

Road Map for Development and Implementation of Permeable Pavement

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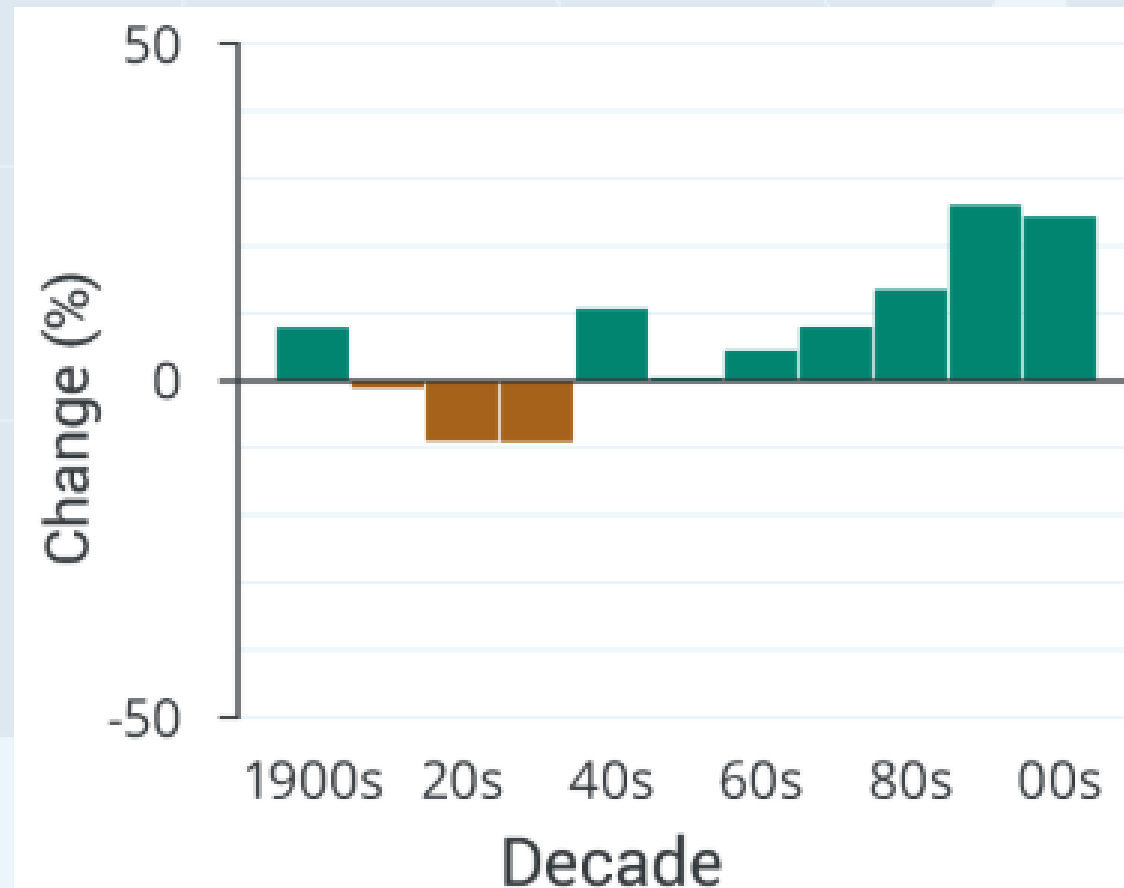
University of California, Davis



Observed Change in Intensity of Very Heavy Precipitation Events in US 1958 to 2012

National Climate Assessment 2014

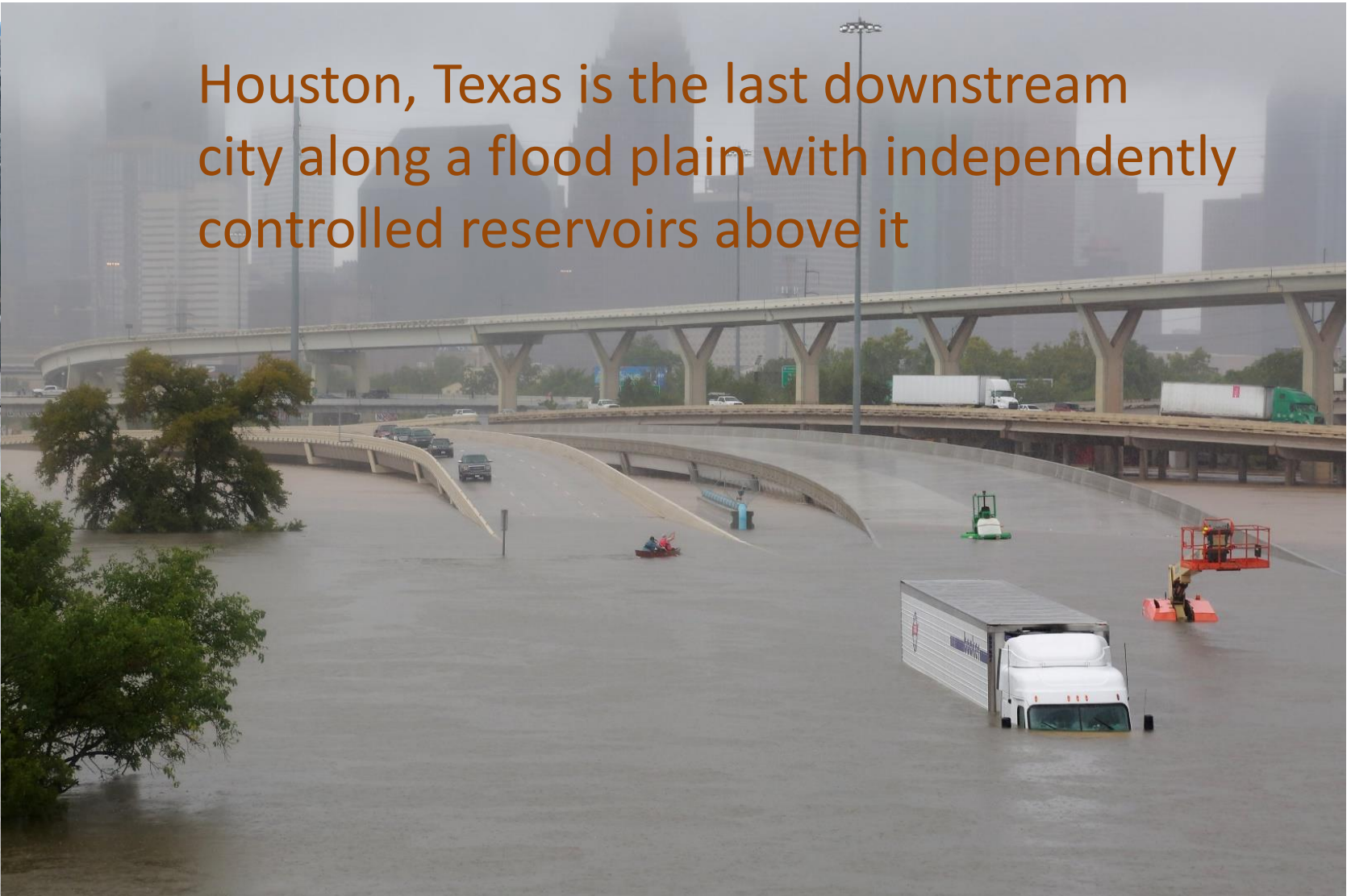
U.S. Average



- Defined as 99th percentile events
- By 2080
 - Approximately 2X more often with rapid reductions in CO₂ emission rate
 - Up to 5X more often with current CO₂ emission rates

Repeated flooding in coastal plains of eastern USA under extreme storms

Houston, Texas is the last downstream city along a flood plain with independently controlled reservoirs above it

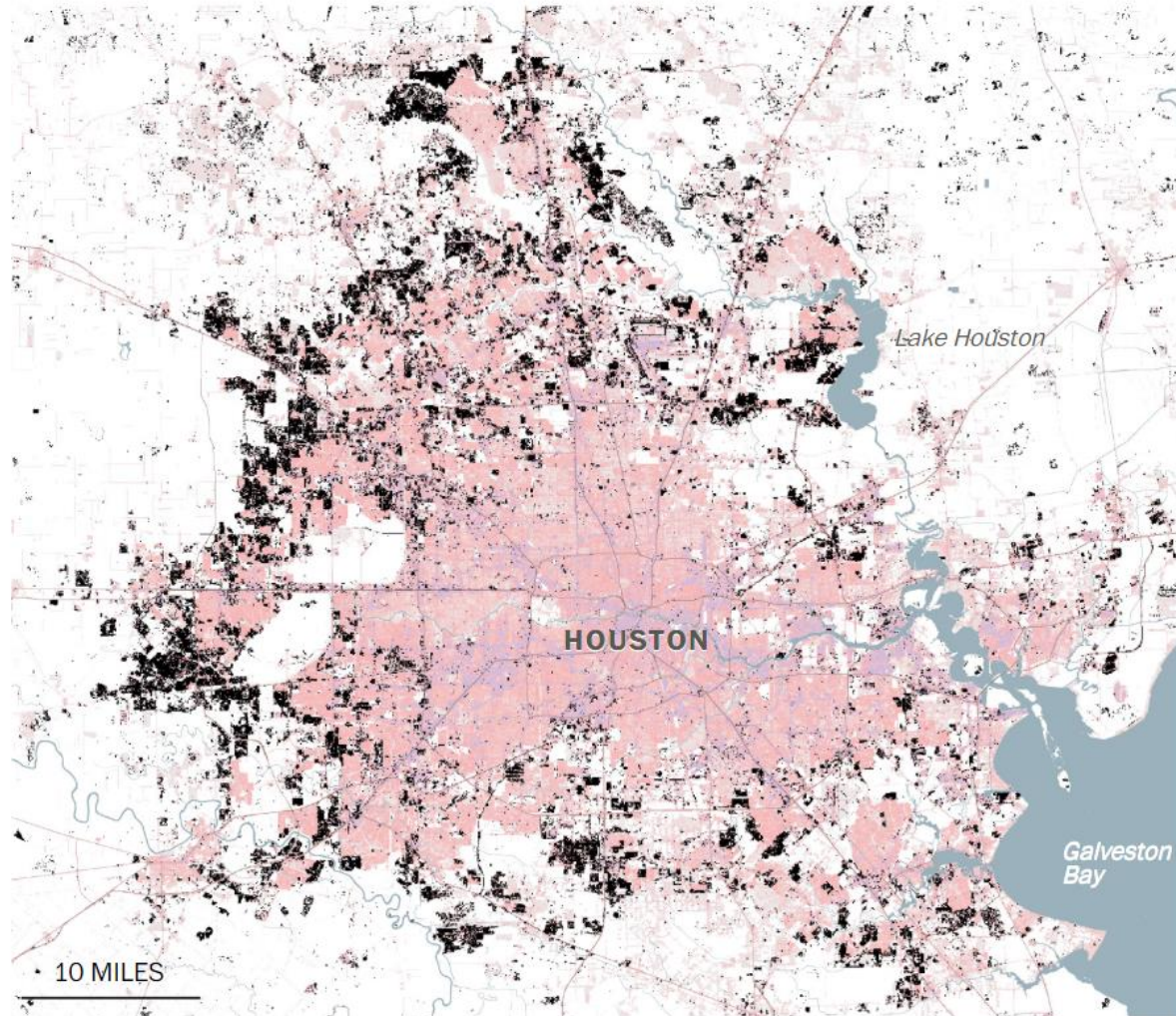


Cities at risk must increase their resilience

Drainagecoalition.com

Impermeable surfaces ■ As of 2011 ■ Added between 1996 and 2010

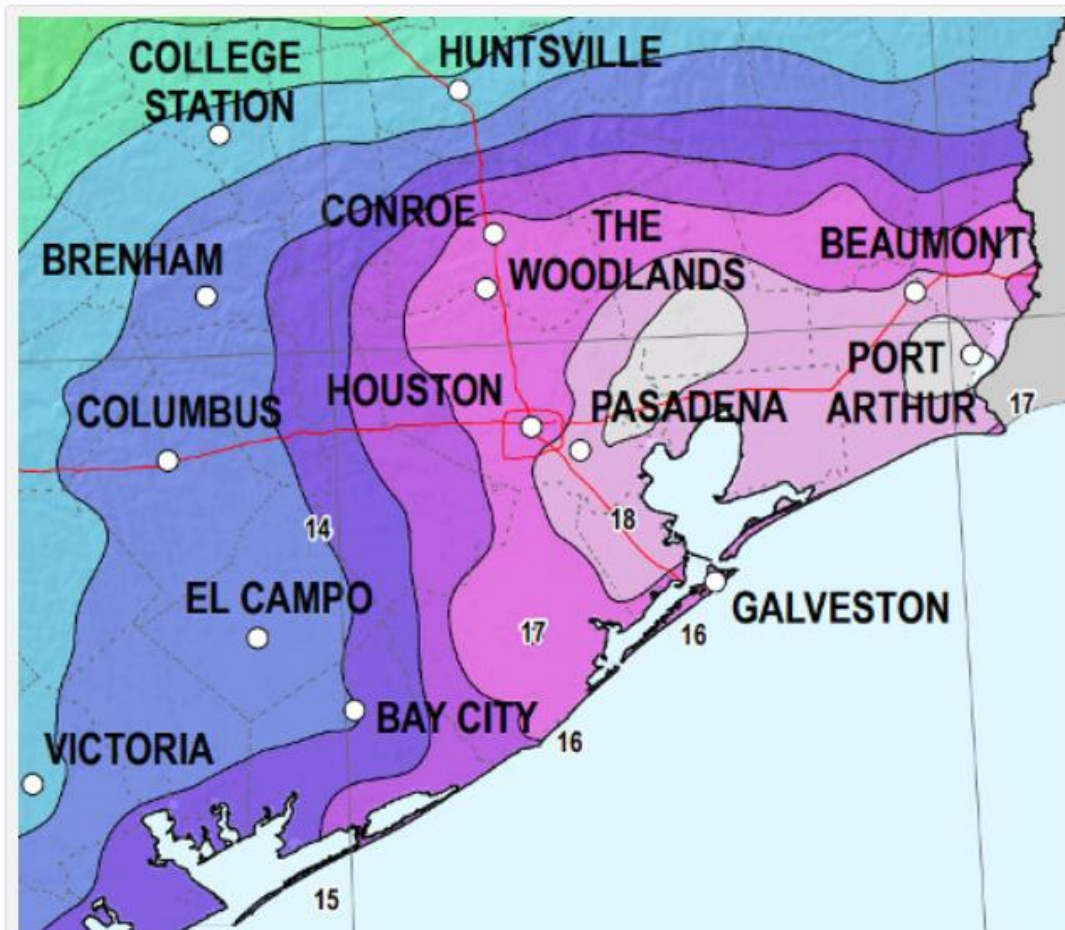
- About 65% of Houston is hardscape
- Houston has been steadily increasing its impermeable surfaces
- So have cities upstream in the flood plain



Sources: NOAA, U.S. Geological Survey

Cities at risk must increase their resilience

- Houston changed its 100 year storm maps after hurricane
- Houston requires development to have 15 cm storm detention; new 100 year flood map shows 100 year storm event is 45 cm
- Haselbach discussed how upstream development and detention releases increase floods



Originally proposed new 100-year rainfall amounts posted shortly before hurricane Harvey. It shows 18" of water falling across a large swath of the city. Houston only requires 6" of detention. Where does the other ~12" of water go?

Can Permeable Pavement Help Solve Stormwater Quality and Flood Problems?

- Permeable hardscape in urban areas can help
 - Reduce water pollution (*oil, metal, sediment, etc.*)
 - Reduce rate and amount of flood runoff
 - Improve groundwater recharge where subgrade permits
 - Potentially improve local heat island effect (*more evaporation*)



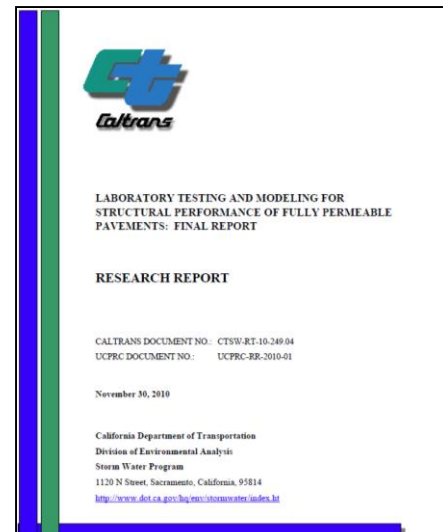
So then, why are permeable pavements not being used extensively?

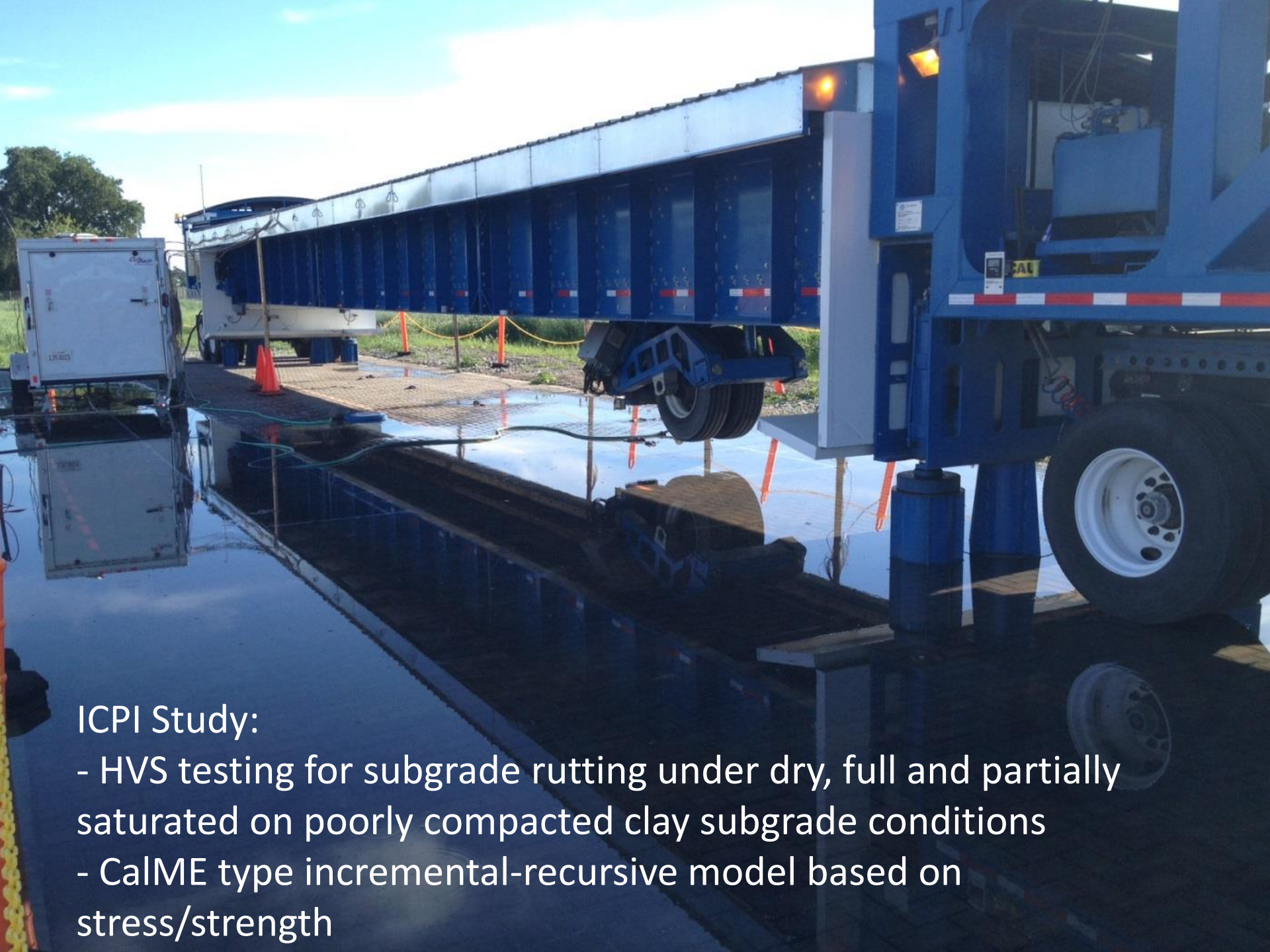
Wasn't the needed research done?

- Extensive work on materials, designs, permeability, permeability and structural performance
 - Work by Kayhanian, Kevern, Haselbach, Univ of New Hampshire, Univ Central Florida, Hein, others
 - Previous research and development by UCPRC
 - Concrete and asphalt design manual for Caltrans
 - Structural validation and design method for Interlocking Concrete Pavement Institute (pavers)
- 2017 TRB workshop summarizing progress

UCPRC Development of Design Methods (2010, 2014)

- Pervious Concrete and Porous Asphalt for Heavy Truck Traffic
 - Preliminary permeable pavement designs for typical California traffic and environmental conditions
 - Includes use of permeable concrete subbase
 - <http://www.ucprc.ucdavis.edu/PDF/UCPRC-RR-2010-01.pdf>
- Permeable Interlocking Concrete Pavement for Heavy Truck Traffic
 - Design method and validation results
 - Being incorporated into ICPI and ASCE designs
 - <http://www.ucprc.ucdavis.edu/PDF/UCPRC-RR-2014-04.pdf>





ICPI Study:

- HVS testing for subgrade rutting under dry, full and partially saturated on poorly compacted clay subgrade conditions
- CalME type incremental-recursive model based on stress/strength

ICPI Study: HVS testing



What was the problem?

- National feedback from ASCE conferences in transportation and water
 - Success stories in a number of places
 - Millions of \$\$ saved in Atlanta using permeable pavement in place of cisterns
 - Grant program for cities from California Water Board
 - But also
 - Concern about costs, maintainability, who is responsible for maintaining functionality
 - Not generally being considered for use with other stormwater best management practices

What was the problem?

- UCPRC/Caltrans survey of agencies and consultants in early 2017
 - 33 with experience
 - 31 without experience
- Conclusions:
 - There are still many gaps
 - Stormwater and pavement people both have concerns



November 2017
Technical Memorandum: UCPRC-TM-2017-03

**Fully Permeable Pavement for
Stormwater Management:
Progress and Obstacles to
Implementation in California**

Authors:
J. Harvey, S. Shan, H. Li, D. J. Jones, and R. Wu

Work Conducted Under Partnered Pavement Research Center Strategic Plan Element No. 2.8:
Advanced Pavement Research for Long-Term Future Needs

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| PREPARED FOR: California Department of Transportation Division of Research, Innovation, and System Information Office of Materials and Infrastructure | PREPARED BY: University of California Pavement Research Center UC Davis, UC Berkeley |
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PERMEABLE PAVEMENT

Road Map Workshop 2017

Workshop Nov 14-15, 2017 in Davis, CA

- Goal of workshop:
 - Identify knowledge, information, and communication barriers to adoption of permeable pavement of all types
- Outcome:
 - Road map document with program of projects to fill gaps, to be used to fund, organize and deliver the recommended program

PERMEABLE PAVEMENT Road Map Workshop 2017

- Organized by:



- Sponsored by:



Who was invited and why?

| | Practice Sector | | | | |
|------------------------|-----------------|------------|--------------------------|----------|-------|
| Expertise | Government | Consulting | Construction & Materials | Academia | Total |
| Pavement | 4 | 1 | 12 | 10 | 27 |
| Stormwater Quality | 6 | 3 | 0 | 2 | 11 |
| Flood Control | 10 | 3 | 0 | 0 | 13 |
| Planning | 3 | 1 | 0 | 0 | 4 |
| Landscape Architecture | 1 | 1 | 0 | 0 | 2 |
| Total | 24 | 9 | 12 | 12 | 57 |

Day 1:

prepared presentations to get all perspectives

| | |
|---|--|
| Overview | Where are we and what is missing? Summary of survey results; workshop goals, deliverables and structure; <i>John Harvey</i> |
| Pavement industry perspectives | Thoughts on the future of permeable pavement from materials producer and contractor perspectives, meeting pavement and stormwater needs <i>Richard Willis (NAPA), David Smith(ICPI), Brian Killingsworth (NRMCA)</i> |
| Stormwater and pavement, thoughts on the future from recent experience | Thoughts on the future of permeable pavement from a stormwater perspective, what kind of future do permeable pavements have meeting pavement and stormwater needs? <i>Amir Ehsaei/Tom Sweet, AECOM</i> |
| Planning and conceptual design | How and where do decisions about permeable pavement occur in planning and conceptual design, what is working, what is not, what is missing? <i>Janet Attarian, City of Detroit</i> |
| Stormwater regulation and codes | What do pavement people need to know about stormwater regulation, codes, and basic stormwater considerations? <i>Keith Lichten, California Water Board</i> |

| | |
|---|--|
| Design, maintenance and performance | What are gaps regarding permeable pavement design, maintenance, and performance, for vehicle traveled ways and other urban hardscapes? <i>Dave Hein, ARA</i> |
| Specifications and Construction | What are gaps regarding permeable pavement specifications and construction, and are specs and other technical information enough to overcome pre-conceived notions, fears, the status quo, and the personal bias of civil engineers who are permeable pavement skeptics? <i>Mike Adamow, San Francisco Public Utilities Commission</i> |
| Life cycle cost analysis | Is the framework correct (just pavement or does it capture stormwater benefits and costs)? Do we have the numbers for both permeable pavement and other BMPs? <i>Dave Hein, ARA</i> |
| Life cycle assessment (LCA) and other demands on streets | What are the new demands on pavement besides safety and structural capacity and how does permeable fit in or not? What is an LCA framework to look at these new pavement demands and stormwater? <i>John Harvey</i> |
| Communication between storm water and pavement | What are common communications gaps between the knowledge domains and goals of stormwater and pavement, and ideas on fixing them? <i>Mike Carlson, Contra Costa County Flood Control and Water Conservation District</i> |

Fundamental disconnects stopping the widespread use of permeable pavement

- Stormwater function managed by environmental engineers controlled by water quality discharge permits
 - They get taken to court and fined if too much pollution
 - Requires frequent measurement of water quality
- Transportation function managed by pavement people using pavement management system
 - No consideration of permeability, pollutant measurement
 - Uncertainty about maintenance and rehabilitation practices and costs for both stormwater and transportation functions
- Flood control function is managed through planning and development codes
 - Permeable pavement generally not allowed to be considered in planning and development because of performance uncertainty
 - Flood control people have no maintenance money and no control
- Who owns permeable pavement, who is responsible for maintaining multi-functionality, who pays?

Day 1: Participants developed unanswered 76 questions grouped in these areas:

- Costing and cost-decision support
- Materials and pavement performance
- Education and training
- Communication
- Project-level design issues
- Watershed and flood control design issues
- Designing for additional benefits and impacts
- Construction standards and issues
- Maintenance
- Asset management
- Funding for research, development, implementation
- Planning and development codes

Day 2:

Breakout sessions and group discussions

- Small groups of 5 to 7 people with different backgrounds
 - Discussion of assigned questions, identify gaps
 - Ideas for projects to fill gaps
- Presentations by groups
- Summary discussion with everyone together



Main points from presentations and discussion

- “Permeable pavement” is a system for meeting four functional requirements: transportation, stormwater quality, flood control, and place making, needing a new name:
 - Integrated Stormwater Pavement Systems
 - Combined Stormwater Transportation Systems
- Enough technical information available for all topic areas for practitioners to move ahead, while efforts are underway to fill gaps and update outdated elements
 - Information needs to be pulled together and organized
 - Comprehensive detailed package of guidance, standards, example specifications, and tools usable in practice at each step in project development
 - Communication strategy

Main points from discussion

- Guidance must take an integrated view addressing watershed, urban area, neighborhood, and project scales; also life cycle impacts not just initial
- Communications strategy to address all audiences who need information, covering the four functional areas
- Existing training programs need to be targeted, links established and training delivered
- Information for use in university classes across the four functionalities needs to be developed
- New work processes, code changes need to address multi-functionality
- Partnerships needed between pavement, stormwater and flood control agencies to identify and standardize roles and responsibilities, get funding, work together

Main points from discussion

- New potential stakeholders need to be identified and engaged
 - Flood insurance industry
 - Federal Emergency Management Agency (FEMA)
- Establish a university-based research, development, and implementation center to organize efforts to create and communicate the information needed
 - Regional associated centers
- Central clearinghouse for organization and dissemination of quality, up-to-date information, maybe at center
- Program of intense, focused, well-funded research, development, and implementation work to fill gaps
 - Funding and program model could be the 1988-1993 Strategic Highway Research Program (SHRP)
- Starting point is the Road Map

Road Map

- 10 routes to arrive at the destination
- Each route in road map has:

| Objectives | Gap | Approach to Fill Gap | Proposed Projects | Time line | Estimated Cost | Who Should Do It |
|------------|-----|----------------------|-------------------|-----------|----------------|------------------|
|------------|-----|----------------------|-------------------|-----------|----------------|------------------|

Road Map Routes

- **Route 1. Infrastructure management organizations that consider the full functionality of permeable pavements**
 - **Integration of Multi-Functional Priorities and Responsibilities**
 - **Planning and Development Codes**
 - institutional changes, i.e., bridging the gap between stormwater agency and road agency priorities and cultures
- **Route 2. Planning guidance that considers the multi-functionality of permeable pavements**
 - **Comprehensive Planning**
 - **Planning and Designing for Benefits and Impacts Across the Four Functions**

Road Map Routes

- **Route 3. Accurate life cycle cost analysis and environmental life cycle assessment tools**
- **Route 4. Reduction of target pollutants to meet water quality requirements**
 - Develop design decision trees/menus for reduction of target pollutants from existing and additional research
 - Include runoff reduction as an integral part of water quality management objectives, pollutant reduction credits
- **Route 5. Reduction of urban flooding risks**
- **Route 6. Reliable pavement structural designs**
 - **Pavement Structural Design Approaches**
 - Hybrid designs using pavers, asphalt and concrete
 - Permeable next to impermeable pavement and foundations
 - **Materials and Pavement Performance**

Road Map Routes

- **Route 7. Routine achievement of high-quality construction**
- **Route 8. Maintenance and rehabilitation costs and methods**
 - Standard maintenance practices and cost guidance
 - Rehabilitation and end-of-life guidance
- **Route 9. Incorporation of permeable pavements into asset management systems**
- **Route 10. Efficient and comprehensive access to the best information**
 - **Communication between Industries and Users**
 - **Education and Training**
 - **Funding for Research, Development, Implementation**

Next Steps

- Summer 2018:
 - Identify potential partners and existing groups
 - Begin to apply for funding
- Fall 2018:
 - Identify a Technical Working Group with existing and new stakeholders to guide implementation of road map
- 2018 to 2025:
 - Based on road map, implement a comprehensive plan and funding mechanism for collecting, communicating, and distributing information for use by local government, consultants, private developers, and state agencies
- 2019 to 2021:
 - Based on road map, complete a focused, intensive program of research, development, implementation tasks to fill gaps

The logo features a dark grey background. On the left, there are two horizontal bands: the top one contains white water droplets on a blue background, and the bottom one contains blue dots on a dark grey background. To the right of these bands, the words "PERMEABLE PAVEMENT" are written in large, bold, blue capital letters. Below that, "Road Map Workshop 2017" is written in a smaller, grey font.

PERMEABLE PAVEMENT

Road Map Workshop 2017

- Road map downloadable
 - Search “national center sustainable transportation permeable pavement”
 - https://ncst.ucdavis.edu/wp-content/uploads/2018/08/NCST-Harvey_Permeable-Pave-Road-Map-Sym_Aug-2018.pdf
- All presentations, breakout documentation, road map at web site:
 - Search “permeable pavement workshop davis 2017”
 - <http://www.ucprc.ucdavis.edu/permPvmt/>

Questions?