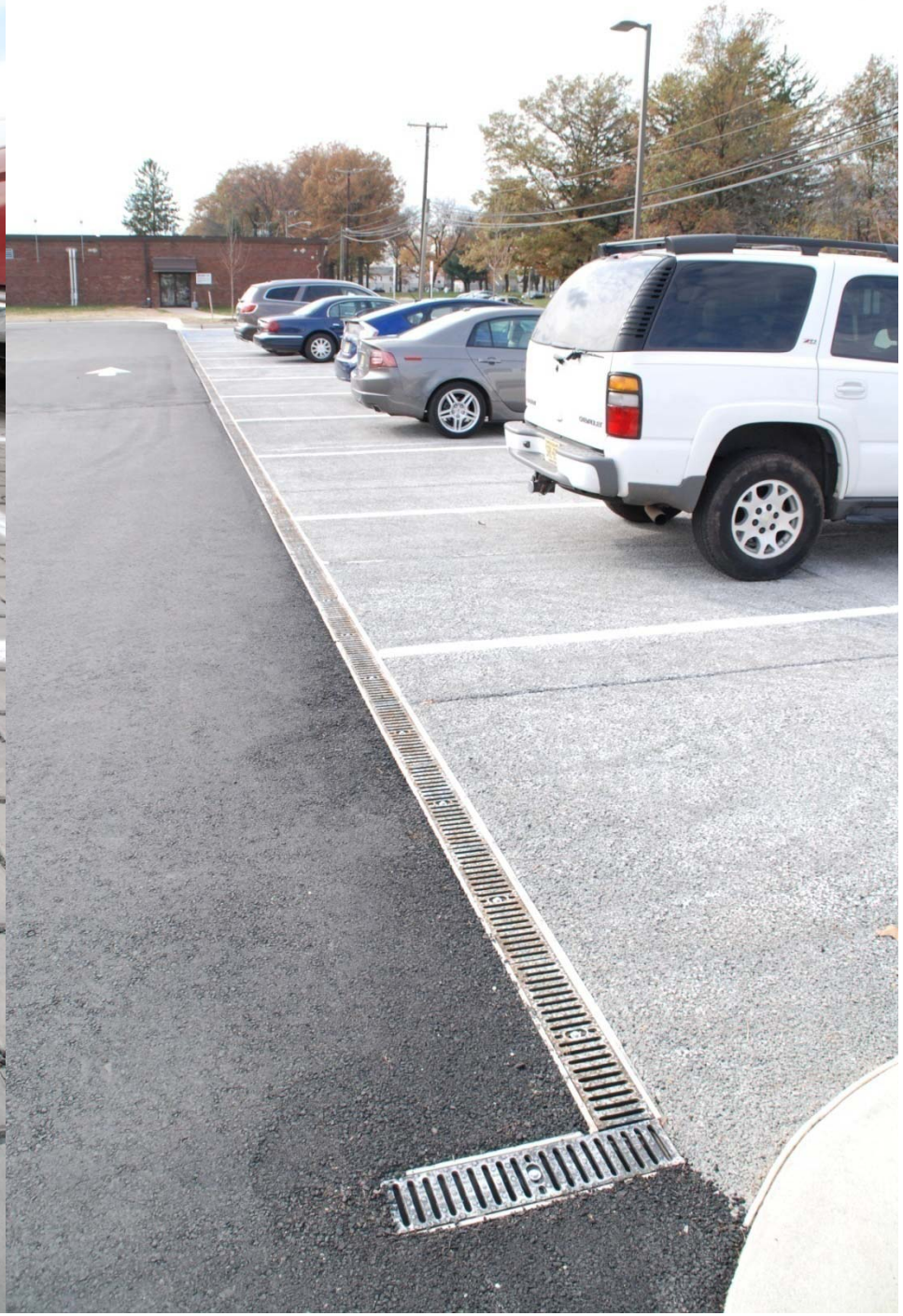
Warrenville, IL


Charles City, IA
No upsizing storm sewers

US EPA Research, Edison, NJ

Monitoring Objective	Parameters Measured
Hydrologic performance	Volume, exfiltration rate
Water quality performance	Soils, indicator organisms, metals, nutrients, organic compounds
Urban heat island effects	Net radiation, infrared radiation, temperature
Maintenance effects	Surface infiltration rate, visual assessment
Use	Car counter, visual assessment
Infiltrating water parameters	Water depth, redox, pH, conductivity, chloride





University of New Hampshire

Preliminary Desktop Site Assessment

Identify

- Current/future land uses draining onto the site
- Drainage patterns from topographical maps
- Streams, wetlands, wells and structures
- NRCS hydrologic soil groups (A, B, C, D)
- Exfiltration type
    - Full - no underdrains
    - Partial – underdrains
    - No – liner & underdrains

Verify history of fill soil, previous disturbances or compaction

Confirm absence of stormwater hotspots

No risk of groundwater contamination

Site Guidelines

- Pedestrian areas, parking lots, low-speed residential roads
- 30 m from wells
- Avoid “hotspots” – high contamination risk areas
- 3 m from building foundations unless waterproofed
- No affects from freezing – no base heaving
- Infiltrating base: Min. 0.6 m to seasonal high water table
- Lined base: Min. 0.3 m to seasonal high water table
- Capacity: base designed for future impervious cover
- No more than 5X impervious area inflow to PICP
  - Based on Dierks 2002 research
  - Site/soil/rainfall dependent
  - TRCA recommendation: 2x reduced clogging & cleaning
  - Recognizes lack of owner maintenance

What About Clay Soils?

Monitoring in "impermeable" clay soils shows significant volume reductions

- **Slow infiltration into subgrade**
- **Storage & evaporation significant in small storms**

Runoff Reduction over Clay Soils	
Study	**% Runoff Reduction**
Roseen et al (2011)	25%
Fassman and Blackbourn (2010)	28%
Dreelin et al (2009)	93%
Collins et al (2008)	13-48%

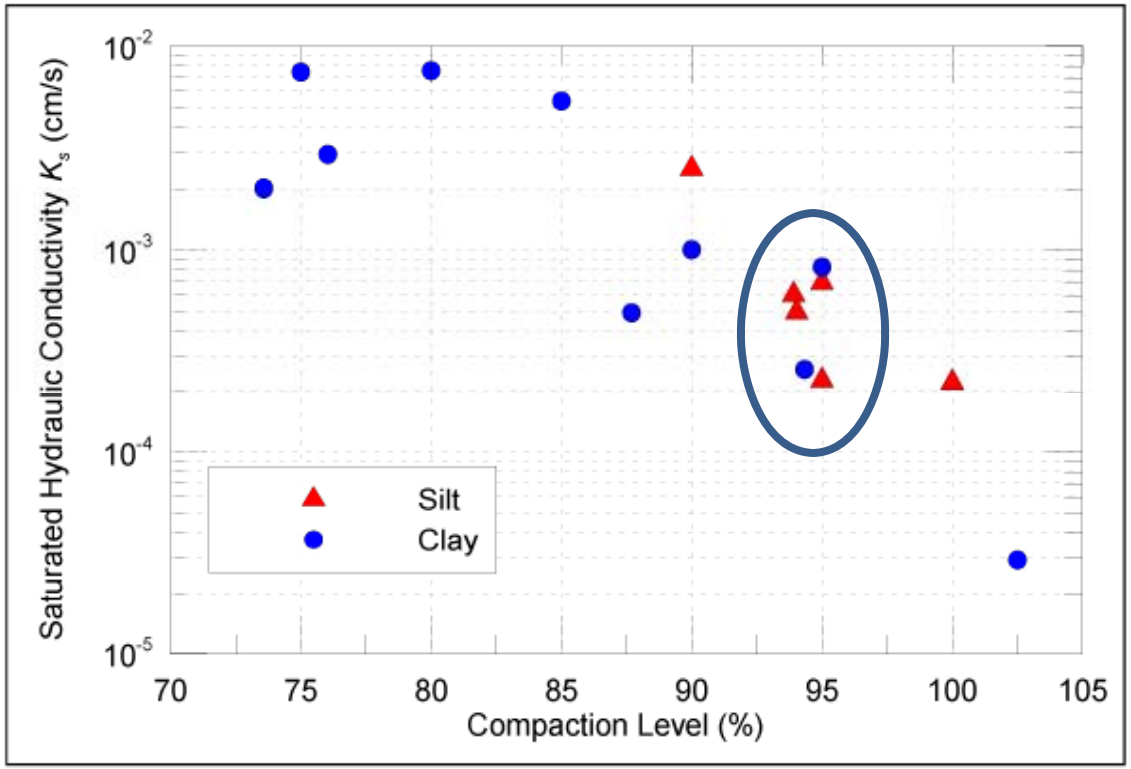
On-site Analysis

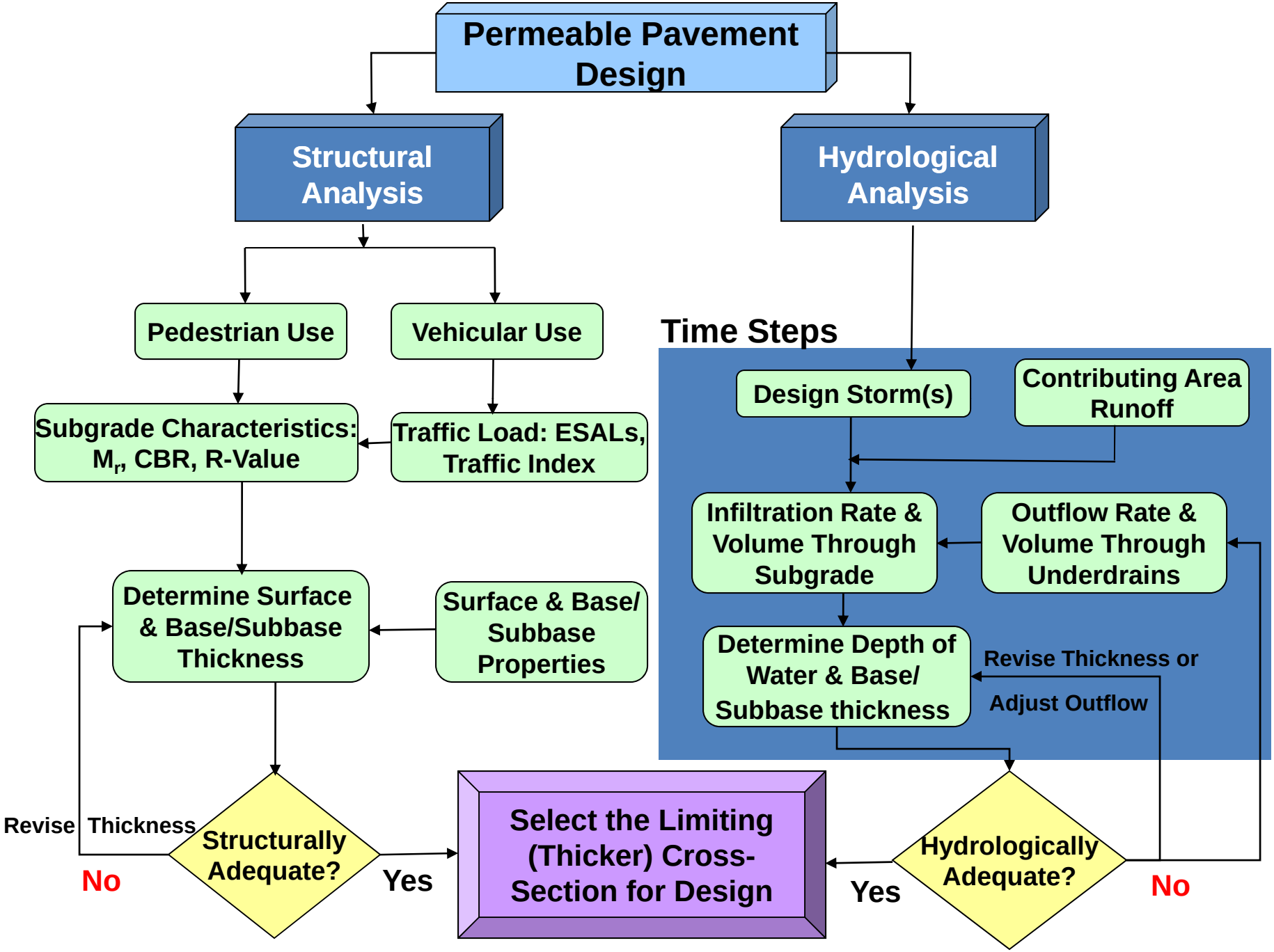
- Soil classification per ASTM D4287
- Laboratory Proctor density per ASTM 698
- Density tests on compacted soil
- Soil infiltration test on compacted soil per ASTM 3385/5093

Clay soils have <u>some</u> Infiltration when compacted - Laboratory study by UC Davis, Jones, et al. for Caltrans

10^{-2} cm/sec = 14.2 in./hr
10^{-3} cm/sec = 1.4 in./hr
10^{-4} cm/sec = 0.13 in./hr
10^{-5} cm/sec = 0.014 in./hr

Per AASHTO T-215 constant head test




Permeable Pavement Design
Structural Analysis
Hydrological Analysis
Pedestrian Use
Vehicular Use
Subgrade Characteristics: M_r, CBR, R-Value
Traffic Load: ESALs, Traffic Index
Determine Surface & Base/Subbase Thickness
Surface & Base/ Subbase Properties
Revise Thickness
No
Structurally Adequate?
Yes
Select the Limiting (Thicker) Cross-Section for Design
Time Steps
Design Storm(s)
Contributing Area Runoff
Infiltration Rate & Volume Through Subgrade
Outflow Rate & Volume Through Underdrains
Determine Depth of Water & Base/ Subbase thickness
Revise Thickness or
Adjust Outflow
Yes
Hydrologically Adequate?
No

PICP Structural Design

Based on 1993 AASHTO Design Guide – Flexible Pavements

Minimum soil strength:

- **4% soaked CBR**
- **R-value = 9**
- **Resilient modulus = 6,200 psi (43 MPa)**

Pavement layer coefficients *(conservative)*

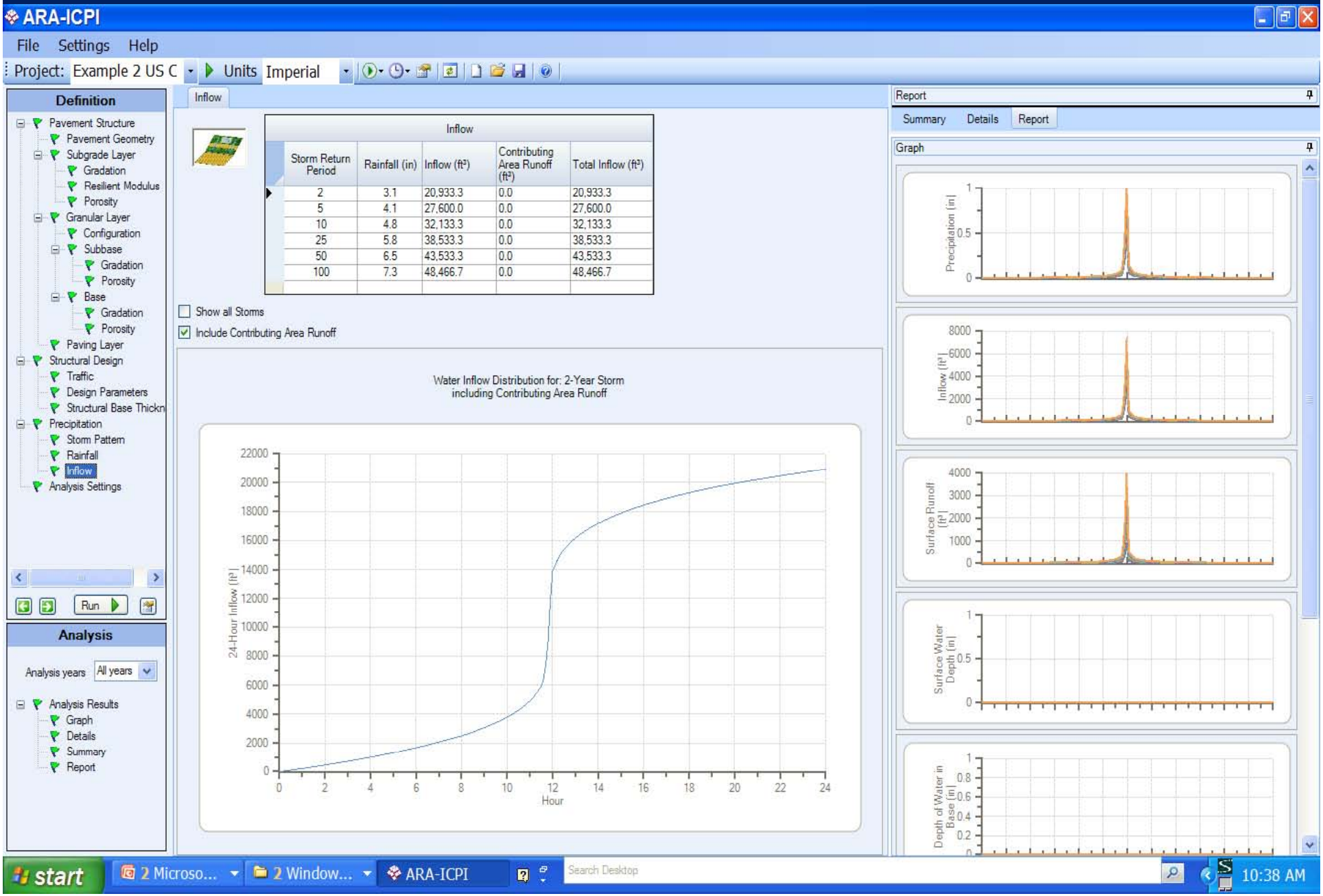
- **3 1/8 in. (80 mm) thick pavers + 2 in. (50 mm) bedding = 0.3**
- **4 in. (100 mm) thick ASTM No. 57 stone base = 0.09**
- **Variable thickness ASTM No. 2, 3 or 4 stone subbase = 0.06**
  - **MTO Granular A base ~ 0.12 to 0.14**
- **No frost layer required**

ICPI design chart: max. 1 million 18,000 lb (80 kN) ESALs or TI=9

PEDESTRIAN	**Soaked CBR (R-value)**	4 (9)	5 (11)	6 (12.5)	7 (14)	8 (15.5)	9 (17)	10 (18)
	Resilient Modulus, psi (MPa)*	6,205 (43)	7,157 (49)	8,043 (55)	8,877 (61)	9,669 (67)	10,426 (72)	11,153 (77)
	Base thickness, in. (mm) ASTM No. 57	6 (150)						

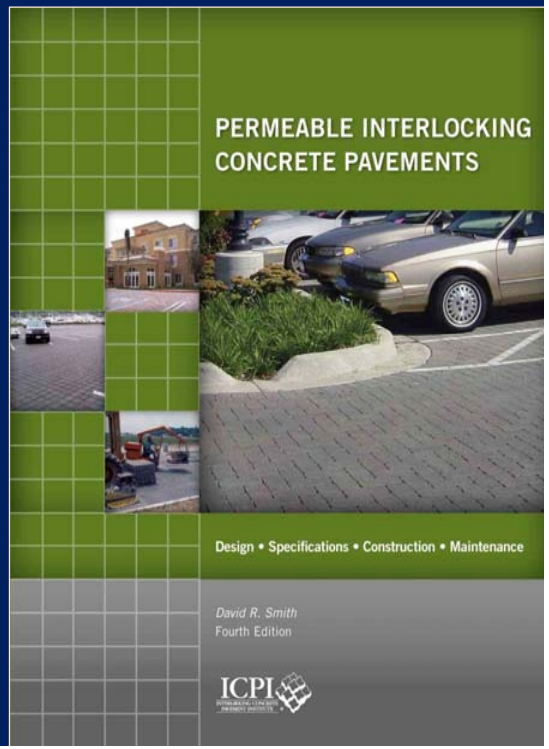
VEHICULAR	**Soaked CBR (R-value)**	4 (9)	5 (11)	6 (12.5)	7 (14)	8 (15.5)	9 (17)	10 (18)
	Resilient Modulus, psi (MPa)*	6,205 (43)	7,157 (49)	8,043 (55)	8,877 (61)	9,669 (67)	10,426 (72)	11,153 (77)
Lifetime ESALs (Traffic Index)								
50,000 (6.3) and Residential Driveways	Base thickness, in. (mm) ASTM No. 57	4 (100)						
	Subbase thickness in. (mm) ASTM No. 2	6 (150)						
100,000 (6.8)	Base thickness, in. (mm) ASTM No. 57	4 (100)						
	Subbase thickness in. (mm) ASTM No. 2	8 (200)	6 (150)					
200,000 (7.4)	Base thickness, in. (mm) ASTM No. 57	4 (100)	4 (100)					
	Subbase thickness in. (mm) ASTM No. 2	13 (325)	11 (275)	9 (225)	7 (175)	6 (150)		
300,000 (7.8)	Base thickness, in. (mm) ASTM No. 57	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)		
	Subbase thickness in. (mm) ASTM No. 2	16 (400)	14 (350)	12 (300)	10 (250)	9 (225)	8 (200)	7 (175)
400,000 (8.1)	Base thickness, in. (mm) ASTM No. 57	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)
	Subbase thickness in. (mm) ASTM No. 2	19 (475)	16 (400)	14 (350)	12 (300)	11 (275)	10 (250)	9 (225)
500,000 (8.3)	Base thickness, in. (mm) ASTM No. 57	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)
	Subbase thickness in. (mm) ASTM No. 2	21 (525)	18 (450)	16 (400)	14 (350)	12 (300)	11 (275)	10 (250)
600,000 (8.5)	Base thickness, in. (mm) ASTM No. 57	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)
	Subbase thickness in. (mm) ASTM No. 2	22 (550)	19 (475)	17 (425)	15 (375)	14 (350)	12 (300)	11 (275)
700,000 (8.6)	Base thickness, in. (mm) ASTM No. 57	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)
	Subbase thickness in. (mm) ASTM No. 2	24 (600)	21 (525)	18 (450)	17 (425)	15 (375)	14 (350)	12 (300)
800,000 (8.8)	Base thickness, in. (mm) ASTM No. 57	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)
	Subbase thickness in. (mm) ASTM No. 2	25 (625)	22 (550)	20 (500)	18 (450)	16 (400)	15 (375)	13 (325)
900,000 (8.9)	Base thickness, in. (mm) ASTM No. 57	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)
	Subbase thickness in. (mm) ASTM No. 2	26 (650)	23 (575)	21 (525)	19 (475)	17 (425)	16 (400)	14 (350)
1,000,000 (9)	Base thickness, in. (mm) ASTM No. 57	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)
	Subbase thickness in. (mm) ASTM No. 2	27 (675)	24 (600)	21 (525)	19 (475)	18 (425)	16 (400)	15 (375)

Permeable Design Pro Software



PICP Material Specifications

- Concrete Pavers
  - Meets CSA A231.2
- Aggregates
  - Crushed & LA abrasion loss of <40
  - Vehicular traffic – hardest materials available
  - ASTM Sizes
    - Jointing – No. 8, 89 or 9
    - Bedding – No. 8
    - Base – No. 57 or similar
    - Subbase – No. 2, 3, or 4
- Geotextiles
  - AASHTO M-288 Class II
  - Drainage applications spec



Construction

- **Subgrade grading – slope as required**
- **Soil compaction (when needed)**
- **Optional geotextile/impermeable liner**
- **Perforated pipe (when needed)**
- **Subbase/base placement & compaction with 10 T roller initial vibration, then static roll**
- **Bedding layer: max. 2 in. (50 mm) thick**
- **Pavers placed, openings filled**
- **Surface swept & compacted**

PICP Guide spec on www.icpi.org


No. 2 stone subbase
Morton Arboretum
Lisle, Illinois


No. 57 stone
No. 2 stone

Wal-Mart Rehobeth Beach, DE
4,000 m^2 on sandy soil

Screeding No. 8 stone bedding layer over No. 57 base

Construction – Mechanical Installation

Construction

Filling the openings with No. 8 stone


Weber
TC 565

Maintenance

New Construction

100 in./hr (250 cm/hr) minimum infiltration rate

C1701 test method - same as pervious concrete

Maintenance Guidelines

Vacuuming

Assumes 80%-90% infiltration reduction over time

Minimum 10 in./hr (25 cm/hr) per ASTM C1701

Completely clogged surfaces require restorative vacuum cleaning

Inspect & vacuum sweep 2x annually with standard equipment - no water

Sweeping only equipment not effective in removing sediment

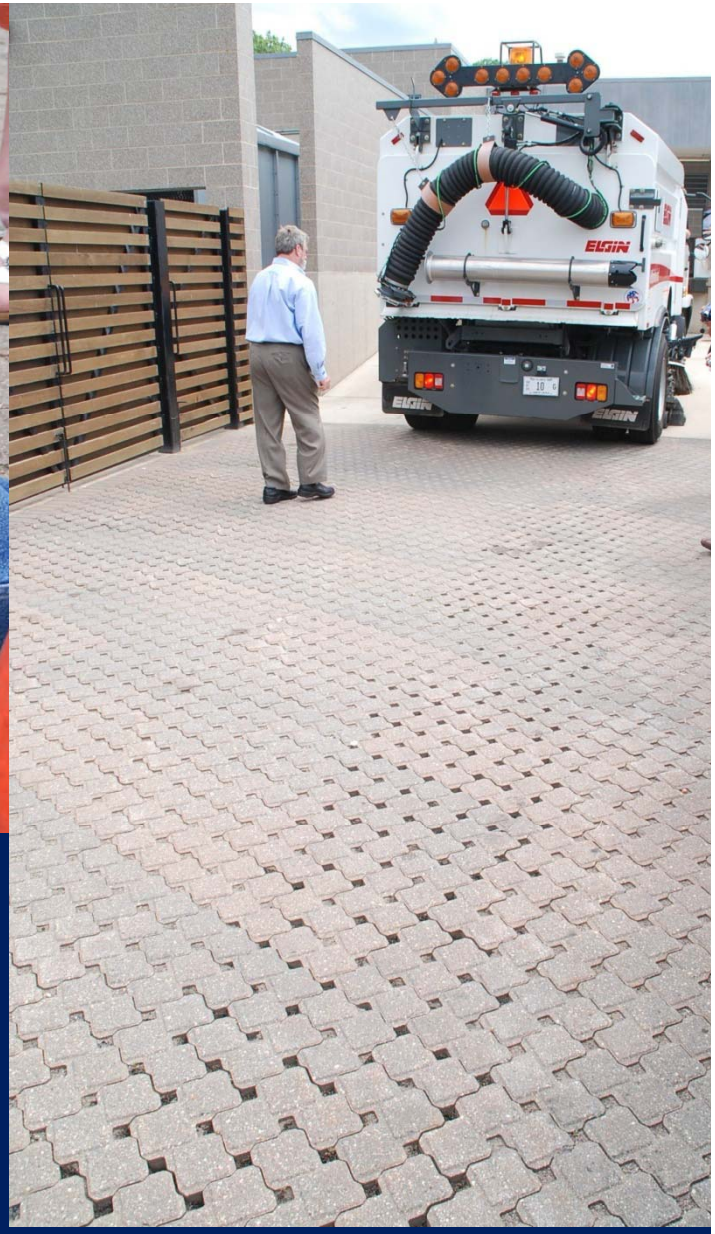
Check infiltration in small areas with water - Use ASTM C1701 as needed

Sweeper Effectiveness

Regenerative air vacuum sweeper - use 1-2 times/year for routine cleaning

True vacuum sweeper – very powerful – for restoring highly clogged surfaces

Restoring Surface Infiltration Video



Sediment collects in top ½ - 1 in. (13-25 mm)

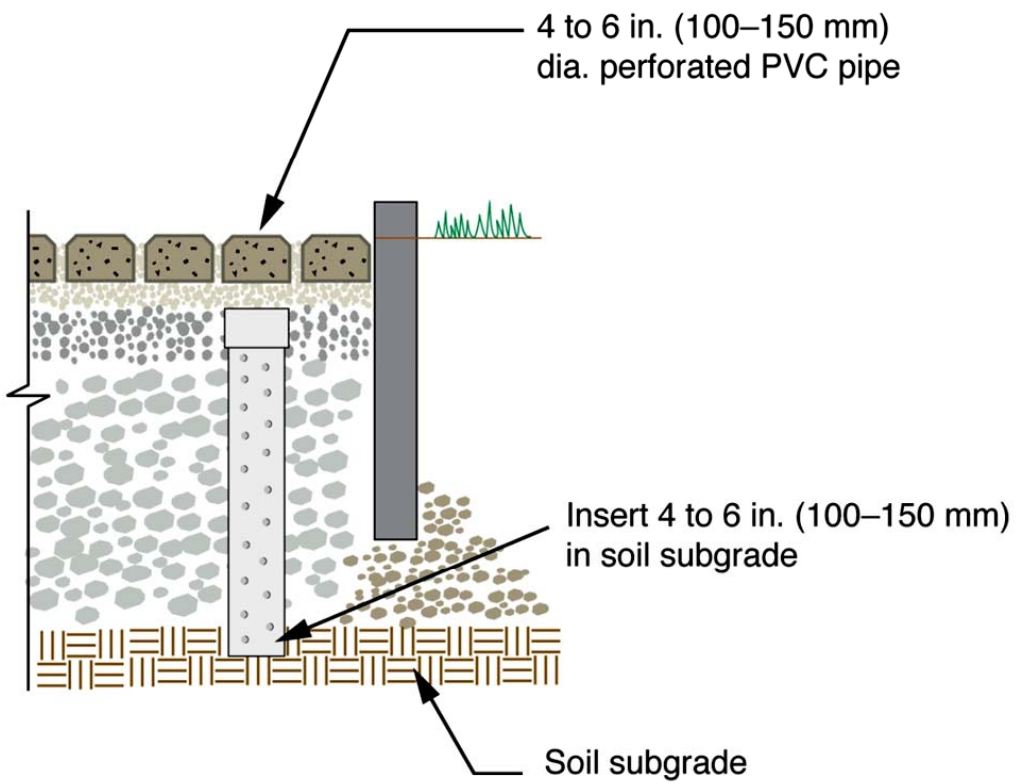
True vacuum sweeper cleans out clogged stone & restores surface infiltration – refill with clean stone

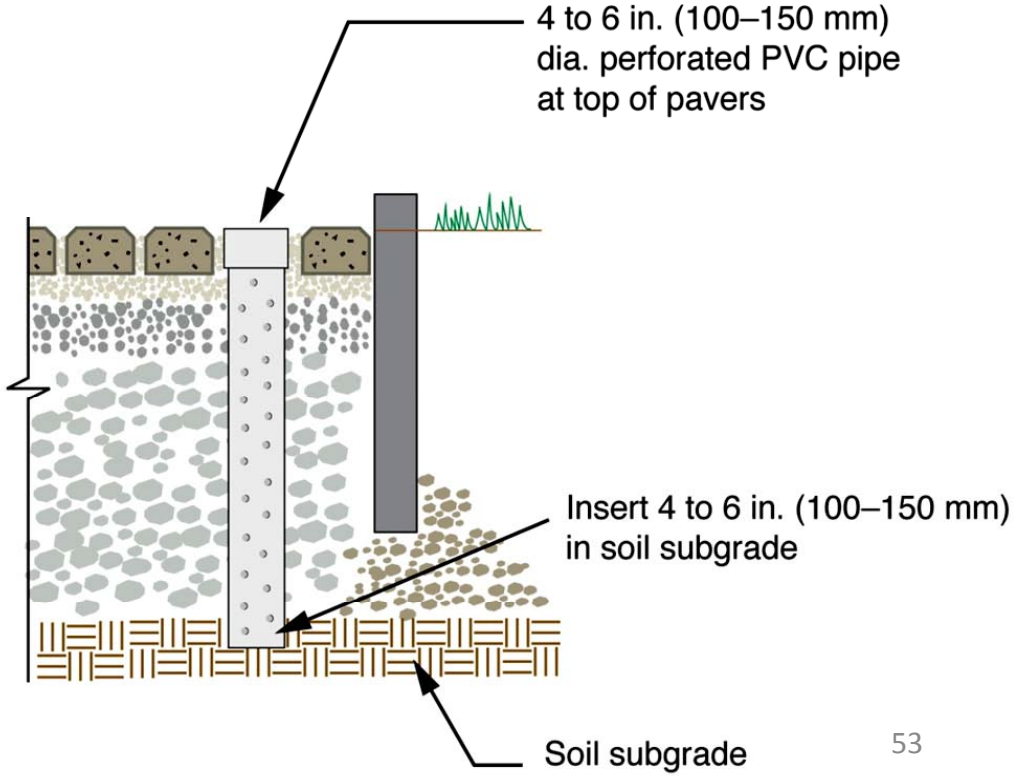
Reinstated surface without damage or reduced service life


Monitor Base Inflow & Outflow
• Observation well at lowest point
• Min. 100 mm dia. perforated pipe w/cap
• Monitor drainage rate, sediment, water quality

Covered cap

Exposed cap

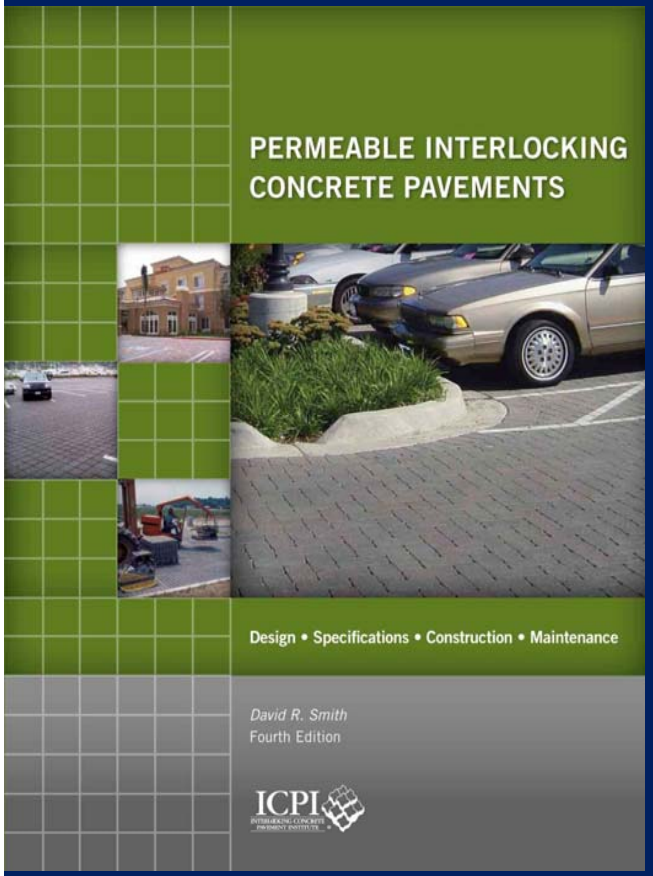




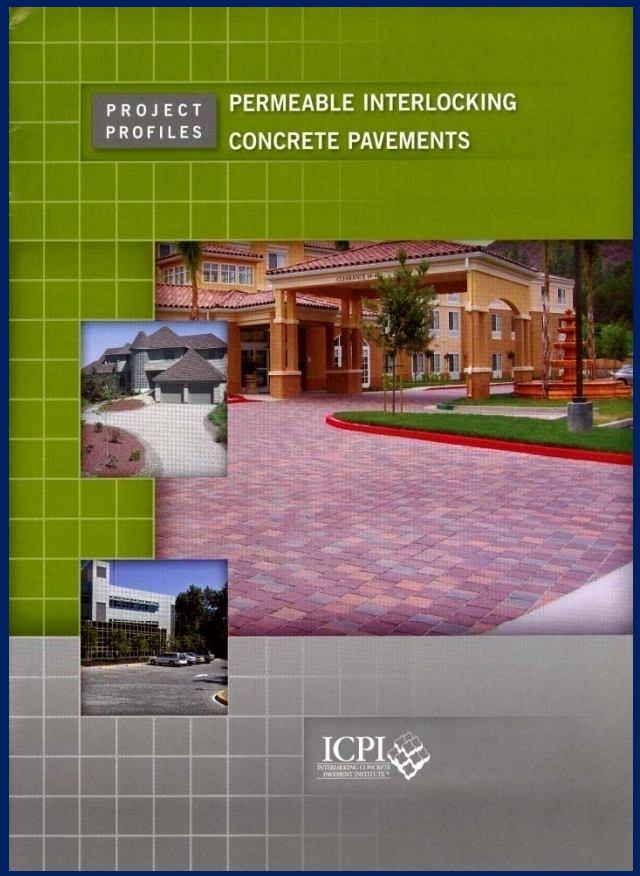
PICP Inspection Checklist

Vacuum surface	1 to 2 times annually, adjust per sediment loading
Replenish aggregate in joints	As needed
Inspect vegetation around PICP perimeter for cover & soil stability	Annually, repair/replant as needed
Repair all deformations exceeding 1/2 in. (13 mm)	Annually, repair as needed
Repair pavers offset by more than 1/4 in. (6 mm) above/below adjacent units	Annually, repair as needed
Replace broken units impairing surface structural integrity	Annually
Check drain outfalls for free flow of water & outflow from observation well	Annually, after a major storm

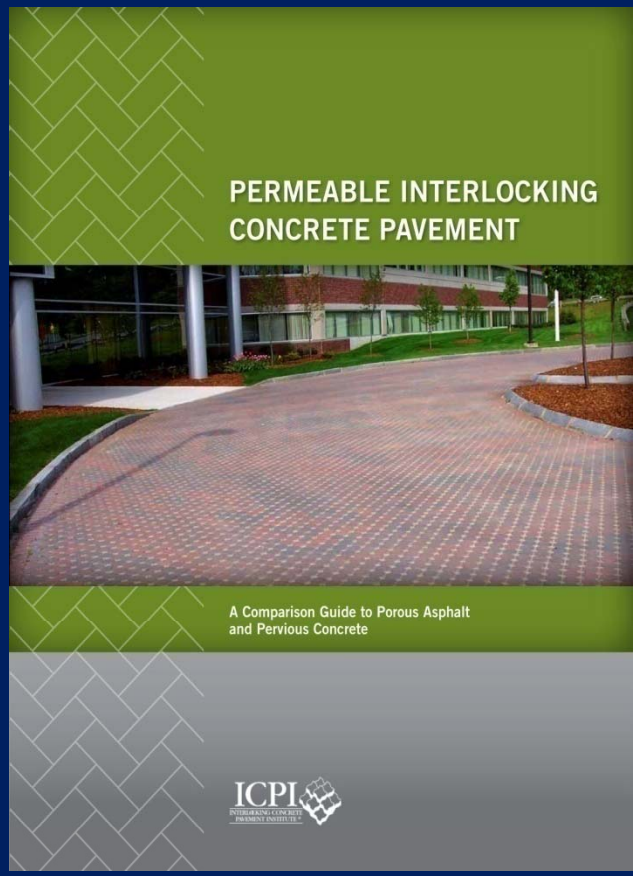
PICP Resources from icpi.org



Design Manual



Project Profiles



Pavement Comparison

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- Reduces water run-off

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INDUSTRY PROFESSIONALS SAY

"From day one, the Board wanted a permeable lot, a view heightened by the long-term drought in the southeast which drastically lowered lake levels and threatened drinking water supplies. They

Design Tools

ICPI's technical and educational resources provide design professionals with the latest design insights and technical developments on interlocking concrete pavement and permeable interlocking concrete pavement. As an ICPI member, you will receive timely updates on new publications, trends and industry news through subscription to the Interlocking Concrete Pavement Magazine and ICPI Design Professional Update. Visit our comprehensive Membership area and learn how ICPI can improve your business.

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Browse our Idea Gallery for design solutions that meet your project's needs.


Commercial


Industrial


Municipal


Residential

LEED®

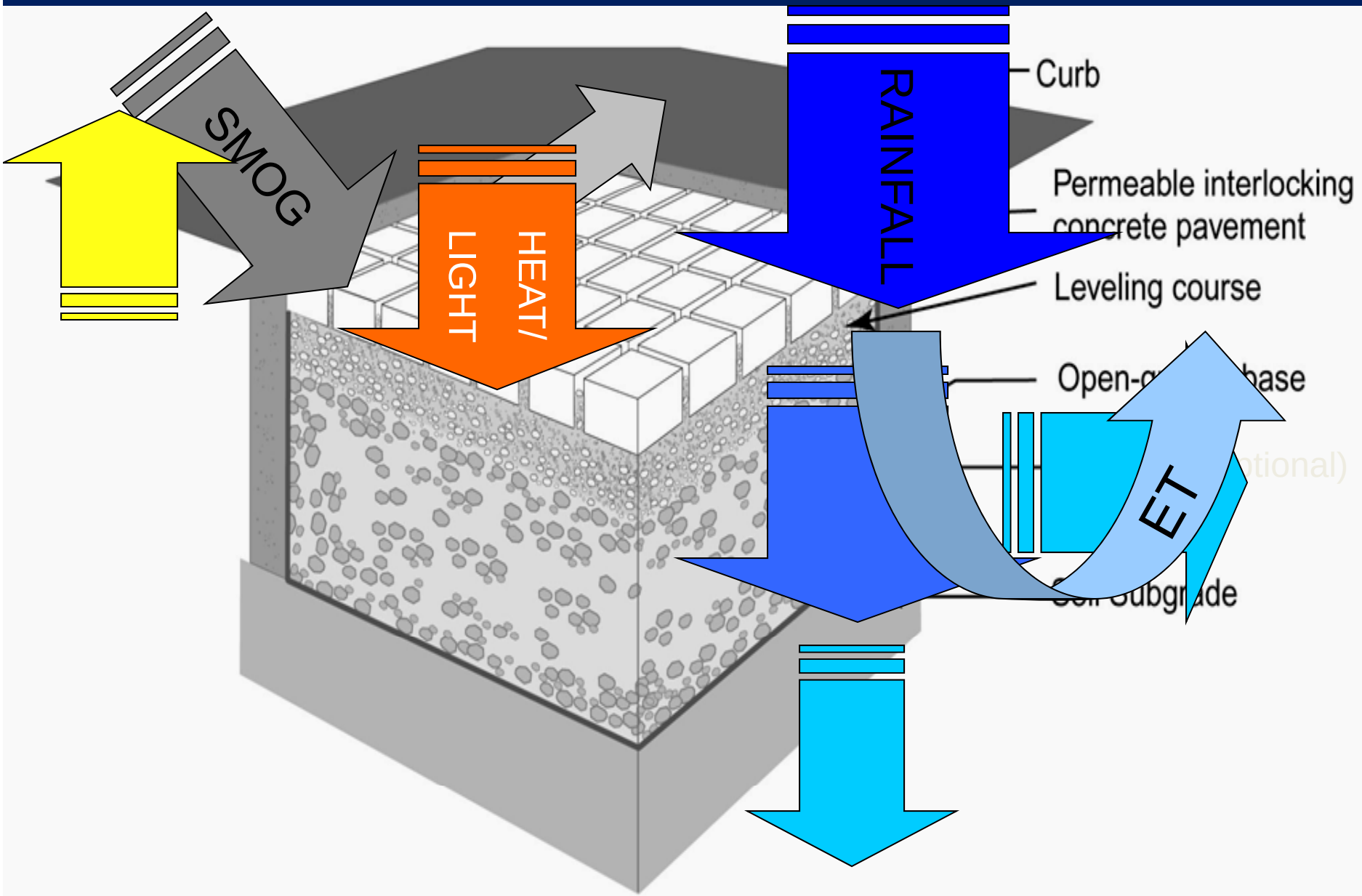
United States | Canada

Developed by the U.S. Green Building Council (USGBC) in 1998, LEED® is a voluntary system of design for buildings and sites that provides a rating system which encourages the use of technologies that reduce energy and conserve non renewable resources.

Sustainable Design

Permeable Interlocking Concrete Pavements (PICPs) meet LEED® credit requirements under Sustainable Sites. These requirements limit runoff and water pollution by managing stormwater. The pavements can reduce runoff-generating impervious cover and decrease the rate and quantity of runoff. Learn more about

PICP Eco-Machine




29

Sustainable Paving

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