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# MANAGING STORMWATER IN THE HUDSON VALLEY:
## A COST-BENEFIT ANALYSIS OF PERMEABLE PAVEMENT

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# ROAD MAP

- Motivation
- Background
- Methods
- Results
- Discussion & policy recommendations
- Next Steps

# Stormwater management is key to maintaining water quality & human health

Hudson River estuary

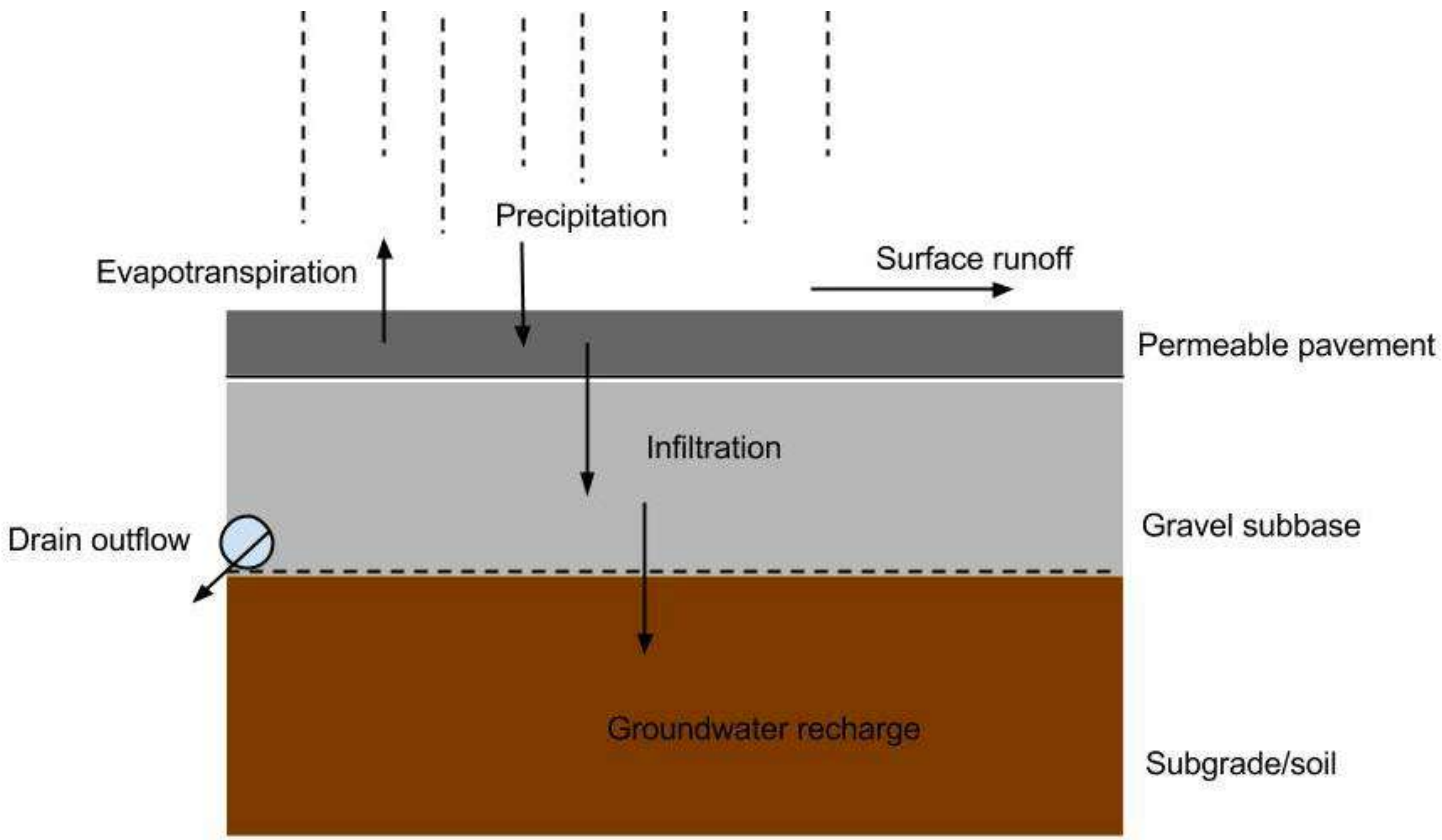
- 150 sewer systems, 13 Combined Sewer Systems (CSS)
- 695 CSS outfalls
- 29 billion gallons discharge
- Separate systems also lead to discharge

Exacerbated by climate change and urbanization

# Stormwater managed historically using gray infrastructure

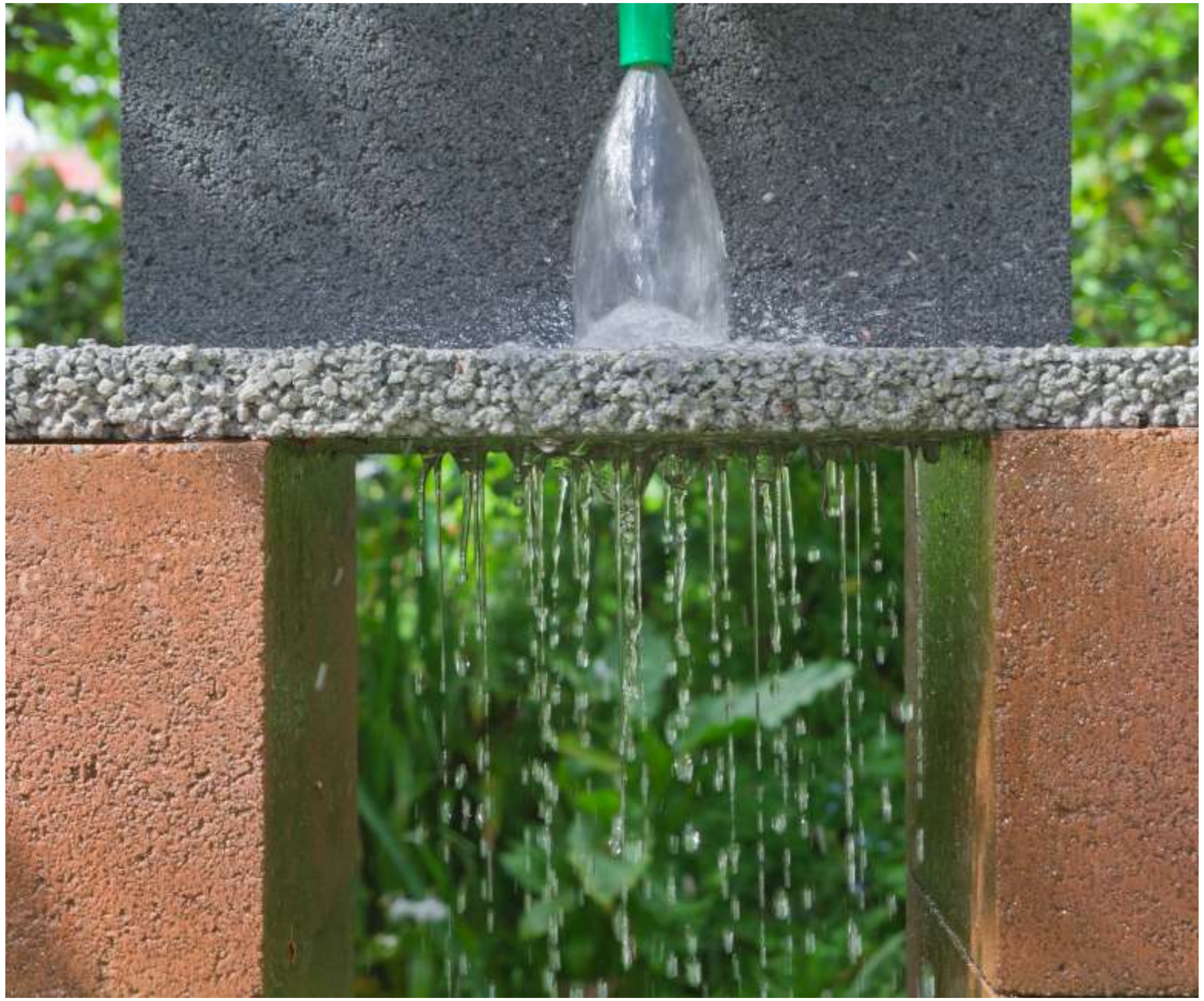
# Emerging stormwater management alternative: green infrastructure

# Permeable pavement: An example of green infrastructure




# Who is adopting permeable pavement in the Hudson Valley?

# What is the lifecycle value of permeable pavement?



I created a robust **cost-benefit analysis tool** to estimate the **value of porous pavement** for the **Hudson Valley**

# What are the primary costs and benefits of permeable pavement?

***Costs***

- Installation
- Operating and maintenance

***Benefits***

- Avoided gray infrastructure
- Reduced runoff
- Pollutant removal
- Reduced deicing

# Assumptions

- ***Project size***: one acre or 34,560 square feet
- ***Type***: Pervious asphalt parking lot with 100-150 spaces
- ***Benefits realized***: All (new development, CSS municipality)
- ***Install cost***: $5 per square foot
- ***Life expectancy***: 30 years
- ***Discount rate***: 3%

# Cost #1: Installation

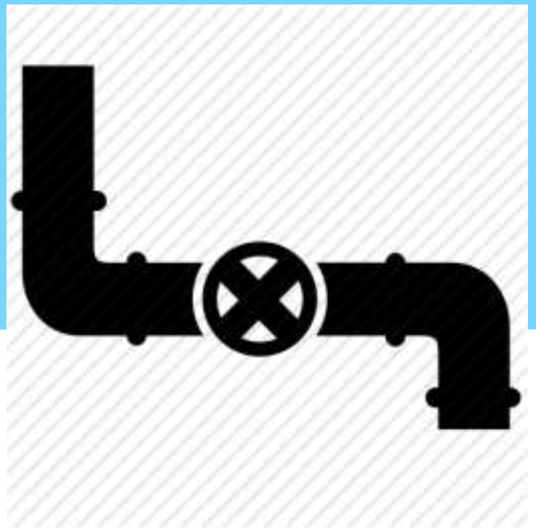
- Upfront investment
- $0.50 to $5 per square foot
- Sources: Booth, 1999; Houle et al., 2013; UNHSC, 2012

| **Installation Costs** | |
|---|---|
| Unit cost (dollars per square feet) | 5 |
| **Project installation cost (dollars)** | **217,800** |

# Cost #2: Operating + Maintenance

- Annual cost
- Vacuuming and inspection
- $1.14 mil per square foot and $25 per acre
- Sources: Houle et al., 2013; UNHSC, 2012

| **Operating & Maintenance Costs** | |
|---|---|
| Unit vacuuming cost (dollars per square feet) | 0.0114 |
| Project vacuuming cost (dollars per year) | 497 |
| Vacuuming frequency (times per year) | 2 |
| Inspection (dollars per year) | 25 |
| **Total annual O&M cost (dollars per year)** | **1,018** |



# Benefit #1: Avoided gray Infrastructure

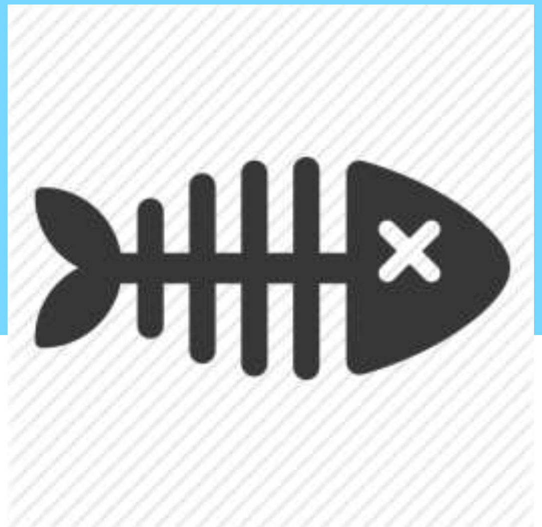
- Upfront avoided cost
- $2.71 per square foot
- Source: CNT, 2009

| **Avoided Costs** | |
|---|---|
| Unit cost of stormwater treatment (dollars per square feet) | 2.71 |
| **Avoided gray infrastructure (dollars)** | **118,048** |

# Benefit #2: Reduced runoff

- Annual avoided cost
- $0.743 mil per square foot
- NRCS rainfall-runoff model, sewage rates
- Sources: CNT, 2010; Battiata et al., 2008; Hunt, 2012; USDA NRCS, 2004; Roseen et al., 2012; UNHSC, 2012

| Runoff reduction | |
|---|---|
| Wastewater or sewage treatment fee (dollars per gallon) | 0.007429 |
| Average annual precipitation (inches per year) | 47.50 |
| Avoided annual runoff volume (gallons) | 867,064 |
| **Annual runoff benefit (dollars per year)** | **6,441** |



# Benefit #3: Pollutant removal

- Annual avoided cost
- $0.17 for TSS and $0.035 mil for TP per square foot
- Pollutant concentration reduction method
- Sources: CWP, 2013; Houle et al., 2013; NYSDEC, 2010; Roseen et al., 2012

| Pollutant removal | |
|---|---|
| Drainage area | |
| Approximate proportion institutional parking lot (%) | 100 |
| Annual TSS pollutant removed (miligrams) | 454,207,418 |
| Annual TP pollutant removed (miligrams) | 767,952 |
| **Pollutant removal benefit (dollars per year)** | **8,509** |

# Benefit #4: Reduced deicing

- Annual avoided cost
- $0.33 mil per square foot
- 75% reduction recommended
- Sources: DOT, 2013; Houle, 2008; Houle et al., 2013; Shafer & Kevern, 2013; UNHSC, 2012

| Deicing reduction | |
|---|---|
| Typically road salt application (tons per acre) | 3 |
| Unit cost of road salt (dollars per ton) | 51 |
| Proportion reduction for permeable (%) | 75 |
| **Deicing benefit (dollars per year)** | **115** |

# Results

| Financial Analysis | |
|---|---|
| NPV (dollars) | 175,573 |
| Annual Savings (dollars) | 8,958 |
| Payback Period (years) | 8.11 |
| Return on Investment (%) | 14 |

# Discussion

| Financial Analysis | |
|---|---|
| NPV (dollars) | 175,573 |
| Annual Savings (dollars) | 8,958 |
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- Compare to existing studies
- Model is more robust but there are still weaknesses
  - Installation costs, repair, gray infra, climate change, etc.
- Permeable pavement could have a significant impact on municipal annual budget
- If NPV really is significantly positive, why are there roadblocks?

# Why are more municipalities not adopting permeable pavement?

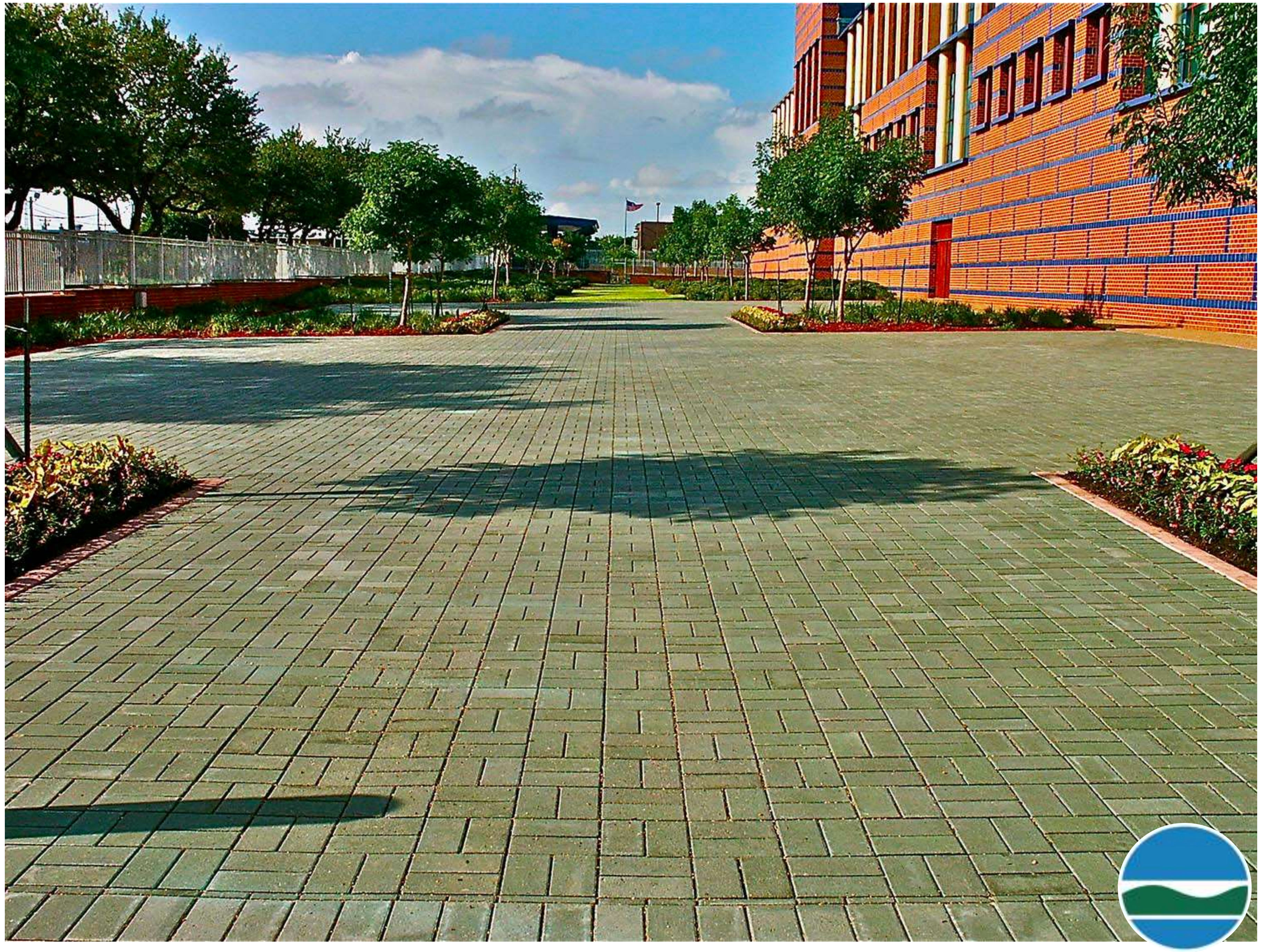
- Traditional pavement technology well known
- Installation costs are higher for permeable
- Permeable technology requires experienced engineers and installers
- Lenders may be reticent to fund because of uncertainty around lifecycle costs and benefits

# Policy recommendations

- Need better education and institutionalization through outreach, funding, and successful demo projects
- Lenders need to decouple risk and funding roles by outsourcing their risk-taking to a third party insurer

# Next steps

- Incorporate climate change projections for NYS
- Improve model
- Transform into user-friendly online tool
- Apply to real life projects
- U. Albany campus center



# Questions?

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# Equations

- Installation

$$C_i = A * c$$

where *A* is the area of the project, and *c* is the unit installation cost of permeable pavement.

- O&M

$$C_m = A * (c_v * f) + c_i$$

where *A* is the area of the project, $c_v$ is the unit cost of vacuuming, *f* is the annual vacuuming frequency, and $c_i$ is the annual cost of inspection.

# Equations

- Gray infrastructure

Where $A$ is the area of the project and $c_g$ is the avoided cost of gray infrastructure that would have been required per unit of impervious surface.

$$B_i = A * c_g$$

- Runoff reduction

where $c_s$ is the unit cost to treat stormwater and $Q_{vol}$ is the annual runoff volume reduced. $Q_{vol}$ is derived from the NRCS Method, where $P$ is annual precipitation, $S_{IP}$ and $S_{PP}$ are the potential maximum retention after runoff begins for impervious pavement and permeable pavement, and $A$ is the area of the project. $S$ is also part of the NRCS Method, where $CN$ is the Curve Number assigned to each surface given its infiltration properties.

$$B_r = c_s * Q_{vol}$$

$$Q_{vol} = (\frac{P^2}{P + S_{IP}} - \frac{P^2}{P + S_{PP}}) * A$$

$$S = \frac{1000}{CN} - 10$$

# Equations

- Pollutant removal

where $P_{in}$ is the unit pollutant loading based on land use in drainage area, $P_{red}$ is the proportion of pollutant concentration reduction provided by permeable pavement, $W$ is the water volume treated, and $c_p$ is the unit cost to remove pollutant.

$$B_p = P_{in} * P_{red} * W * c_p$$

- Reduced deicing

where $A$ is the area of the project, $r$ is the reduction in road salt application, $t$ is the standard rate of road salt application for impervious pavement, and $c_s$ is the unit cost of road salt.

$$B_s = A * r * t * c_s$$

# NPV Equation

$$NPV = PV of Benefits - PV of Costs$$

$$= \{B_i + \frac{B_r + B_p + B_s}{1+i} + \frac{(\frac{B_r+B_p+B_s}{(1+i)^2})(1 - \frac{1}{(1+i)^t})}{1 - \frac{1}{1+i}}\}$$

$$-\{C_i + \frac{C_m}{1+i} + \frac{(\frac{C_m}{(1+i)^2})(1 - \frac{1}{(1+i)^t})}{1 - \frac{1}{1+i}}\}$$

Where $C_i$ is the initial investment in the form of installation cost of permeable pavement, $C_m$ is the annual cost of operating and maintenance, $i$ is the discount rate, $B_i$ is the initial benefit of avoided gray infrastructure, $B_r$ is the annual benefit of runoff reduction, $B_p$ is the annual benefit of pollutant removal, and $B_s$ is the annual benefit of reduced road salt application.

# Data

*Table 4. Municipal sewage fee rates for the mid-Hudson Valley area.*

| | Municipality | County | Sewage treatment fee (dollars per gallon) |
|---|---|---|---|
| 1 | Rosendale | Ulster | 0.004500 |
| 2 | New York | New York | 0.007607 |
| 3 | Fishkill | Dutchess | 0.012995 |
| 4 | Kingston | Ulster | 0.006007 |
| 5 | Newburgh | Orange | 0.010195 |
| 6 | Poughkeepsie | Dutchess | 0.002674 |
| 7 | Saugerties | Ulster | 0.005357 |
| 8 | Woodstock | Ulster | 0.010100 |
| | **Simple average sewage fee** | | **0.007429** |

# Data

*Table 5. Annual average precipitation from five sites in the Hudson Valley, NY, 1983-2013.*

| | Station location | County | Precipitation (inches) |
|---|---|---|---|
| 1 | Alcove | Albany | 52.7 |
| 2 | Hudson | Columbia | 41.6 |
| 3 | Yorktown Heights | Westchester | 54.1 |
| 4 | Mohonk Lake | Ulster | 42.0 |
| 5 | Walden | Orange | 47.1 |
| | **Simple average for five sites** | | **47.5** |

*Source: Northeast Climate Center.*

# Data

*Table 6. Representative pollutant loading by landuse type.*

*Source: Hunt et al., 2012*

| | TSS (mg/L) | TP (mg/L) | TN (mg/L) |
|---|---|---|---|
| Institutional | | | |
| Parking lot | 654.81 | 1.48 | 5.45 |
| Open/landscaped | 100.30 | 1.67 | 8.48 |
| Roof | 102.20 | 0.57 | 4.09 |
| Commercial | | | |
| Parking lot | 219.53 | 0.61 | 5.45 |
| Roof | 27 | 0.15 | 1.08 |
| Open/landscaped | 100.30 | 1.67 | 8.48 |
| Residential | | | |
| Driveway | 654.81 | 1.48 | 5.45 |
| Roof | 27 | 0.15 | 1.08 |
| Lawn | 100.30 | 1.67 | 8.48 |
| Transportation | | | |
| Sidewalks | 113.55 | 1.78 | 4.31 |
| Low density | 113.55 | 1.63 | 13.89 |
| Medium density | 93 | 0.52 | 1.40 |
| Industrial | | | |
| Parking lot | 173 | 0.39 | 1.44 |
| Roof | 27 | 0.15 | 1.08 |
| Open/landscaped | 26.50 | 0.44 | 2.24 |
| Other | | | |
| Woods | 427.71 | 0.95 | 5.56 |
| Maintained grass | 75.70 | 2.23 | 11.58 |
| Pasture | 317.94 | 5.90 | 13.66 |
| Open water | 102.20 | 0.57 | 4.09 |