Analysis of Permeable Surfaces on the Campus of UC Davis

Jia Ma, Stephanie Wen, Taran Sahota

Abstract

Permeable pavements have been proven to reduce surface runoff and been effective in filtering pollutants from water. The campus of UC Davis has a large number of bicycle parking lots. These parking spots are usually filled with a sand-gravel dirt mixture and have been compacted due to excess pedestrian walking. Much of the water during the raining season is waterlogged in the bicycle parking area. The water can overflow on to the impermeable surfaces around the parking areas and pick up any fertilizer, litter, and other unwanted solids, which then flow into bodies of water.

The overall objective of this project is to replace much of the dirt parking with a permeable pavement. The permeable pavement would allow water to infiltrate down into the ground and would be collected underneath the pavement to be reused for other purposes. We believe this would reduce water usage by reusing the collected water.

We will be comparing the amount of water that is typically trapped within the dirt of the bike parking with the amount of water that can go through a permeable surface after every rain event. We will then take the calculated amount of water collected from a permeable surface and calculate the potential price of how much water is saved for reusing the water to water the plant life on campus or recharge groundwater supplies. All of these calculations will be used in a cost-benefit analysis of replacing the surfaces of the bicycle parking lots around campus.

Permeable pavements would be able to reduce solid pollution runoff into bodies of water. The water collected by permeable pavements could be reused to reduce water usage when watering plants and can be used to help replenish groundwater supplies. The city of Davis utilizes groundwater for most of its water usage and the state of California is currently in a drought. Permeable pavements can help ameliorate some of the pressure of water usage.

Introduction

The overall context of this project is to contrast the amount of water that is being captured in the dirt biking lots versus biking lots with permeable pavements. This project focuses on the sustainability factor of permeable pavements and its impact on stormwater compared to the pavement of dirt biking lots. Permeable pavements consist of a base and sub-base that allows water to flow through the surface. The current surface of bicycle parking is composed of sycamore silt loam composed of decomposed granite, which is not permeable (SoilWeb, 2014). It reduces runoff and prevents fertilizer, litter, and other unwanted solids from entering the water. Permeable pavements allows stormwater to infiltrate and percolate through its porous paving material. This reduces runoff as well as improving the water quality by filtering litter, fertilizers, and other unwanted solids through its pervious material (Weinston, Neil, 2014). The pavement of dirt biking lots negatively contribute to the water quality after a storm. The stormwater that is captured is extremely dirty due to the debris, dirt, and other pollutants that are on the dirt biking lots (EPA, 2003). The stormwater runoff will be untreated and flow towards waterbodies that are used for human activities (i.e. swimming, fishing, and drinking water). The quality of water is extremely important, especially for human use, and the amount of water that can be obtained through permeable pavements may contribute to higher quality water and allows aquifers to become replenished.

Objective

Similar to many other cities, Davis relies on its groundwater supplies to sustain its population. However, due to the severe, ongoing drought in California, these supplies are dwindling and finding more efficient ways to retain water is necessary. One of the ways the city of Davis can maximize groundwater infiltration (while reducing surface runoff) is to use permeable pavements in biking lots rather than the typical dirt lots. In particular, the UC Davis campus has huge dirt biking lots that can flood in rainy seasons and transfer sediment, pollutants or debris through storm gutters into local bodies of water. Utilizing permeable pavements could reduce the degradation of water quality in such bodies of water while also maximizing the groundwater storage potential.

The main objective of this project is to compare the differences in the amount of water that is trapped in dirt biking lots versus biking lots with permeable pavements. Based on the water that can be collected from a permeable surface, the next task will be to calculate the potential price of how much water is saved that can be utilized either on campus (to sustain plant life) or to recharge groundwater supplies.. All of these calculations will be used to determine if replacing the surfaces of the bicycle parking lots around campus would be beneficial environmentally and financially. Through analysis of data collected on campus during rain events, this project will determine whether there is a potential to save more water using one of these methods for biking lots over the other. The project will essentially be broken up into 4 main tasks: (1) collecting data on how much surface area that needs to be replaced, how much water can be collected and used, this task will be done by the whole team, (2) data rendering, this will be conducted by the whole team, (3) analysis of the economic feasibility of campus reuse or ground water recharge of permeable surfaces and the amount of prevented surface pollution, this task will be done by the whole team, and (4) conclusion, this will be done by the whole team.

Hypothesis

Due to its ability to absorb and retain water, areas with permeable pavements are likely to be a cost-effective way to reuse water for irrigation and reduce the use of water supplies.

Data Sources

The data used for this analysis was drawn from multiple sources.

- Amount of students who ride a bicycle to UC Davis was obtained from the City of Davis City of Davis 2009 Bicycle Plan
- Amount of irrigation water used and projected by the University of California, Davis was drawn from the UC Davis Water Dashboard for the year of 2015
- Cost of water used for irrigation in UC Davis was calculated by the City of Davis Public Works Water Rates Calculator under the 2014 Rates
  - o Water Rates are projected to increase every 1-2 years
  - o

Rates adopted by City Council September 2014					
	Rates effective 11/1/2014	Rates effective 1/1/2016	Rates effective 1/1/2017	Rates effective 1/1/2018	Rates effective 1/1/2019
Base Rate$/ meter size	Shown on the January 2015 City Service Bill	Shown on the March 2016 City Service Bill	Shown on the March 2017 City Service Bill	Shown on the March 2018 City Service Bill	Shown on the March 2019 City Service Bill
5/8" or 3/4"	$8.88	$9.87	$10.97	$12.20	$13.07
1"	$13.48	$15.00	$16.66	$18.53	$19.86
1 1/2"	$23.85	$26.66	$29.71	$33.15	$35.57
2"	$37.75	$42.15	$46.91	$52.28	$56.06
3"	$68.36	$76.81	$85.95	$96.25	$103.49
4"	$104.43	$117.47	$131.59	$147.49	$158.65
6"	$201.43	$227.15	$254.96	$286.31	$308.27
8"	$316.57	$357.45	$401.67	$451.53	$486.41
Single-Family Varriable Rate	$2.92 per ccf	$3.44	$3.98	$4.61	$5.01

Figure 1 – *Water rates adopted by the City of Davis.*

- Average rainfall of Davis, CA for the years of 2012-2014 was obtained from the U.S. Climate Data
- Information of what type of soil is composed of was drawn from the UC Davis Land Air and Water Resources SoilWeb database systems
- Data for the cost of permeable surfaces was obtained from the University of Maryland Extension Permeable Pavement Fact Sheet Information for Howard County, Maryland Homeowners

Methods and Assumptions

Steps to Calculate the Surface Area of Bicycle Parking

1. Obtain bike census data of how many UC Davis students and employees use bicycling at their main form of transportation.
2. Multiply the average number of bicycle commuters by the square footage needed for a typical bicycle parking spot.

Steps to Calculate the Average Rainfall of 3 Years

1. Average the yearly rainfall for the years of 2012-2014 by using the total monthly of each year.
2. Average the average yearly rainfall for the years of 2012-2014.

Steps to Calculate the Average Rainfall on Bicycle Parking

1. Convert the surface area of bicycle parking from square feet to square inches.
2. Multiply the surface area of bicycle parking with the average rainfall.
3. Convert from cubic inches to gallons.

Steps to Calculate the Water Rate

1. Collect data on how much water UC Davis uses for irrigation purposes.
2. Take the total amount of water used for irrigation and convert the value from gallons to square feet.
3. Plug the new converted value into the City of Davis Water Rates Calculator.
4. Change the "Property Type" to "Irrigation."

Steps to Calculate the Possible Amount of Money Saved with Permeable Surfaces

1. Convert the average rainfall of bicycle parking from gallons to cubic feet.
2. Plug the new converted value into the City of Davis Water Rates Calculator.
3. Change the "Property Type" to Irrigation."

Steps to Calculate the Cost of Permeable Surfaces

1. Take the value of total bicycle parking in UC Davis.
2. Multiply the total surface area of bicycle parking with the highest and lowest cost of the four different types of permeable surfaces.

3. Multiply the total surface area of bicycle parking with the cost of highest and lowest cost of construction with the three different types of construction methods

<u>Steps to Calculate the Time to Payback</u>

1. Divide the cost of construction with the amount of money saved with permeable surfaces.

Calculations and Results

<u>Surface Area of Bicycle Parking</u>

15000 bicycles/day x 10 ft^2 = ***150,000 ft^2 of bicycle parking***

<u>Average Rainfall of Three Years</u>

Average Rainfall of 2012	
Month	**Amount (in)**
January	3.05
February	0.53
March	4.06
April	2.01
May	0
June	0.04
July	0
August	0
September	0
October	0.66
November	3.55
December	7.33
Average	1.769166667

Average Rainfall of 2013	
Month	**Amount (in)**
January	0.85
February	0.18
March	0.9
April	0.79
May	0.62
June	0.14
July	0
August	0
September	0.67
October	0
November	0.68
December	0.39
Average	0.435

Average Rainfall of 2014	
Month	**Amount (in)**
January	0.16

Overall Average	***1.038888889***

February	4.24
March	1.56
April	2.29
May	0
June	0
July	0
August	0
September	0
October	0.43
November	0.27
December	2
Average	0.9125

Average Rainfall on Bicycle Parking

Convert surface of bicycle parking from square feet to square inches

150,000 ft^2 x 144 in^2/ft^2 = ***21,600,000 in^2***

Surface Area of Bike Parking x Average Rainfall of Three Years

21,600,000 in^2 x 1.039 in. = ***22,442,400 in^3***

Convert from cubic inches to gallon

22,442,400 in^3 x 1 gallon/231 in^3 = ***97,153 gallons***

Calculate the Water Rate of UC Davis

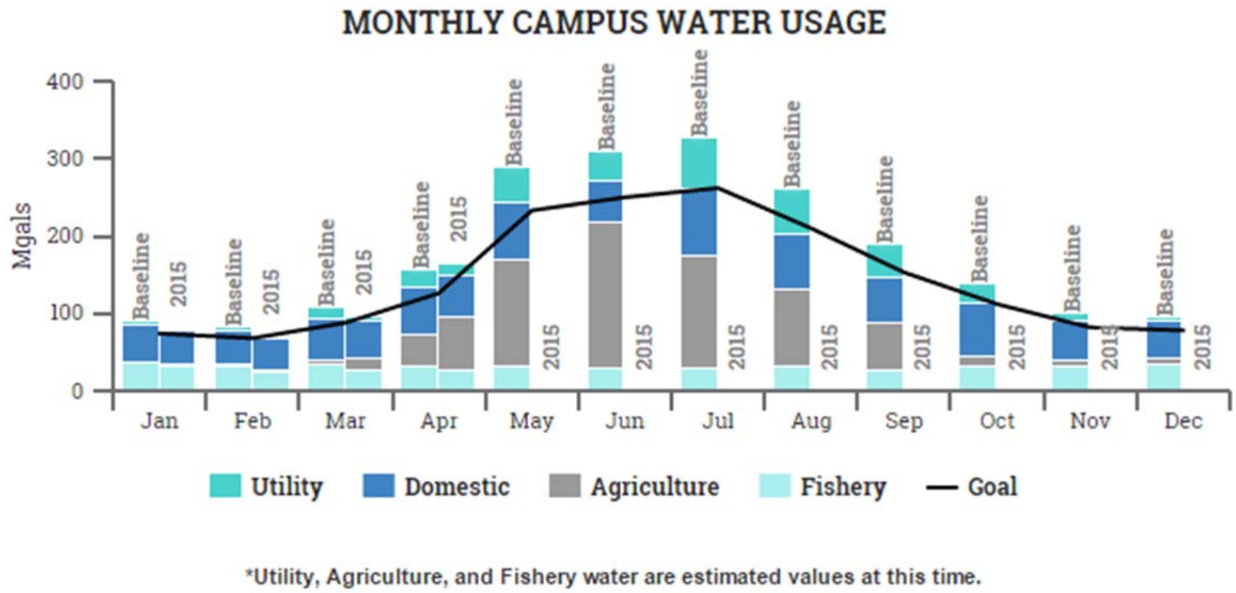


Figure 2 – *UC Davis Monthly Water Use and Projections for 2015*

354,000,000 gallons x $1ft^3/7.48052$ gallons = ***47,322,916.6533*** $\boldsymbol{ft^3}$

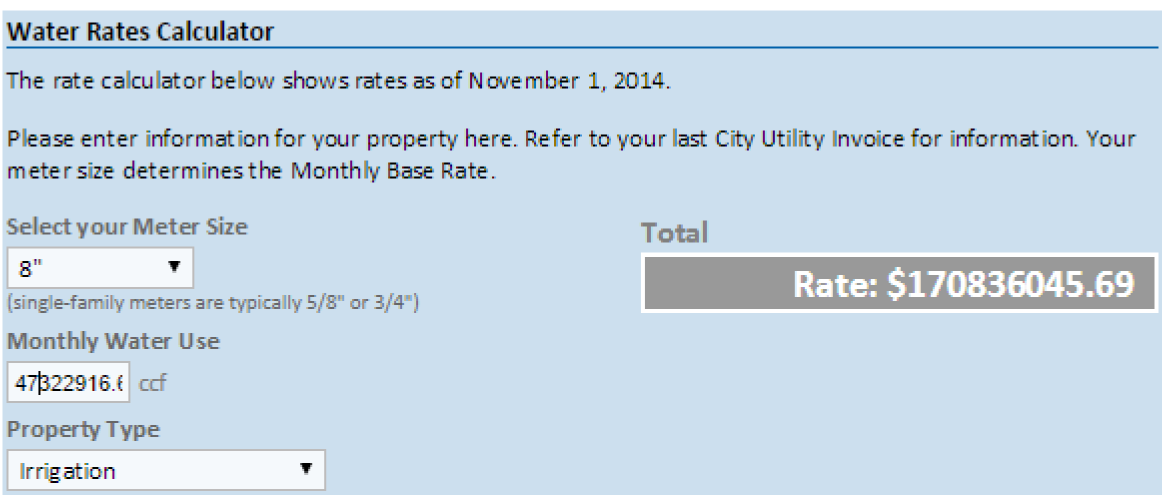


Figure 3 – *Cost of water for irrigation for the City of Davis. City of Davis Public Works.*

Possible Amount of Money Saved with Permeable Surfaces

Convert gallons to cubic feet

97,153 gallons x $1ft^3/7.48052$ gallons = ***12,987.467*** $\boldsymbol{ft^3}$

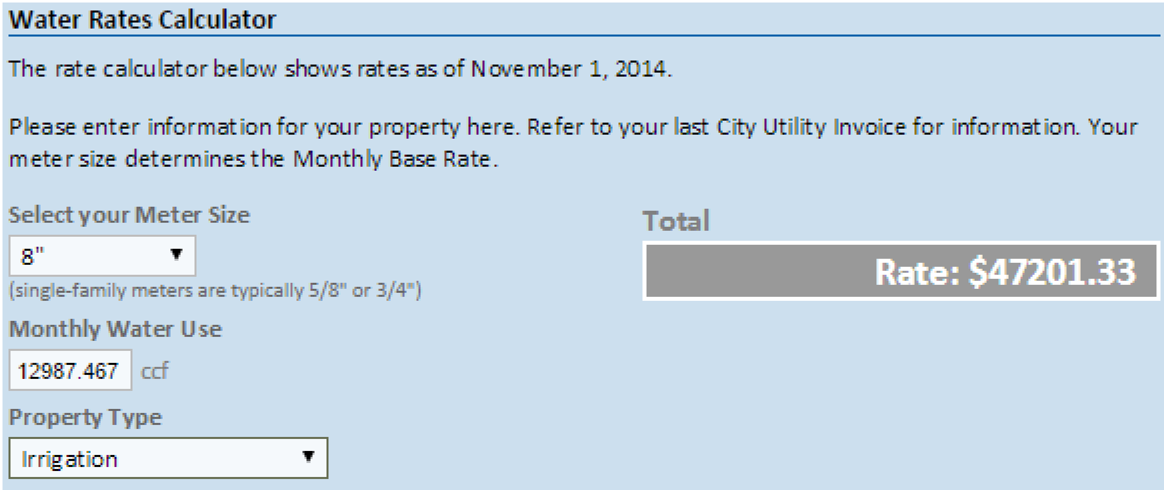
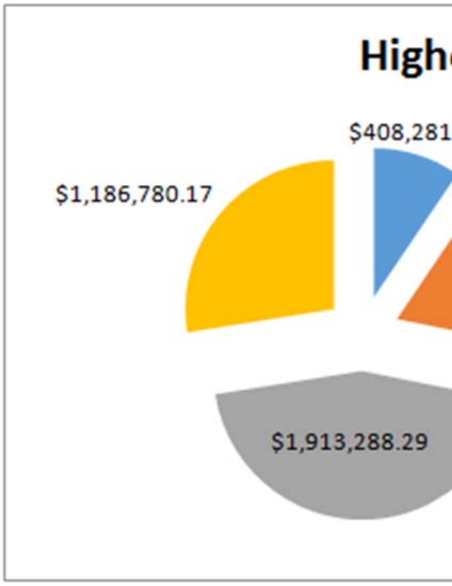


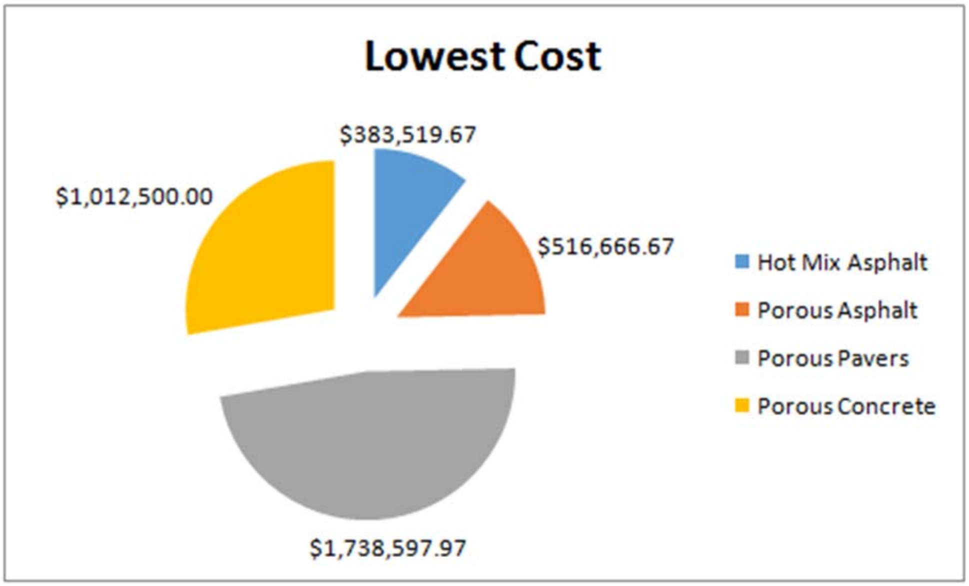
Figure 4 – *Projected savings of water using permeable surfaces. City of Davis Public Works.*

<u>Cost of Permeable Surfaces</u>

Surface Area of Bike Parking	150,000	sq. ft.

Type of Surface	**Highest $/sq. ft.**	**Lowest $/sq. ft.**	**Highest**	**Lowest**
Hot Mix Asphalt	$2.72	$2.56	$408,281.57	$383,519.67
Porous Asphalt	$5.38	$3.44	$806,587.84	$516,666.67
Porous Concrete	$7.91	$6.75	$1,186,780.17	$1,012,500.00
Porous Pavers	$12.76	$11.59	$1,913,288.29	$1,738,597.97





Payback Time of Permeable Surface

Type of Surface	Highest $/sq. ft.	Lowerst $/sq. ft.	Highest	Lowest	Longest (Years)	Shortest (Years)
Hot Mix Asphalt	$2.72	$2.56	$408,281.57	$383,519.67	9	8
Porous Asphalt	$5.38	$3.44	$806,587.84	$516,666.67	17	11
Porous Concrete	$7.91	$6.75	$1,186,780.17	$1,012,500.00	25	21
Porous Pavers	$12.76	$11.59	$1,913,288.29	$1,738,597.97	41	37

Conclusions and Results

In conclusion, we believe that in the short-term it is not economically feasible to. However, in the long-run it would be economically feasible and a wise investment for the future. According to the

City of Davis proposed water rate the City plans to increase the rate of water incrementally until 2019 by 47%. The 47% water rate increase is only adopted Prices of water will still increase after the year 2019, but these are only the adopted plans. The price of water will only become more expensive in the future. Also, with proper maintenance permeable surfaces can last up to 20 years (Century West Engineering).

Recommendations and Limitations

We found various limitations when conducting our analysis. The available data for maintenance cost was sparse, even from different contractors that provided permeable surface construction. It was difficult to obtain certain values even after consulting with on campus experts that did not have exact data or did not respond back. Values such as the amount of bicycle parking that we obtained were rough approximations from limited data by calculating the average of bicyclist with an estimate of how much room a bicycle would take up when parked. We had originally wanted to compile a more detailed set of data projecting the annual water usage throughout the same time frame as the annual rainfall data we collected and cross-reference the a more realistic projection, but the University did not have the information readily available. Though, we ran into a few limitations when conducting our analysis, we were able to have some of our questions answered by one of the guest speakers, Lisa Moretti, from class. Having a more direct access to someone we could contact was beneficial for our project to move forward. A recommendation for this project is to continue looking for other outside personnel if your previous contact did not respond to you in order to acquire the most accurate data.

Reference

California Soil Resource Lab University of California, Davis. (2014) “SoilWeb” < http://casoilresource.lawr.ucdavis.edu/gmap/> (May 26, 2015)

City of Davis Bicycle Advisory Commission. (2009) “City of Davis Bicycle Plan” < http://bicycles.cityofdavis.org/Media/Default/Documents/PDF/Bicycles/Bike-Plan-2009.pdf> (May 26, 2015)

City of Davis Public Works. (2014) “Water Rates” < http://water.cityofdavis.org/rates/water-rates> (May 1, 2015)

EPA. (2003) “After the Storm’ < http://water.epa.gov/action/weatherchannel/stormwater.cfm> (May 1, 2015)

Interlocking Concrete Pavement Institute. (2014) < http://www.icpi.org/sustainable> (May 1, 2015)

U.S. Climate Data. (2015) “Weather History Davis” < http://www.usclimatedata.com/climate/davis/california/united-states/usca0284/2014/11> (May 26, 2015)

University of California, Davis. (2015) “Water Dashboard” < http://wateroncampus.ucdavis.edu/#!/> (May 26, 2015)

University of Maryland Extension. (2012) “Permeable Pavement Fact Sheet Information for Howard County, Maryland Homeowners” < https://extension.umd.edu/sites/default/files/_docs/programs/master-gardeners/Howardcounty/Baywise/PermeablePavingHowardCountyMasterGardeners10_5_11%20Final.pdf> (May 26, 2015)