

LID 201: LID Technical Considerations

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Pervious Pavements



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Pervious Pavements

- Introduction
- Design Considerations
- Construction
- Maintenance

Introduction to Porous (Permeable) Pavements

What are Permeable Pavements?

- Designed transportation surfaces that incorporate void spaces that allow water to infiltrate into an underlying storage reservoir or soil
- Permeable Pavement Types:
 - **Permeable Blocks (Pavers)**
 - **Synthetic Geomatrix**
 - **Pervious Concrete**
 - **Porous Asphalt**

System Selection

- The most important aspect of selection is the intended use.
- Pavers and geomatrices may be best-suited for residential and low use surfaces, like fire lanes.
- Pavements may be best used for parking lots and low traffic roadways

Pavers and Geomatrix

- Gradients for grass porous paving surfaces can vary from flat to 20%
- Sub-base materials would be consistent with any typical porous pavement application
- Pavers can be installed year round QC applies only in construction as the product comes preformed.



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Porous Pavements

Porous Pavements

- Aggregate gradation: No fines added to mix
- Air voids: 18-20%
- Cold climate and WQ functionality dependent on sub base design
- Long-term FX dependent on production, not maintenance



Pervious Concrete

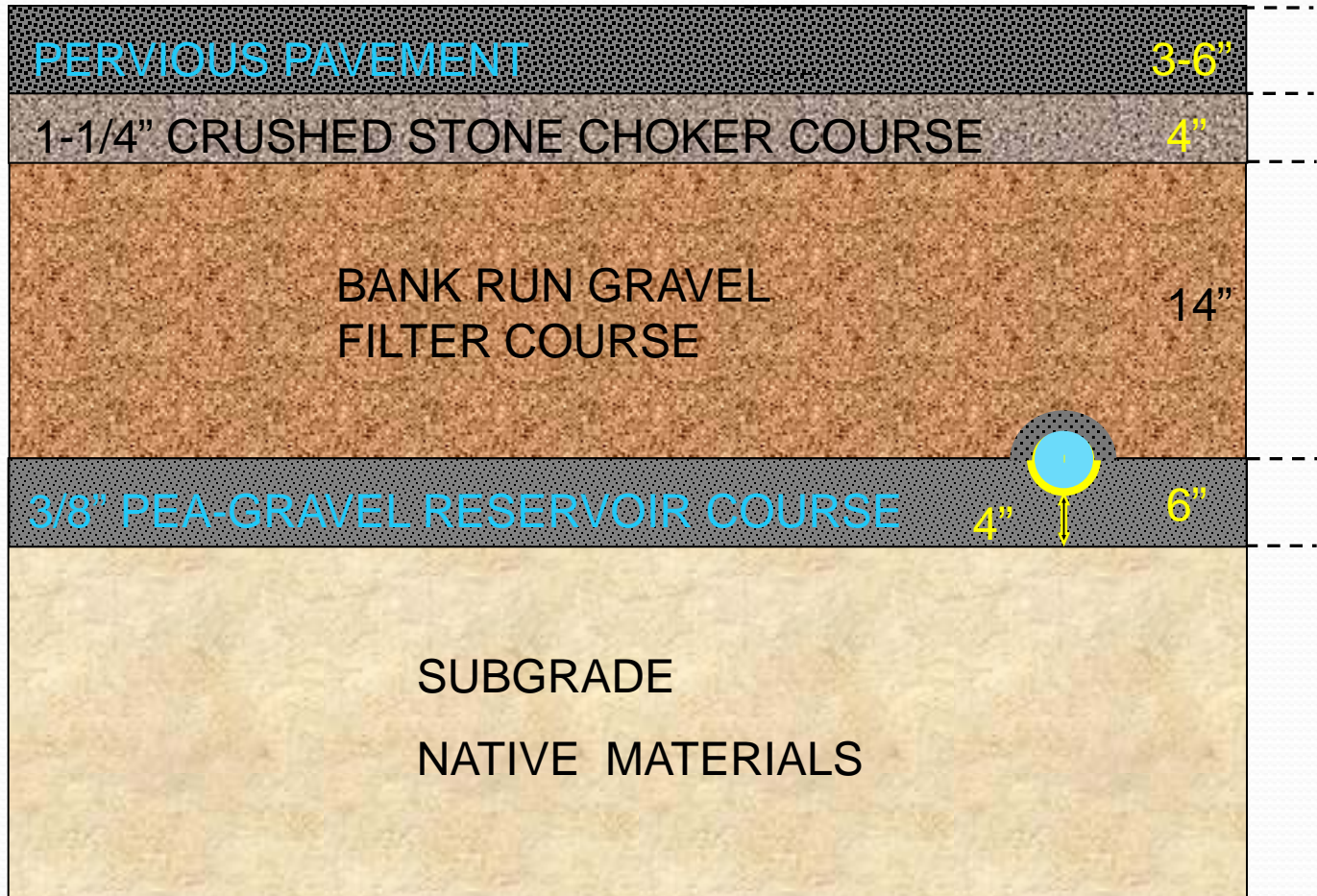
- Placement is challenging and requires certified installers
- Curing is a challenge
- Compressive strength: 3000 psi at 7 days
- Concrete is very resistant to aging



Porous Asphalt

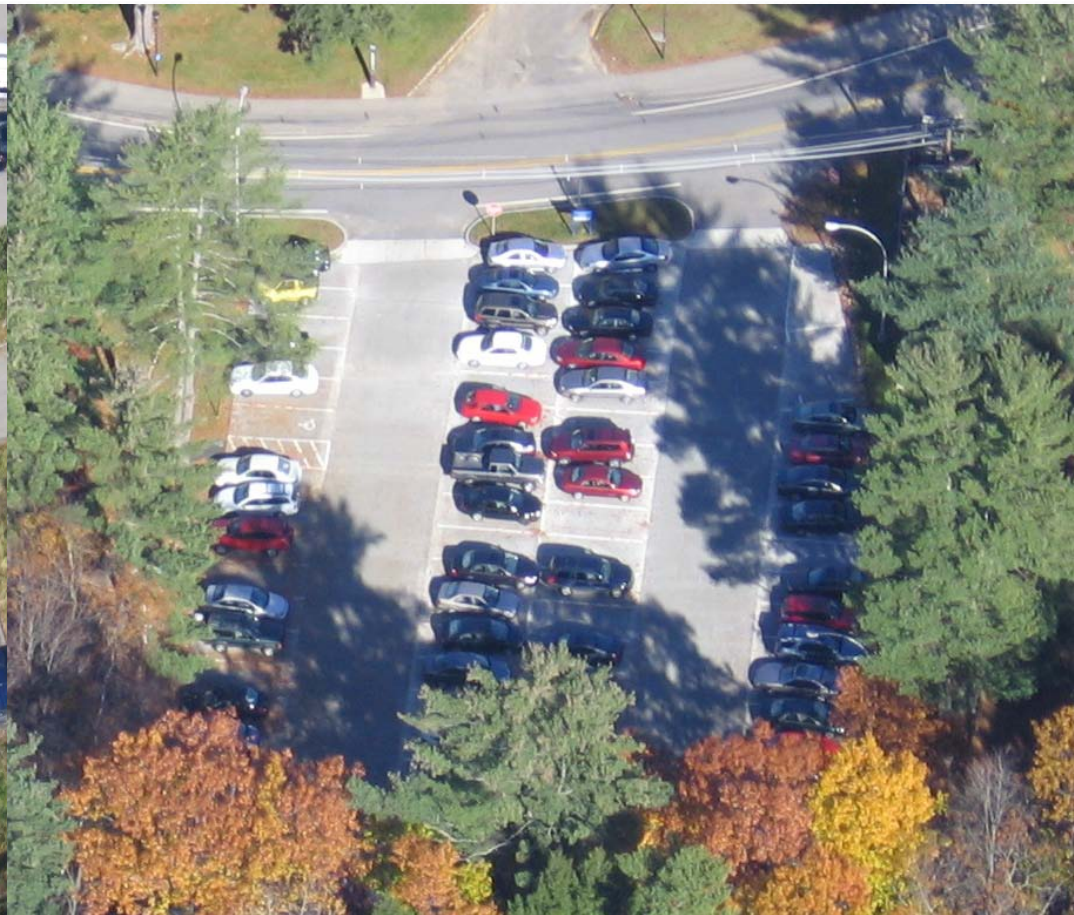
- Modification of Open Grade Friction Course (OGFC)
- Asphalt binder often modified (polymers, fibers) but not necessary
- QC production at plant is crucial, install is simple

Typical Cross-Section Construction



Sub-base design matches that of the UNHSC Porous Asphalt Parking Lot

Permeable Pavement Sites



UNHSC Porous Asphalt Lot

UNHSC Porous Concrete Lot

Permeable Pavement Sites



**Great Bay
Discovery Center
Greenland, NH:
Porous Asphalt,
Pervious Concrete,
and Permeable
Concrete Pavers
(Eco-stone).**



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Permeable Pavement Sites

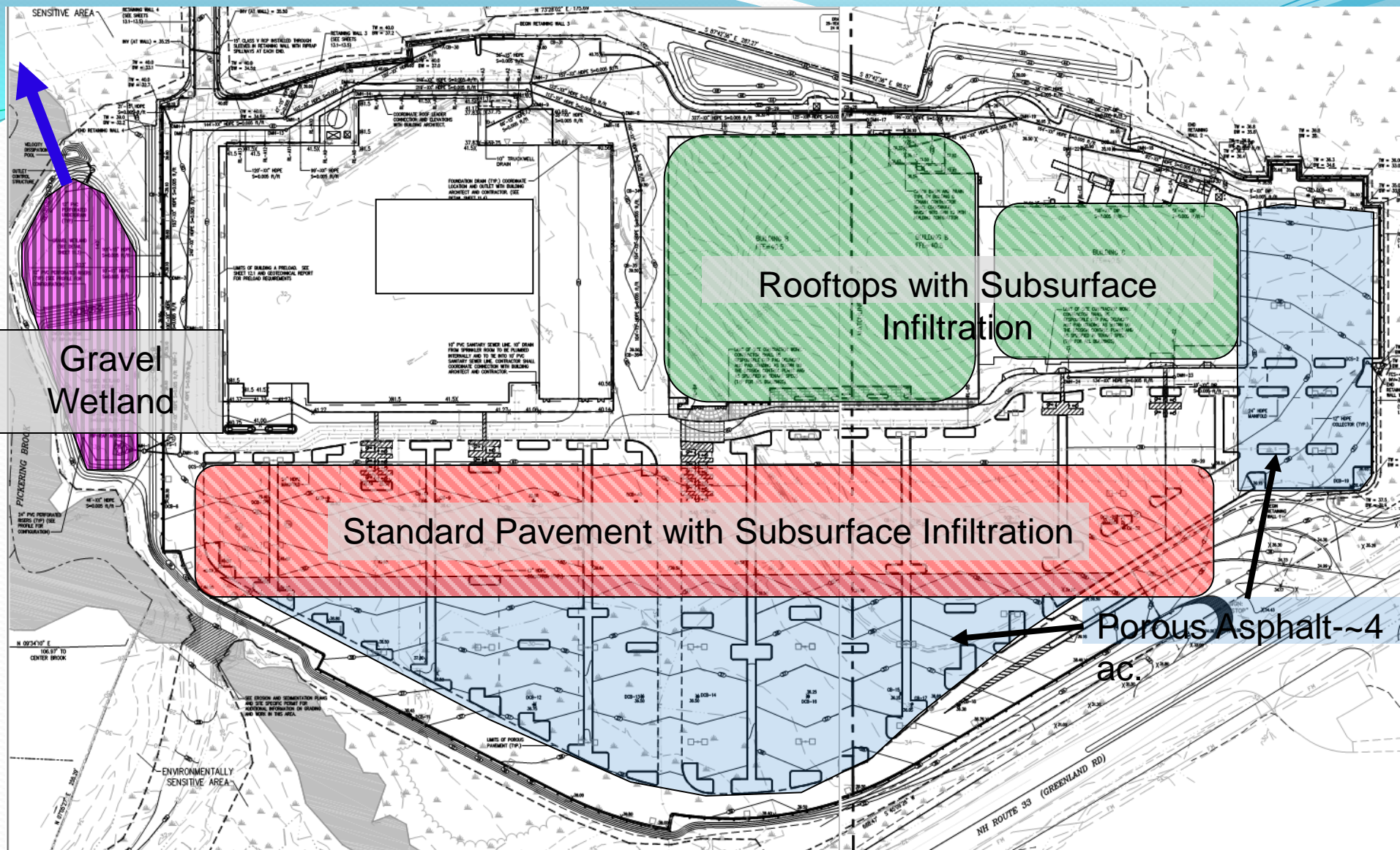


**Greenland Meadows,
Packard Development LLC, Target and Lowes Complex in Greenland NH: Porous Asphalt**



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28 ac site, initially >95% impervious, now <10% EIC, with all drainage through filtration, expected to have minimal WQ impact except thermal and chloride



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Permeable Pavement Sites



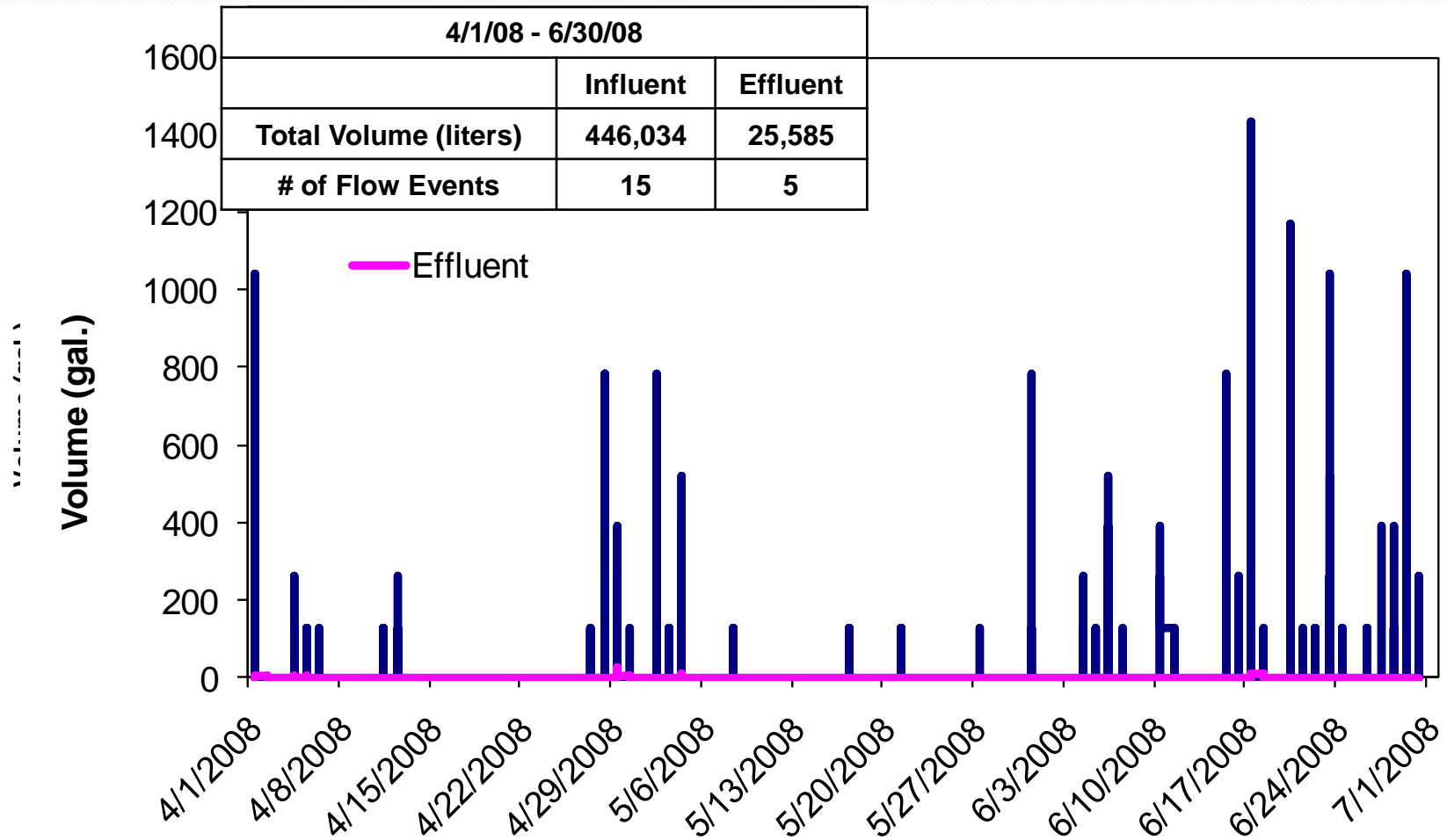
**Boulder Hills
Subdivision Road
Pelham, NH**



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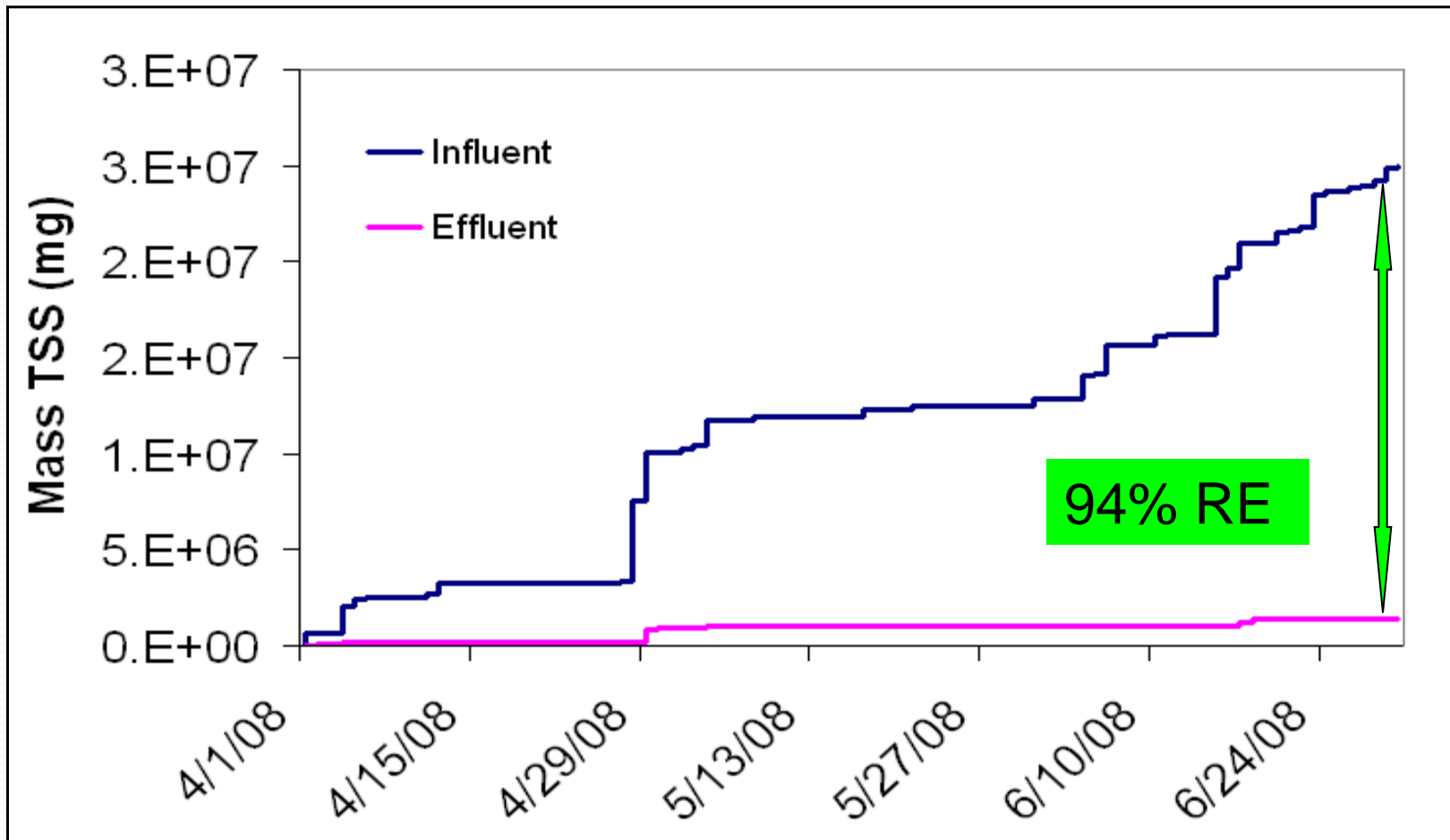


PC Flow Attenuation



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Effective Salt Reductions

Pavement Type	2006-2007		2007-2008		Reductions Possible when compared to DMA with 100% App. Rate	
	Anti-Icing Apps.	Deicing Apps.	Anti-Icing Apps.	Deicing Apps.	App. Rate	Average Mass Reduction*
						('06-'08)
DMA	15	14	23	22	100%	0%
PA	15	6	23	27	25%	75%
PC - shade	-	-	23	31	100%	-20%
PC - sun	-	-	23	23	100%	-2%

Conclusions

- Porous pavements are not a silver bullet
- PP are a watershed-based strategy that can both mitigate impacts for new development and reverse impacts in areas with redevelopment.
- Porous pavements are a filtration/infiltration system as well as a transportation surface. Dual function means:
 - ✓ Greater site evaluation and design effort
 - ✓ Strict engineering oversight and skilled personnel through all phases of the project
 - ✓ Requires a comprehensive maintenance schedule

Conclusions

- Porous pavements significantly improve post development hydrology:
 - Dramatically increase attenuation
 - Dramatically reduce peak flow and storm volumes
- Porous pavements significantly improve water quality for the range of contaminants with the exception of nitrogen
- Can be used as an effective transportation runoff BMP for chloride reduction (0-25% for PA)
- Shading and pavement color a factor in PC results
 - Shading typically not an issue in commercial settings
 - Black pavement melts faster than white pavement
- Routine plowing is a must
- Deicing is needed after freezing-rain for all pavements

DESIGN

Where Should We Use PP?

- Parking Areas
- Low use/residential roadways
- Porous Asphalt strength $1/3$ - $1/2$ that of DMA
- Pervious Concrete may be limited by cost and where deicing is an issue
- Permeable Pavers may be best for small sites and where aesthetics are a priority

Where Should We NOT Use PP?

- Heavy load areas commercial/industrial
- Drinking water wells (75 ft min)
- *Pollution “hot spots” or anywhere infiltration may not be suitable
- *Areas with shallow seasonal high
- *High groundwater table or shallow depth to bedrock
- *Any threat to groundwater contamination

* These areas could be lined and underdrained

Why Don't We Use PP Everywhere?

Barriers to Implementation

Perceived Performance Concerns

- Long-term-clogging and durability
- Water quality performance

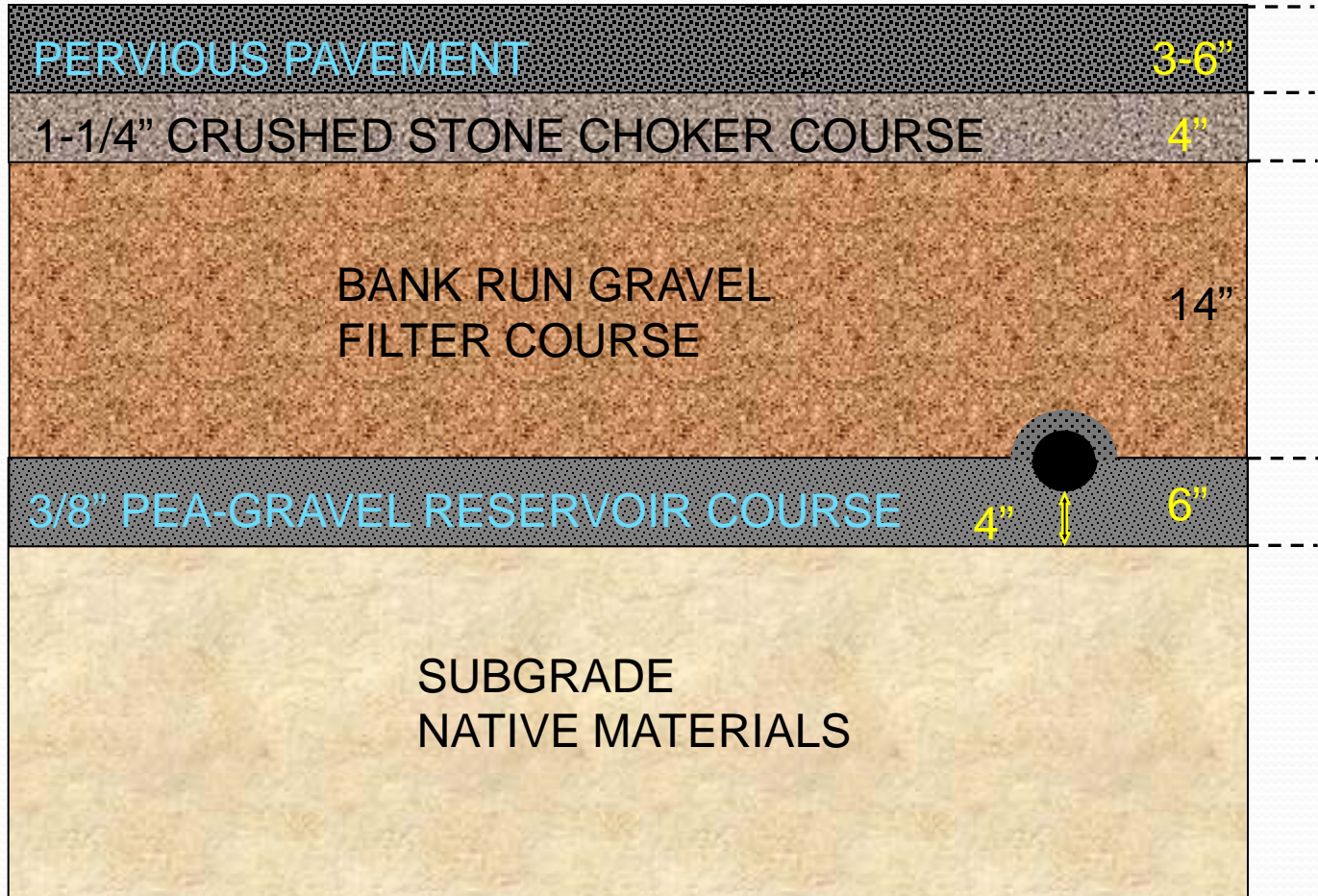
Construction Challenges

- Staging Issues: logistics and placement
- Proper mix

Maintenance Misperceptions

- Cleaning frequency
- Snow and ice treatments

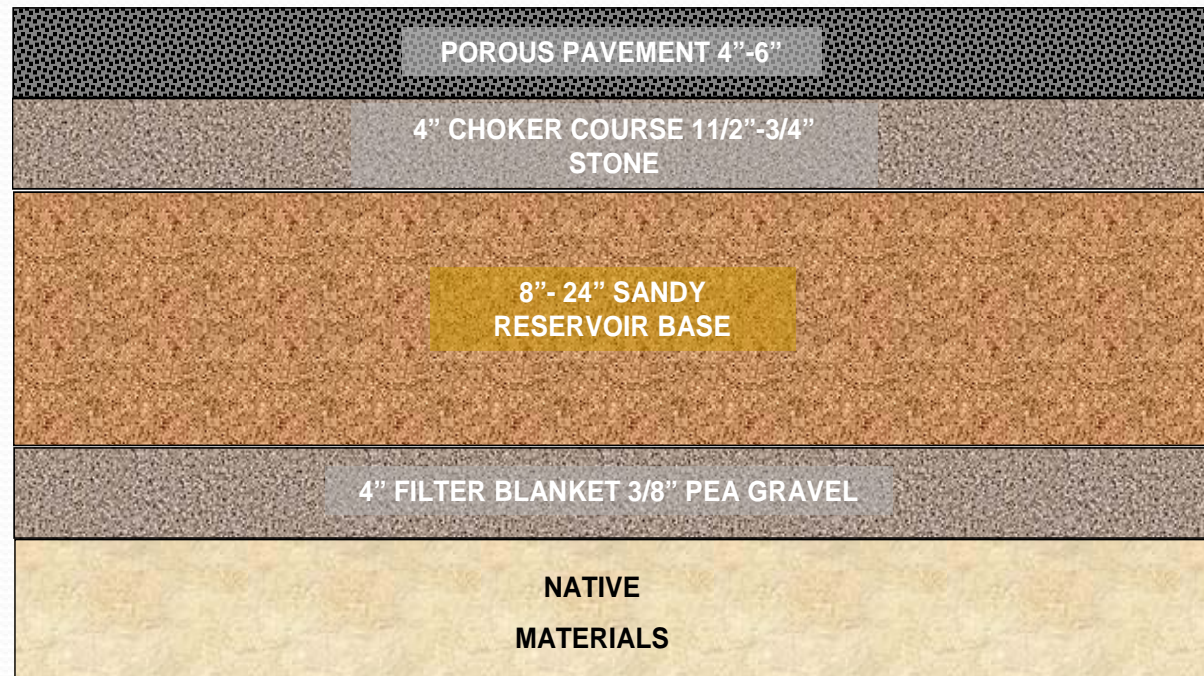
Typical Cross-Section Construction



Sub-base design matches that of the UNHSC Porous Asphalt Parking Lot

System Components

- Porous Pavement Course: 3-6"
- Choker Course: 4" 3/4"+ Stone



- Filter Course: Minimum 8-12" of poorly graded bank run sand
- Filter Blanket/Reservoir Course: 3/8" pea gravel of variable thickness – site specific

Subgrade Preparation

- Do not compact the native subgrade prior to the placement of the sub-base materials
- Follow same guidelines for construction of any BMP (erosion control, site stabilization)
- Use of geo-fabrics should be limited to stabilization of the sides
- Non-woven Mirafi[®] 160N or equivalent, placement should occur after excavation and prior to installation of the sub-base
- Some new geo-fabrics may be considered if threat of their clogging can be eliminated.

Liners

- State guidelines regulate groundwater protection standards. Most states require 1-3 ft separation between the system and the seasonal high water table (or bedrock).
- Liners can be used for sites where the infiltration is not appropriate (eg. high water table, bedrock karst sites and hot spots where hazardous materials may be handled).
- The use of Liners will preserve water quality through detention and filtration but limit any infiltration.
- Liners can be made from HSG 'D' soils, HDPE, or clay

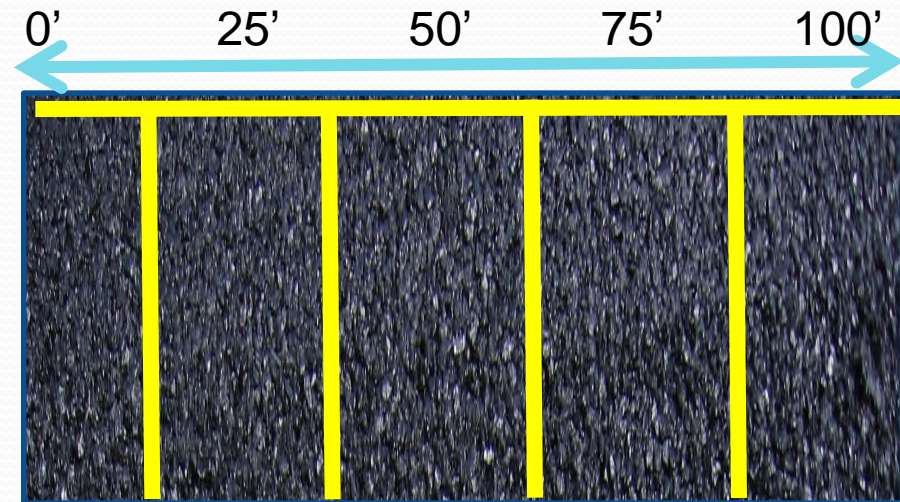
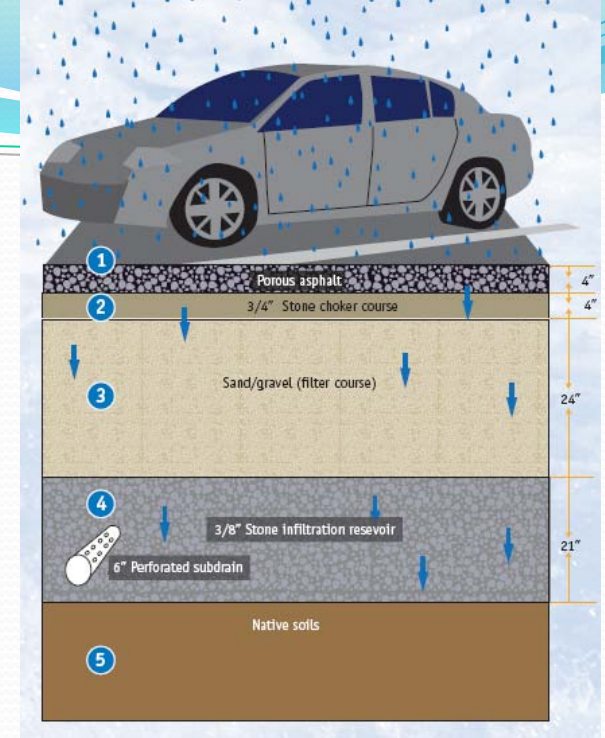
Sub-Base Materials

Thickness of sub-base materials is determined based on various factors

1. In cold climates / penetration of freezing
Total sub-base thickness $\geq 0.65 * D_{\text{max}}$ frost depth (Ex. if $D_{\text{max}} = 48''$ sub-base depth = $32''$)
2. Sub-base materials have sufficient void space to store the design storm.
3. Underlying native materials: if over poor soils (Hydrologic Group C and D soils) consider under-drains and min larger reservoir course.

Subdrains

- Subdrains, if included, are elevated at minimum 4” above subgrade to provide storage and/or infiltration for 1” water quality volume.
- Subdrains are perforated or slotted pipe, 4-6” diameter with 2” cover
- Spacing should be a 25’ on centers or appropriate to the discretion of the design engineer.
- Use of leaching catchbasins as system redundancy



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Filter Course

- A bank run sand (NHDOT 304.1) or equivalent should be used for the filter course.
- The materials should have a final hydraulic conductivity of 5-30 ft/day at 95% compaction by modified proctor (ASTM-D1557)

Filter Blanket/Reservoir Course

- Where applicable reservoir course and setting bed can be combined and constructed with pea gravel (3/8" stone)
- Setting bed prevents migration of fine materials from the filter course to the reservoir course. Aggregate size is calculated based on HEC 11 (3/8" stone is most common)

$$\frac{D_{15 \text{ coarse layer}}}{D_{85 \text{ fine layer}}} < 5 < \frac{D_{15 \text{ coarse layer}}}{D_{15 \text{ fine layer}}} < 40$$

- The reservoir course is designed such that materials have sufficient void space to store the design storm (Ex. 25 year storm, 5.1" rainfall depth, 0.3 reservoir void space sub-base thickness = 17" > 5.1" / 0.3)

Choker Course

- Material for the choker course shall have the AASHTO No. 57 + and AASHTO No. 3 gradations
- If the AASHTO No. 3 gradation cannot be met, AASHTO No. 5 is acceptable with approval of the Engineer.
- Compaction maximum possible

Gradations of choker, filter, and reservoir course materials

US Standard Sieve Size Inches/mm	Percent Passing (%)			
	Choker Course (AASHTO No. 57)	Filter Course (Modified NHDOT 304.1)	Reservoir Course (AASHTO No. 3)	Reservoir Course Alternative* (AASHTO No. 5)
6/150	-	100	-	
2½/63	-		100	-
2 /50	-		90 – 100	-
1½/37.5	100		35 – 70	100
1/25	95 - 100		0 – 15	90 – 100
¾/19	-		-	20 - 55
½/12.5	25 - 60		0 - 5	0 - 10
3/8/9.5	-		-	0 - 5
#4/4.75	0 - 10	70-100	-	
#8/2.36	0 - 5		-	
#200/0.075		0 – 6**		
% Compaction ASTM D698 / AASHTO T99	95	95	95	95



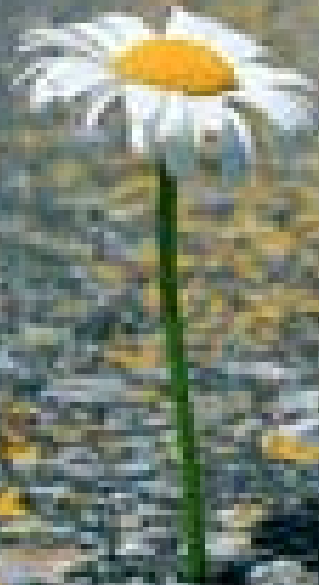
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**may need to process native material to achieve this PSD



2009 UPDATE OF UNHSC DESIGN SPECIFICATIONS FOR POROUS ASPHALT PAVEMENT AND INFILTRATION BEDS

http://www.unh.edu/erg/cstev/pubs_specs_info/unhsc_pa_spec_10_09.pdf



Binder



1. PG-64-28 modified with SBR, SBS, and/or fibers
2. Use an asphalt binder range of 5.75% to 6.5% in specs, based upon specific gravity of aggregate.


Porous Asphalt Mixes



- PG 64-28 with 5 pounds of fibers per ton of asphalt mix. This mix is recommended for smaller projects with lower traffic counts or loading potential. This mix is manageable at common batch plants.
- Pre-Blended PG 64-28 SBS/SBR with 2.5 -5 pounds of fibers per ton of asphalt mix. This mix is recommended for large projects > 1acre where high durability pavements are needed.
- Pre-Blended PG 76-22 modified with SBS/SBR and 5 pounds of fibers per ton of asphalt mix. This mix is recommended for large sites anticipating high wheel load (H-20) and traffic counts for maximum durability.

Porous Asphalt Mix Criteria

Sieve Size (inch/mm)	Percent Passing (%)
0.75/19	100
0.50/12.5	85-100
0.375/9.5	55-75
No.4/4.75	10-25
No.8/2.36	5-10
No.200/0.075 (#200)	2-4
Binder Content (AASHTO T164)	6 - 6.5%
Fiber Content by Total Mixture Mass	0.3% cellulose or 0.4% mineral
Rubber Solids (SBR) Content by Weight of the Bitumen	1.5-3% or TBD
Air Void Content (ASTM D6752/AASHTO T275)	16.0-22.0%
Draindown (ASTM D6390)*	≤ 0.3 %
Retained Tensile Strength (AASHTO 283)**	≥ 80 %
Cantabro abrasion test on unaged samples (ASTM D7064-04)	≤ 20%
Cantabro abrasion test on 7 day aged samples	≤ 30%



Polymer modifiers and Poly fiber quantities

Mixes call for either

1. 1.5% by weight of liquid asphalt for SBR (latex), and/or
2. 5 pounds per ton of fibers.



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Porous Asphalt Binder Specs

Binder Content (AASHTO T164)	6.0-6.5%
Air Void Content by Corelok (ASTM D6752)*	16.0-20.0%
Air Void Content by Paraffin wax (AASHTO T275)*	18.0-22.0%
Draindown (ASTM D6390)**	$\leq 0.3 \%$
Retained Tensile Strength (AASHTO 283)***	$\geq 80 \%$

Pervious Concrete Mix Design

- Aggregate gradation
 - No fines added to mix
- Admixture design
 - Hydrator: DELVO®
 - Strength agent: PolyHead® 1025
 - Plasticizer: Rheomac® VMA 362
- Unit weight: 132 lb/ft³
- Air voids: 18%
- Compressive strength:
 - >3000 psi
- Test pour to finalize mix



Construction

PA QA/QC During Production

- Recommended that the Contractor shall provide at Contractors' expense and the Engineer's approval a third-party QA Inspector to oversee and document mix production. All mix testing results during production should be submitted to the QA Inspector.
- The QC plan may be altered at the discretion of the Engineer and based on feasible testing as suggested by the asphalt producer.
- Certain QC testing requirements during production may not be feasible for small projects in which limited asphalt is generated.
- Some testing methods cannot be completed during the time needed during small batch production.

Bedrock covered by
HDPE liner & BRG

Stone reservoir course and subdrains

Plastic over bedrock



Filter course

Choker course placed for stability



Under-drains set in crushed gravel

Stone reservoir course and subdrains



Subgrade at Sandy Point
after excavation to subgrade
and 5 minutes after 4-in rain



Paving individual lots first



Top course for road





First layer paving at Greenland



First layer paving at Greenland



First layer paving at Greenland



DMA at Greenland



Filter course and subdrains
On compacted soil liner clay



Filter course with
Rooftop infiltration lines



Filter course with
Rooftop infiltration lines



Stone reservoir and choker course

Compaction and Rutting



- Install filter, choker, gravel, and stone base course aggregate in 8-inch maximum lifts to a MAXIMUM of 95% standard proctor compaction (ASTM D698 / AASHTO T99).
- The density of subbase courses shall be determined by AASHTO T 191 (Sand-Cone Method), AASHTO T 204 (Drive Cylinder Method), or AASHTO T 238 (Nuclear Methods), or other approved alternate
- The infiltration rate (ASTM D3385 or approved alternate) shall be no less 5-30 ft/day or 50% of the hydraulic conductivity (D2434) at 95% standard proctor compaction

Multiple lift installation

- PA can be installed as 1 or 2 lifts depending on site
- 2nd lift improves pavement compaction
- Paving sequencing is important---plan to minimize traffic on completed lifts
- Should be up to the contractor. Small simple jobs may be easier in a single lift, larger jobs in two lifts.
- Two-lift scenario may require use of a light application of tackifier between the first and second lift.
- Enables installation of curbs and castings in typical fashion
- Simplifies use of “tacky” 64-28SBR/SBS or 76-22SBR/SBS as top layer and 64-28 with fibers as base course

Asphalt Compaction

- Immediately after the asphalt mixture has been spread, struck off, and surface irregularities adjusted, it shall be thoroughly and uniformly compacted by rolling. The compaction objective is 16% - 19% in place void content (Corelock).
- Breakdown rolling shall occur when the mix temperature is between 135-163°C (275 to 325°F).
- Intermediate rolling shall occur when the mix temperature is between 93-135°C (200 to 275°F).
- Finish rolling shall occur when the mix temperature is between 66-93°C (150 to 200°F).
- The cessation temperature occurs at approximately 79°C (175°F), at which point the mix becomes resistant to compaction and will not achieve adequate durability.
- Rolling should not cause undue displacement, cracking, or shoving.



Curing time needs are site specific but there should be at least 24-48 hrs of curing. Common sense clause may lead to lower threshold for small jobs with lighter loading such as when pavement surface is less than 100 F (one-time measurement). Problems occur when the surface temperature is greater than 120 F.

Installation Tips

- PP should be placed as late as possible during the project
- Ensure traffic controls to protect placement until fully cured/hardened.
- Avoid placement under the following conditions in cold climate areas:

*Nov. 15 to March 15 (winter)
at Temperatures $<60^{\circ}\text{F}$
Soil temperatures $<60^{\circ}\text{F}$



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* unless installing permeable pavers



Maintenance



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Regenerative Air

Direct Vacuum

Frequency

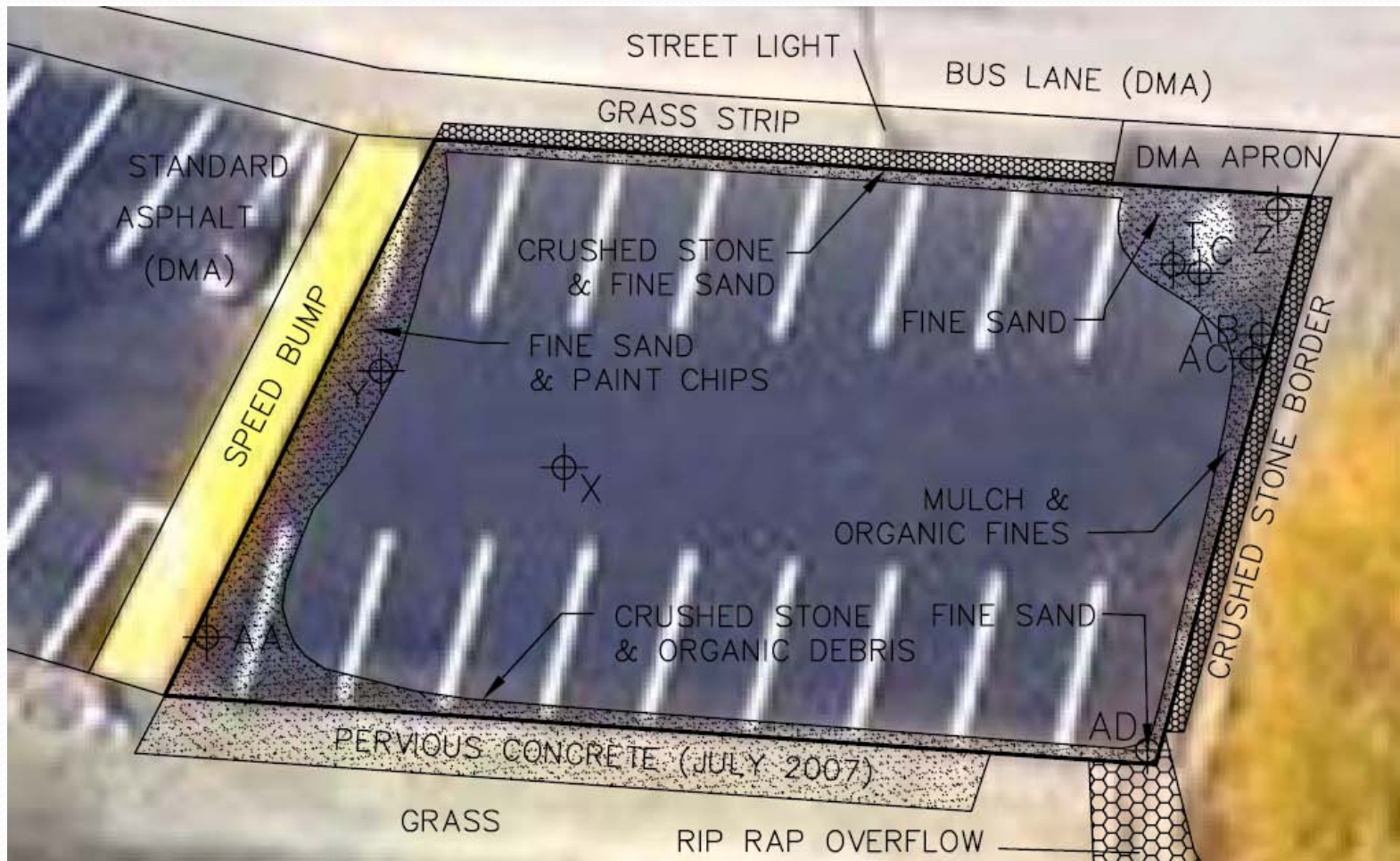
- 2-12 times per year
- Daily to weekly for high load of fines (organics, butts, etc.)
- Seasonal variations (end-of-winter, etc.)

Aggressive Cleaning

- When obvious loss of high infiltration capacity is observed

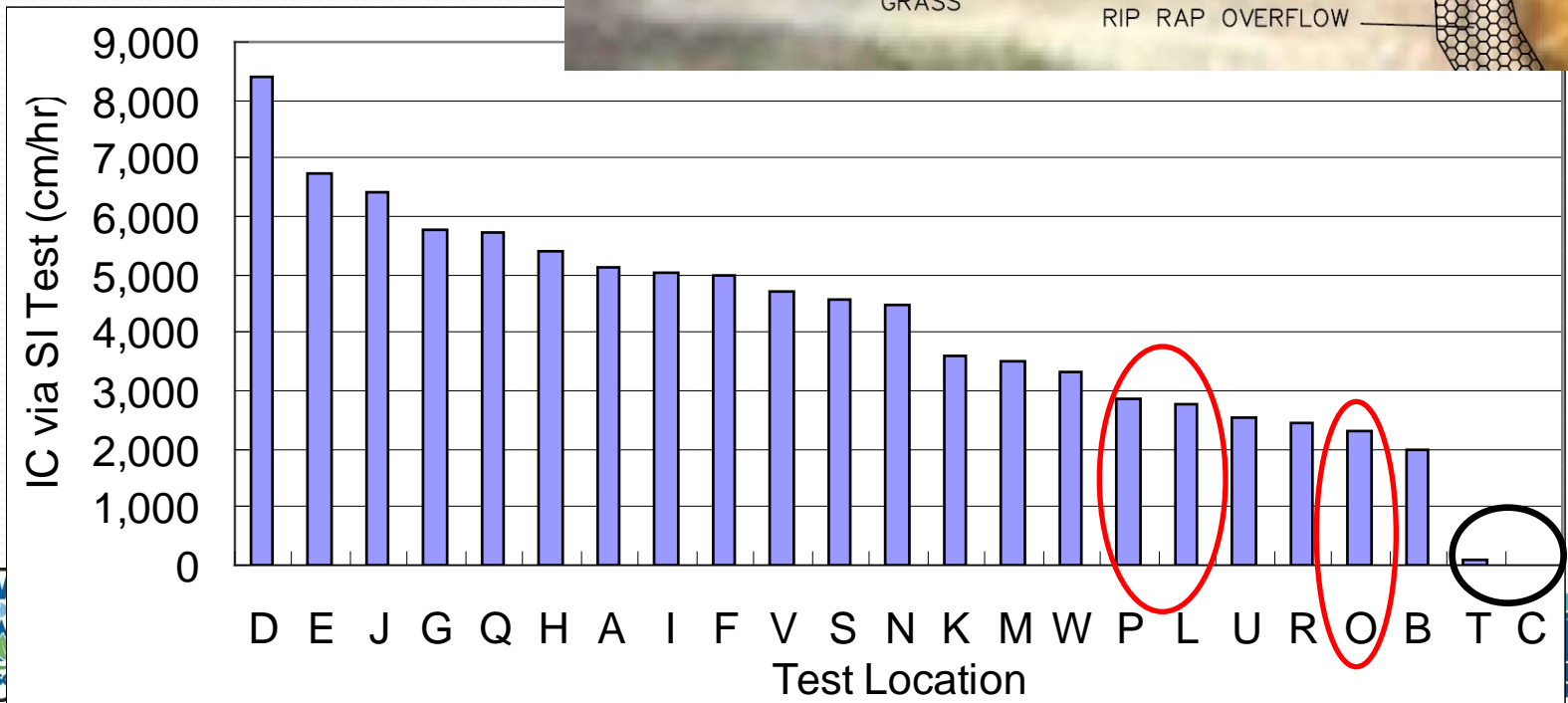
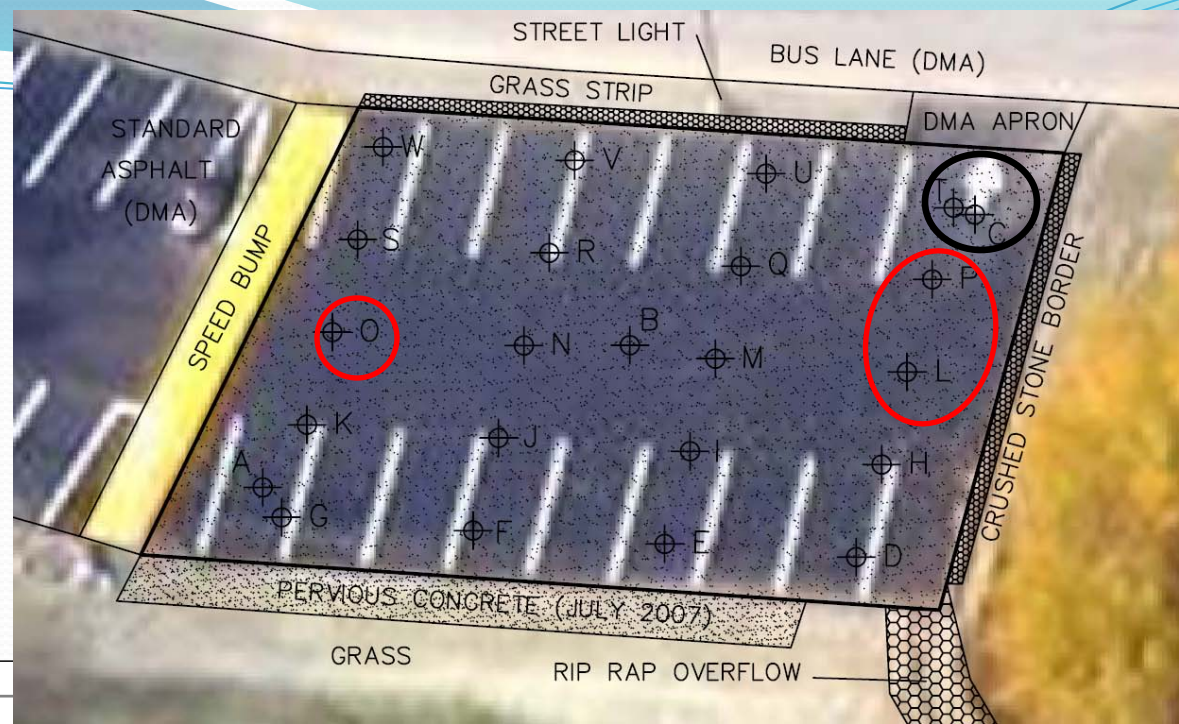


Pre-Tx Extent of Debris/Clogging

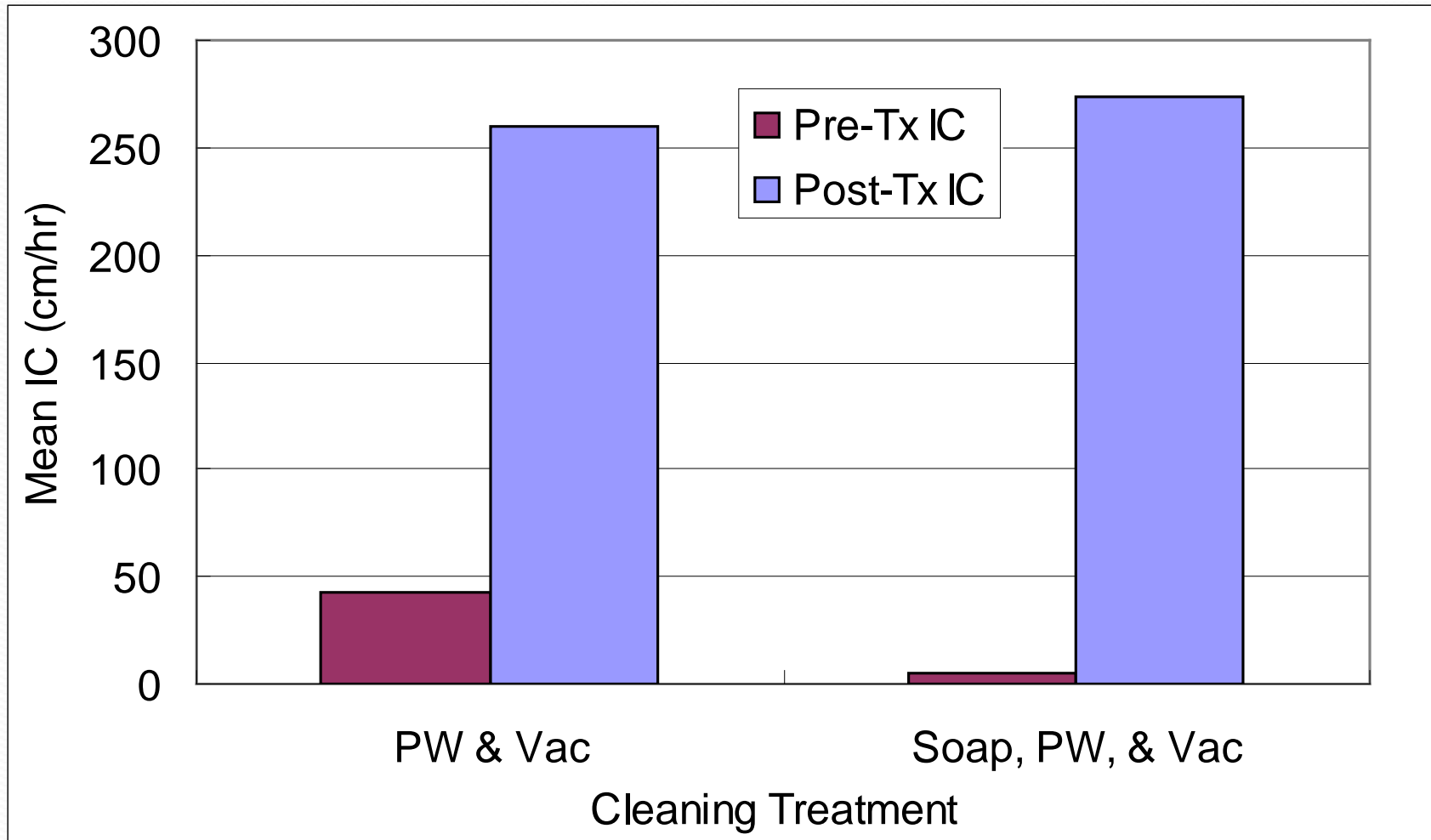


Infiltration capacity via the Pre-Tx DRI test varied from 0 to 53 cm/hr, all effectively clogged when slope is considered.

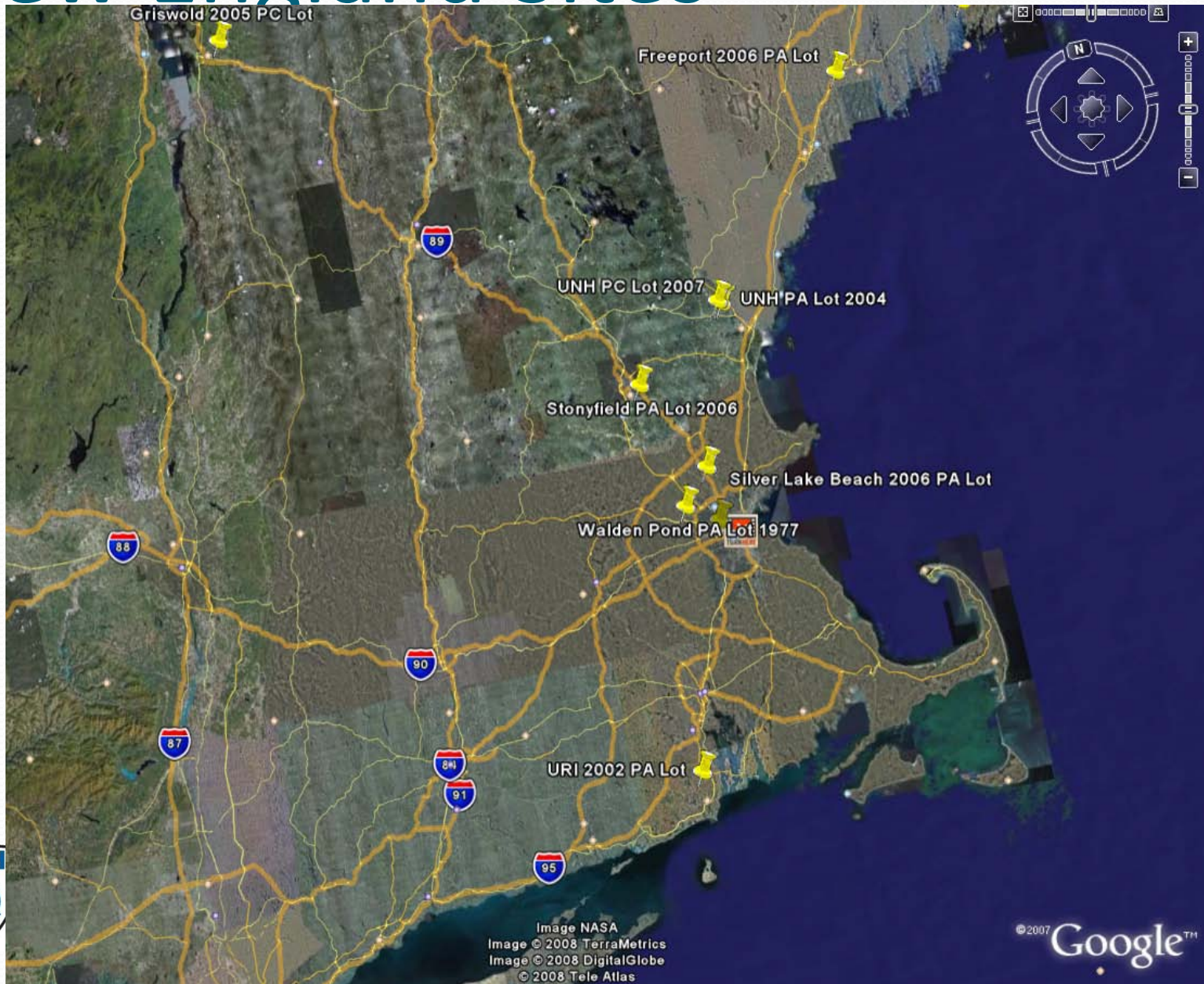
Pre-Tx Infiltration at Grid Locations

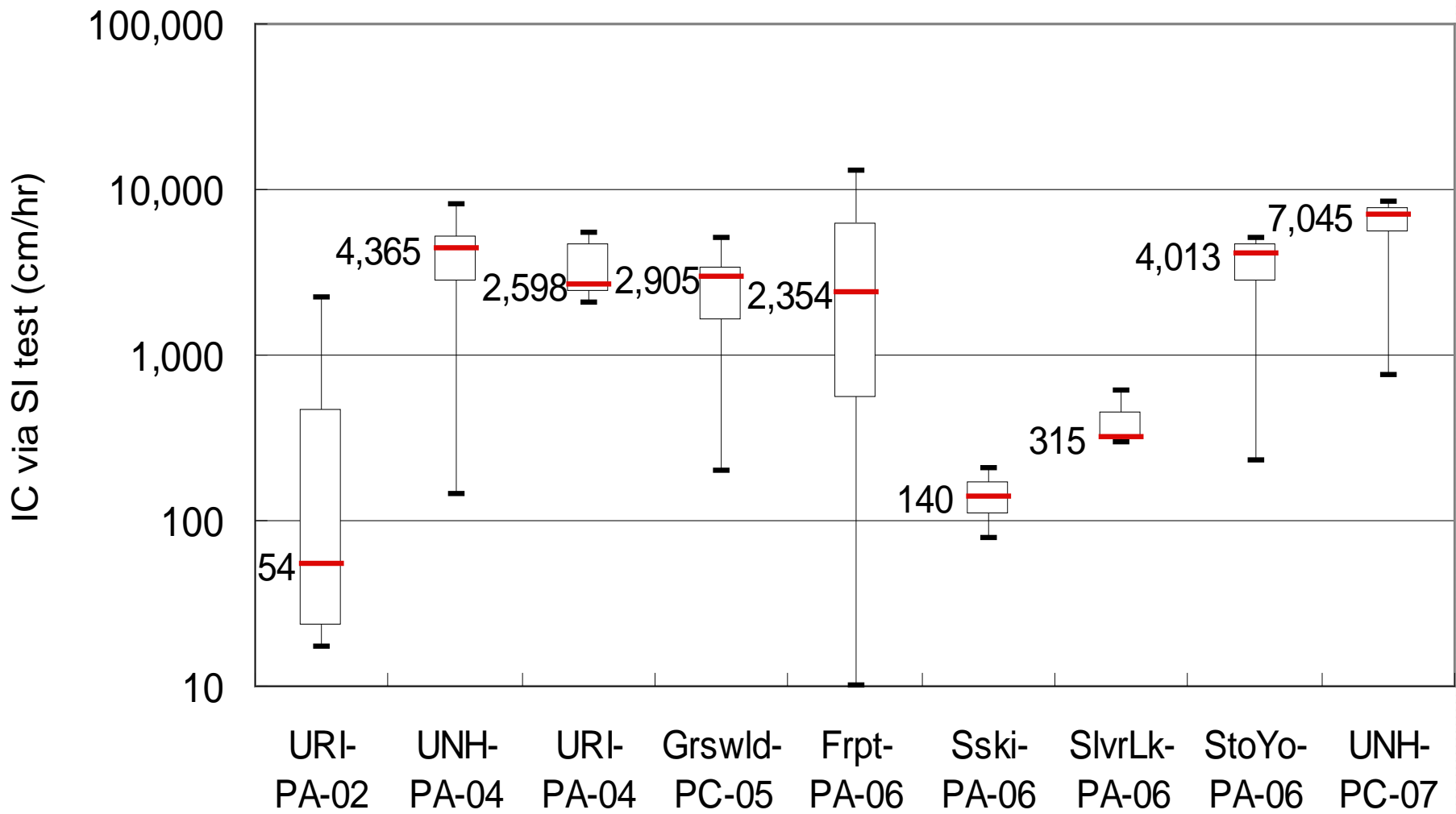


Treatment Effectiveness for Clogged



New England Sites





Repairs and Replacement

- Damage can occur to PA from non-design loads
- Repairs may be needed from cuts for utilities
- Repairs can be made with standard HMA for most damages up to 15% of surface area
- PA can be repaired by heating and rerolling
- When pavement reaches end of life, it is replaced by milling to choker coarse.

Tractor trailer damage



Repairs

After repairs



- Used for repairs around manholes, catch basins, and for reworking rough pavement areas
- Asphalt in the repair area can be raked and rolled back into place and additional hot mix can be added when
- Repairs cost ~\$2000



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Usage Suggestions

- Design to avoid misuse—only the intended application
- Anticipate the unexpected
- Clear signage—No Double Wheel Axle for less durable pavements
- Clearance bars

Planning Costs

- ~10-20% more for materials
- DMA \$75-100/ton, PA \$89-125/ton placed by machine for parking and residential road and driveways
- Complicated jobs with handwork are more expensive
- DMA \$2.25/sf, PA \$2.80/sf, PC \$4-5/sf not including subbase
- Costs offset by lack of stormwater infrastructure
- Cost break even is achieved when designing for quantity management ~Q10-Q25

Residential Install Costs

- 1200 square feet paved
- Cost estimate \$3700 for PA, \$3900 for DMA'
- \$2000 for PA subbase prep for 8" stone with cut
- Cost estimate for \$2000 minimum for conventional drainage
- \$3.20/sf PA, \$3.30/sf DMA

REFERENCES

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- G. Section 02725 - General Porous Pavement and Groundwater Infiltration Beds, specification from NAPA Porous Asphalt Seminar handout, Cahill Associates, Inc., 2004.
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QUESTIONS

