UNIVERSITY OF NEW HAMPSHIRE
STORMWATER CENTER
35 Colovos Rd
Durham, NH 03824
www.unh.edu/unhsc

Triverus Cleaning Technology Demonstration Report

10/18/2019

University of New Hampshire, Durham, NH

Task 1. Identify and test locations around campus to complete surface infiltration testing:

A series of surface infiltration testing on various pervious pavements was conducted using ASTM C1701 prior to and following maintenance and cleaning activities. Testing sites were located in areas that have previously been tested by the University of New Hampshire Stormwater Center (UNHSC) including:

1. West Edge UNHSC Porous Asphalt Lot, West Edge Drive, Durham, NH
2. Elliot Alumni Center Porous Asphalt Lot, 9 Edgewood Road, Durham, NH
3. Peter T. Paul Business School Parking Area, 10 Garrison Ave, Durham, NH
4. Hood House Drive PICP, 89 Maine St, Durham, NH

Task 2. Cleaning:

Technology description from the manufacturer: "The Triverus Municipal Cleaning Vehicle (MCV) integrates Triverus 3800 PSI spray cleaning and recovery technology onto a Bobcat® Toolcat™ all-wheel steer carrier. This packaging provides maximum flexibility for surface cleaning in congested areas such as airport ramps, airside loading bridge and terminal areas, walkways, dock areas, and enclosed parking structures. An overall height of 81 inches gives the MCV free reign in almost any covered parking area." (https://www.triverus.com/vehicles/municipal-cleaning-vehicles/, accessed 7/19/19)

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Figure 1: Triverus MCV cleaning West Edge Porous Asphalt (UNHSC).

Two locations were identified on the UNH campus for detailed testing:

1. West Edge UNHSC Porous Asphalt Lot, West Edge Drive, Durham, NH
2. Elliot Alumni Center Porous Asphalt Lot, 9 Edgewood Road, Durham, NH

Details for each location and results are provided below:

The West Edge Porous Asphalt Lot: The west edge porous asphalt lot is 14 years old and received maintenance for at least the first 5 years of operation. Since 2010, minimal studies and maintenance have taken place. The area is approximately 5,000 square feet in size and had an average pre-cleaning infiltration rate of 3 in/hr. Due to the variability of the testing method any permeable pavement with a surface infiltration rate less than 10 in/hr is considered failed from a hydraulic perspective. The average post-cleaning infiltration rate was 94 in/hr as shown in Figure 3, which is functional and effectively restored.

Tests were conducted on 7/8/2019; see the weather statistics in Table 1.

Table 1: Climate statistics for Durham, NH on 7/8/2019.

Parameter	Value
High Temperature	79 °F
Low Temperature	57 °F
Day Average Temperature	69.29 °F
Precipitation (past 24 hours from 04:56:00)	0.00 in
Dew Point	52.33 °F
High Dew Point	56 °F
Low Dew Point	49 °F
Average Dew Point	52.33 °F
Maximum Wind Speed	10 mph
Visibility	10 mi

Figure 2: West Edge Porous Asphalt Parking Lot

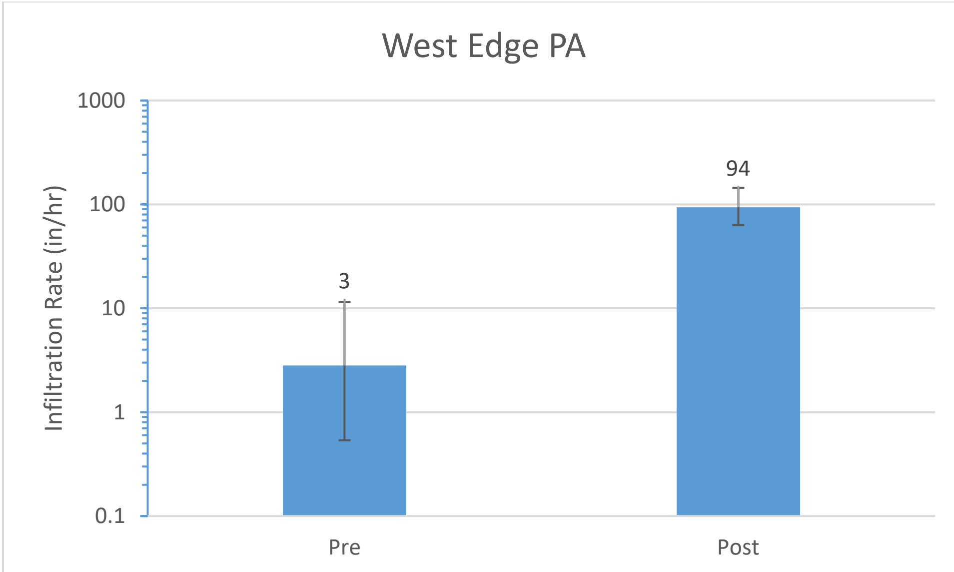

Figure 3: Pre and post-cleaning surface infiltration rate measured summer of 2019. Numbers above each blue bar represent the mean infiltration rates, and error bars show the range of values (minimum to maximum). The number of tests (n) were 12 and 6 for pre- and post-cleaning, respectively.

The restoration process was inevitably longer and more time-intensive than typical routine maintenance. The cleaning took approximately 6 hours, and 150 lbs of coarse sediment were removed from the area.

Alumni Center Porous Asphalt Parking Lot: The Alumni Center Porous Asphalt Lot is 7 years old and received maintenance for at least the first 2 years of operation. Since 2014, it is unclear how much maintenance or the overall effectiveness of any maintenance has been characterized. From the very low pre-cleaning infiltration rate, it would appear that no maintenance has occurred in the past 5 years.

In 2015, a small test area of approximately 200 square feet in a parking spot and 200 square feet in a driving lane was conducted to assess restoration potential. The cleaning was conducted by UNHSC staff and consisted of low angle power washing into a vacuum. The overall restoration work took two staff approximately 2 hours per location. The experiment demonstrated the restoration potential of the technology however at just over 50,000 square feet the effort using staff and handwork is not insignificant (~125 hours for two staff). The infiltration results from this testing are shown in 4.

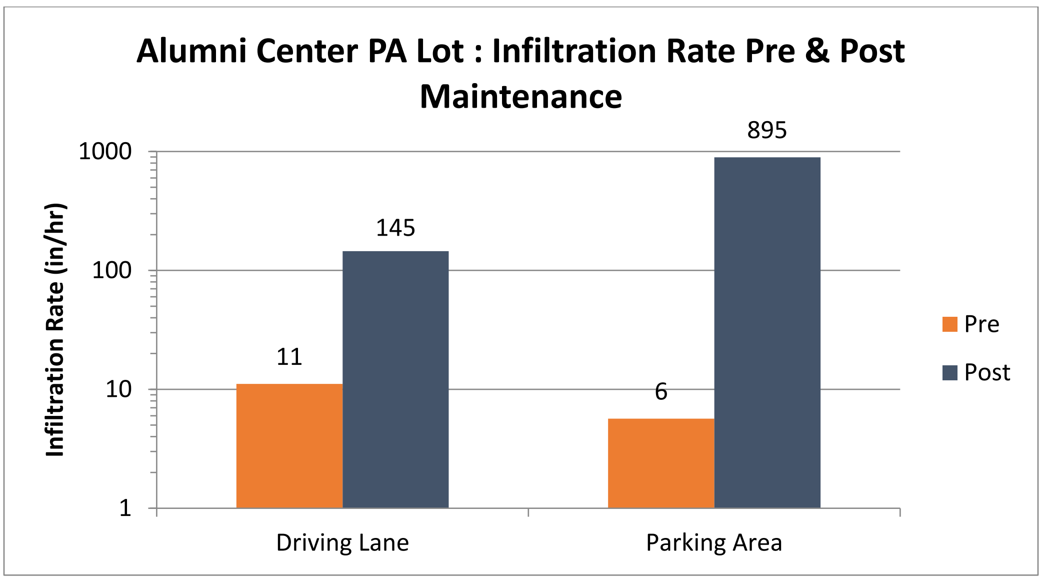

Figure 4: 2015 restoration experiment of the Alumni Center Porous Asphalt

Vacuum Testing

The area tested by Triverus MCV was approximately 3,575 square feet in size and had an average pre-cleaning infiltration rate of 3 in/hr (see figure 5). Due to the variability of the testing method, any permeable pavement with a surface infiltration rate of less than 10 in/hr is considered failed from a hydraulic perspective. The average post-cleaning infiltration rate was 84 in/hr as shown in Figure 6, which is functional and effectively restored.

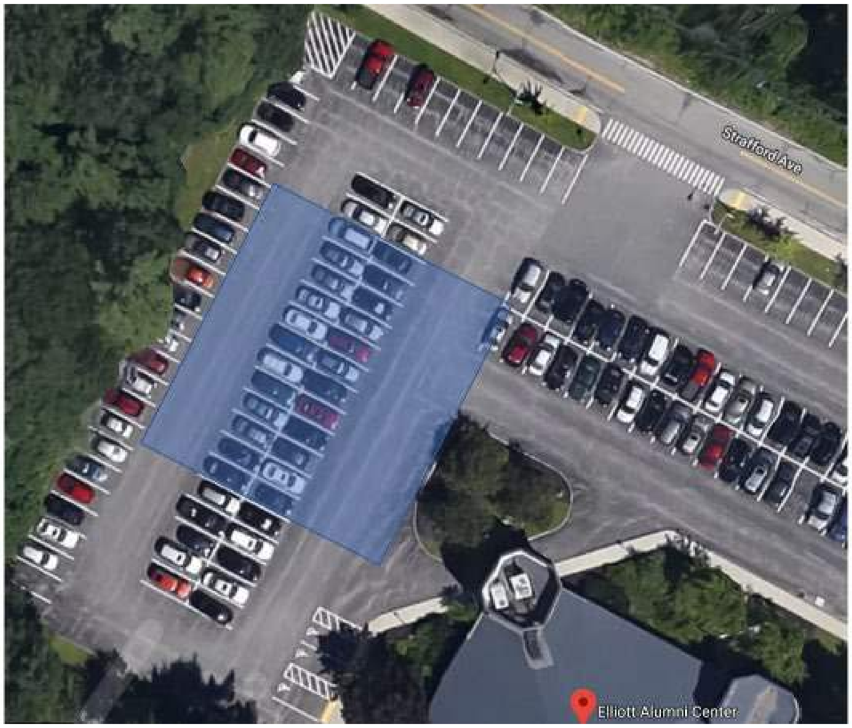

Figure 5: Elliot Alumni Center Porous Asphalt Parking Lot

Tests were conducted on 7/10/2019; see the weather statistics in Table 2.

Table 2: Climate statistics for Durham, NH on 7/10/2019.

Parameter	**Value**
High Temperature	86 °F
Low Temperature	63 °F
Day Average Temperature	72.21 °F
Precipitation (past 24 hours from 04:56:00)	0.00 in
Dew Point	58.46 °F
High Dew Point	62 °F
Low Dew Point	54 °F
Average Dew Point	58.46 °F
Maximum Wind Speed	14 mph
Visibility	10 mi

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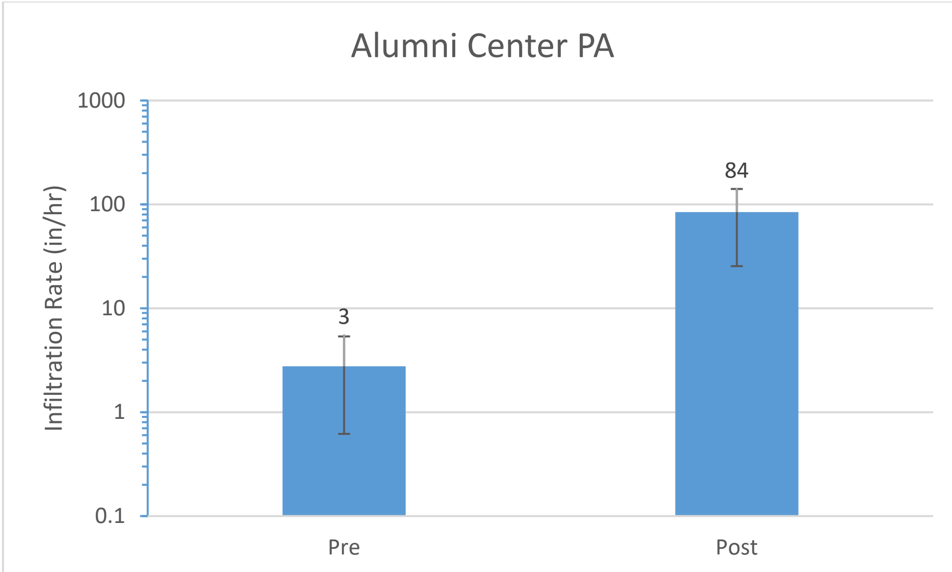

Figure 6: Pre and post-cleaning surface infiltration rate measured summer of 2019. Bars represent the mean infiltration rates, and error bars show the range of values (minimum to maximum). The number of tests (n) were 12 and 6 for pre- and post-cleaning, respectively.

The restoration process is inevitably longer and more time-intensive than typical routine maintenance. The cleaning took approximately 4 hours, and 350 lbs of coarse sediment were removed from the area. The decrease in cleaning time from the West Edge lot was due in part to process efficiencies. Additional time reductions could be realized, particularly with respect to MCV support with a vactor truck to reduce downtime associated with the disposal of removed material and refilling the water reservoir on the MCV. The detailed characterization and testing of the efforts take time and reduce restoration efficiency as well.

Water Quality: The removed material is separated in the MCV by a coarse screen and tray to hold coarse solids as the water and fines pass into a holding tank in the MCV. Once full, the tray with solids may be removed to be disposed of, and the water/fines slurry is pumped out to be filtered and disposed of properly. The tray of coarse solids is shown in Figure 7 after several passes on the West Edge porous asphalt.

Figure 7: The coarse solids collected in the solids tray after several passes on the West Edge PA.

The coarse solids were weighed and samples collected for laboratory analysis. Grab samples of the water slurry were taken and sent as a composite sample for laboratory analysis. A picture of the fines after the water was pumped out of the holding tank is shown in Figure 8.

Figure 8: The fines collected in the collection tank after coarse solids were removed in the tray screen and the water was pumped out. Note the center where the fines were moved to show the bottom of the tank (white).

The summary of performance by site is shown in Table 3. Note that some samples were below the detection limit (BDL). NH_4 was BDL from the West Edge site and NO_2 was BDL for both sites. Values that returned BDL area shown here in italics and assumed to be half the BDL value.

Table 3: Summary of performance by site for the total removal of the solids, water, and slurry. Note the Equivalent Detection Limit is converted to removal units from laboratory detection limits in units of mg/L. Detection Limits for Ca, Hardness, and Mg were not tested in the solids. Laboratory values BDL were assumed to be half the DL and are shown in italics.

	Total Removal (lb/ac)			Equivalent Detection Limit (lb/ac)	
Analyte	**West Edge**	**Alumni Center**	**Average**	**Solids**	**Water**
Ca	0.19	0.27	0.23	-	0.02
Cu	0.03	0.06	0.05	0.00	0.00
Hardness	1.10	1.42	1.26	-	0.11
Mg	0.15	0.18	0.17	-	0.00
NH4	0.10	0.38	0.24	0.04	0.02
NO2	*0.00*	*0.01*	*0.00*	*0.00*	*0.00*
NO3-N	0.02	0.02	0.02	0.00	0.00
ortho-P	0.01	0.02	0.01	0.00	0.00
TKN	0.58	0.95	0.77	0.01	0.04
TN	0.60	0.96	0.78	0.01	0.04
TP	0.26	1.99	1.12	0.01	0.00
TSS	1253	3376	2310	0.00	0.75
TZn	0.05	0.99	0.52	0.00	0.00

Figure 9 shows the same summary of performance in graphical form. Note the logarithmic scale, and NH_4 for the West Edge and NO_2 for both sites are not graphed (BDL).

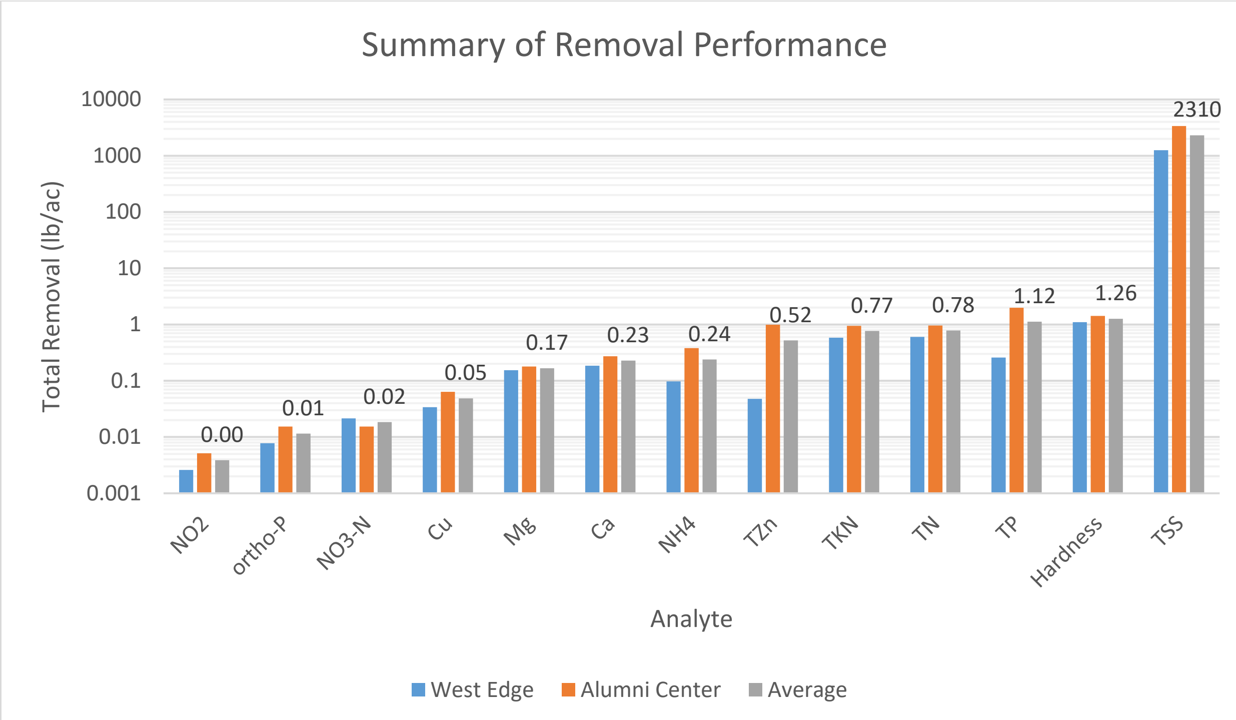

Figure 9: Summary of performance by site for the total removal of the solids, water, and slurry. Not the logarithmic scale.

In addition to the total material removed, the analytes were partitioned into fractions consisting of the coarse solids tray and the slurry containing water and fines. This is also known as solids and decant. Table 4 shows the percentages of the analytes found in each fraction of the removed materials.

Table 4: Percentages of the total mass of analyte found in the coarse solids and slurry (water & fines) fractions.

Analyte	Coarse Solids	Water & Fines
NO_3-N	12%	88%
ortho-P	16%	84%
NO_2	47%	53%
TN	63%	37%
TKN	64%	36%
TP	90%	10%
NH_4	91%	9%
TZn	93%	7%
Cu	95%	5%
TSS	96%	4%

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Combining the removal rates and the percentages in coarse solids and slurry yields a summary of removal performance for material removed via the coarse solids and the slurry (water and fines) as shown in Table 5.

Table 5: Summary of average analyte removal rates for coarse solids, water and fines slurry, and the total removed. Note the italicized values were measured BDL and assumed to be half the DL.

	Removal (lb/ac)		
Analyte	**Coarse Solids**	**Water & Fines**	**Total**
Ca	-	0.23	0.23
Cu	0.05	0.00	0.05
Hardness	-	1.26	1.26
Mg	-	0.17	0.17
NH_4	*0.22*	0.02	0.24
NO_2	*0.00*	*0.00*	*0.00*
NO_3-N	*0.00*	0.02	0.02
ortho-P	*0.00*	0.01	0.01
TKN	0.49	0.27	0.77
TN	0.49	0.29	0.78
TP	1.01	0.12	1.12
TSS	2210	100	2310
TZn	0.48	0.04	0.52

Overall, the restoration effort was extremely successful. Our research supports further exploration of restoration activities followed by more routine operation and maintenance such as vacuum sweeping twice per year. This data also reveals some significant differences in the pollutant partitioning between the liquid and solid fractions of the removed materials. It underscores the importance, particularly in nitrogen sensitive areas, of properly treating the removed waste materials.