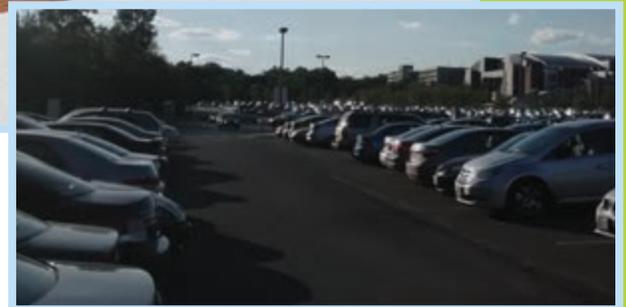


PERFORMANCE PARKING

Reimagining Lot 11B



Project Leads

Kathleen Hayes, Plant Science and Landscape Architecture
George Sorvalis, Plant Science and Landscape Architecture
Matt Zerfas, Plant Science and Landscape Architecture

Experiment Lead

Emma Giese, Environmental Science and Technology

Soils Consultant

Sharon Hartzell, Environmental Science and Technology

Climate Change Consultant

Jason Renkenberger, Civil Engineering

Advisory Team

Dr. Victoria Chanse, Plant Science and Landscape Architecture
Michael Carmichael, Facilities Management
Dennis Nola, Plant Science and Landscape Architecture
Stephen Reid, Facilities Management
Dr. Mitch Pavao-Zuckerman, Environmental Science and Technology

Additional Advisors

Dean David Conrath, School of Architecture
Darwin Fuerstein, Facilities Management
Diane Cameron, Audubon Naturalist Society
Dr. Peter May, Environmental Science and Technology
Karen Petroff, Facilities Management
Elisabeth Walker, Student, Urban Studies and Planning
Rick Scaffidi, Environmental Quality Resources
Harris Trobman, University of the District of Columbia

PROJECT ABSTRACT

An interdisciplinary team composed of individuals from the University of Maryland's Landscape Architecture program (3), Civil Engineering program (1), and Environmental Science and Technology program (2) has developed this project, **Performance Parking: Reimagining Lot 11B**, for EPA's 2015 Campus RainWorks Challenge. At the recommendation of UMD's Facilities Management, the team designed a stormwater retrofit for parking lot 11B, a 5-acre lot of 100% impervious surface delivering large quantities of untreated runoff into the adjacent Campus Creek, an adjacent wetland and the Paint Branch stream. Facilities Management requested that the team produce a stormwater retrofit for parking lot 11B that could serve as a template for other surface parking lots on campus.

The retrofit features a treatment train consisting of tree canopy, permeable interlocking concrete pavers, and bioretention cells. This is an approach that achieves reductions in stormwater quantity and improvements to stormwater quality. Other project features include plants that have phytoremediation capabilities for heavy metal and petroleum, tolerate both extreme dry and wet conditions and salt conditions. The design improves pedestrian circulation with the addition of sidewalks, and climate resilience is achieved by engineering the design to capture, detain and treat a future 1-year storm under a climate change scenario that predicts a 53% increase in precipitation.¹ The design will also test bioretention media amendments in two distinct catchment areas to advance the science of bioremediation media performance, and soil testing was conducted to determine pollution loads in soils.

1. Stouffer et al., "GFDL's CM2 Global Coupled Climate Models. Part IV."

SITE SELECTION AND BACKGROUND



Figure 1. Project site context

UMD's Facilities Management presented a number of stormwater-troubled sites on campus to address for the EPA RainWorks Competition. Among the sites presented, our group chose parking lot 11B because of its proximity to a sensitive wetland and Campus Creek. Once the team chose parking lot 11B, Facilities Management asked us to design a stormwater retrofit that could be used as a template for other surface parking lots on campus. Of note are two unmaintained legacy research rain gardens installed in 2002—the first ever on the UMD campus—located at the southeast corner of the lot, near the confluence of Campus Creek and the Paint Branch stream. Though no longer monitored, these rain gardens are notable as the first bioretention research on the campus. The team has incorporated a research experiment into this design to continue UMD's contribution to the science of stormwater, and it also conducted soil testing to determine the level of automobile-related pollution in the area. This site's location in the 100-year floodplain and proximity to the three water bodies offers significant challenges in utilizing infiltration-oriented stormwater mitigation approaches.

Stakeholder Involvement and Interdisciplinary Collaboration

The team chose this site based on a strong recommendation by UMD's Facilities Management. The team had an interim review with the Dean of the School of Architecture; members of the University Architectural Review Board, including the Dean; Facilities Management; and design and civil engineering leaders from regional landscape architecture firms and non-profit organizations. The team consisted of members from three UMD programs: Landscape Architecture, Environmental Science and Technology, and Civil Engineering.

Site Analysis

Bounded by Campus Creek to the south, a wetland to the north, and the Paint Branch stream to the east, parking lot 11B is used for daily commuter student parking, as well as for event parking and tailgating during the football and basketball seasons. Existing stormwater management is negligible, with most stormwater runoff from the lot entering directly into the abutting streams and wetland. An on site saturated percolation test conducted by the team found percolation rates at or below $\frac{1}{3}$ " per hour. Such low percolation rates necessitated the use of underdrains in the teams design, per Maryland Department of Environment standards.²

2. Maryland Department of the Environment, "2000 Maryland Stormwater Manual Design Manual, Volumes I & II."

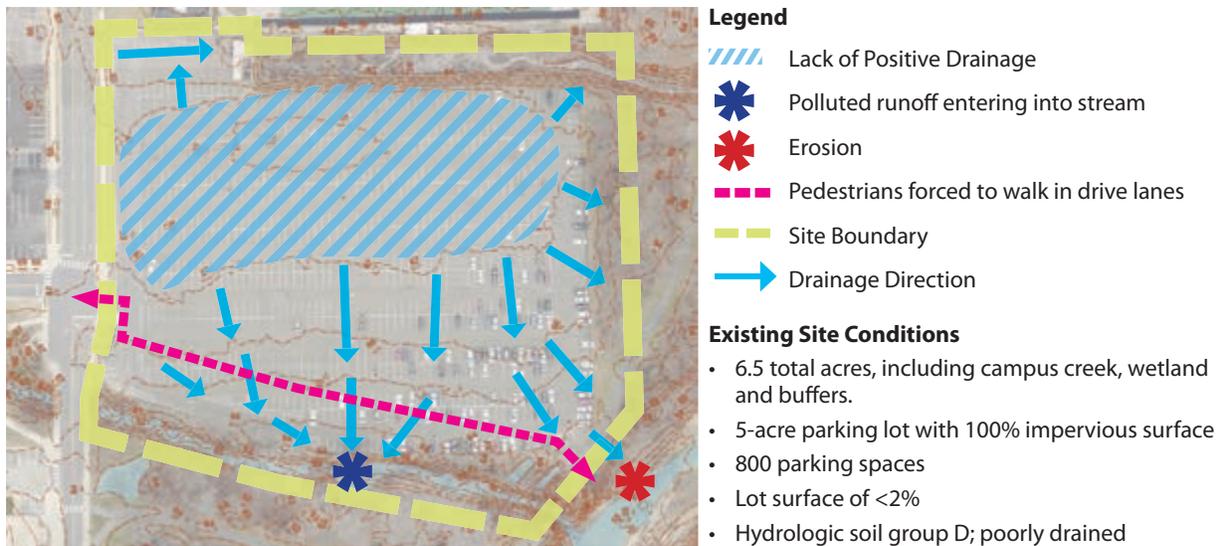


Figure 2. Site analysis and existing conditions

Metals and PAH Results

The team collected soil samples from the areas where runoff was observed from parking lot 11B and sent the samples to Waypoint Analytical to be tested for heavy metals and PAH compounds. The tests found both heavy metals and organic pollutants like polycyclic aromatic hydrocarbons (PAHs), which have the potential to enter waterways or accumulate in soil.³

The table below compares soil concentrations to EPA soil screening levels. Only compounds above the method detection limit are included, and those in red are above the screening level for protection of groundwater based on groundwater maximum contaminant loads.⁴ Compounds above the screening level may warrant further investigation at the site.

TABLE 1. METALS AND PAH RESULTS

Metals			PAHs		
Compound	Concentration in Soil (mg/kg)	Soil Screening Level (mg/kg)	Compound	Concentration in Soil (µg/kg)	Soil Screening Level (µg/kg)
Arsenic	2.36	0.29	Benzo(a)anthracene	292	4.2
Beryllium	0.255	3.2	Benzo(a)pyrene	275	240†
Cadmium	0.162	0.38	Benzo(b)fluoranthene	476	41
Chromium (total)	15.1	180,000	Benzo(g,h,i)perylene	156	–
Copper	12.8	46	Benzo(k)fluoranthene	187	400
Lead	17.5	14	Chrysene	370	1200
Mercury	0.03555	0.1	Fluoranthene	810	89,000
Nickel	13.1	26*	Indeno(1,2,3-cd)pyrene	178	130
Zinc	42.5	370*	Phenanthrene	313	–
			Pyrene	577	13,000

*All screening levels are based on maximum contaminant loads in groundwater, except where only risk-based values were available (nickel, zinc). †All screening values are risk-based, except benzo(a)pyrene, for which a maximum contaminant load-based value was available.⁵

3. Li et al., “Temporal Variation of Heavy Metal Pollution in Urban Stormwater Runoff [electronic resource].”; Mahler et al., “Parking Lot Sealcoat.”

4. U.S EPA, “Regional Screening Level Summary Table.”

5. Ibid.

Results from the soil test show that two metals—arsenic and lead—and four PAH compounds exceed screening levels based on protection of groundwater. All compounds except lead also exceed basic screening levels for residential soil. These values are used purely for screening processes, to rule out contaminants of concern. None of the data observed at this location should be used to declare the site contaminated or in need of cleanup, but they do indicate measurable levels of pollutants that could warrant further investigation.

Lot Uses and Circulation

Lot 11B is used for many functions including commuter student parking, tailgating, and parking for special events at UMD’s basketball arena. Lot 11B is also a significant thoroughfare for students residing in two large apartment complexes located adjacent to campus. These two complexes, University View Apartments I and II, house a combined 1,573 beds.⁶ Students residing in these apartments access campus via a pedestrian bridge over the Paint Branch stream, and those heading to the north of campus are routed through parking lot 11B. Therefore parking lot 11B accommodates pedestrian movement of not only those who park there, but also students walking to the north end of campus from the sizable apartment complexes. There are currently no sidewalks or dedicated paths to accommodate pedestrian circulation in parking lot 11B, posing a potential safety issue.

The southeast corner of parking lot 11B is adjacent to the Anacostia Tributary Trail system which serves UMD students, the greater College Park community and bicyclists throughout the metropolitan area use the trail and have visual access to the parking lot. The southeast corner also sits very near to the confluence of Campus Creek with the Paint Branch River.

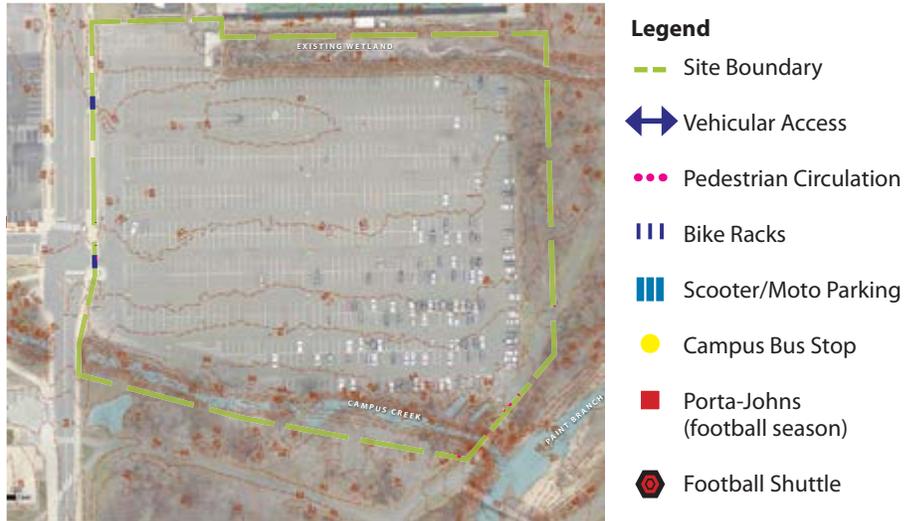


Figure 3. Circulation and use diagram

LITERATURE REVIEW: TECHNIQUES TO REDUCE STORMWATER POLLUTION FROM PARKING LOTS

Pollutant Loads from Parking Lots

Global studies estimate there are 600,000,000 passenger cars on the road and that number continues to grow. In the US, it is estimated that 3,515 square miles are occupied by parking lot. Parking lots predominately contain surface dusts of fine particles, which are too small for street sweepers to pick up. Therefore fine sediments are a big problem in parking lots. EPA found that pollutant levels were almost five times higher on a slow one-way street compared to a busy, wider and faster moving road

6. Clark Construction, “University View Apartments II.”

because of lower traffic speed and less frequent street sweeping. A treatment train incorporating permeable paving and bioretention was recommended as the most effective way of maximizing pollution removal efficiency.⁷

Permeable Paving

A study from 2013 examined the water quality performance of three permeable pavement systems, compared to a conventional asphalt pavement in Ontario. The article found that runoff from porous asphalt reduced loading of suspended sediments by 59%, Pb by 84%, Cd by 77% and Zn by 73%. These studies concluded that significant improvements to stormwater quality can be achieved through the use of permeable pavements even without exfiltration to native soils because improvements to water quality are achieved by filtration through the permeable surface and aggregate layers. The effluent in these studies contained 80% less total suspended solids than the asphalt runoff and contained fewer heavy metals, as the permeable pavement system captured 65% to 93% of Cu, Fe, Mn and Zn.⁸

Bioretention Cells

Bioretention cells are increasingly being constructed as a means to collect, infiltrate and treat stormwater runoff. Bioretention cells are shallow vegetated depressions in which the native soil has been removed and replaced with a bioretention media comprised primarily of sand and compost or mulch. The sand is used to promote infiltration while the organic rich compost or mulch is used to enhance plant growth. An investigation of six bioretention cells suggests that bioretention cells can provide more than six years of effective infiltration and over 25 years of effective metal removal performance. The organic matter added to bioretention cells bonds with the positively charged metal contaminants found in stormwater runoff, removing them from the water before it is infiltrated or released back into the surrounding environment. Organic matter also absorbs petroleum hydrocarbons, removing automobile pollution in stormwater.⁹

Field studies of bioretention cells typically report good to excellent pollution removal (64% to >90%) for many metals including cadmium (Cd), lead (Pb), and zinc (Zn), many of the same pollutants found in parking lots (Davis et al. 2003; Glass and Bissouma 2005; Li and Davis 2008a).¹⁰

THE DESIGN SOLUTION: PERFORMANCE PARKING

Applying a Treatment Train Approach to Parking Lot 11B

Based on this literature review of techniques to reduce stormwater pollution from parking lots, the team decided to incorporate a treatment train approach as the best means of maximizing pollution removal efficiencies. The first part of the treatment train in the design is the installation of trees, using their canopy to slow rainwater. Rainwater that is not captured by the tree canopy is directed into permeable interlocking concrete pavers, which are installed on the parking pads. The below-grade structure on which the concrete pavers are placed consists of a 36-inch deep reservoir of varying-sized stone aggregates. This reservoir of stones stores rainwater in the void spaces between the stones, and also filters metals that the stormwater picks up from the parking lot.

7. Revitt et al., “The Sources, Impact and Management of Car Park Runoff Pollution.”

8. Drake, Bradford, and Van Seters, “Stormwater Quality of Spring–summer–Fall Effluent from Three Partial-Infiltration Permeable Pavement Systems and Conventional Asphalt Pavement.”

9. Paus et al., “Assessment of the Hydraulic and Toxic Metal Removal Capacities of Bioretention Cells After 2 to 8 Years of Service.”

10. Ibid.



Figure 4. Illustration of the proposed Performance Parking design

Rainwater that does not infiltrate after it is filtered through the stone media is underdrained into bioretention cells that further clean the water. Plants chosen for the bioretention cells have phytoremediation capabilities, a capacity to tolerate salt, and a unique ability to survive through both prolonged dry periods and prolonged wet periods. The bioretention cells contain 18 inches of engineered soil media designed to filter out parking lot pollutants. Water that does not infiltrate after passing through the bioretention plants and media is underdrained into either the wetland or Campus Creek.

It is only after water has passed through the tree canopy, has been filtered once by the below-grade permeable pavers stone media, and filtered again by the bioretention plants and bioretention media, is it discharged from 2 outfalls into Campus Creek and 2 outfalls into the Northern wetland.

This design eliminates 200 of the 800 parking spots.

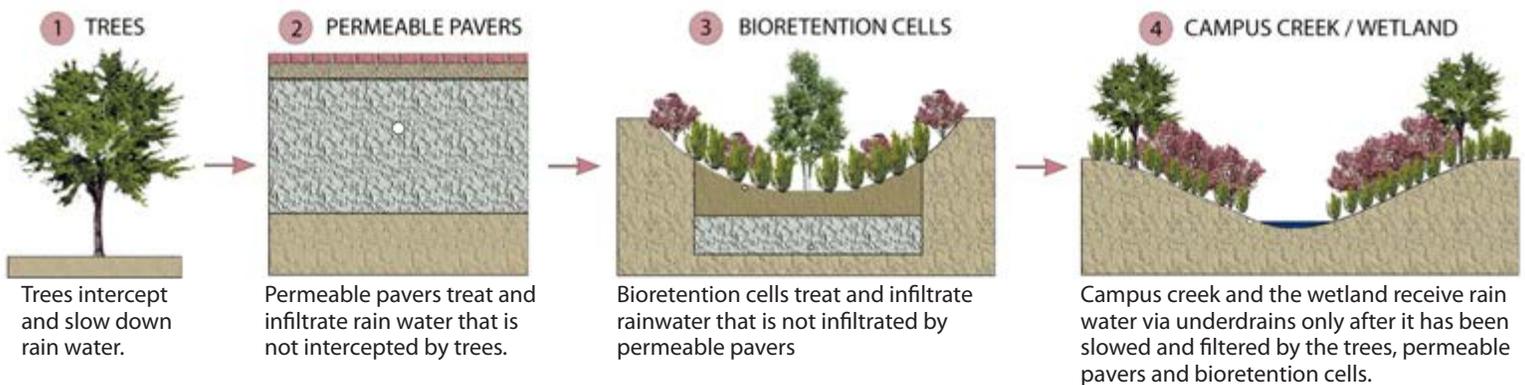


Figure 5. Treatment train approach to stormwater management

Climate Resiliency

While most stormwater retrofits are designed to treat the first flush that the 1-inch storm delivers, the team designed this stormwater retrofit to treat the 1-year storm, a much larger storm. While the historic 1-year storm in this region is a 2.65-inch rain event, our approach was designed to the IPCC's A-2 extreme climate change scenario, which predicts a 53% increase in precipitation in this region, looking up to 60-years into the future.¹¹ Therefore, this team engineered the volume of the stone reservoir underneath the permeable pavers to be capable of treating and detaining a 3.9-inch rain event (or for this site equals 1.53 acre-feet of water)—the 1-year storm of the future.

Climate Mitigation

In addition to designing a stormwater mitigation project that would be resilient to the impacts of greater precipitation that climate change is bringing, the team also sought to mitigate climate change impacts by installing measures that would reduce carbon dioxide pollution and mitigate urban heat island effect. Carbon dioxide reductions are achieved by the installation of 4,600 ft² of photovoltaic cells. This installation shades 56 parking spaces, provides power for 4 new electric vehicle-charging stations, produces 17,150 kW of power production per year, and reduces 12.3 metric tons of carbon dioxide per year.¹² Urban heat island effect is mitigated by the installation of 56 new trees on the lot, 17,640 ft² of new ground vegetation and the installation of 72,000 ft² of permeable interlocking concrete pavers, which have a lighter albedo than dark asphalt.

Landscape Performance

Little literature has been published on the pollution removal efficacy of a system that incorporates the treatment train approach implemented in this stormwater retrofit. In order to add to the literature and advance the science of bioretention and treatment train approaches, the team collaborated with UMD's Environmental Science and Technology Department to design an experiment on the parking lot to measure the pollution removal effectiveness of different bioretention designs in this treatment train approach. The experiment is described in the Learning Laboratory section on page 11.

HYDROLOGY

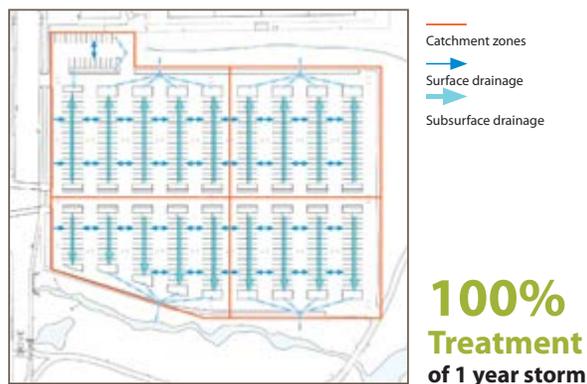


Figure 6. Proposed hydrology

IMPERVIOUS SURFACE



Figure 7. Proposed impervious removal

11. Stouffer et al., "GFDL's CM2 Global Coupled Climate Models. Part IV."

12. Henry, "Toledo Zoo Dedicates New \$1.5M SolarWalk."

CIRCULATION

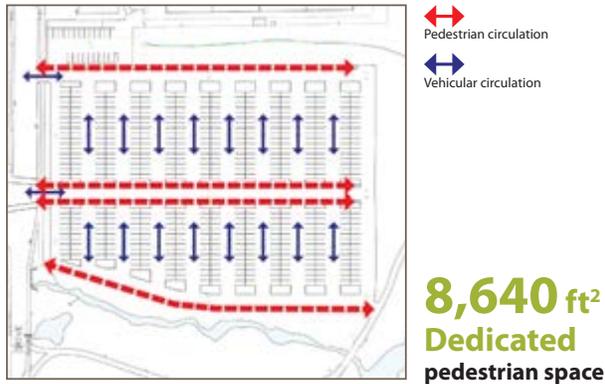


Figure 8. Proposed circulation

VEGETATED COVER



Figure 9. Proposed vegetated cover

TABLE 2. LANDSCAPE PERFORMANCE METRICS

Goal	Technique Implemented	Outcomes
Store and treat the 1-year A-2 extreme climate change scenario storm	Treatment Train of Trees to Permeable Pavers to Bioretention Cells	<ul style="list-style-type: none"> Permeable paver reservoir capable of removing 13%–67% of Cu; 71% to 88% of Zn; 67% of Pb; 34%–65% of TP; 35% to 65% of TN.¹³ Permeable paver reservoir capable of detaining the 1-year climate change scenario A-2 storm, a 3.9 inch rain event. Bioretention cells capable of removing 43%–97% Cu; 70%–95% Pb; 64%–95% Zn; 65%–87% TP; 92% Ammonium; 49% TN.¹⁴ 80%–95% removal of oil and grease (toluene, naphthalene, and motor oil hydrocarbons)¹⁵ Create 88,560 ft² of pervious surfaces, a 41% reduction in impervious surface.
Improve public safety	Installed sidewalks	<ul style="list-style-type: none"> Added 8,640 square feet of sidewalk to accommodate pedestrian movements from lot Sidewalks also accommodate students commuting to off-campus housing that use the lot as a cut-through.
Mitigate Heat Island effect	Install trees and lighter pavement treatments	<ul style="list-style-type: none"> 56 new trees installed 17,640 ft² of new ground vegetation installed 71,962 ft² of lighter permeable pavers installed
Reduce Carbon Dioxide Emissions	Install Solar Array	<ul style="list-style-type: none"> 12.3 metric tons of carbon dioxide reductions per year¹⁶ 17,150 kilowatts of power production per year¹⁷ Provides shade for 56 parking spaces
Plant bioretention cells with plants that will thrive and remove pollutants	Plants with multiple performance characteristics were chosen	<ul style="list-style-type: none"> Plants were chosen based on best practice recommendations in current phytoremediation research.¹⁸ Plants chosen will withstand drought and flooding, salt, and filter out parking lot contaminants.

13. US EPA, “Permeable Interlocking Concrete Pavement.”

14. US EPA, “Bioretention (Rain Gardens).”

15. Hong, Seagren, and Davis, “Sustainable Oil and Grease Removal from Synthetic Stormwater Runoff Using Bench-Scale Bioretention Studies.”

16. Henry, “Toledo Zoo Dedicates New \$1.5M SolarWalk.”

17. Ibid.

18. Dropkin and Bassuk, “Woody Shrubs for Stormwater Retention Practices Northeast and Mid-Atlantic Regions”; Hinman, “Low Impact Development Technical Guidance Manual for Puget Sound.”

Maintenance

Interlocking Concrete Permeable Pavers

The team recommends referencing the Federal Highway Administration (FHWA) Permeable Interlocking Concrete Pavement TechBrief published in January 2015 for a complete maintenance regime for the permeable paver system.¹⁹ Some of the fundamental maintenance activities listed in the FHWA TechBrief to keep the permeable paving system performing include:

- Inspecting the pavers 1-2 times annually, especially after a storm event.
- Look for buildup of sediment in joints.
- If necessary, clean the surface using regenerative air equipment in the spring and late fall
- Clean and flush underdrain system and outfall features if slow draining, to ensure free flow of water and outflow
- For winter traction, avoid the use of sand, and do not stockpile snow on the pavers.
- Anti-icing materials such as sodium chloride, calcium chloride, or magnesium calcium acetate may be used.
- Standard snowplow/snow blowing equipment may be used.

Bioretention Cells

EPA's online factsheet on Bioretention (Raingardens) recommends the following maintenance regime for bioretention cells:²⁰

- After installation, water plants daily for 2 weeks;
- Inspect soil and repair eroded areas and remove litter and debris at least monthly, or after UMD events that would entail tailgating.
- Remove and replace dead and diseased vegetation twice per year.
- Remulch void areas, treat diseased trees and shrubs as needed.
- Avoid leaving void areas to suppress weed growth.

Modeling and Calculations

The team used TR-55 modeling to determine that the historic 1-year storm would deliver 1 acre-ft. of water to the site. A 53% increase in precipitation according to the IPCC A-2 Climate Scenario would increase the 1-year storm to 1.53 acre feet of water.

The team referenced the Virginia DEQ Stormwater Design Specification No. 7, version 2.0, published on January 1, 2013, Permeable Pavement, to size the permeable pavement reservoir.²¹ The 1-year climate change IPCC A-2 storm is a 3.9-inch rain event in this region. The team used the following equation from the Virginia DEQ manual to determine the depth of the stone reservoir needed:

$$d_{\text{stone}} = \frac{(P \times A_1 \times R_{v1}) + (P \times A_p)}{n_r \times A_p}$$

19. Federal Highway Administration, "Permeable Interlocking Concrete Pavement."

20. US EPA, "Bioretention (Rain Gardens)."

21. Virginia Department of Environmental Quality, "Virginia DEQ Stormwater Design Specification No. 7 Permeable Pavement."

Where:

- d_{stone} = Depth of the stone reservoir layer (ft.)
 P = The rainfall depth (in ft.) for the Treatment Volume = 3.9 inch or 0.325 ft.
(this is the 1-year climate A-2 extreme scenario storm)
 A_i = Contributing impervious drainage area (ft²) = 213,929 ft²
 R_{vl} = Volumetric runoff coefficient for impervious cover = .95
 A_p = Area of permeable pavement (ft²) = 71,962 ft²
 n_r = Porosity of reservoir layer = 0.4

$$d_{stone} = \frac{(.325 \text{ ft.} \times 213,929 \text{ ft}^2 \times .95) + (.325 \text{ ft.} \times 71,962 \text{ ft}^2)}{0.4 \times 71,962 \text{ ft}^2}$$

$$d_{stone} = 3.1 \text{ ft.}$$

The stone reservoir under the permeable paving system will be designed 3.1 ft. deep in order to accommodate a 3.9 inch rain event, the 1-year rain event under IPCC's extreme A-2 climate scenario.

Learning Laboratory

Recent review papers have identified a need for research on bioretention media composition and amendments to optimize pollutant removal.²² In particular, few field experiments have been conducted on media amendments to date. Lot 11B provides an excellent opportunity for a field experiment that will advance the science of bioretention design.

Biochar is a soil and water amendment that can adsorb nutrients, organic contaminants, and metals due to its high surface area and porosity.²³ It is created by slowly burning waste organic material (wood, plants material, or manure) at a low temperature. Biochar filter media has been shown to remove metals, nutrients, and polycyclic aromatic hydrocarbons from simulated stormwater runoff in a laboratory study.²⁴ We propose the following field experiment on Lot 11B to evaluate the effectiveness of a biochar media amendment in removal of nitrogen, phosphorus, metals, and hydrocarbons from stormwater runoff.

The site design of Lot 11B includes four equally sized drainage areas, each with a separate outflow pipe where samples will be collected. Two catchments will be assigned to the control group and two to the treatment group in a systematic design (see below). Bioretention cells in the control catchment will be constructed with a recommended media mixture of 50% construction sand, 25% topsoil, and 25% organic material.²⁵ Bioretention cells in the treatment catchment will be constructed with the same media ratio and will be amended with 5% biochar.²⁶

22. Davis et al., "Bioretention Technology."

23. Ahmad et al., "Biochar as a Sorbent for Contaminant Management in Soil and Water."

24. Reddy, Xie, and Dastgheibi, "Evaluation of Biochar as a Potential Filter Media for the Removal of Mixed Contaminants from Urban Storm Water Runoff."

25. "Prince George's County Stormwater Management Design Manual."

26. Jiang et al., "Immobilization of Cu(II), Pb(II) and Cd(II) by the Addition of Rice Straw Derived Biochar to a Simulated Polluted Ultisol."

Control 1	Biochar treatment 1
Biochar treatment 2	Control 2

Water samples will be collected at the pavement surface and at the outflow pipe for each catchment during storm events. The samples will be analyzed for nitrogen, phosphorus, hydrocarbons, and metals. The results from the treatment catchments will be compared with the control catchments to determine if there is a statistically significant difference in pollutant removal capacity due to the biochar amendment. The results of this experiment will inform future bioretention design for pollutant removal.

CONCLUSION

Not only did the team work collaboratively across disciplines, closely with facilities, determined pollution loads in the soil, gathered percolation data, set up an experiment to measure performance and advance the science of bioremediation, but also produced an aesthetically appealing parking lot design that can serve as a model retrofit for other lots on campus. The team appreciates the opportunity to enter this submission into EPA RainWorks competition and commends EPA for encouraging innovation in solving our country's stormwater issues through this competition.



Figure 10. Section plan of proposed Performance Parking design

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