FINAL REPORT ON A COLD CLIMATE PERMEABLE INTERLOCKING CONCRETE PAVEMENT TEST FACILITY AT THE UNIVERSITY OF NEW HAMPSHIRE STORMWATER CENTER

May 2013

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INTERLOCKING CONCRETE PAVEMENT INSTITUTE FOR EDUCATION AND RESEARCH
NEW ENGLAND CONCRETE MASONRY ASSOCIATION
NORTHEAST CEMENT SHIPPERS ASSOCIATION

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BY THE UNIVERSITY OF NEW HAMPSHIRE STORMWATER CENTER

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FINAL REPORT ON UNHSC COLD CLIMATE PERMEABLE INTERLOCKING CONCRETE PAVEMENT TEST FACILITY-THE UNIVERSITY OF NEW HAMPSHIRE STORMWATER CENTER-MAY 2013

1.0 EXECUTIVE SUMMARY

University of New Hampshire Stormwater Center (UNHSC) completed a two year field verification study of a permeable interlocking concrete pavement (PICP) stormwater management system. The purpose of this study was to evaluate the cold climate functionality of a PICP in an institutional setting. Monitoring took place from October 2010 through April 2012 on the University of New Hampshire (UNH) main campus in Durham, NH. The installation converted Hood House Drive and adjoining J Lot from a standard asphalt surface to a PICP system in the summer of 2010. The pre-existing condition included no stormwater control measures and conveyed surface runoff into the municipal storm sewer. The PICP system was designed by Appledore Engineering, Inc. in association with UNHSC and the Interlocking Concrete Pavement Institute (ICPI). An ICPI recommended PICP profile was used for the study site for the drive and a modified section with reservoir was used in the parking area. The treatment area includes direct rainfall over the system area and run-on from three pedestrian walkways and Memorial Union Building Drive. Concrete pavers and the surrounding grassed landscaping are separated by granite curbing. Rainfall is designed to filter down through the PICP system and into an infiltration reservoir. Excess stormwater is drained through internal drainage which discharges subsurface to the municipal storm sewer system.

Pollutant loading is estimated by monitoring runoff from an adjacent parking lot at Thompson Hall (T Lot) which is similar in size, usage, and location. Project objectives included: 1) Water Quantity and Water Quality Monitoring, 2) Surface Infiltration Testing, 3) Thermal Performance and Comparisons, and 4) Educational Outreach. In particular the Test Facility has been examined with respect to cold climate functionality. Assessment of eleven water quality parameters comparing the PICP lot and a reference lot was used to evaluate performance metrics for the system. All analyses and procedures comply with the Technology Acceptance and Reciprocity Partnership (TARP), and the Technology Acceptance Protocol – Ecology (TAPE) guidelines to the maximum extent possible. The UNHSC operates under a detailed Quality Assurance Project Plan (QAPP) which is available on request.

Following 2 years of monitoring that included 26 storms and 18 water sampling events, the performance for volume reduction and pollutant load reduction was exceptional for an instillation on a sandy clay soil (HSG-C). The USDA Soil Survey for the site is a Hollis-Charlton (very rocky, fine sandy loam). Local infiltration measurements are consistent with rates of a HSG-B soil at 3 in/hr. Volume reduction and subsequently pollutant mass removal exceeds 95% for all contaminants measured including sediment (TSS and SSC), metals (total Zinc - TZn), petroleum hydrocarbons (TPH), and nutrients (TP, ortho-P, TN, TKN, DIN = NO3, N02, NH4). Reductions in effluent concentrations were not observed for these same contaminants. This was presumably due to a concentration of pollutants caused by an exceptional volume

reduction. Effluent volumes in any single event never exceeded 5 gallons and peak flows were all less than 1 gallon per minute (with one exception).

Surface infiltration testing shows modest average performance for the PICP installation. A substantial decline in infiltration was observed for areas subjected to run-on. Infiltration rates declined 69% over 21 months yet still retained greater than 1000 inches per hour capacity. Minimal maintenance was performed during the period of monitoring. Impacts from run-on underscore the importance of designs minimizing run-on.

Thermal analyses were conducted comparing four pavement surface types at three different times. PICP surface temperatures were observed to be lower than that for porous asphalt, pervious concrete, and standard asphalt.

Outreach activities were conducted during 2011 and 2012. Three porous pavement design workshops were performed. A full-day ICPI training was performed in collaboration with David Smith, the ICPI Technical Director. The training included a field visit to the Test Facility alongside other porous pavement installations throughout the UNH campus and the region. Participants learned key design principles necessary to successfully design, evaluate, specify, and install porous pavements for stormwater management.

2.0 INTRODUCTION

Under an agreement with the Interlocking Concrete Pavement Institute (ICPI), field verification testing of a permeable interlocking concrete pavement (PICP) treatment system was conducted by the University of New Hampshire Stormwater Center (UNHSC) on the University campus in Durham, NH. Testing consisted of determining the water quality and quantity performance for a range of parameters including sediments, metals, nutrients, petroleum hydrocarbons, net effluent flow, and surface infiltration rates.

PICP performance evaluations were conducted across two seasons and a range of rainfall conditions: important variables reflective of natural field performance conditions. This report presents the analyses and monitoring from October 2010 through April 2012. This included monitoring of 26 rainfall events and sampling of 18 events in total.

3.0 FIELD FACILITY

3.1 System Description, Configuration and Sizing

The climatology of the area is characterized as a coastal, cool temperate forest. Average annual precipitation is 45 inches that is nearly uniformly distributed throughout the year, with average monthly precipitation of 4.02 in +/- 0.5. The mean annual temperature is 48°F, with the average low in January at 14°F, and the average high in July at 83°F.

The UNH test site is a 13,500 square foot PICP system installed in the summer of 2010 on the UNH main campus in Durham, NH (Figure 1, Figure 2). The pre-existing Hood House Drive (7,000 square foot) and J Lot (6,500 square foot) were standard asphalt surfaces. The areas previously had no stormwater controls and conveyed surface runoff to the downslope road and existing municipal stormwater system. Hood House Drive and J Lot are heavily used parking and driving surfaces during the school year. The PICP system was designed to: provide treatment by filtration through the subbase; promote infiltration and groundwater recharge; and underdrain to a central monitoring location, eventually flowing to the municipal storm sewer. The PICP installation treats direct rainfall and run-on from three intersecting pedestrian pathways and one moderately used road. While the entire installation was monitored for long-term infiltration capacity and surface temperature, only the J Lot portion was monitored for water quality.

Figure 1: August 2010 installation of PICP system (clockwise from top left) demolition and excavation, placement of subbase aggregate, finished product, underdrain installation.

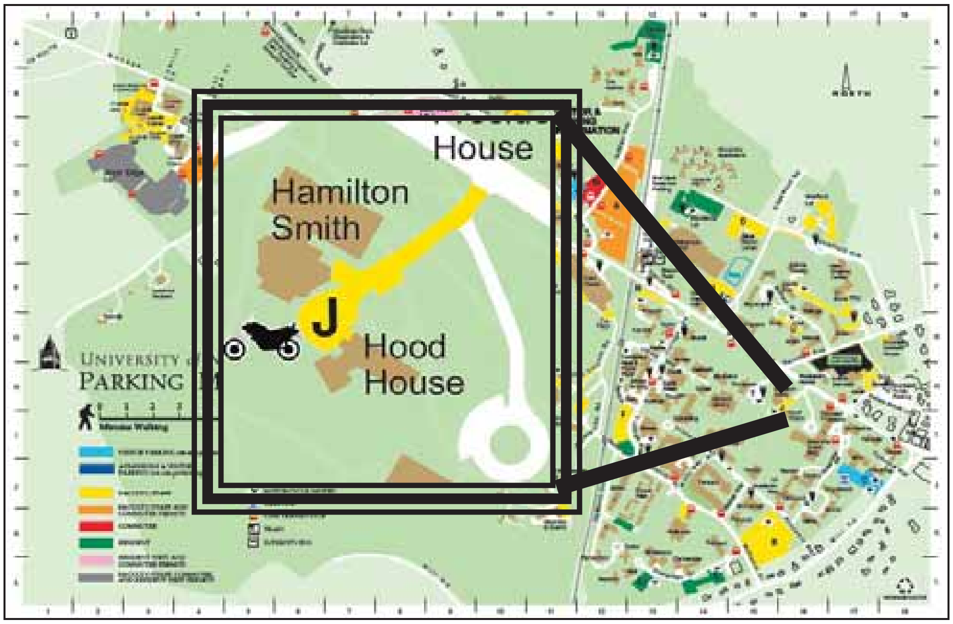


Figure 2: Location map of the PICP Test Site.

Appendix A includes project construction drawings and details. System configuration is an ICPI recommended profile (Figure 3). Concrete pavers were placed on a 2-inch bedding course of ASTM No. 8 aggregate. Appendix H provides test results on the concrete pavers which conform to ASTM C 936. The No. 8 aggregate was also used to fill the joints between the pavers. The bedding course is supported by a 4-inch open graded base layer of No. 57 aggregate. This layer was placed on a stone subbase reservoir of variable thickness of ASTM No. 2 aggregate. The thickness of the No. 2 subbase was 20 inches in the J Lot (the upper portion) areas, and 17 inches thick along the drive portion leading to Main Street. Below the subbase are native soils of sandy loam which have a high infiltration capacity of approximately 3 in/hr., measured in a test pit location prior to installation. The subbase and surface slopes of the PICP system are 6% and designed with internal grade controls. Two check dam and perforated underdrain configurations (Figure 4) were installed in the reservoir layer; one draining J Lot and the other Hood House Drive into an underground monitoring chamber. The J Lot underdrains are installed downstream of the check dams while the Hood House Drive underdrains are installed upstream. The check dams are constructed of 30 mil (0.762 mm) impermeable PVC liner installed in a stepped pattern (Figure 4). The perforated underdrains are placed 4 inches above the native soils. The J Lot configuration is intended to retain stormwater between events to promote denitrification within the subbase. The Hood House Drive configuration is intended to allow high flow events to bypass through the system more quickly. Both configurations allow the design storm event to infiltrate into the native soils. Each configuration has a unique outlet into the monitoring chamber. To date monitoring efforts have focused on the main parking area (J Lot) of the PICP system.

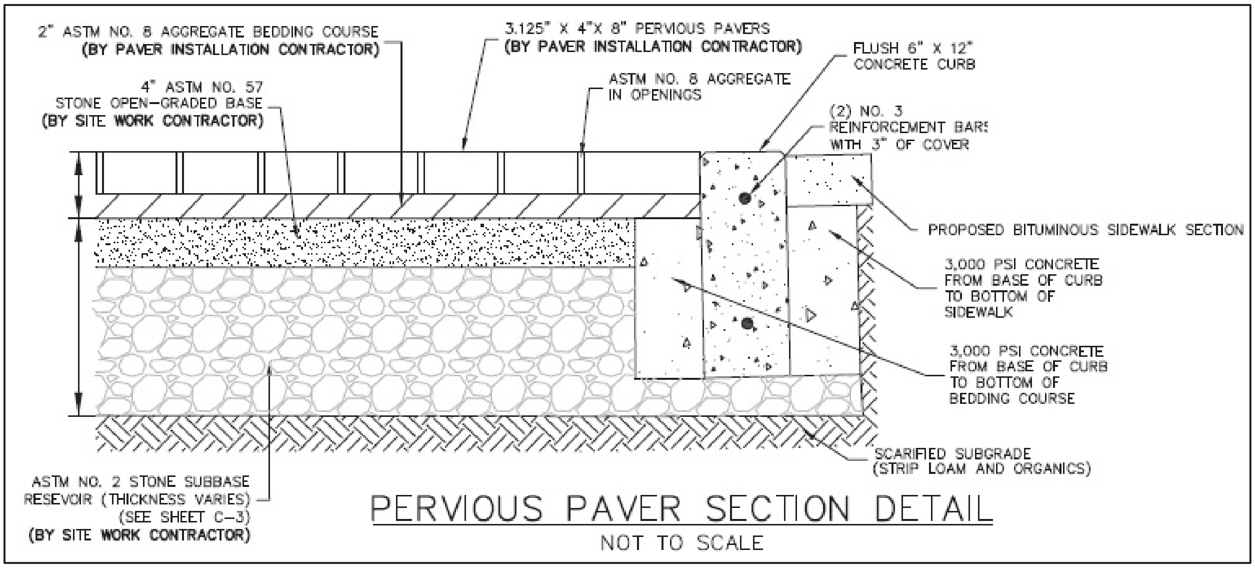


Figure 3: Typical PICP Hood House Drive Cross Section. The concrete haunches on both sides of the granite curbs are not typical to most PICP applications. The use of the concrete in this detail is specific to the University of New Hampshire.

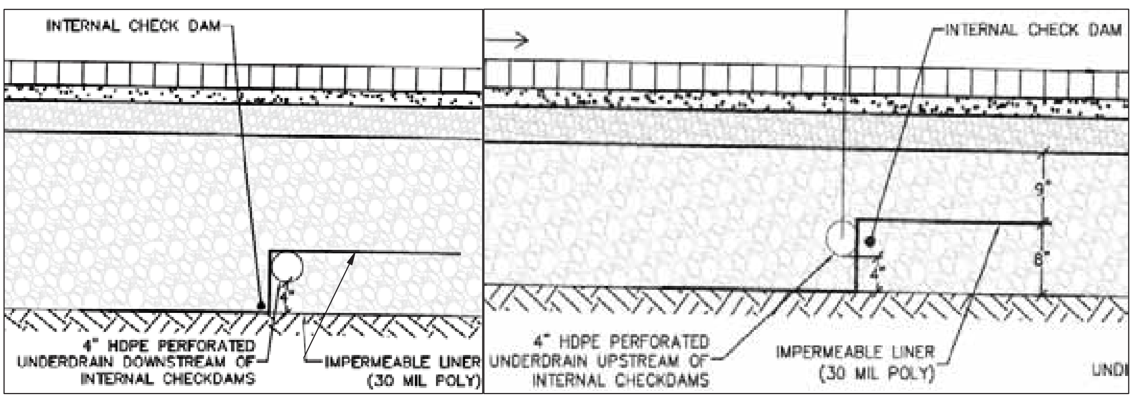


Figure 4: Check dam and perforated underdrain configurations. On the left is J Lot and the right is Hood House Drive. J Lot is the section being monitored for this study.

The reference influent monitoring and rain gauge were located off T Lot (Figure 5), which is approximately 400 feet from the PICP effluent monitoring location. T Lot is adjacent to Thompson Hall and Dimond Library on the main University campus and is similar in size, usage, and rainfall characteristics. T Lot is a 12,000 square foot standard asphalt lot with approximately 50 parking spaces, granite curbing, and traffic consisting of both passenger vehicles and routine bus traffic. The area, like Hood House Drive and J Lot, is subject to frequent plowing, and deicing (salting) throughout winter months. Literature reviews indicate that pollutant concentrations from T Lot are above or equal to national norms for parking lot runoff. T Lot is drained by a typical catch basin and piping network. A 12 inch HDPE pipe conveys a portion of T Lot runoff to a surface location (Figure 6) where monitoring equipment is installed to collect data, gather samples, and monitor flow and rainfall depths.

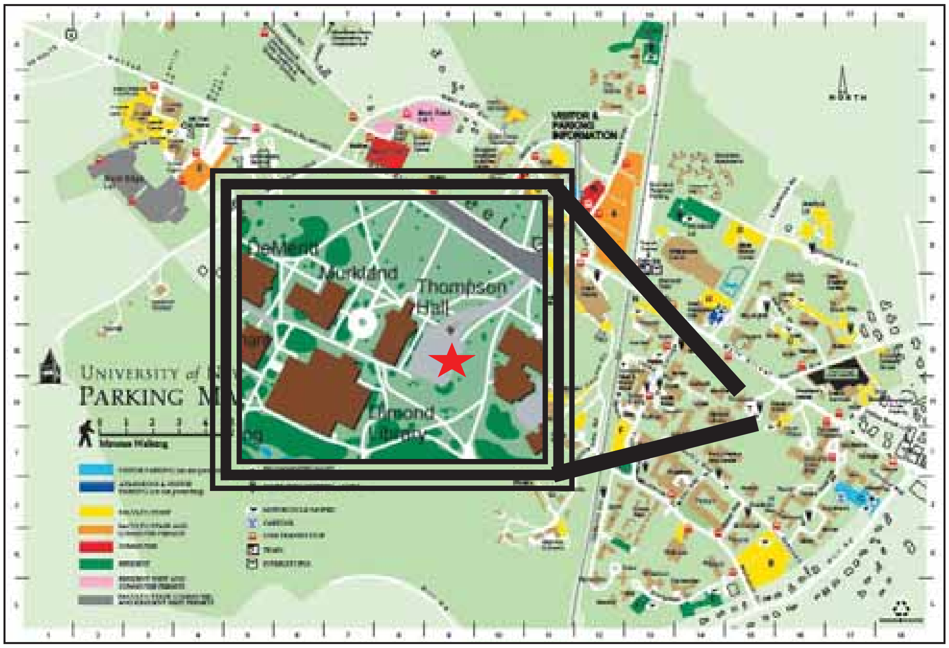


Figure 5: T Lot – PICP influent monitoring location

Figure 6: Picture of T Lot effluent location. T Lot is to the upper right in this picture.

3.2 Subgrade Soils

Prior to system design and construction, subgrade soils were examined. Soils categorized as Hydrologic Soil Group (HSG) B (NEH630.07, 2007) with an average infiltration rate of 3 inches per hour. Three test pits were dug however due to ledge outcrops were discovered at two of the test locations average infiltration rate from measured at one location on Hood House Drive was used. Appendix B (page 32) details test pit investigations. Two test pits (test pit #1 and #3) were dug down to 48 inches or until ledge outcrops impeded further excavation. Appendix B contains infiltration capacity (IC) and particle size distribution (PSD) of subbase soils located under Hood House Drive. Infiltration data is only available for Test Pit #2 and was measured at an average 3 inches per hour.

3.3 Reference TSS Information

Comparisons of the TSS concentrations for varied land uses are presented in Figure 7. Urban highway pollutant concentrations tend to be twice the mean concentration measured for parking lots and residential uses. Historical data collected from the UNH facility is within the national norm for commercial parking lots and is within the range of typical concentrations observed for a range of land uses. Occasional storms are monitored that have exceptionally high solids concentrations.

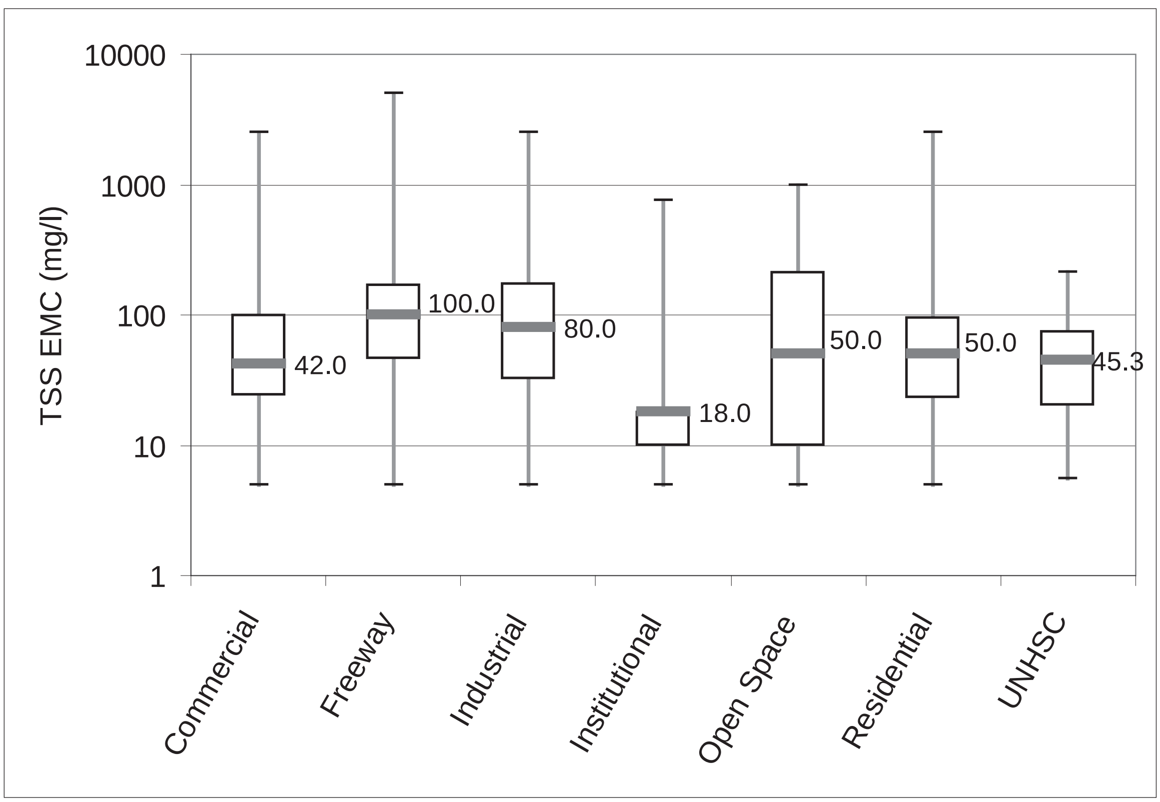


Figure 7: Total suspended solids (TSS) concentrations for varied land uses and at UNH Stormwater Center (Source: National Stormwater Quality Database, 2005, UNHSC, 2007)

4.0 INSTRUMENTATION AND MEASURING TECHNIQUES

4.1 Flow

Influent and effluent flow monitoring is accomplished with the use of Teledyne ISCO 6712 automated samplers. The samplers are equipped with Teledyne ISCO 730 Bubbler Flow Modules which work in conjunction with Thelmar compound weirs. Pre-established flow rating curves (Lehigh University, 1992) are used to convert depth readings to flow rates.

4.2 Rainfall Collection and Measurement

Rainfall is monitored using a Teledyne ISCO 674 Rain Gauge. The gauge collects direct rainfall through a 6-inch diameter opening in a 2-foot high anodized aluminum housing; water flows through an HDPE funnel and into a tipping bucket. The tipping bucket is calibrated to take a reading every 0.01-inch of rainfall depth. The rain gauge connects to and stores data in the ISCO 6712 sampler located off T Lot.

4.3 Other Measurements

Temperature, pH, specific conductivity, and dissolved oxygen are monitored using YSI 600XL multi-parameter sondes. These parameters are monitored at the effluent location during wet weather events only. Moisture, temperature, and electrical conductivity are measured within the system base materials using Decagon Devices 5TE probes in conjunction with Decagon Devices Em50 Data Loggers. The 5TE probes were installed during placement of the PICP system. Probes were installed in pairs at each interface of the base materials (i.e. two between the native soils and No. 2 stone reservoir; two between the No. 2 and No. 57 stone layers, etc.) Probes are paired for redundancy and because access to their location is impossible once installed.

4.4 Water Quality Analysis

Samples were processed and analyzed by an EPA and National Environmental Laboratory Accreditation Conference (NELAC) certified laboratory using the standard methodologies outlined in Table 1.

Table 1: Laboratory analytical methods and detection limits for each analyte.

Analyte	Analytical Method	Sample Detection Limit (mg/L)	Method Detection Limit (mg/L)[a]
Nitrate/Nitrite in water	EPA 300.0A	0.1	0.008
Total Suspended Solids	SM 2540 D	Variable, 1-10	0.4
Suspended Sediment Concentration	ASTM D-3977	Variable, 1-2	1
Total Phosphorus	EPA 365.3	0.01	0.008
Zinc in water	EPA 200.7	0.01	0.001-0.05
Total Petroleum Hydrocarbons –Diesel Range	SW 3510C 8015B	Variable ≤ 3.5	0.1-3.0

[a]Method detection limit is different than sample detection limit which will often be higher due to available sample volume.
SM = Standard Method, SW = Solid Waste

5.0 TEST PROCEDURES

5.1 Field Sampling Procedures

PICP effluent is captured by an automated sampler (large runoff events) or a 5-gallon bucket (small runoff events). For the majority of events a 5-gallon bucket was sufficient to hold the entire effluent volume. In these cases full sample (total capture) methods were used as opposed to automated composite samples. Total capture methods were utilized due to the increased accuracy associated with system performance and the tremendous volume reduction occurring by infiltration into the native soils. The total capture volume is homogenized, measured, and split into 1 liter ISCO Pro-Pak bags using a United States Geological Survey (USGS) Dekaport Cone Sample Splitter. PICP influent sampling was achieved using a portable ISCO 6712 automated sampler. Influent samples were collected using a flow weighted sampling program. Programs are set to achieve a minimum of 70% coverage over the duration of the storm event. Individual samples are automatically discharged into 1 liter Pro Pak bags. Post-processing consists of compositing all relevant samples into identical 1 liter samples using the USGS Dekaport Cone Splitter. The 1 liter disposable LDPE sample bags are used to assure clean, non-contaminated sample containers. Samples are sealed and labeled with a unique, water proof, adhesive bar code that corresponds with a field identification label containing information relating to the stormwater treatment unit and date of sampling. Records are kept that correlate sample bar code with sample time, date, flow, and other real time water quality parameters. This begins the chain-of-custody record that accompanies each sample to track handling and transportation throughout the sampling process.

Figure 8: Surface Inundation Test Equipment; A variation on ASTM C 1701 and D 3385-03

Infiltration rate (IR) measurements are developed using a modified surface inundation (SI) device. The modified SI is a falling head test that measures the time to infiltrate a known volume of water (0.56 gallons) through the permeable surface (Figure 8). SI measurements were taken at three separate locations on the PICP lot over 11 times throughout the study. The SI test is a modification of an ASTM Standard D 3385-03 (ASTM, 1988) in which the falling head SI test involves placing a cylinder of known diameter onto the pavement surface which is then sealed to the pavement surface (Briggs, 2006). The UNHSC SI test is similar to ASTM C 1701 for pervious concrete in which both methods measure the infiltration rate of a known volume of water through a pervious pavement. The difference is that the SI is a falling head test that starts time zero when the full volume of water is delivered to the infiltration device. C 1701 specifies that the known volume be delivered to the device at a rate that maintains a surface depth between 10mm to 15mm and starts time zero as soon as water contacts the pavement surface. Another difference is that the SI uses a closed-cell foam foot to seal the cylinder to the pavement surface and C 1701 specifies the use of plumbers putty as a sealant. Also, C 1701 generally requires at least 5 gallons of water to conduct, whereas the modified SI requires 0.56 gallons.

SI tests were used to monitor the infiltration capacity of the PICP system through the duration of the study. Locations for infiltration capacity measurement were chosen to represent different use scenarios. Location 1 is located near the entrance to Hood House Drive and represents a high use area. This location receives run on from Memorial Union Building Drive, sediment tracking from vehicles entering the lot, and leaf litter from a pair of deciduous trees. Location 2 is subject to less vehicle traffic, less impervious surface run on, is located on a more gradual slope, and has an evergreen tree that drops needles onto the surface of the test lot. Location 3 is located in a level parking stall that receives little traffic, has no organic litter build up, and is representative of a low loading area. IR measurements over the research period are shown in Figure 9. A site average for the study area is plotted and based on relative area contributions and infiltration capacity.

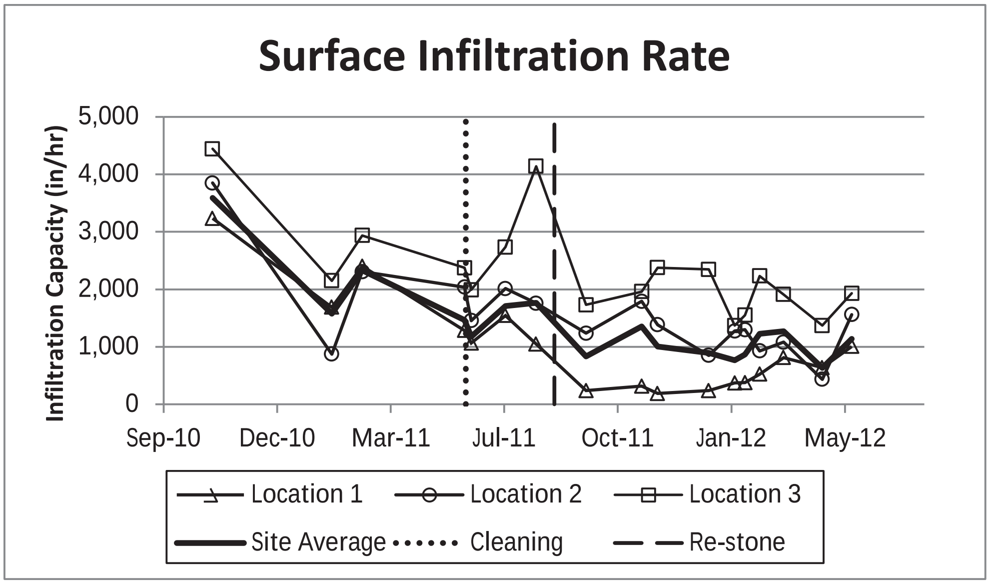


Figure 9: Infiltration rate monitoring over time of 3 separate locations representing different loading and usage characteristics.

6.0 MAINTENANCE

Throughout the monitoring period UNHSC worked with ICPI and Stormwater Compliance, Inc. to develop a long-term maintenance strategy to maintain aesthetics and infiltration capacity of the PICP system. The first attempt to clean the pavement in the fall of 2010 with a Tymco 210 Regenerative Air Sweeper (see Appendix C, page 41, for general specifications) was stopped due to the excessive removal of stone from between the pavers. A decision was made to postpone vacuum cleaning until clogging was more evident. In the spring of 2011 three areas of concern were identified and are described as follows:

- A pair of deciduous trees located near the entrance to Hood House Drive drop leaves onto the pavement. The leaves then pack between the pavers and clog the joints.
- A large evergreen located near the middle of Hood House Drive drops pine needles onto the pavement, which are subsequently ground into the joints from vehicle traffic.
- Areas of run-on from intersecting pedestrian paths convey sediment onto the pavement. Sediment has clogged the joints and grass has begun to grow.

A second attempt at vacuum cleaning was conducted with a Tymco 500X High Side Dump Regenerative Air Sweeper (see Appendix D, page 42, for general specifications). The machine alone was ineffective at removing packed debris from between the pavers in these areas of concern. The use of a leaf blower and pressure washer helped to dislodge some of the upper layer of debris, but more was packed underneath. In areas that were not clogged the No. 8 joint stones had settled approximately 1 inch. In these areas debris such as cigarette butts, sticks, and trash were observed lodged in the paver joints. With the stones at this depth the Tymco could dislodge more of the stones, but did not pull many directly into the hopper. Some of the stones were seen bouncing away from the vacuum head as the Tymco passed over the pavement. It was also evident that many of the pavers were loose and could be wobbled by foot. Winter plowing and freeze-thaw did not dislodge any of the pavers. In August 2011, additional No. 8 joint stone was used to fill in the seams. This proved to stabilize the loose pavers and no further settling was observed through the monitoring period. Photo documentation of various conditions is provided in Appendix E. An operation and maintenance procedure for PICP placements is an area of acute interest for additional research.

Results from work by Smith and Hunt (2010) indicated if a regenerative air machine is not used regularly, withdrawal of accumulated sediment requires use of a full vacuum machine. These machines have greater suction power than regenerative air machines which requires stone replenishment after cleaning.

Winter maintenance including plowing and anti-icing/de-icing was handled independently by UNH facilities. A memo regarding equipment and procedures used is included in Appendix I.

7.0 DATA EVALUATION

Data analyses are presented to examine PICP performance for water quality, quantity, infiltration, and surface reflectivity. Data and results are presented along with simple statistical analyses to examine performance trends. Data analyses included a range of approaches:

- evaluation of storm characteristics
- table of influent and effluent event mean concentrations (EMC), volume and pollutant mass summaries
- simple statistics summary
- particle size distribution (PSD) analysis
- thermal survey information from various pavements

Storm characteristics for each sampled storm event are presented in Table 2. Included in this table are characteristics of 8 events that could not be sampled for water quality analyses. Out of these 8 events 6 had 100% total volume reduction and thus no effluent volume with which to produce water quality results. This helps to illustrate the infiltration capacity of the native materials providing excellent groundwater recharge and runoff reduction.

EMC's are presented in Table 4 through Table 7 along with volume and mass reduction for a range of seasons. EMC's are used to represent the flow-proportional average concentration of a given parameter during a storm event. An EMC is the total constituent mass divided by the total runoff volume. When combined with flow measurement data, the EMC can be used to estimate the pollutant loading from a given storm, or on an annual basis. With respect to determination of EMC samples for the effluent flows both flow-weighted composite samples and total capture samples were taken. Total capture (entire storm volume) was used when available due to the higher data quality expectation. Total pollutant mass in the effluent samples were flow weighted to produce a relative EMC from total capture samples as a function of rainfall depth and the square footage of the test lot. Calculations are made according to the following equations:

$$V_i = A_p * P_e * 0.98 * 7.48 \text{ (gallons)} \quad \text{(Equation 1)}$$
$$V_r = 1 - (V_o/V_i) \quad \text{(Equation 2)}$$
$$Mass_{in} = V_i * EMC_{in} * 3785 \quad \text{(Equation 3)}$$
$$Mass_{out} = V_o * TC_{out} * 3785 \quad \text{(Equation 4)}$$
$$\%\text{Mass Reduction} = 1 - (Mass_{out}/Mass_{in}) \quad \text{(Equation 5)}$$

Where:

V_i = Direct volume into the system, or the runoff volume from impervious surface.
A_p = Area of the pavement (6,500 ft^2).
P_e = The precipitation associated with the event.
V_o = The volume out of the system collected and directly measured out of the system underdrain.
V_r = The amount of water volume reduction expressed as a percentage.
$Mass_{in}$ = the total mass, in grams, of pollutant entering the system
$Mass_{out}$ = the total mass, in grams, of pollutant leaving the system
EMC_{in} = the measured laboratory results from the flow weighted composite sample taken at the reference influent location (T Lot).
TC_{out} = the measured laboratory results from the total capture sample taken at the effluent location.

And with:

0.98 = a runoff conversion typical of paved or impervious surfaces.
7.48 = volume conversion factor to yield gallons from cubic feet.
3785 = a conversion factor to get from gallons to liters and milligrams to grams.

8.0 RESULTS

8.1 Water Quality and Quantity Performance

Results presented below for the PICP Test Facility represent data collected from the period of monitoring from October 2010 through April 2012 conducted at the UNHSC field facility. The data set reflects rainfall across four seasons and covers a wide range of rainfall characteristics. Table 2 displays rainfall event characteristics and influent and effluent volume for 26 storms of which 18 events had sufficient volume to monitor for water quality. Storms ranged in size from low intensity to high intensity, small volume to large volume.

Table 2: Rainfall-Runoff event characteristics for 26 storm events; 18 events sampled for water quality analyses.

Date	Storm Duration (min)	Rainfall		Influent		Effluent		Antecedent Dry Period (days)	Season	Water Quality** (yes/no)
		Peak Intensity (in/5min)	Rainfall Depth (in)	Peak Flow (gpm)	Total Volume* (gal)	Peak Flow (gpm)	Total Volume (gal)			
6/1/2011	270	0.09	0.13	69	516	0.000	0.000	8	Spring	No
6/9/2011	510	0.10	0.36	76	1429	0.009	0.410	8	Spring	Yes
6/11/2011	1485	0.04	1.08	31	4288	0.013	0.285	2	Spring	Yes
6/18/2011	4005	0.10	0.17	76	675	0.000	0.000	1	Spring	No
6/22/2011	2520	0.03	0.81	23	3216	0.005	1.395	4	Summer	Yes
6/24/2011	800	0.15	0.50	115	1985	0.022	0.155	1	Summer	No
6/29/2011	215	0.03	0.11	23	437	0.000	0.000	4	Summer	No
7/13/2011	310	0.18	0.40	137	1588	0.000	0.000	7	Summer	No
7/25/2011	1805	0.03	0.23	23	913	0.016	3.815	7	Summer	No
7/29/2011	505	0.04	0.25	31	993	0.009	0.125	3	Summer	Yes
8/2/2011	660	0.06	0.11	46	437	0.000	0.000	4	Summer	No
8/6/2011	985	0.04	0.53	31	2104	0.035	0.955	4	Summer	Yes
8/8/2011	580	0.12	0.37	92	1469	0.000	0.000	1	Summer	No
8/9/2011	630	0.03	0.50	23	1985	0.024	0.530	1	Summer	Yes
8/15/2011	1330	0.08	1.85	61	7346	0.044	5.000	5	Summer	Yes
8/21/2011	500	0.19	0.61	145	2422	0.095	4.000	2	Summer	Yes
9/6/2011	520	0.04	0.87	31	3454	0.035	1.294	9	Summer	Yes
9/22/2011	1700	0.05	0.40	38	1588	0.027	1.545	2	Summer	Yes
9/23/2011	835	0.07	0.59	53	2343	0.018	0.310	1	Summer	Yes
10/2/2011	1075	0.03	0.64	23	2541	0.020	0.660	1	Fall	Yes
10/13/2011	2510	0.07	1.28	53	5082	0.016	0.835	9	Fall	Yes
11/10/2011	710	0.06	0.98	46	3891	0.039	0.898	11	Fall	Yes
11/30/2011	335	0.04	0.64	31	2541	0.020	0.920	7	Fall	Yes
1/17/2012	1780	0.05	0.10	45	357	6.600	2.853	3	Winter	Yes
1/26/2012	1280	0.03	1.11	49	4407	0.200	1.585	3	Winter	Yes
4/22/2012	1660	0.04	2.32		9212	0.120	2.985	27	Spring	Yes

* Total Influent Storm Volume calculated from Rainfall Depth, system area, and runoff coefficient of 0.98
** Indicates whether or not storm samples were sent for water quality analyses

Table 3 presents the volume reduction for the PICP system for each of 26 events monitored. Figure 10 presents rainfall depth and influent and effluent volumes for monitored storms. Table 4 through Table 7 present the water quality, volume reduction, and pollutant mass reductions for each monitored storm and simple summary statistics.

EMC effluent concentrations were typically higher than the influent concentration for nearly every concentration measure however this must be considered in the context of volume reduction. Volume reduction was so exceptional that the effluent concentration appears to have been concentrated. However the median effluent volumes were less than 1 gallon and as such quality performance must be evaluated in the context of load reduction. Mass load reduction was typically greater than 95% for all contaminants.

Table 3: Rainfall-Runoff event statistics for 26 storm events including volume reduction calculations.

Date	Total Influent Volume (V_i) (gal)	Total Effluent Volume (V_o) (gal)	% Volume Reduction (V_r)
6/1/2011	516	0.00	100.00%
6/9/2011	1430	0.41	99.97%
6/11/2011	4289	0.29	99.99%
6/18/2011	675	0.00	100.00%
6/22/2011	3216	1.40	99.96%
6/24/2011	1985	0.16	99.99%
6/29/2011	437	0.00	100.00%
7/13/2011	1588	0.00	100.00%
7/25/2011	913	3.82	99.58%
7/29/2011	993	0.13	99.99%
8/2/2011	437	0.00	100.00%
8/6/2011	2105	0.96	99.95%
8/8/2011	1469	0.00	100.00%
8/9/2011	1985	0.53	99.97%
8/15/2011	7346	5.00	99.93%
8/21/2011	2422	4.00	99.83%
9/6/2011	3455	1.29	99.96%
9/22/2011	1588	1.55	99.90%
9/23/2011	2343	0.31	99.99%
10/2/2011	2541	0.66	99.97%
10/13/2011	5083	0.83	99.98%
11/10/2011	3891	0.90	99.98%
11/30/2011	2541	0.92	99.96%
1/17/2012	357	2.85	99.20%
1/26/2012	4408	1.59	99.96%
4/22/2012	9213	2.99	99.97%
n	26	26	26
Average	2586	1.18	99.93%
Median	2045	0.75	99.97%
Standard Deviation	2145	1.41	0.00
Coefficient of Variation	0.83	1.20	0.00

Figure 10: Total Volume of Influent and Effluent and Rainfall Depth for the Research Period of the Permeable Interlocking Concrete Pavement Treatment System.

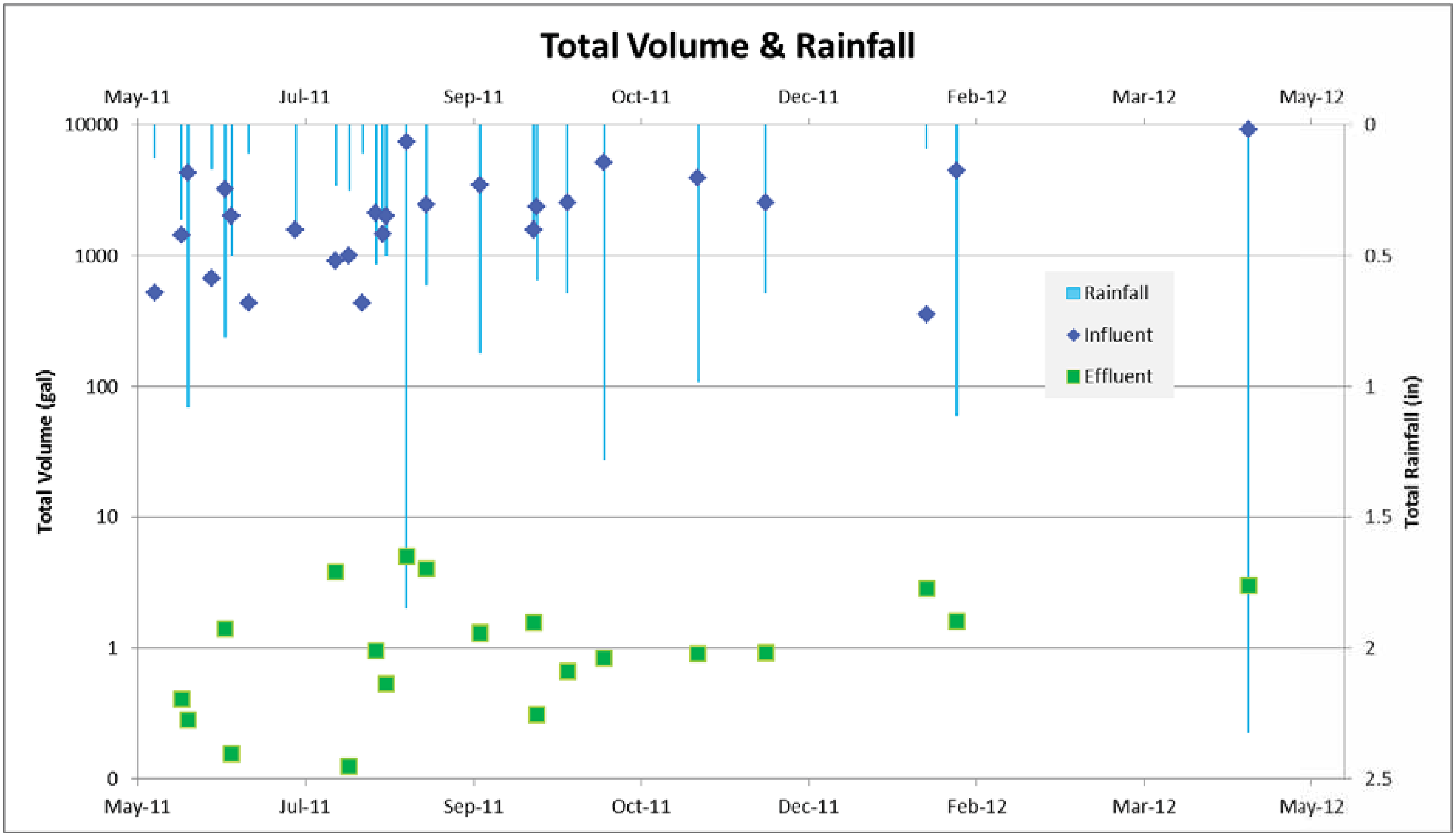


Table 4: Water quality performance for sediments with pollutant mass balance.

Total Suspended Sediments (TSS)								
Date	**V_i (L)**	**V_o (L)**	**%V_r**	**EMC in (mg/L)**	**EMC out (mg/L)**	**Mass in (g)**	**Mass out (g)**	**% Mass Reduction**
6/9/2011	5,411	1.40	99.97%	400	540	2164	0.76	99.97%
6/11/2011	16,233	3.00	99.98%	29	140	471	0.42	99.91%
6/22/2011	12,175	3.00	99.98%	10	12	122	0.04	99.97%
7/29/2011	3,758	1.10	99.97%	51	45	192	0.05	99.97%
8/6/2011	7,966	5.00	99.94%	38	29	303	0.15	99.95%
8/9/2011	7,515	9.50	99.87%	75	100	564	0.95	99.83%
8/15/2011	27,806	18.93	99.93%	24	110	667	2.08	99.69%
8/21/2011	9,169	15.14	99.83%	360	940	3301	14.23	99.57%
9/6/2011	13,077	4.90	99.96%	22	74	288	0.36	99.87%
9/22/2011	6,012	1.00	99.98%	42	280	253	0.28	99.89%
9/23/2011	8,868	0.80	99.99%	56	100	497	0.08	99.98%
10/2/2011	9,620	0.75	99.99%	31	48	298	0.04	99.99%
10/13/2011	19,239	3.16	99.98%	80	130	1539	0.41	99.97%
11/10/2011	14,730	3.40	99.98%	150	70	2209	0.24	99.99%
11/30/2011	9,620	3.34	99.97%	140	51	1347	0.17	99.99%
1/17/2012	1,353	10.80	99.20%	110	8	149	0.09	99.94%
1/26/2012	16,684	6.00	99.96%	77	15	1285	0.09	99.99%
4/22/2012	34,871	11.30	99.97%	320	17	11159	0.19	100.00%
n	18	18	18	18	18	18	18	18
Average	12,450	5.70	99.91%	112	151	1,489	1.15	99.92%
Median	9,620	3.37	99.97%	66	72	530	0.22	99.97%
St Dev	8,389	5.31	0.00	121	234	2,573	3.30	0.00
Coefficient of Variation	0.67	0.93	0.00	1.08	1.56	1.73	2.88	0.00

Suspended Sediment Concentration (SSC)								
Date	**V_i (L)**	**V_o (L)**	**%V_r**	**EMC in (mg/L)**	**EMC out (mg/L)**	**Mass in (g)**	**Mass out (g)**	**% Mass Reduction**
6/11/2011	16,233	3.00	99.98%	29	140	471	0.42	99.91%
6/22/2011	12,175	3.00	99.98%	18	19	219	0.06	99.97%
8/6/2011	7,966	5.00	99.94%	29	20	231	0.10	99.96%
8/9/2011	7,515	9.50	99.87%	53	69	398	0.66	99.84%
8/15/2011	27,806	18.93	99.93%	21	100	584	1.89	99.68%
8/21/2011	9,169	15.14	99.83%	320	390	2,934	5.91	99.80%
9/6/2011	13,077	4.90	99.96%	32	160	418	0.78	99.81%
10/2/2011	9,620	0.75	99.99%	42	530	404	0.40	99.90%
11/10/2011	14,730	3.40	99.98%	140	49	2,062	0.17	99.99%
11/30/2011	9,620	3.34	99.97%	61	48	587	0.16	99.97%
1/17/2012	1,353	10.80	99.20%	110	1	149	0.01	99.99%
1/26/2012	16,684	6.00	99.96%	79	16	1,318	0.10	99.99%
n	12	12	12	12	12	12	12	12
Average	12,162	6.98	99.88%	78	129	815	0.89	99.90%
Median	10,897	4.95	99.96%	48	59	445	0.28	99.93%
St Dev	6,517	5.53	0.00	85	165	861	1.66	0.00
Coefficient of Variation	0.54	0.79	0.00	1.09	1.29	1.06	1.88	0.00

Table 5: Water quality performance for hydrocarbons and zinc, with pollutant mass balance.

Total Petroleum Hydrocarbons - Diesel Range (TPH-D)								
Date	V_i (L)	V_o (L)	$\%V_r$	EMC in (ug/L)	EMC out (ug/L)	Mass in (mg)	Mass out (mg)	% Mass Reduction
6/22/2011	12,175	3.00	99.98%	430	157.5	5,235	0.47	99.99%
7/29/2011	3,758	1.10	99.97%	800	158	3,006	0.17	99.99%
8/6/2011	7,966	5.00	99.94%	610	410	4,859	2.05	99.96%
8/9/2011	7,515	9.50	99.87%	410	350	3,081	3.33	99.89%
8/15/2011	27,806	18.93	99.93%	320	158	8,898	2.98	99.97%
8/21/2011	9,169	15.14	99.83%	1,400	158	12,836	2.38	99.98%
10/13/2011	19,239	3.16	99.98%	710	5,100	13,660	16.12	99.88%
11/10/2011	14,730	3.40	99.98%	660	1,100	9,722	3.74	99.96%
11/30/2011	9,620	3.34	99.97%	570	370	5,483	1.24	99.98%
n	9	9	9	9	9	9	9	9
Average	12,442	6.95	99.94%	657	884	7,420	3.61	99.96%
Median	9,620	3.40	99.97%	610	350	5,483	2.38	99.97%
St Dev	7,297	6.23	0.00	318	1,609	4,018	4.85	0.00
Coefficient of Variation	0.59	0.90	0.00	0.48	1.82	0.54	1.34	0.00

Total Zinc - (TZn)								
Date	V_i (L)	V_o (L)	$\%V_r$	EMC in (mg/L)	EMC out (mg/L)	Mass in (mg)	Mass out (mg)	% Mass Reduction
6/9/2011	5,411	1.40	99.97%	0.14	0.26	758	0.36	99.95%
6/11/2011	16,233	3.00	99.98%	0.03	0.12	487	0.36	99.93%
6/22/2011	12,175	3.00	99.98%	0.03	0.01	365	0.03	99.99%
7/29/2011	3,758	1.10	99.97%	0.10	0.07	376	0.08	99.98%
8/6/2011	7,966	5.00	99.94%	0.05	0.07	398	0.35	99.91%
8/9/2011	7,515	9.50	99.87%	0.03	0.05	225	0.48	99.79%
8/15/2011	27,806	18.93	99.93%	0.03	0.05	834	0.95	99.89%
8/21/2011	9,169	15.14	99.83%	0.11	0.3	1,009	4.54	99.55%
9/6/2011	13,077	4.90	99.96%	0.03	0.29	392	1.42	99.64%
9/22/2011	6,012	1.00	99.98%	0.07	0.08	421	0.08	99.98%
9/23/2011	8,868	0.80	99.99%	0.03	0.07	266	0.06	99.98%
10/2/2011	9,620	0.75	99.99%	0.02	0.03	192	0.02	99.99%
10/13/2011	19,239	3.16	99.98%	0.05	0.12	962	0.38	99.96%
11/10/2011	14,730	3.40	99.98%	0.11	0.09	1,620	0.31	99.98%
11/30/2011	9,620	3.34	99.97%	0.05	0.06	481	0.20	99.96%
1/17/2012	1,353	10.80	99.20%	0.24	0.03	325	0.32	99.90%
1/26/2012	16,684	6.00	99.96%	0.06	0.03	1,001	0.18	99.98%
4/22/2012	34,871	11.30	99.97%	0.01	0.005	349	0.06	99.98%
n	18	18	18	18	18	18	18	18
Average	12,450	5.70	99.91%	0.07	0.10	581	0.57	99.91%
Median	9,620	3.37	99.97%	0.05	0.07	410	0.32	99.96%
St Dev	8,389	5.31	0.00	0.06	0.09	374	1.05	0.00
Coefficient of Variation	0.67	0.93	0.00	0.86	0.95	0.64	1.86	0.00

Table 6: Water quality performance for total nitrogen and dissolved inorganic nitrogen (NO_2, $N0_3$, NH_4), with pollutant mass balance.

Total Nitrogen (TN)								
Date	V_i (L)	V_o (L)	$\%V_r$	EMC in (mg/L)	EMC out (mg/L)	Mass in (mg)	Mass out (mg)	% Mass Reduction
6/9/2011	5,411	1.40	99.97%	4.0	7.6	21,644	10.64	99.95%
6/11/2011	16,233	3.00	99.98%	0.8	3.1	12,986	9.30	99.93%
6/22/2011	12,175	3.00	99.98%	1.1	2.7	13,392	8.10	99.94%
7/29/2011	3,758	1.10	99.97%	2.0	6.3	7,515	6.93	99.91%
8/6/2011	7,966	5.00	99.94%	0.9	5.0	7,170	25.00	99.65%
8/9/2011	7,515	9.50	99.87%	0.6	3.7	4,509	35.15	99.22%
8/15/2011	27,806	18.93	99.93%	0.8	2.9	22,245	54.89	99.75%
8/21/2011	9,169	15.14	99.83%	2.1	2.9	19,254	43.91	99.77%
9/6/2011	13,077	4.90	99.96%	0.5	1.6	6,538	7.84	99.88%
9/22/2011	6,012	1.00	99.98%	1.3	3.1	7,816	3.10	99.96%
9/23/2011	8,868	0.80	99.99%	0.6	1.9	5,321	1.52	99.97%
10/2/2011	9,620	0.75	99.99%	0.8	1.5	7,696	1.13	99.99%
10/13/2011	19,239	3.16	99.98%	1.0	3.4	19,239	10.74	99.94%
11/10/2011	14,730	3.40	99.98%	1.5	1.3	22,095	4.42	99.98%
11/30/2011	9,620	3.34	99.97%	1.6	3.5	15,391	11.69	99.92%
1/17/2012	1,353	10.80	99.20%	2.9	2.5	3,923	27.00	99.31%
1/26/2012	16,684	6.00	99.96%	0.9	1.1	15,015	6.60	99.96%
4/22/2012	34,871	11.30	99.97%	1.1	4.9	38,358	55.37	99.86%
n	18	18	18	18	18	18	18	18
Average	12,450	5.70	99.91%	1.36	3.28	13,895	17.96	99.83%
Median	9,620	3.37	99.97%	1.05	3.00	13,189	9.97	99.93%
St Dev	8,389	5.31	0.00	0.90	1.74	8,858	17.97	0.00
Coefficient of Variation	0.67	0.93	0.00	0.66	0.53	0.64	1.00	0.00

Dissolved Inorganic Nitrogen (DIN)								
Date	V_i (L)	V_o (L)	$\%V_r$	EMC in (mg/L)	EMC out (mg/L)	Mass in (mg)	Mass out (mg)	% Mass Reduction
6/9/2011	5,411	1.40	99.97%	0.2	0.05	1,082	0.07	99.99%
7/29/2011	3,758	1.10	99.97%	0.5	2.9	1,879	3.19	99.83%
1/17/2012	1,353	10.80	99.20%	0.6	0.25	812	2.70	99.67%
n	3	3	3	3	3	3	3	3
Average	3,507	4.43	99.72%	0.43	1.07	1,258	1.99	99.83%
Median	3,758	1.40	99.97%	0.50	0.25	1,082	2.70	99.83%
St Dev	2,041	5.52	0.00	0.21	1.59	555	1.68	0.00
Coefficient of Variation	0.58	1.24	0.00	0.48	1.49	0.44	0.84	0.00

Table 7: Water quality performance for total phosphorus and ortho-phosphate with pollutant mass balance

Total Phosphorus (TP)								
Date	V_i (L)	V_o (L)	$\%V_r$	EMC in (mg/L)	EMC out (mg/L)	Mass in (mg)	Mass out (mg)	% Mass Reduction
6/9/2011	5,411	1.40	99.97%	0.81	1.10	4,383	1.54	99.96%
6/11/2011	16,233	3.00	99.98%	0.17	0.50	2,760	1.50	99.95%
6/22/2011	12,175	3.00	99.98%	0.11	0.14	1,339	0.42	99.97%
7/29/2011	3,758	1.10	99.97%	0.17	0.27	639	0.30	99.95%
8/6/2011	7,966	5.00	99.94%	0.13	0.48	1,036	2.40	99.77%
8/9/2011	7,515	9.50	99.87%	0.09	0.49	676	4.66	99.31%
8/15/2011	27,806	18.93	99.93%	0.06	0.37	1,668	7.00	99.58%
8/21/2011	9,169	15.14	99.83%	0.27	0.92	2,476	13.93	99.44%
9/6/2011	13,077	4.90	99.96%	0.10	0.21	1,308	1.03	99.92%
9/22/2011	6,012	1.00	99.98%	0.21	0.36	1,263	0.36	99.97%
9/23/2011	8,868	0.80	99.99%	0.06	0.17	532	0.14	99.97%
10/2/2011	9,620	0.75	99.99%	0.12	0.21	1,154	0.16	99.99%
10/13/2011	19,239	3.16	99.98%	0.16	0.13	3,078	0.41	99.99%
11/10/2011	14,730	3.40	99.98%	0.39	0.19	5,745	0.65	99.99%
11/30/2011	9,620	3.34	99.97%	0.12	0.26	1,154	0.87	99.92%
1/17/2012	1,353	10.80	99.20%	0.26	0.05	352	0.54	99.85%
1/26/2012	16,684	6.00	99.96%	0.14	0.12	2,336	0.72	99.97%
4/22/2012	34,871	11.30	99.97%	0.06	0.05	2,092	0.57	99.97%
n	18	18	18	18	18	18	18	18
Average	12,450	5.70	99.91%	0.19	0.33	1,888	2.07	99.86%
Median	9,620	3.37	99.97%	0.14	0.24	1,323	0.68	99.96%
St Dev	8,389	5.31	0.00	0.18	0.28	1,414	3.45	0.00
Coefficient of Variation	0.67	0.93	0.00	0.93	0.85	0.75	1.67	0.00

Ortho - Phosphate (OrP)								
Date	V_i (L)	V_o (L)	$\%V_r$	EMC in (mg/L)	EMC out (mg/L)	Mass in (mg)	Mass out (mg)	% Mass Reduction
6/9/2011	5,411	1.40	99.97%	0.250	0.010	1,353	0.014	100.00%
6/11/2011	16,233	3.00	99.98%	0.080	0.005	1,299	0.015	100.00%
6/22/2011	12,175	3.00	99.98%	0.040	0.005	487	0.015	100.00%
7/29/2011	3,758	1.10	99.97%	0.060	0.050	225	0.055	99.98%
8/6/2011	7,966	5.00	99.94%	0.060	0.250	478	1.250	99.74%
8/9/2011	7,515	9.50	99.87%	0.040	0.120	301	1.140	99.62%
8/15/2011	27,806	18.93	99.93%	0.020	0.030	556	0.568	99.90%
9/6/2011	13,077	4.90	99.96%	0.060	0.005	785	0.025	100.00%
9/22/2011	6,012	1.00	99.98%	0.078	0.008	469	0.008	100.00%
9/23/2011	8,868	0.80	99.99%	0.030	0.025	266	0.020	99.99%
10/2/2011	9,620	0.75	99.99%	0.059	0.015	568	0.011	100.00%
10/13/2011	19,239	3.16	99.98%	0.082	0.017	1,578	0.054	100.00%
11/10/2011	14,730	3.40	99.98%	0.123	0.002	1,812	0.007	100.00%
11/30/2011	9,620	3.34	99.97%	0.026	0.007	250	0.023	99.99%
1/17/2012	1,353	10.80	99.20%	0.003	0.001	4	0.011	99.73%
1/26/2012	16,684	6.00	99.96%	0.010	0.009	167	0.054	99.97%
4/22/2012	34,871	11.30	99.97%	0.001	0.003	35	0.034	99.90%
n	17	17	17	17	17	17	17	17
Average	12,643	5.14	99.92%	0.06	0.03	625	0.1943	99.93%
Median	9,620	3.34	99.97%	0.06	0.01	478	0.0234	99.99%
St Dev	8,606	4.90	0.00	0.06	0.06	552	0.3996	0.00
Coefficient of Variation	0.68	0.95	0.00	0.97	1.90	0.88	2.06	0.00

8.2 Particle Size Distribution

One set of influent and effluent samples were sent to Microtrac Inc. in Largo, FL for analysis of particle size distribution by laser diffraction. The requested range was 0.02 – 1500 microns. The influent sample was a composite from the influent reference parking lot (T-Hall) and the effluent was a sub-sample of the effluent total capture. Samples were taken from the 8/9/2011 event. The median particle diameter for both samples were very fine, approximately 42-47 microns. Results are included as Appendix F on page 44.

8.3 Real-Time Water Quality Parameters

Water quality parameters were monitored for 14 of the 18 sampled events using an YSI 600XL Multi-parameter probe. Parameters include dissolved oxygen, conductivity, pH, and temperature. Table 8 lists the average values over the duration of each event with summary statistics covering the entire monitoring period. During August and September of 2011 the conductivity / temperature probe began to malfunction and were recording either static or inaccurate values, therefore they have been removed from the data set.

Table 8: Real-time water quality parameters per event.

Average Real-Time Water Quality Parameters				
Date	Dissolved Oxygen (mg/l)	Conductivity (uS/cm)	pH	Temperature (°F)
6/9/2011	No Data			
6/11/2011	No Data			
6/22/2011	No Data			
7/29/2011	9.5	327.2	8.0	68.9
8/6/2011	7.6	460.4	7.9	69.2
8/9/2011	9.5	430.5	8.4	68.6
8/15/2011	8.9	217.9	8.0	67.1
8/21/2011	9.9		7.8	
9/6/2011	3.2		9.1	
9/22/2011	17.1		7.6	
9/23/2011	17.4		7.6	
10/2/2011	No Data			
10/13/2011	5.3	44.6	6.3	61.7
11/10/2011	11.2	84.6	7.3	55.0
11/30/2011	8.0	54.5	6.2	54.3
1/17/2012	16.8	429.3	6.7	42.2
1/26/2012	13.1	97.4	7.1	41.0
4/22/2012	11.5	108.1	8.9	54.7
n	14	10	14	10
Average	10.7	225.5	7.6	58.3
Median	9.7	163.0	7.7	58.4
St Dev	4.1	161.6	0.8	10.1
Coefficient of Variation	0.4	0.7	0.1	0.2

8.4 Thermal Performance and Comparison

Thermal performance in the form of surface reflectivity was examined on June, 21, 2012 for the PICP lot in comparison with three other pavements types. Thermal performance examined the surface temperature of various pavements when exposed to direct sunlight throughout an entire summer day. Measurements were taken on each surface at 7 a.m., 12 p.m., and 5 p.m. with an infrared thermometer, Mastercool model #52224-A. The device measures near infrared or 750 to 2,500 nm wavelengths, and emissivity is set at 0.95. Pavement types selected to compare with PICP are porous asphalt, pervious concrete, and conventional asphalt. This nm range is similar to that used to determine solar reflective index or SRI. Results can be found in Figure 11.

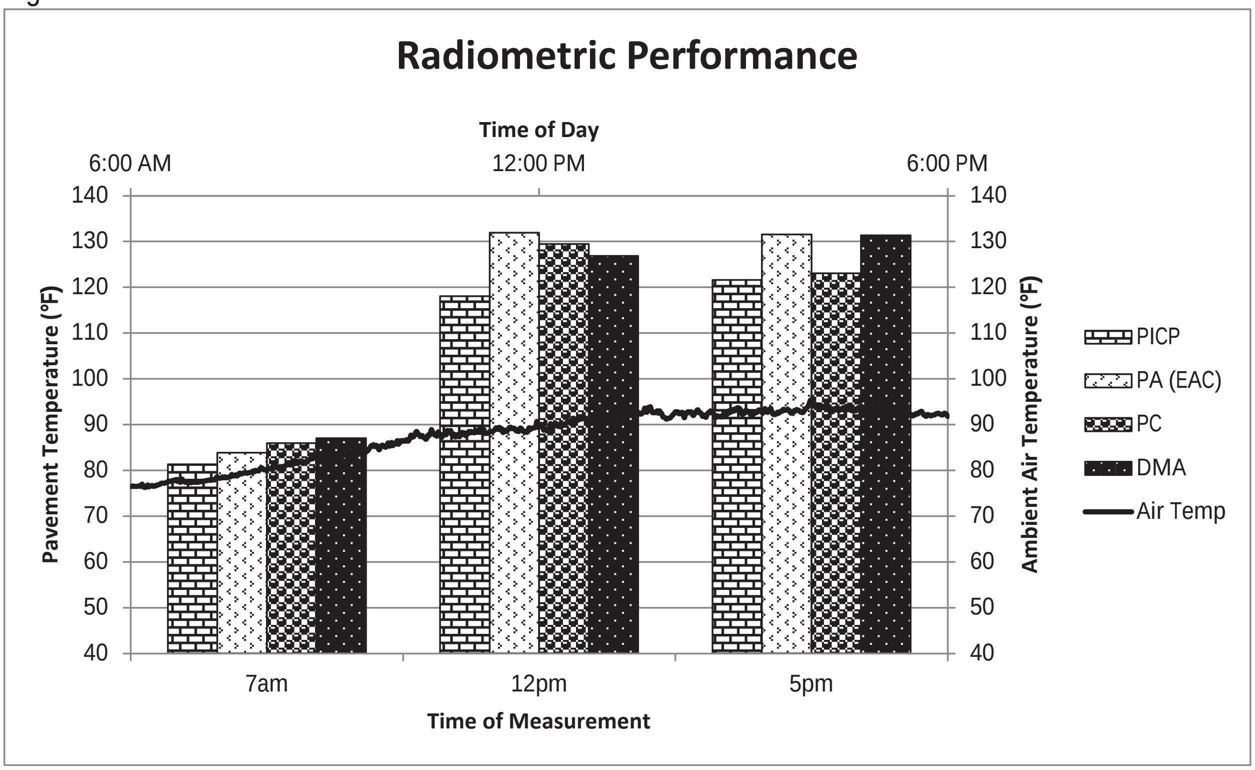


Figure 11: Thermal performance comparison of PICP, porous asphalt, pervious concrete and conventional asphalt. Measurements taken on June 21, 2012.

9.0 OUTREACH AND EDUCATION

The UNHSC has conducted numerous outreach and education efforts including workshops, presentations at national conferences, and publications.

Two porous pavement workshops and one PICP specific workshop were performed during the monitoring period on 06/02/2011, 10/06/2011, and 06/11/2012 (PICP only). The PICP workshop was conducted in partnership with ICPI and David Smith. The workshops provided stormwater management professionals with the most up to date characteristics of successful porous pavement/PICP applications. The full-day training included a field visit to the PICP Test Facility, and in some cases, alongside with other porous pavement installations throughout the UNH campus and the region. Participants learned key design principles necessary to successfully design, evaluate, specify, and install porous pavements for stormwater management. Additional workshop events may be organized and conducted following project completion.

UNHSC will use additional educational outreach as follows. UNHSC produces a biennial report on the testing results of the various stormwater systems and management practices. PICP research results are in the next report and a copy has been included in Appendix G. An electronic version of the full biennial report is available for download at the UNHSC website at http://unh.edu/unhsc/sites/unh.edu.unhsc/files/docs/UNHSC.2012Report.10.10.12.pdf.

10.0 SUMMARY AND CONCLUSIONS

The range of statistical analyses presented reveals constant and repeatable performance trends. Mass pollutant removals were calculated to best represent overall system performance. While conceivable that the PICP systems have diverse unit operations and processes to address and effectively remove sediments, and sediment associated pollutants (SSC, TSS, TZn, TPH-D), all pollutant reduction recognized in this analysis is associated with mass reduction through volume control (infiltration). Thus, the final performance report for the PICP system indicates very strong volume reduction and overall pollutant mass reduction. Of course, a large volume spill would be an issue for any infiltration system. In general appropriate design and siting would be critical criteria to ensure groundwater protection.

The surface vacuuming of the PICP did not prove to be an effective method of regenerating the infiltration capacity of the system. Manipulation of the vacuum sweeper to maintain appropriate suction proved difficult. A more thorough investigation is needed to determine the full impact of vacuuming however vacuuming less frequently with greater suction and replacement of the No. 8 joint stone may be a worthwhile direction to investigate. While infiltration rates were seen to decline following the installation of new No. 8 joint stone, average IR still remained upwards of 1,000 in/hr. The replacement of missing No. 8 within the top 1 inch of the joints should not be viewed as a means to increase surface infiltration. In the same respect overall infiltration rate declined by 69% over 21 months however with average IR upwards of 1,000 inches/hour the system is working as expected.

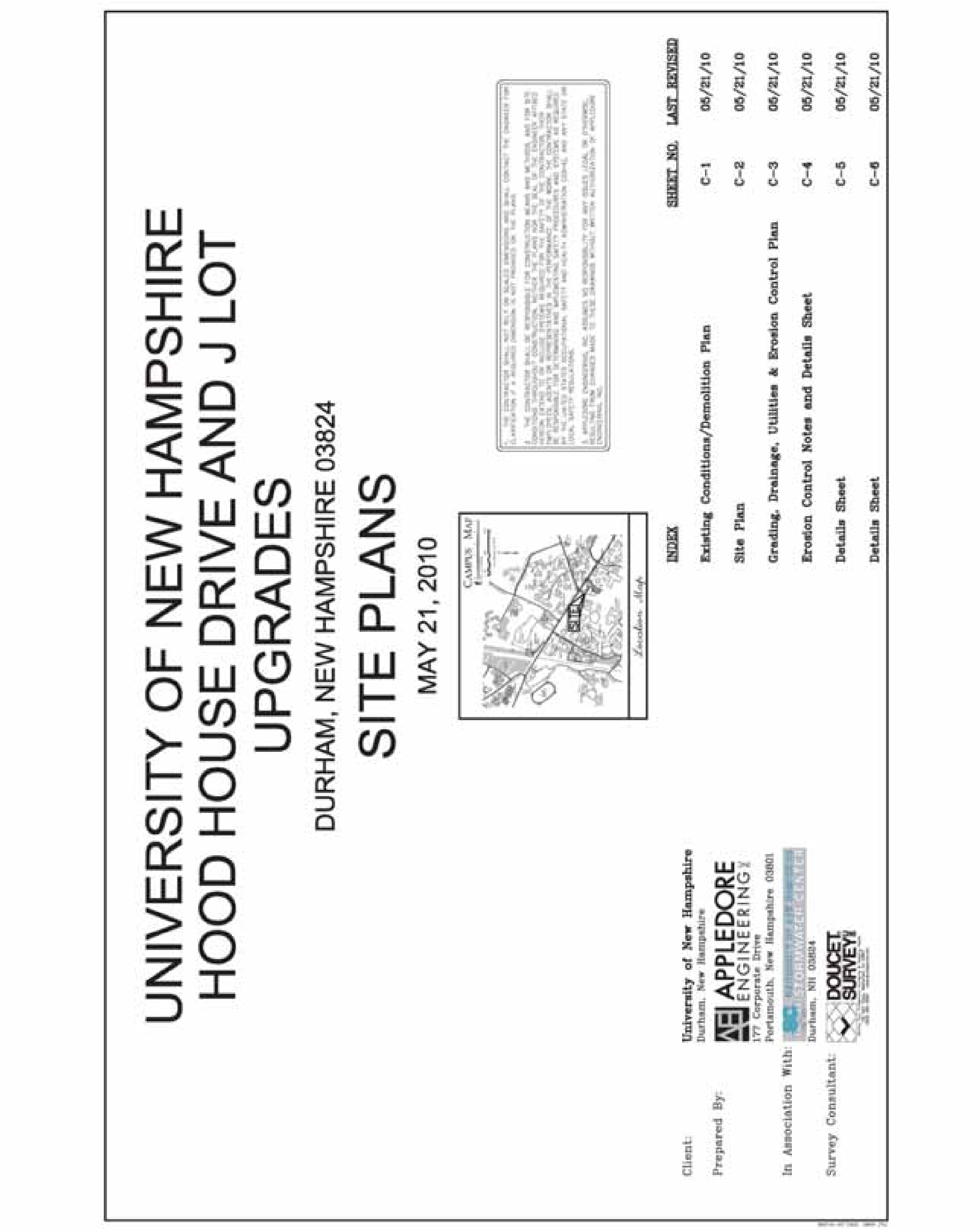
The thermal performance of the PICP surface was compared to porous asphalt, pervious concrete, and standard dense mix asphalt on June 21, 2012. The weather was sunny all day and the measurement locations were exposed to direct sunlight throughout the study period. The average ambient air temp was 88°F. The PICP consistently remained cooler than each of the other pavement types indicating the potential for thermal buffering. Previous studies have demonstrated that that stormwater control measures like PICP that provide treatment by infiltration and filtration can moderate runoff temperatures by thermal exchange with cool subsurface materials (Roseen et al 2011). Numerous agencies and locales are beginning to consider the thermal impacts of stormwater management upon cold water streams.

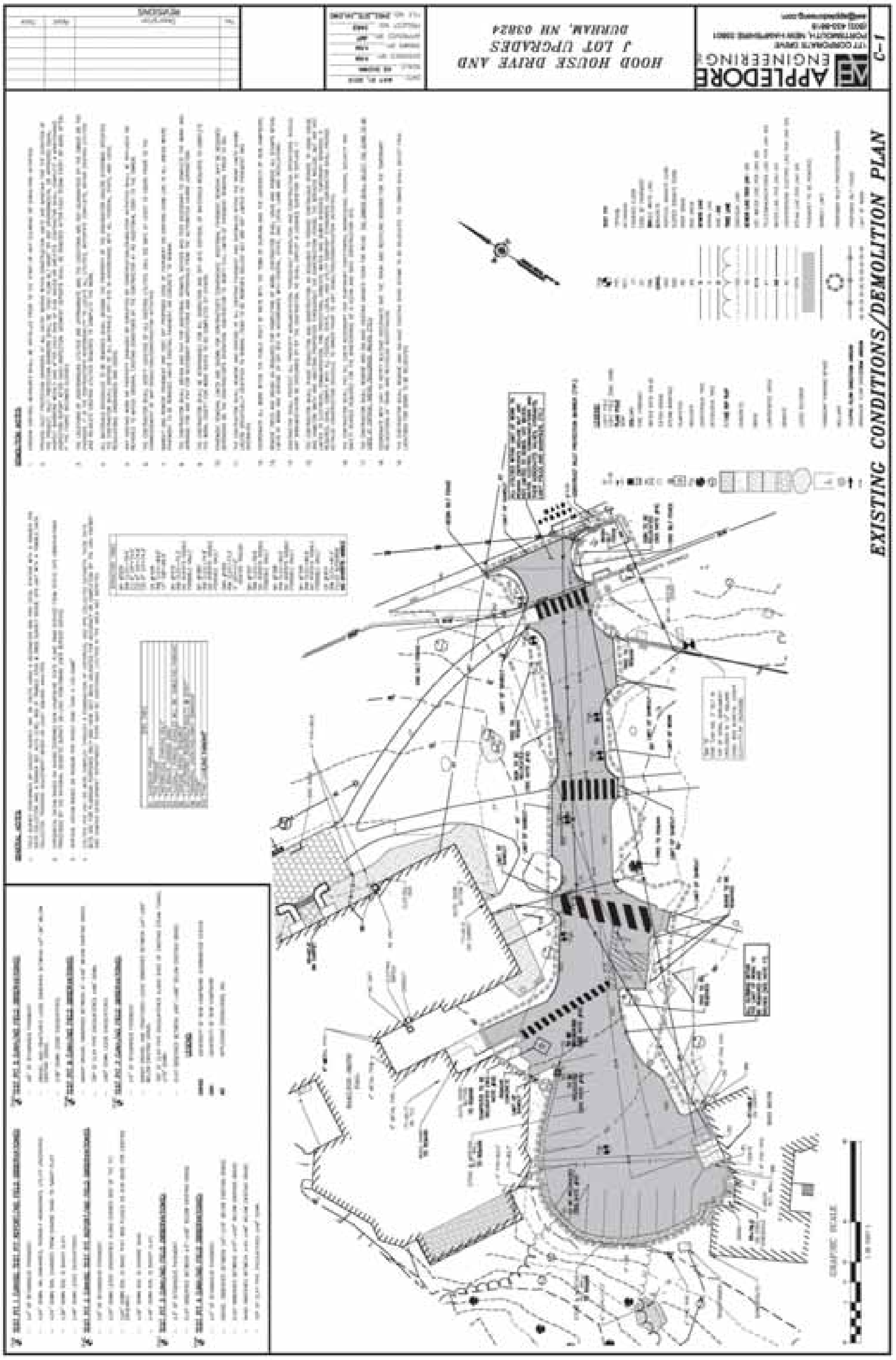
Of future interest is to explore the winter maintenance and performance for PICP. Research on porous asphalt (PA) at the UNHSC has shown that PA exhibits greater frictional resistance and can become clear of snow and ice faster than conventional pavements. Substantial reductions of up to 77% in annual salt loads for anti-icing/deicing practices were demonstrated. Winter maintenance of the PICP, including plowing and anti-icing/de-icing was handled independently by UNH facilities. A memo regarding equipment and procedures used is included in Appendix I. UNH Facilities Department staff was not instructed to reduce application rates on Hood House Drive and managed the PICP like all other dense pavements on campus.

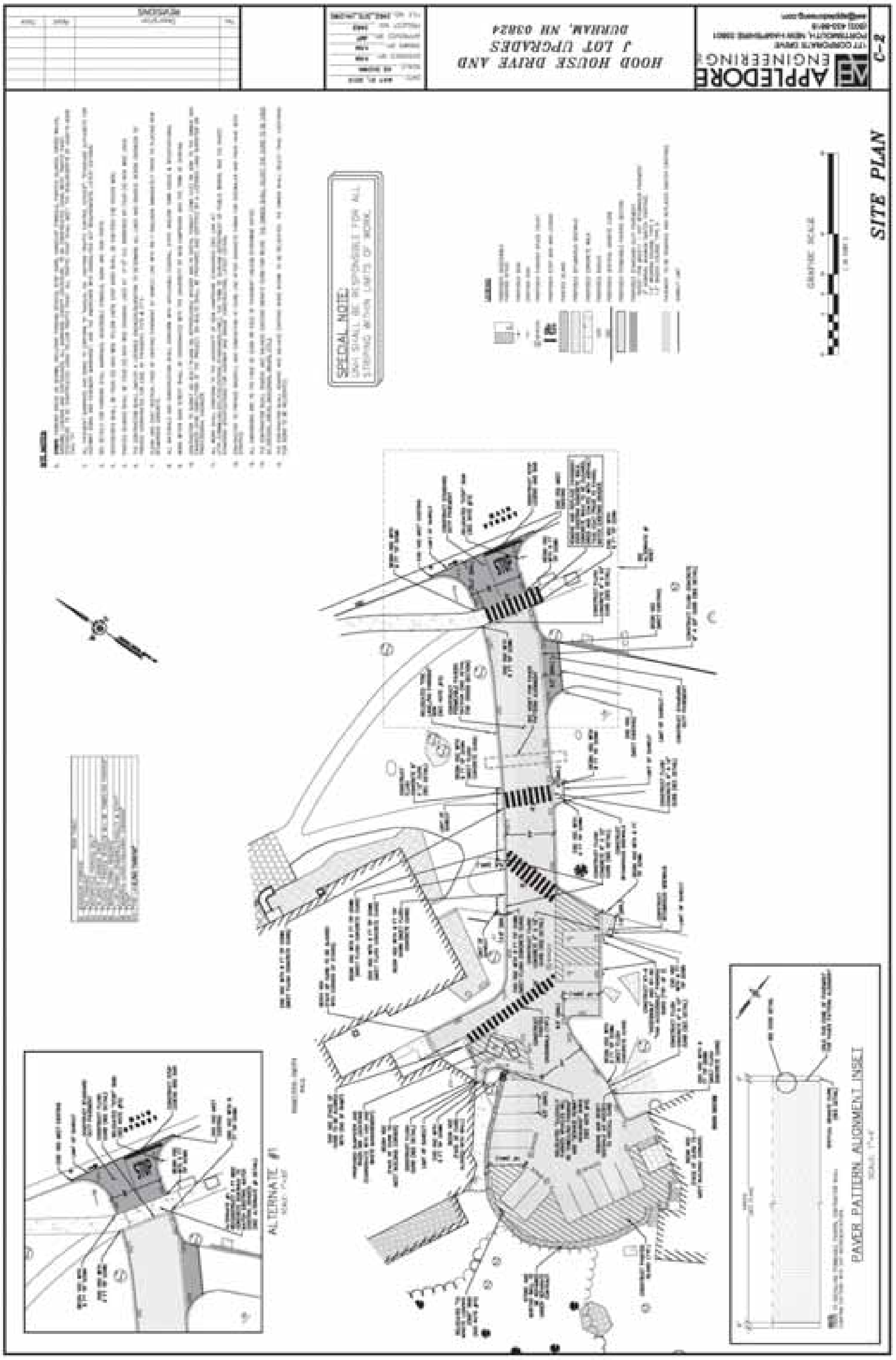
11.0 REFERENCES

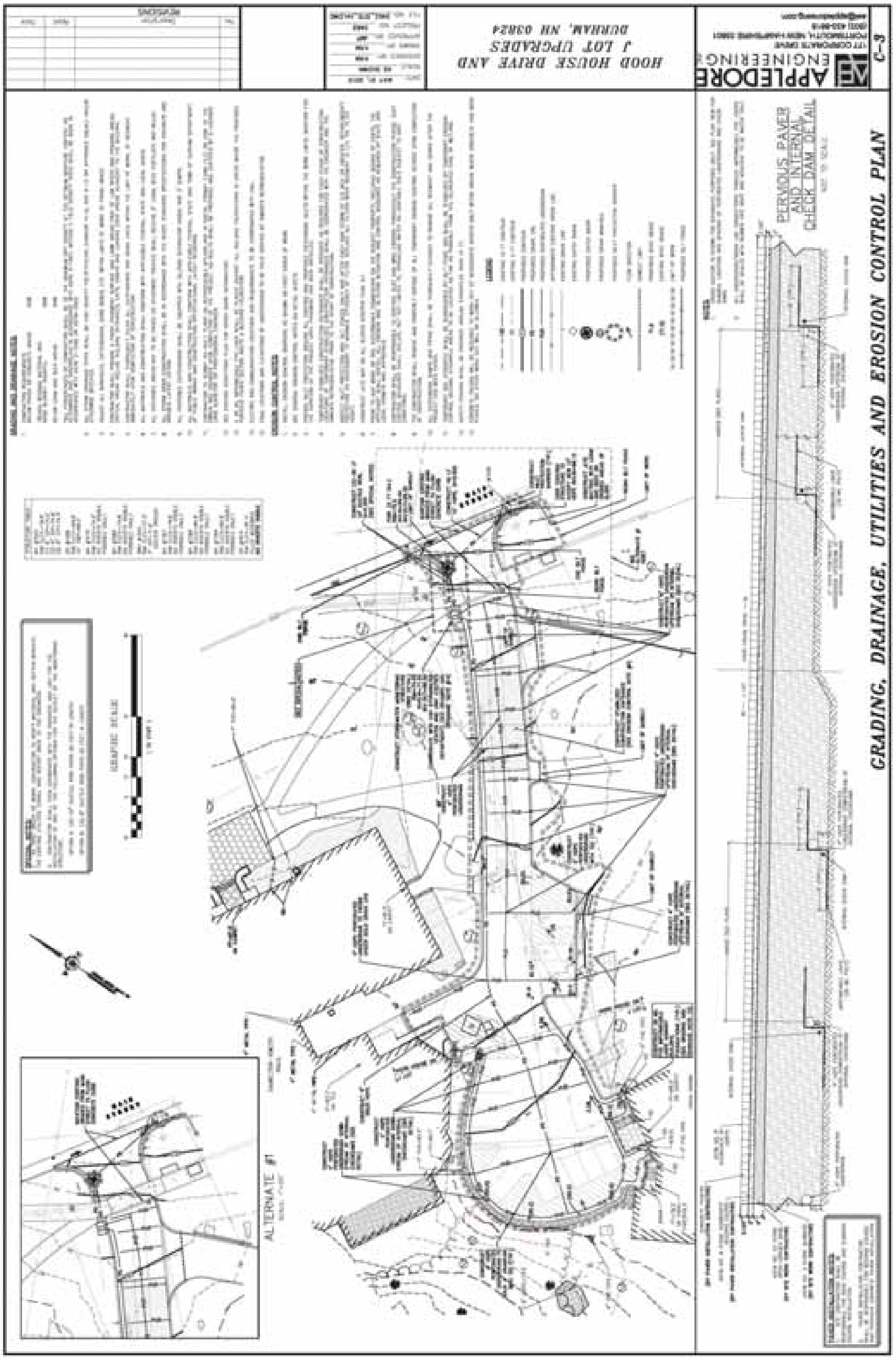
1. Roseen, R., A. Watts, et al. (2011). Examination of Thermal Impacts From Stormwater Best Management Practices. Durham, NH, University of New Hampshire Stormwater Center Prepared for US EPA Region 1.
2. Smith, D. and B. Hunt (2010). Structural/Hydrologic Design and Maintenance of Permeable Interlocking Concrete Pavements. Green Streets and Highways, Denver, Colorado, ASCE.
3. National Engineering Handbook, Part 630 Hydrology, Chapter 7 Hydrologic Soil Groups, 2007, NEH630.07, United States Department of Agriculture.

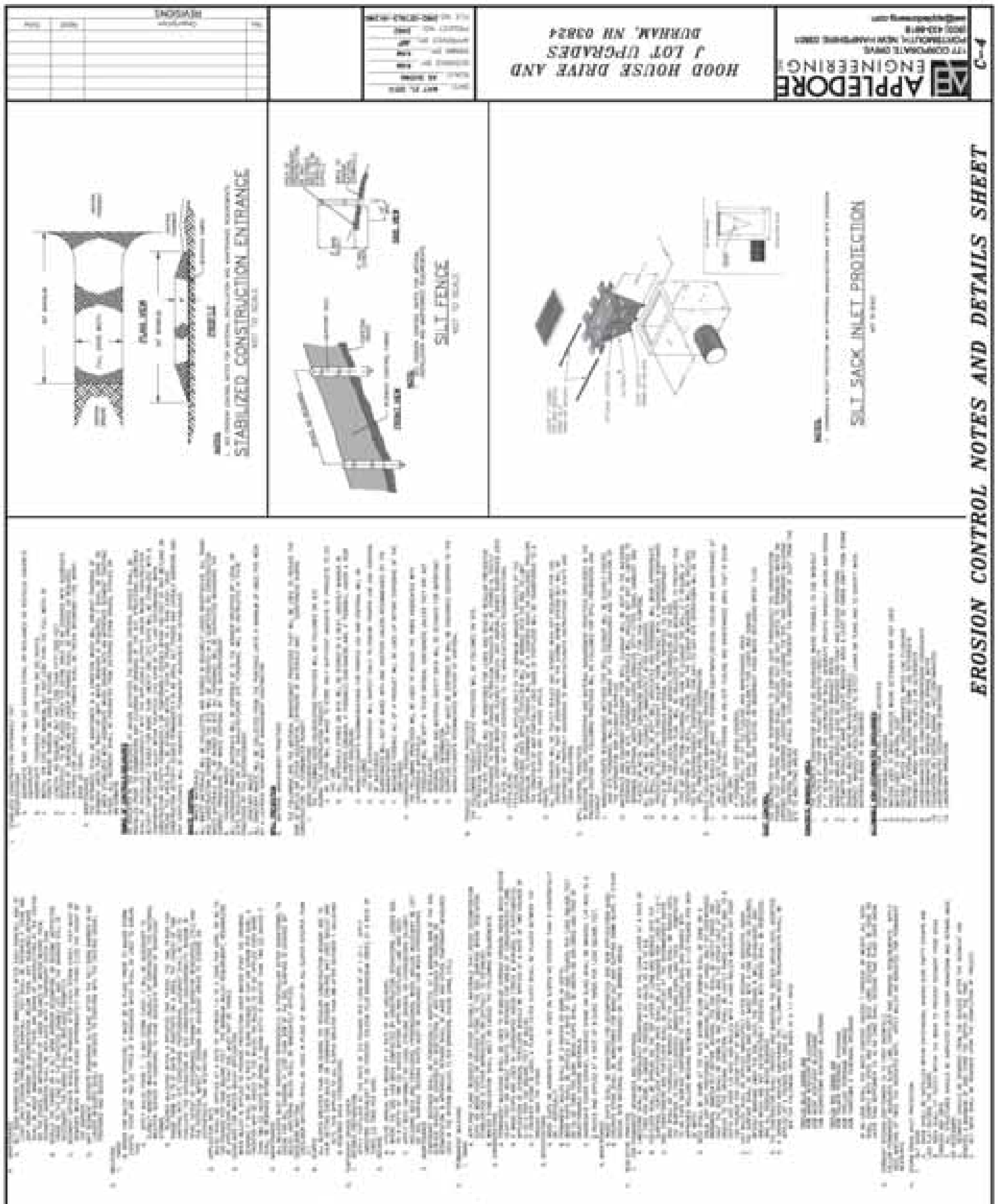
APPENDIX A: University of New Hampshire Hood House Drive and J Lot Upgrades: Site Plans.

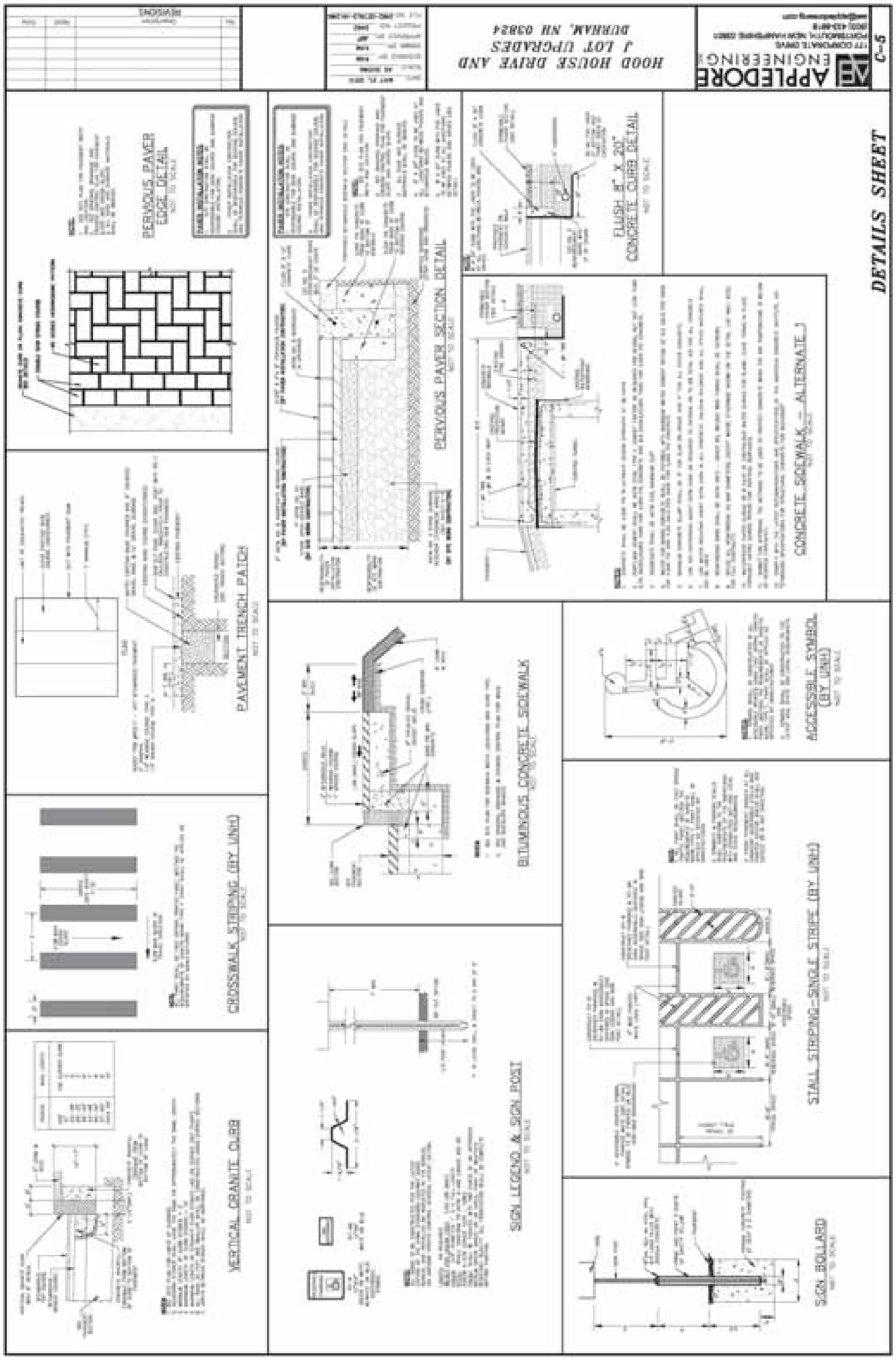


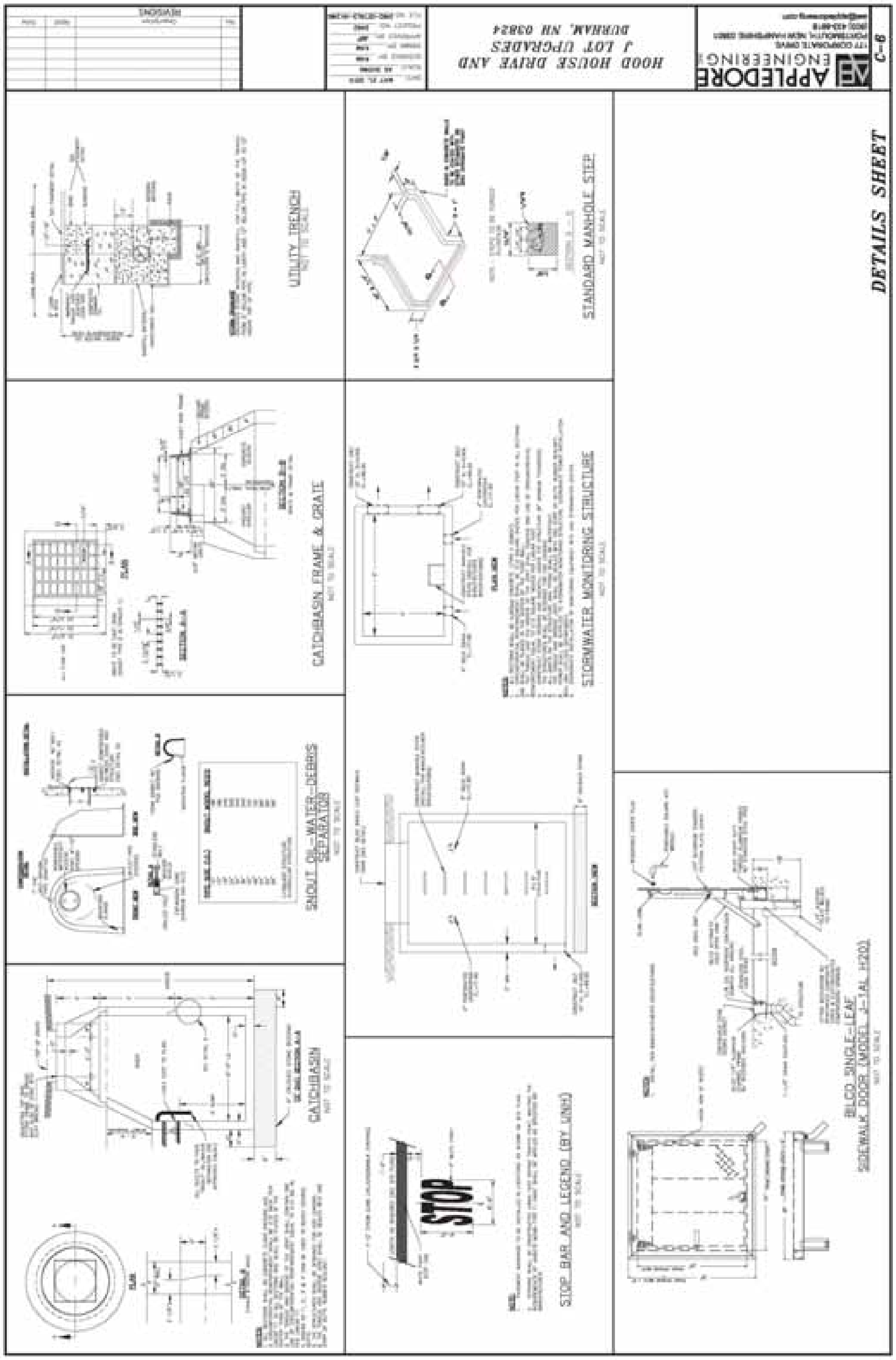

EXISTING CONDITIONS/DEMOLITION PLAN
HOOD HOUSE DRIVE AND
J LOT UPGRADES
DURHAM, NH 03824
APPLEDORE ENGINEERING
C-1


APPLEDORE ENGINEERING
HOOD HOUSE DRIVE AND
J LOT UPGRADES
DURHAM, NH 03824
C-2
SITE PLAN
SPECIAL NOTE:
ALTERNATE #1
PAVER PATTERN ALIGNMENT INSET


GRADING, DRAINAGE, UTILITIES AND EROSION CONTROL PLAN
HOOD HOUSE DRIVE AND
J LOT UPGRADES
DURHAM, NH 03824
APPLEDORE
ENGINEERING
C-3
PERVIOUS PAVER
AND INTERNAL
CHECK DAM DETAIL
ALTERNATE #1
GRAPHIC SCALE


EROSION CONTROL NOTES AND DETAILS SHEET
STABILIZED CONSTRUCTION ENTRANCE
SILT FENCE
SILT SACK INLET PROTECTION
HOOD HOUSE DRIVE AND
J LOT UPGRADES
DURHAM, NH 03824
APPLEDORE ENGINEERING
C-4
REVISIONS


APPLEDORE ENGINEERING
HOOD HOUSE DRIVE AND
J LOT UPGRADES
DURHAM, NH 03824
C-5
DETAILS SHEET
PERVIOUS PAVER EDGE DETAIL
PERVIOUS PAVER SECTION DETAIL
FLUSH 8" X 20" CONCRETE CURB DETAIL
CONCRETE SIDEWALK – ALTERNATE 1
PAVEMENT TRENCH PATCH
BITUMINOUS CONCRETE SIDEWALK
ACCESSIBLE SYMBOL (BY UNH)
CROSSWALK STRIPING (BY UNH)
STALL STRIPING-SINGLE STRIPE (BY UNH)
VERTICAL GRANITE CURB
SIGN LEGEND & SIGN POST
SIGN BOLLARD


HOOD HOUSE DRIVE AND
J LOT UPGRADES
DURHAM, NH 03824
APPLEDORE ENGINEERING
C-6
REVISIONS
DETAILS SHEET
UTILITY TRENCH
NOT TO SCALE
STANDARD MANHOLE STEP
NOT TO SCALE
CATCHBASIN FRAME & GRATE
NOT TO SCALE
STORMWATER MONITORING STRUCTURE
NOT TO SCALE
SNOUT OIL-WATER-DEBRIS SEPARATOR
NOT TO SCALE
CATCHBASIN
NOT TO SCALE
STOP
STOP BAR AND LEGEND (BY UNH)
NOT TO SCALE
BILCO SINGLE-LEAF
SIDEWALK DOOR (MODEL J-1AL H20)
NOT TO SCALE

APPENDIX B: Analysis of soils from test pits at Hood House, University of New Hampshire Durham, NH dug on April 15, 2010.
April 30, 2010

Performed By: Timothy Puls, Field Facility Manager
Reviewed By: Robert Roseen, Director
UNH Stormater Center
35 Colovos Road
Durham, NH 03824

RE: Analysis of soils from test pits at Hood House, University of New Hampshire Durham, NH dug on April 15, 2010.

Introduction
This report contains infiltration capacity (IC) and particle size distribution (PSD) of sub-base soils located under Hood House driveway on the University of New Hampshire (UNH) main campus. Refer to attached map for location of test pits. Test pits 1 and 2 were dug down 48 inches or until ledge impeded further excavation. Test pits 3-5 are not included in this report.

Test Pit 1

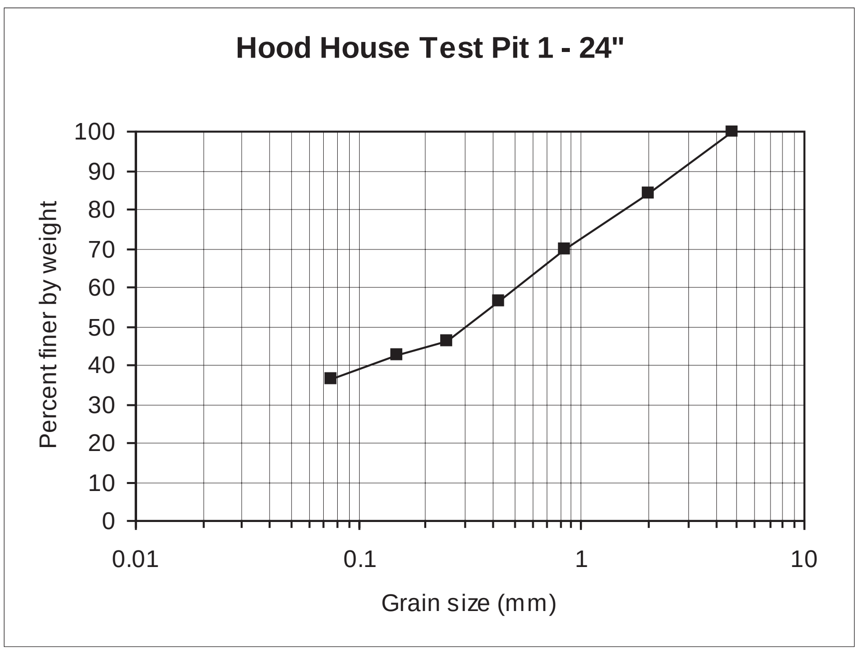
Excavation
- At 24" down an unmarked utility was found. This was an old rusted pipe 1.5" in diameter that was of unknown use. UNH facilities personnel came out to inspect pipe, but there was no determination of what the pipe was used for or if it was in use. It was assumed to be an abandoned pipe, but we moved the pit location over to avoid and work around the pipe.
- At 24" down soil changed from coarse sand to sandy clay. Soil sample was taken.
- At 36" down soil is sandy clay. Soil sample was taken.
- At 48" down the excavator hit ledge that seemed to be continuous throughout the pit.

Infiltration Capacity
- No IC test was done due to ledge.

Particle Size Distribution of Soil Samples

- Soil Sample taken at 24" depth

US sieve number	Sieve opening (mm) d	Mass retained (g) M	Mass passing (g) M_p	Percent finer by weight p
4	4.750		988.70	100.00
10	2.000	156.50	832.20	84.17
20	0.850	143.30	688.90	69.68
40	0.425	130.80	558.10	56.45
60	0.250	99.50	458.60	46.38
100	0.150	36.70	421.90	42.67
200	0.075	63.40	358.50	36.26
pan		358.50	0.00	0.00



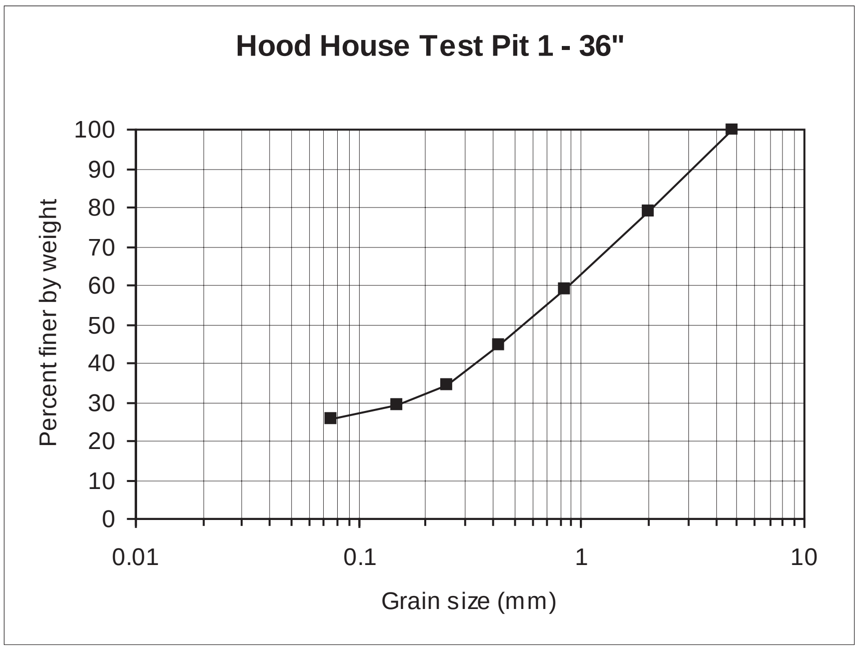
D_{10} = < 0.075mm
D_{30} = < 0.075mm
D_{50} = 0.300 mm
D_{60} = 0.500 mm

- Other Information

- o 17.77% moisture content as a percentage of oven-dried mass. Determined using ASTM Designation: D 2974-00.

- Soil Sample taken at 36" depth

US sieve number	Sieve opening (mm) d	Mass retained (g) M	Mass passing (g) M_p	Percent finer by weight p
4	4.750		978.30	100.00
10	2.000	204.40	773.90	79.11
20	0.850	199.40	574.50	58.72
40	0.425	137.00	437.50	44.72
60	0.250	101.70	335.80	34.32
100	0.150	51.60	284.20	29.05
200	0.075	31.70	252.50	25.81
pan		252.50	0.00	0.00



D_{10} = < 0.075mm
D_{30} = 0.160 mm
D_{50} = 0.540 mm
D_{60} = 0.890 mm

- Other Information
    - o 12.85% moisture content as a percentage of oven-dried mass. Determined using ASTM Designation: D 2974-00.

Test Pit 2

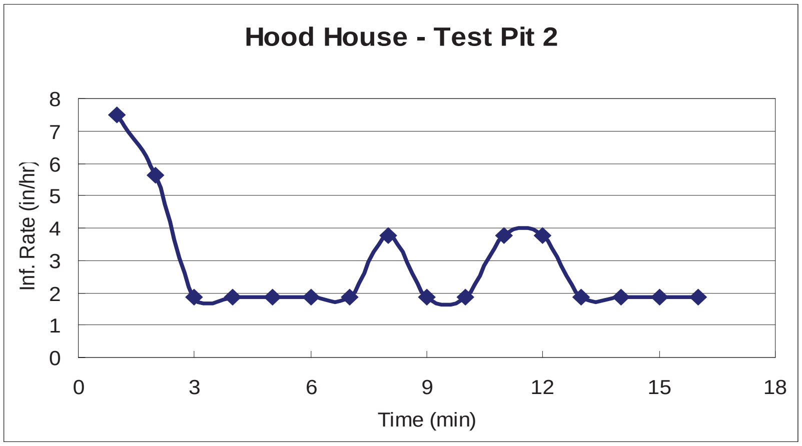
Excavation

- At 24" down ledge along curbed side of the pit was found. The ledge extended approximately 1 foot into the pit. There was enough room to continue digging in the same location.
- At 24" down soil is sand that was placed as sub-base for existing driveway. Soil sample was taken.
- At 36" down soil is coarse sand. Soil sample was taken.
- At 48" down soil is sandy clay. Soil sample was taken.

Infiltration Capacity

- IC test was conducted using a Turf Tech infiltration device. Results are as follows.
-

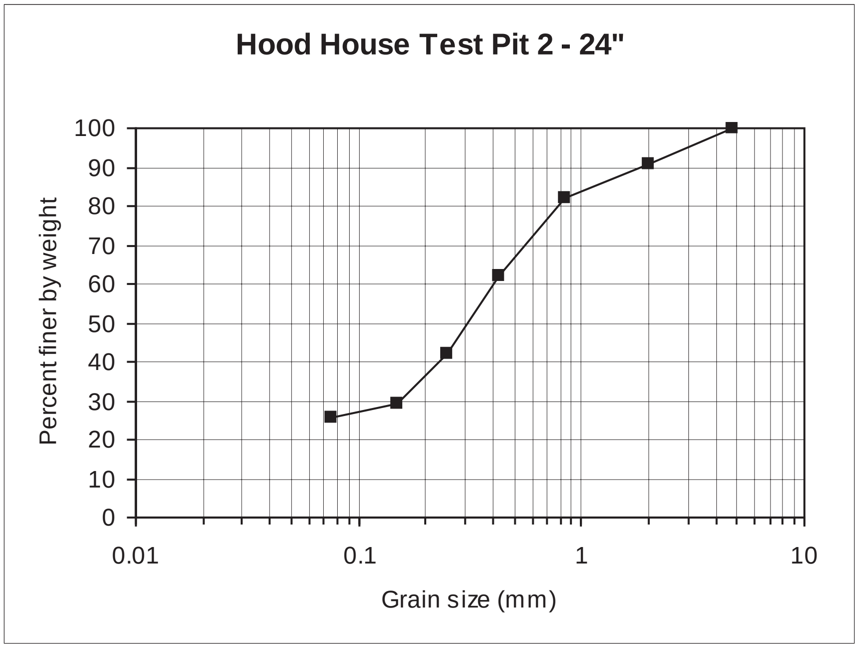
Time (min)	Δ Time (min)	Inner Ring			
		Level (in)	Δ Level (in)	IC (in/min)	IC (in/hr)
0	-	0.250	-	-	-
1	1	0.375	0.125	0.125	8
2	1	0.469	0.094	0.094	6
3	1	0.500	0.031	0.031	2
4	1	0.531	0.031	0.031	2
5	1	0.563	0.031	0.031	2
6	1	0.594	0.031	0.031	2
7	1	0.625	0.031	0.031	2
8	1	0.688	0.063	0.063	4
9	1	0.719	0.031	0.031	2
10	1	0.750	0.031	0.031	2
11	1	0.813	0.063	0.063	4
12	1	0.875	0.063	0.063	4
13	1	0.906	0.031	0.031	2
14	1	0.938	0.031	0.031	2
15	1	0.969	0.031	0.031	2
16	1	1.000	0.031	0.031	2
			Average		**3**



Particle Size Distribution of Soil Samples

- Soil Sample taken at 24" depth

US sieve number	Sieve opening (mm) d	Mass retained (g) M	Mass passing (g) M_p	Percent finer by weight p
4	4.750		977.30	100.00
10	2.000	92.00	885.30	90.59
20	0.850	82.50	802.80	82.14
40	0.425	196.00	606.80	62.09
60	0.250	194.30	412.50	42.21
100	0.150	126.60	285.90	29.25
200	0.075	37.70	248.20	25.40
pan		248.20	0.00	0.00

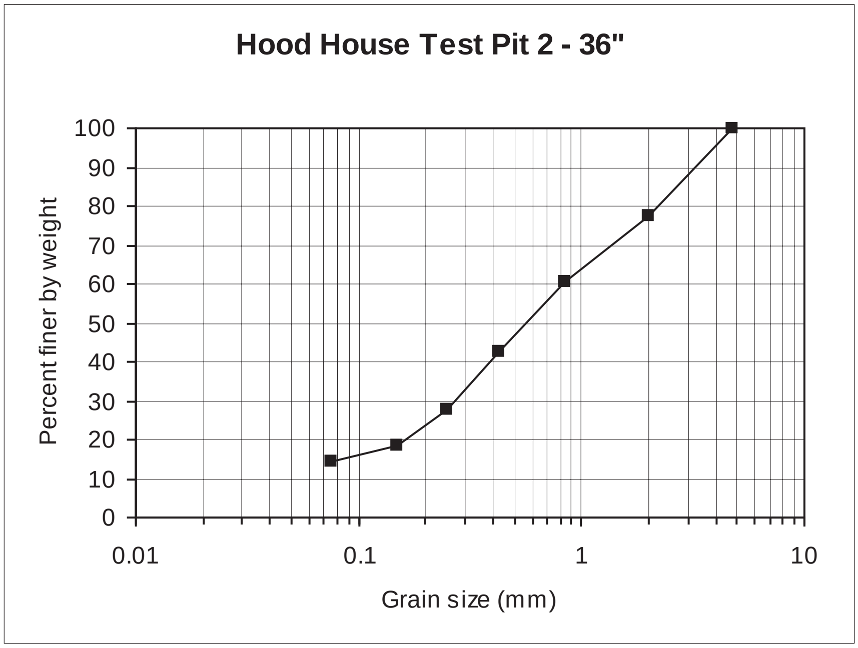


D_{10} =< 0.075mm
D_{30} = 0.160 mm
D_{50} = 0.300 mm
D_{60} = 0.400 mm

- Other Information
  - 6.99% moisture content as a percentage of oven-dried mass. Determined using ASTM Designation: D 2974-00.

- Soil Sample taken at 36" depth.

US sieve number	Sieve opening (mm) d	Mass retained (g) M	Mass passing (g) M_p	Percent finer by weight p
4	4.750		1174.80	100.00
10	2.000	266.50	908.30	77.32
20	0.850	197.00	711.30	60.55
40	0.425	212.60	498.70	42.45
60	0.250	176.20	322.50	27.45
100	0.150	105.30	217.20	18.49
200	0.075	48.10	169.10	14.39
pan		169.10	0.00	0.00

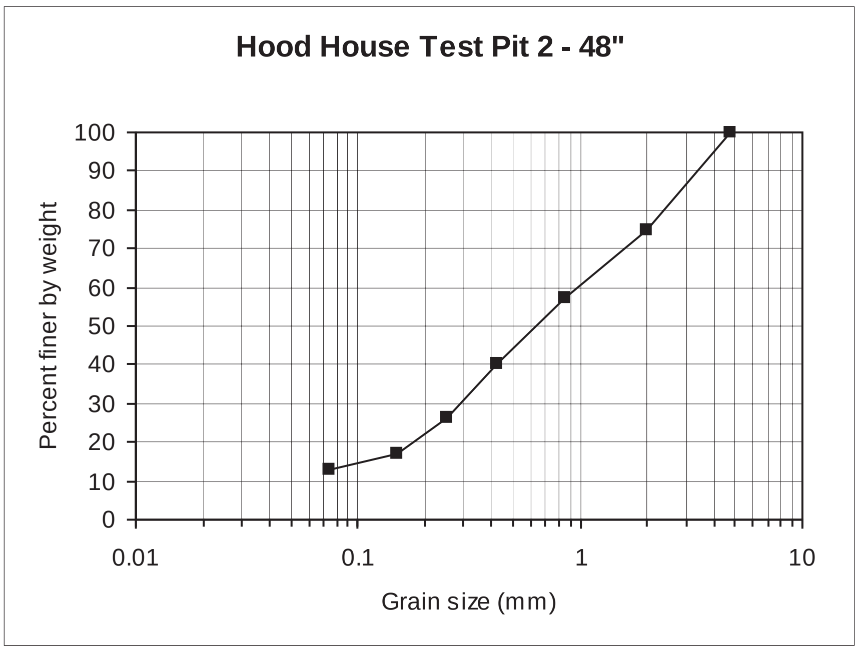


D_{10} = < 0.075mm
D_{30} = 0.270 mm
D_{50} = 0.560 mm
D_{60} = 0.830 mm

- Other Information
  - 8.57% moisture content as a percentage of oven-dried mass. Determined using ASTM Designation: D 2974-00.

- Soil Sample taken at 48" depth.

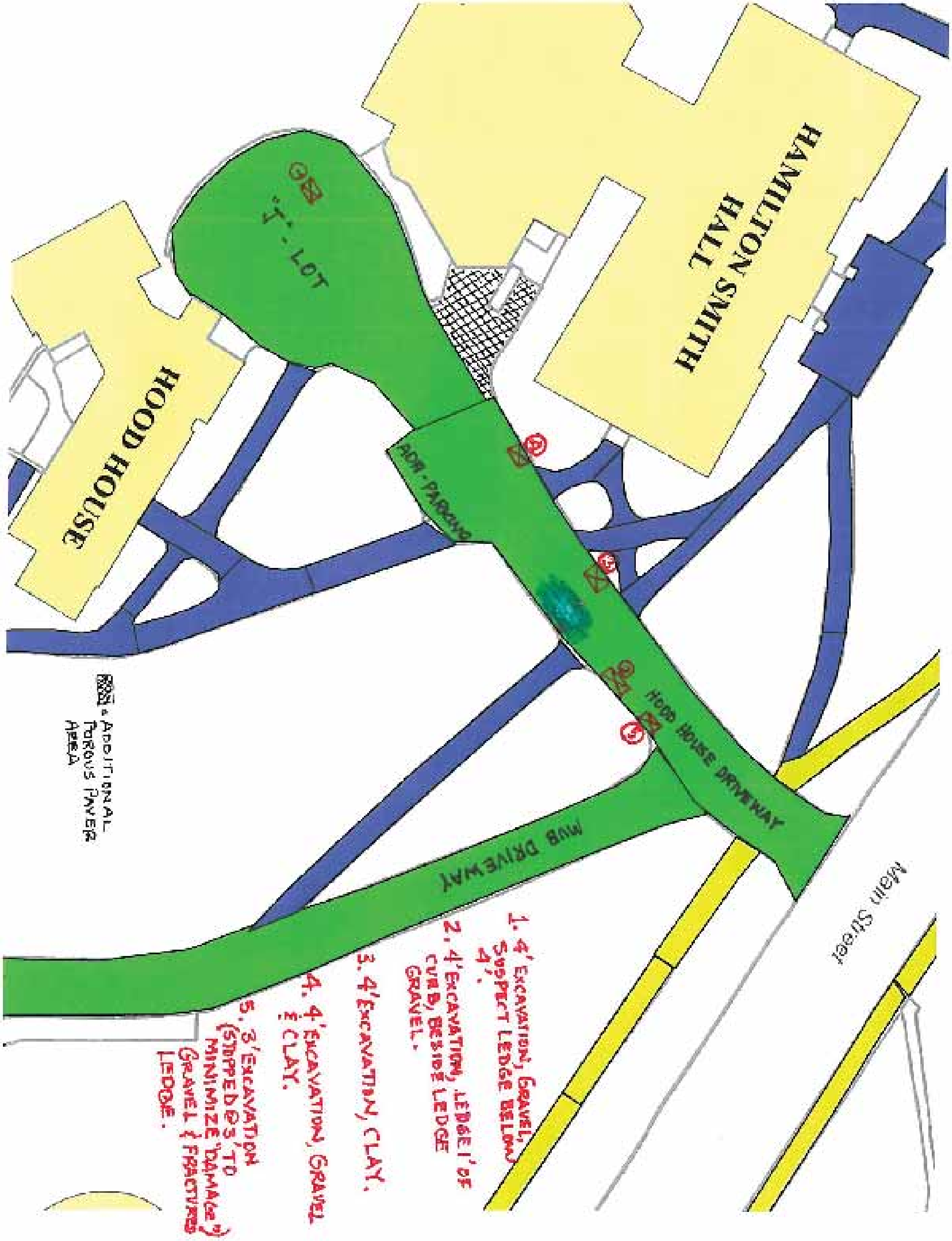
US sieve number	Sieve opening (mm) d	Mass retained (g) M	Mass passing (g) M_p	Percent finer by weight p
4	4.750		1052.00	100.00
10	2.000	266.00	786.00	74.71
20	0.850	185.60	600.40	57.07
40	0.425	176.20	424.20	40.32
60	0.250	147.90	276.30	26.26
100	0.150	98.20	178.10	16.93
200	0.075	43.90	134.20	12.76
pan		134.20	0.00	0.00



D_{10} = < 0.075mm
D_{30} = 0.290 mm
D_{50} = 0.605 mm
D_{60} = 0.990 mm

- Other Information
  - 11.18% moisture content as a percentage of oven-dried mass. Determined using ASTM Designation: D 2974-00.

Location Map for Test Pits at Hood House



APPENDIX C: General specifications for Tymco 210 Regenerative Air Sweeper.

TYMCO®
REGENERATIVE AIR SWEEPERS

Cabover Cab Chassis

MODEL 210® REGENERATIVE AIR SWEEPER® GENERAL SPECIFICATIONS

SWEEPER AUXILIARY ENGINE
Engine ....Kubota V2403MT, 4 cyl. (Tier 4I)
Displacement ....149.5 cubic inches (2426cc)
Horsepower ....56 @ 2,600 RPM (41.7 kW)
Net torque...............121 ft-lb @ 1800 RPM (164 Nm)
Air cleaner, heavy duty .... Dry type
Oil filter, spin on .... Full flow
Cooling .... Liquid
Auxiliary engine shutdown system
Fuel water separator

SWEEPER AUXILIARY ENGINE, GASOLINE
(Consult Factory)

BLOWER
Aluminum alloy high volume open face turbine
Purpose .... Creates blast and suction
Bearings .... Anti-friction
Housing ....Abrasion resistant, replaceable liner
Drive .... Heavy duty power band

DUST SEPARATOR
Type ....Cyclonic, multipass, centrifugal separation
Size .... 20" x 22.5"
cylindrical area (508mm x 1549mm)
Location .... Adjacent to hopper
Particulate removal ....Through 22.5" x .5"
(572 mm x 13 mm) skimmer slot into hopper
Inspection .... Access port for cleaning

HOPPER
Capacity (volumetric) ....2.4 cubic yards
($1.83\ m^3$)
Capacity (useable) ....2 cubic yards
($1.52\ m^3$)
Construction .... Welded steel plate
Dump door size .... 52" x 23"
(1321 mm x 584 mm)
Dumping method........................Hydraulic with tilt up
Dumping height ....60" (1524 mm)

PICK-UP HEAD
Function .... Air blast and suction chamber
Width ....78" I.D. (1981 mm)
Head area........................2,028 sq. inches ($1.31\ m^2$)
Suspension ....4 springs, 2 drag links
Skids .... DUO-SKIDS®
Suction & pressure hose ......12" diameter (305 mm)
Pressure bleeder ....Integral for
leaf/light material pickup
Reverse pick-up head system

HYDRAULIC SYSTEM
Operates gutter broom(s), dump and pick-up head
Drive ....Gear driven from auxiliary engine
Capacity...................................5 GPM (18.925 LPM)
Reservoir ....8 gal. (30.3 L) with 80 mesh suction,
sight / temperature gauge
Filter... 10 micron in-line

CONTROLS
Inside cab (lighted) .... Pick-up head,
gutter broom(s), ignition and tachometer (auxiliary engine), voltmeter, low water warning system (for optional dust control system), all safety lights, hour meter, pressure bleeder
Outside cab ....Dump

OPTIONAL EQUIPMENT
Abrasion protection package
Amber beacon light
Auxiliary fuse panel
Auxiliary hand hose 6" dia. (152 mm)
Cabover extra water capacity
Cabover storage box
Dust control system
Gutter broom (s) ....(Left, right or dual)
Drive .... Constant speed
non-reversible hydraulic motor
Adjustment....................................... Adjustable for
down pressure, pattern and wear
Down pressure................................Automatically
adjusts to requirement
Flexibility .... All directions. Integral anti-damage
"swing away" relief valve
Broom ....Polypropylene wafer 36"
(914 mm) or steel wire digger 32" (812.8 mm)
Hopper drain system
Hopper slide out screens
Hopper up alarm
LED Lights - Alternating Warning Lights, rear mount
Light bar - Cab mounted
Low emissions package
Magnet
Rubber lined blower
Skid bumper extensions
Sound Reduction Engineering (SRE®)
Stainless Steel Hopper
Stainless Steel Blower Housing
Color (other than TYMCO standard white)
Special options are available for your individual requirements. Contact your local dealer or TYMCO.

CAB/CHASSIS
Minimum Requirements
Model ....Isuzu NPR - HD
GVW..14,500 lbs. (6,593 kg)
Engine, turbo diesel ....215 hp 5.19 L
Transmission..Automatic
Alternator...110 amp
Battery ....Dual (2) 750 CCA
Wheelbase......................................132.5" (3365 mm)
Fuel tank, rear mounted ....30 gal. (113 L)
DEF Tank.............................. Diesel Exhaust Fluid
Tires (2-front, 4-rear).............215/85R 16E all season
Steering .... Power
Brakes .... Vacuum assisted
hydraulic brakes w/anti-lock
Instruments & lights ....Full package as required
Back-up alarm
Power windows and door locks
Air conditioned cab
AM / FM CD radio
Consult factory for sweeper specifications and other available truck chassis.

GENERAL SWEEPING WIDTH
Pick-up head only...............................78" (1981 mm)
With 1 gutter broom ....98" (2489 mm)
With 2 gutter brooms ....118" (2997 mm)

OVERALL DIMENSIONS (Approximate)
Length ....223" (5664 mm)
Width ....87.75" (2229 mm)
Height @ truck* ....90" (2286 mm)
Height with light bar ....97" (2464 mm)
Empty weight*............................ 9,440 lbs (4296 kg)
Weight (sweeper)* .... 4,190 lbs (1898 kg)

**Dimensions and weight may vary with equipment.*

1-800-258-9626

www.tymco.com

AQMD PM10 Certified

11/8/11

APPENDIX D: General specifications for Tymco 500X High Side Dump Regenerative Air Sweeper.

TYMCO®

REGENERATIVE AIR SWEEPERS

GENERAL SPECIFICATIONS/ MODEL 500X®
HIGH SIDE DUMP REGENERATIVE AIR SWEEPER®

SWEEPER AUXILIARY ENGINE, Electronic Control, Turbo Diesel

Make ....John Deere, 4045T, 4 cyl. (Tier 3)
Displacement ....275 cubic inches (4.5 L)
Horsepower ....115 @ 2,200 rpm (86 kW)
Net torque ....355 ft/lbs. @ 1500 rpm (481 Nm)
Air cleaner ..... Two stage, radial seal with safety element
Oil Filter, spin on .... Full flow

BLOWER, Rubber Lined

Aluminum alloy high volume open face turbine
Purpose ....creates blast and suction
Bearings ....(2) sealed for life, self aligning
Housing ....Isolation mounted with abrasion resistant, replaceable liner
Housing seal ....Heavy rubber section, non-wiping, spring actuated Tilt-N-Seal™ design
Drive ....Fixed displacement heavy duty hydraulic motor

DUST SEPARATOR

Type ....Cylindrical, cyclonic, multipass, centrifugal separation
Size .... 28" X 48"
Location ....Inside hopper
Particulate removal .... Through skimmer slot into hopper
Housing ....Abrasion resistant, replaceable liner
Inspection ....Self opening, self emptying when hopper tilts

HOPPER, Stainless Steel

Volumetric Capacity ....5.7 cubic yards (4.3m³)
Useable Capacity ....4.0 cubic yards (3.06m³)
Construction .... Welded non-magnetic stainless steel plate with integral stiffeners
Floor dump angle ....50°
Dump door opening .... 68" x 57" (158 cm x 129 cm)
Dump door ....Self locking
Chute .... 72" x 48" stainless steel lined
Chute reach ....22" without side shift
Dumping direction ....Right side
Lifting method ....Two stage scissor lift, dual hydraulic cylinders with integral holding valves
Lift capacity .... 10,000 lbs.
Dump height ....Variable
Minimum ....2' from bottom of chute to ground
Maximum ....11' from bottom of chute to ground
Hopper screen ....2 piece stainless steel screen with access for cleaning top side
Hopper drain system

BROOM ASSIST PICK-UP HEAD (BAH®)

Function .... Air blast and suction chamber with broom assist
Width ....87" (2210 mm)
Head area ....3567.0 square inches (2.3m²)
Broom .... 12" x 79"
Location: Enclosed in rear of pick-up head
Suspension ....4 springs 2 drag links
Suction hose ....12" diameter (305 mm)
Pressure hose ....14" diameter (356)
Skids .... (DUO SKID®) Double wide, long-life carbide
Pressure bleeder .... Integral for leaf/light material pick-up.

AQMD PM_{10} Certified

GUTTER BROOMS, Dual Patented

Standard equipment, includes floodlights and parabolic mirrors
Drive ....Variable speed non-reversible hydraulic motor
Adjustment ....Adjustable for down pressure, pattern and wear
Down pressure .... Automatically adjusts to requirement
Flexibility .... All directions, integral anti-damage "swing away" relief valve
Brooms .... 43" dia. (1.1 m) steel wire, vertical diggers
Hydraulic tilt ....Left & Right gutter brooms adjust for curb depth

HYDRAULIC SYSTEM

Dual hydraulic pumps .... Sweeper pump operates gutter brooms, pick-up head (BAH®), stabilizers, hopper lift, hopper dump, and hopper door. Blower pump hydrostatically drives blower
Drive ....Direct drive from auxiliary engine
Blower pump ....Heavy duty variable displacement piston pump
Sweeper pump .... Pressure compensated piston pump
Blower pump flow ....45 GPM (170 LPM)
Sweeper pump flow ....16 GPM (61 LPM)
Reservoir ....30 Gal (110 L) dual mesh strainers
Safety features ....Low oil shut down
Filters(2) .... (1) 10 micron spin-on, in-line return, (1) cartridge, charge loop
Vent Filter ....(1) 10 micron spin-on
Cooler ....Air to Oil with thermostatically controlled electric fan

DUST CONTROL SYSTEM

System of water spray nozzles for airborne dust suppression
Pump ....Electric diaphragm
Reservoir ....Polyethylene 250 gallon (946 L) with hydrant fill hose
Filter ....80 mesh stainless steel, in-line
Low water shut-off .... Safety shut-off with low water warning light in cab
Spray nozzles:
Pick-up head 4
Gutter brooms (each) 2
Hopper inlet 1

CONTROLS

Inside cab: (lighted) pick-up head, left and right hand gutter broom tilt, gutter broom, ignition, blower speed control, low water warning system (dust control), all safety lights, dump controls, pressure bleeder, LCD multi-function display, which includes re-settable and non-resettable hour meters for auxiliary engine; left hand, right hand and BAH brooms; pick-up head and blower.

Steering: Dual

STANDARD EQUIPMENT

Auxiliary engine-diesel, fuel/water separator, automatic shutdown system, auxiliary hydraulic system, broom assist pick-up head (BAH®), dual steering, DUO-SKID®, dust control system, gutter brooms, right and left, includes floodlights and parabolic mirrors, gutter broom tilt adjuster-left and right, pressure bleeder, stainless steel hopper, severe weather wiring package, TYMCO decals/stripes, water fill hose and storage area, storage compartment, hopper drain system

1-800-258-9626
www.tymco.com

STANDARD SAFETY EQUIPMENT

Solid state proximity switches, right and left side stabilizers (automatically engage when lifting hopper), blower actuation interlock, minimum dump interlock, stabilizer down warning system, alternating LED rear flashers, front mounted amber beacon light, back-up alarm, hopper load indicator, scissor lift safety props.

OPTIONAL EQUIPMENT

Abrasion Protection Package
Air Purge
Auto Sweep Interrupt (ASI)
Auxiliary Hand Hose
DCVA
Engine block heater
Gutter Broom-Drop Down
High output water system
Hi-low pressure washdown system with CAT water pump
Hopper load indicator alarms
Hydrant wrench
Hydraulic Tank Heater
Linear actuator (Pressure bleeder)
Low Emissions Package
Magnet
Pick-up head front curtain lifter
Reverse Pick-Up Head System
Sweeper Deluge System
Sweeper odometer
Screen vibrator

Color (other than TYMCO standard white)

Special options are available for your individual requirements. Contact your local dealer or TYMCO

CAB/CHASSIS

MODEL ....International 4300M7
GVW ....33,000 lbs. (14,982 kg)
Axle capacity, rear ....23,000 lbs. (10,442 kg)
Axle capacity, front .... 10,000 lbs. (4,540 kg)
Frame .... 80,000 psi
Engine .... Maxx Force 7(6.4L) diesel engine, 220 HP @ 2600 RPM, 560 lb-ft torque @ 1400 RPM
Transmission ....Allison 2500 RDS-P
Alternator ....120 amp
Batteries .... 12 v dual 1850 CCA
Wheelbase .... 152" (3861 mm)
Fuel tank ....50 gallons,(189 L) shared with sweeper
Tires ....(2-front, 4-rear) Tubeless radial 11 R x 22.5, 14 ply
Steering - Dual with gauges ....Full power w / tilt
Mirrors .... Electric remote and heated
Brakes ....Full air with 13.2 CFM air compressor
Rear suspension ....Hendrickson™ air suspension
Instruments & lights ....Full package as required

GENERAL SWEEPING WIDTH

Pick-up head only ....87" (2210 mm)
With 1 gutter broom ....110" (2794 mm)
With 2 gutter brooms ....up to 142" (3607 mm)

OVERALL DIMENSIONS (Approximate)

Height ....112" (2845 mm)
Width ....96" (2438 mm)
Empty weight* .... 21,000 lbs. (9,534 kg)
Length ....280" (7112 mm)
Dump clearance height .... 132" (11') (3353 mm)
Overall height dumping ....262" (21.8') (6655 mm)

Weight will vary with equipment

11/6/11

This product is protected by numerous U.S. and Foreign Patents. Specifications subject to change without notice.

APPENDIX E: Photos of various conditions of the UNH PICP installation during the testing period.

Figure 12: Run on from an intersecting pedestrian walkway.

Figure 13: Loss of No. 8 stone along curb line due to erosion and cleaning.

Figure 14: Another area of run on from an intersecting pedestrian walkway.

Figure 15: No. 8 joint stone has settled approximately 1 inch.

Figure 16: Snow cover after plowing but before sun begins to warm up pavement.

Figure 17: Run on from intersecting MUB drive.

APPENDIX F: Results of particle size distribution analysis by laser diffraction.

Influent Sample

University of New Hampshire

Microtrac Inc.

10.6.1

19932

MT 8613, File P2689

04/24/2012 15:08

DB Rec: 8

S3000/S3500

S3220

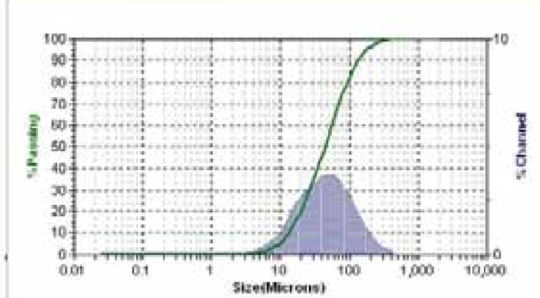
Data	Value
MV(um):	62.05
MN(um):	7.09
MA(um):	26.41
CS:	2.11E-01
SD:	44.25
Mz:	56.41
σi:	47.96
Ski:	0.490
Kg:	1.316

Size(um)	%Tile

%Tile	Size(um)
10.00	13.11
20.00	19.44
30.00	25.28
40.00	34.38
50.00	43.80
60.00	55.31
70.00	70.33
80.00	92.88
90.00	133.9
95.00	176.9

Dia(um)	Vol%	Width
43.80	100.0	88.59

UDefName	UDefData



Warnings: NONE

SOP Name: UNH(*)

Distribution:	Volume	Run Time:	30 Sec	Fluid:	WATER		
Progression:	Geom 8 Root	Run#:	Avg of 2	Fluid Ref Index:	1.333	Loading Factor:	0.1142
Up Edge(um):	2000	Particle:	WATER SUSPENSION	Above Residual:	0	Transmission:	0.810
Low Edge(um):	0.0218	Transparency:	Transparent	Below Residual:	0	RMS Residual:	0.607%
Residuals:	Disabled	Part. Ref. Index:	1.81			Flow:	55 %
#Channels:	132	Particle Shape:	Irregular	Cell ID:	0126	Ultrasonic Power:	N/A
Analysis Mode:	S3000/3500			Multi Run Delay:	0 Min	Ultrasonic Time:	N/A
Filter:	Enabled	DB Record:	8	Recalc Status:	Original	Serial Number:	S3220
Analysis Gain:	Default(2)	Database:	C:\Program Files\Microtrac FLEX 10.6.1\Databases\UNH.MDB				

Size(um)	%Chan	%Pass	Size(um)	%Chan	%Pass	Size(um)	%Chan	%Pass	Size(um)	%Chan	%Pass
2000	0.00	100.00	104.6	2.63	83.76	5.50	0.32	1.25	0.2890	0.00	0.00
1826	0.00	100.00	95.95	2.85	81.13	5.04	0.27	0.93	0.2650	0.00	0.00
1674	0.00	100.00	87.99	3.05	78.28	4.62	0.24	0.66	0.2430	0.00	0.00
1535	0.00	100.00	80.69	3.34	75.23	4.24	0.19	0.42	0.2230	0.00	0.00
1408	0.00	100.00	73.99	3.42	71.89	3.89	0.14	0.23	0.2040	0.00	0.00
1291	0.00	100.00	67.85	3.56	68.57	3.57	0.09	0.09	0.1870	0.00	0.00
1184	0.00	100.00	62.22	3.67	65.01	3.27	0.00	0.00	0.1720	0.00	0.00
1086	0.00	100.00	57.05	3.72	61.34	2.999	0.00	0.00	0.1580	0.00	0.00
995.5	0.00	100.00	52.32	3.72	57.62	2.750	0.00	0.00	0.1450	0.00	0.00
912.9	0.00	100.00	47.98	3.70	53.90	2.521	0.00	0.00	0.1330	0.00	0.00
837.1	0.00	100.00	44.00	3.66	50.20	2.312	0.00	0.00	0.1220	0.00	0.00
767.6	0.00	100.00	40.34	3.58	46.54	2.120	0.00	0.00	0.1110	0.00	0.00
703.9	0.00	100.00	37.00	3.45	42.96	1.944	0.00	0.00	0.1020	0.00	0.00
645.5	0.00	100.00	33.93	3.33	39.51	1.783	0.00	0.00	0.0940	0.00	0.00
591.9	0.00	100.00	31.11	3.22	36.18	1.635	0.00	0.00	0.0860	0.00	0.00
542.8	0.00	100.00	28.53	3.12	32.96	1.499	0.00	0.00	0.0790	0.00	0.00
497.8	0.00	100.00	26.16	3.02	29.84	1.375	0.00	0.00	0.0720	0.00	0.00
456.4	0.00	100.00	23.99	2.90	26.82	1.261	0.00	0.00	0.0660	0.00	0.00
418.6	0.15	100.00	22.00	2.78	23.92	1.156	0.00	0.00	0.0610	0.00	0.00
383.8	0.24	99.85	20.17	2.63	21.14	1.060	0.00	0.00	0.0560	0.00	0.00
352.0	0.27	99.61	18.50	2.45	18.51	0.972	0.00	0.00	0.0510	0.00	0.00
322.8	0.33	99.34	16.96	2.26	16.06	0.891	0.00	0.00	0.0470	0.00	0.00
296.0	0.41	99.01	15.55	2.04	13.80	0.817	0.00	0.00	0.0430	0.00	0.00
271.4	0.51	98.60	14.26	1.81	11.76	0.750	0.00	0.00	0.0390	0.00	0.00
248.9	0.62	98.09	13.08	1.59	9.95	0.687	0.00	0.00	0.0360	0.00	0.00
228.2	0.76	97.47	11.99	1.37	8.36	0.630	0.00	0.00	0.0330	0.00	0.00
209.3	0.91	96.71	11.00	1.18	6.99	0.578	0.00	0.00	0.0300	0.00	0.00
191.9	1.07	95.80	10.09	1.01	5.81	0.530	0.00	0.00	0.02790	0.00	0.00
176.0	1.27	94.73	9.25	0.86	4.80	0.486	0.00	0.00	0.02550	0.00	0.00
161.4	1.47	93.46	8.48	0.73	3.94	0.446	0.00	0.00	0.02340	0.00	0.00
148.0	1.70	91.99	7.78	0.62	3.21	0.409	0.00	0.00			
135.7	1.94	90.29	7.13	0.52	2.59	0.375	0.00	0.00			
124.4	2.18	88.35	6.54	0.44	2.07	0.344	0.00	0.00			
114.1	2.41	86.17	6.00	0.38	1.63	0.315	0.00	0.00			

Effluent Sample

University of New Hampshire

Microtrac Inc. 10.6.1	19936 MT 8614, File P2689	
	04/24/2012 15:15 DB Rec: 12	S3000/S3500 S3220

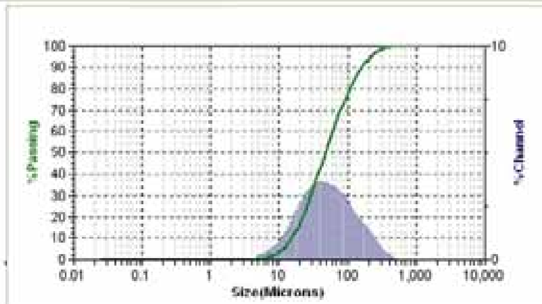
Data	Value
MV(um):	70.46
MN(um):	10.67
MA(um):	32.63
CS:	1.846-01
SD:	52.01
Mz:	63.31
σi:	56.50
Ski:	0.664
Kg:	1.266

Size(um)	%Tile

%Tile	Size(um)
10.00	15.14
20.00	21.89
30.00	28.92
40.00	37.02
50.00	47.16
60.00	60.39
70.00	78.66
80.00	106.6
90.00	160.5
95.00	213.7

Dia(nm)	Vol%	Width
47.16	100.0	104.00

UDefName	UDefData



Warnings: NONE

SOP Name: UNH(*)

Distribution:	Volume	Run Time:	30 Sec	Fluid:	WATER		
Progression:	Geom 8 Root	Run#:	Avg of 3	Fluid Ref Index:	1.333	Loading Factor:	[illegible]
Up Edge(um):	2000	Particle:	WATER SUSPENSION	Above Residual:	0	Transmission:	[illegible]
Low Edge(um):	0.0215	Transparency:	Transparent	Below Residual:	0	RMS Residual:	[illegible]
Residuals:	Disabled	Part. Ref. Index:	1.81			Flow:	[illegible]
#Channels:	132	Particle Shape:	Irregular	Cell ID:	[illegible]	Ultrasonic Power:	N/A
Analysis Mode:	S3000/3500			Multi Run Delay:	0 Min.	Ultrasonic Time:	N/A
Filter:	Enabled	DB Record:	12	Result Status:	Original	Serial Number:	[illegible]
Analysis Gain:	Default(2)	Database:	C:\Program Files\Microtrac FLEX 10.6.1\Databases\UNH.MDB				

Size(um)	%Chan	%Pass	Size(um)	%Chan	%Pass	Size(um)	%Chan	%Pass	Size(um)	%Chan	%Pass
2000	0.00	100.00	104.6	2.68	79.47	5.50	0.25	0.41	0.2890	0.00	0.00
1826	0.00	100.00	95.95	2.85	76.79	5.04	0.16	0.16	0.2650	0.00	0.00
1674	0.00	100.00	87.96	3.01	73.94	4.62	0.00	0.00	0.2430	0.00	0.00
1535	0.00	100.00	80.69	3.15	70.93	4.24	0.00	0.00	0.2230	0.00	0.00
1408	0.00	100.00	73.98	3.25	67.78	3.89	0.00	0.00	0.2040	0.00	0.00
1291	0.00	100.00	67.85	3.35	64.53	3.57	0.00	0.00	0.1870	0.00	0.00
1184	0.00	100.00	62.22	3.43	61.18	3.27	0.00	0.00	0.1720	0.00	0.00
1086	0.00	100.00	57.05	3.49	57.75	2.999	0.00	0.00	0.1580	0.00	0.00
995.5	0.00	100.00	52.32	3.55	54.26	2.750	0.00	0.00	0.1450	0.00	0.00
912.9	0.00	100.00	47.98	3.57	50.71	2.521	0.00	0.00	0.1330	0.00	0.00
837.1	0.00	100.00	44.00	3.58	47.14	2.312	0.00	0.00	0.1220	0.00	0.00
767.6	0.00	100.00	40.34	3.58	43.56	2.120	0.00	0.00	0.1110	0.00	0.00
703.9	0.00	100.00	37.00	3.57	39.98	1.944	0.00	0.00	0.1020	0.00	0.00
645.5	0.00	100.00	33.93	3.52	36.41	1.783	0.00	0.00	0.0940	0.00	0.00
591.9	0.00	100.00	31.11	3.41	32.89	1.635	0.00	0.00	0.0860	0.00	0.00
542.8	0.00	100.00	28.53	3.27	29.48	1.499	0.00	0.00	0.0790	0.00	0.00
497.8	0.03	100.00	26.16	3.12	26.21	1.375	0.00	0.00	0.0720	0.00	0.00
456.4	0.09	99.97	23.99	2.93	23.09	1.261	0.00	0.00	0.0660	0.00	0.00
418.6	0.20	99.88	22.00	2.73	20.16	1.156	0.00	0.00	0.0610	0.00	0.00
383.8	0.30	99.68	20.17	2.52	17.43	1.060	0.00	0.00	0.0560	0.00	0.00
352.0	0.38	99.38	18.50	2.28	14.91	0.972	0.00	0.00	0.0510	0.00	0.00
322.8	0.51	99.00	16.96	2.04	12.63	0.891	0.00	0.00	0.0470	0.00	0.00
296.0	0.67	98.49	15.55	1.79	10.59	0.817	0.00	0.00	0.0430	0.00	0.00
271.4	0.85	97.82	14.26	1.56	8.80	0.750	0.00	0.00	0.0390	0.00	0.00
248.9	1.05	96.97	13.08	1.33	7.24	0.687	0.00	0.00	0.0360	0.00	0.00
228.2	1.22	95.92	11.99	1.13	5.91	0.630	0.00	0.00	0.0330	0.00	0.00
209.3	1.39	94.70	11.00	0.95	4.78	0.578	0.00	0.00	0.0300	0.00	0.00
191.9	1.53	93.31	10.09	0.79	3.83	0.530	0.00	0.00	0.02790	0.00	0.00
176.0	1.67	91.78	9.25	0.66	3.04	0.486	0.00	0.00	0.02550	0.00	0.00
161.4	1.80	90.11	8.48	0.55	2.38	0.446	0.00	0.00	0.02340	0.00	0.00
148.0	1.95	88.31	7.78	0.46	1.83	0.409	0.00	0.00			
135.7	2.11	86.36	7.13	0.38	1.37	0.375	0.00	0.00			
124.4	2.30	84.25	6.54	0.31	0.99	0.344	0.00	0.00			
114.1	2.48	81.95	6.00	0.27	0.68	0.316	0.00	0.00			

APPENDIX G: Final factsheet in the UNHSC 2012 biennial report.

Permeable Interlocking Concrete Pavement

PICP is a high durability and logical choice for effective stormwater management. PICP provides remarkable runoff volume reductions while providing an enhanced aesthetic appeal.

About Permeable Interlocking Concrete Pavement

Permeable Interlocking Concrete Pavements (PICP) are a pervious pavement system comprised of precast paving units. Similar to other permeable pavements, storm water storage and treatment occur in the constructed subsurface. The UNH installation retrofitted Hood House drive located on the main campus in the summer of 2010. A standard Interlocking Concrete Pavement Institute (ICPI) profile was used for the drive lane and a modified section with an internal storage reservoir was used in the parking area. Applications of this technology often include parking areas, driveways, sidewalks, and other low speed driving areas. Permeable pavements have been shown to be active over a wide range of climates. Proper design for cold climate prevents damage from freeze-thaw cycle. PICP can be visually stunning and add a strong architectural flair to pavement while at the same time providing tremendous water quality and hydrologic benefits.

System Performance

Cost & Maintenance

The 2010 installation cost of the PICP lot which includes pavers, jointing and bedding materials and mechanical installation was approximately $4 per square foot. Paving units would have an added expense associated with hand installation if necessary. Individual units typically must be cut and placed along the edge of any nonuniform shape.

The permeability of PICP exists between the paving units themselves. The units have a small gap that is filled with chip stone. Maintenance is performed by cleaning with a regenerative air vacuum. One of the most important elements of maintenance of PICP is a design to minimize run-on. A low maintenance design is the best way to minimize clogging. Other clogging mechanisms include sediment tracking from vehicles, and organic litter buildup between the paving units. Attempts to clean the PICP surface have yielded variable results. Regenerative air vacuums work well to pick up bulk surface debris, but their effectiveness at removing deeper debris from between the pavers is still being researched. A strong vacuum can also result in the removal of the joint stone between the units. Preventative maintenance is essential in preserving high permeability for heavily used areas. This includes routine removal of surface debris through vacuuming or with the use of leaf blowers at a minimum of twice per year. One substantive benefit of PICP over other porous pavements is that they can be completely regenerated. If a system is clogged, a high-

FAST FACTS

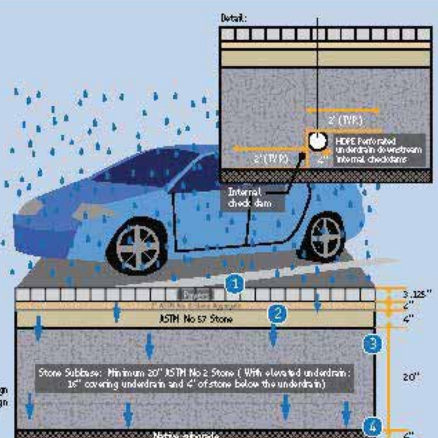
CATEGORY / BMP TYPE Porous Pavement UNIT OPERATIONS & PROCESSES Hydrologic (Flow Alteration) Water Quality: Physical (Sedimentation, Filtration),	Biological (Vegetative & Chemical (Sorption) BASIC DIMENSIONS 6,500 sf DESIGN SOURCE: UNHSC AND ICPI Catchment Area: 0.15 acre	Water Quality Flow: 1 cfs Water Quality Volume: 542 cf INSTALLATION COST $4.00 per sf mechanically installed MAINTENANCE	Maintenance Sensitivity: Low Inspections: Low Sediment Removal: High

How the System Works

WATER QUALITY TREATMENT PROCESS

1. Rainfall infiltrates into the paver joints that are filled with clean aggregate (ASTM No. 8 stone) into the bedding course (ASTM No. 8).
2. Stormwater drains through the bedding course, through the open-graded base (ASTM No. 57 stone), and into the stone subbase reservoir (ASTM No.2 stone). Through these layers the physical process of filtration provides treatment of the stormwater runoff.
3. Installed in the stone subbase are perforated underdrains placed 4 inches above the native soils which provides retention and infiltration. Internal check dams constructed of an impermeable liner are installed for every 12" drop of elevation to provide storage on a sloped grade.
4. Excess water flows through the elevated underdrains to the municipal storm sewers or receiving water.

Please note: This design includes subbase design for cold climates and drainage for low permeability soils.



There is an internal check dam which consists of non-woven geo textile covering the upstream side of the 4" diameter perforated underdrain as shown in the detail in the top right.

16

strength vacuum could be used to remove the joint stone and clogging debris, and the stone would then be replaced along with hydraulic capacity.

Cold Climate

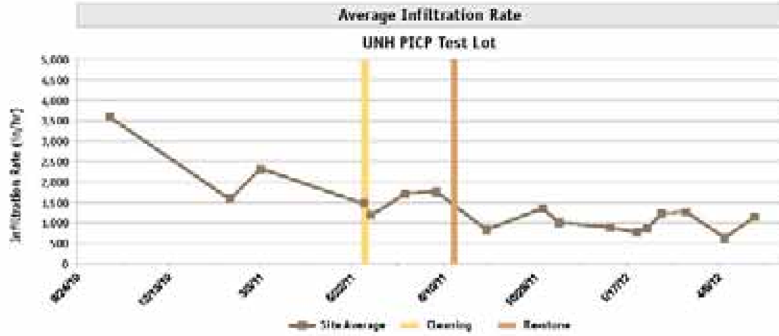
With proper design and installation, the PICP system is a suitable stormwater management system for cold climate regions. The well-drained subbase and capillary barrier limits freeze thaw and reduces damage to the system by winter plowing. Conventional winter maintenance by salt and plowing is effective at removing the majority of snow and ice from the surface. Surface infiltration minimizes black ice formation thereby reducing the salt required for winter maintenance.

Water Quality Treatment

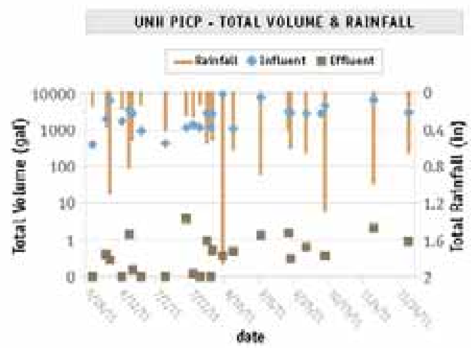
The water quality treatment performance of the PICP system has been excellent. Mass load reduction and removal efficiencies exceed 99% for pollutants due to a tremendous amount of infiltration. Effluent volumes are typically 99% less than the influent volume. The figure and table to the middle right reflect the system's performance in achieving runoff volume reductions and subsiquent pollutant mass load reductions Values represent results recorded over the study period.

Water Quantity Control

The PICP system has performed exceptionally well for stormwater volume reduction. Rainfall drains directly through the joints between the interlocking pavers and infiltrates into the subgrade. This significantly reduces peak flows, decreases runoff temperatures, and reduces runoff volumes. The PICP system is built over HSG-C soils and shallow depth to bedrock. Underdrains are installed 4 inches above the native soil to promote infiltration. It is rare that a storm event generates any effluent in the underdrains.



WATER QUANTITY			
Date	Total Influent Volume (gal)	Total Effluent Volume (gal)	% Volume Reduction
n	26	26	26
Average	2586	1.18	99.93%
Median	2045	0.75	99.97%
Standard Deviation	2145	1.41	0.00
Coefficient of Variation	0.83	1.20	0.00



SYSTEM DESIGN

The PICP lot is designed to handle the WQV and CPV. The design consists of four basic layers:

Top layer: Paving units are placed on top, are 3.13 inches high by 4 inches wide by 8 inches long with a 0.25 inch gap filled with ASTM No. 8 stone with ~13% surface void space for infiltration; pavers are laterally contained by granite curbing or concrete headers.

Second layer: Two inches of an open-graded bedding course of No. 8 stone supports the pavers;

Third layer: Four inches of an open-graded base course of ASTM No. 57 stone to support the bedding course, and provide filtration;

Fourth layer: Seventeen to twenty inches of an open-graded reservoir subbase of ASTM No. 2 stone is installed over native materials as a capillary barrier to minimize frost heaving. Perforated underdrains are installed in the reservoir 4 inches above the native materials and provides storage and infiltration. The sides of the system may be lined with geotextile fabric to prevent migration of fines; a bottom lining is only recommended with poor structural soils or when infiltration is not desired. Geotextiles in horizontal layers should be used with caution as they can lead to premature clogging.

APPENDIX H: Concrete paver test results.

NATIONAL CONCRETE MASONRY ASSOCIATION

Sustainable Concrete Products for Structures and Hardscapes

13750 Sunrise Valley Drive
Herndon, Virginia 20171-4662
703.713.1900 ■ 703.713.1910 Fax
ncma@ncma.org ■ www.ncma.org

ASTM C140-10 Test Report
Sampling and Testing Concrete Masonry Units and Related Units

Job No: 10-523A
Report Date: 11/23/2010

Client: Interlocking Concrete Pavement Institute
Address: 13921 Park Center Road, Suite 270
Herndon, VA 20171

Testing Agency: National Concrete Masonry Association
Research and Development Laboratory
Address: 13750 Sunrise Valley Drive
Herndon, VA 20171-4662

Unit Specification: ASTM C936/C936M-09
Sampling Party: Interlocking Concrete Pavement Institute

Unit Description: Concrete Paver
Date Samples Received: 9/1/2010

Specified Height (mm): 80

Summary of Test Results

	Required	Actual	
Net Area Compressive Strength	8000 min	11360	psi
Absorption	5 max	3.7	%
Density (Oven Dry Condition)	****	142.5	pcf
Net Cross Sectional Area	****	27.96	in^2
Variation from Specified Width Dimensions	.063 max	0.057	in.
Variation from Specified Height Dimensions	.125 max	0.062	in.
Variation from Specified Length Dimensions	.063 max	0.023	in.

Individual Unit Test Results

Full Size Unit Measurements

		Avg. Width (in.)	Avg. Height (in.)	Avg. Length (in.)	Sample Weight (lb)
	Unit #1	3.644	3.212	7.636	7.73
Date Tested:	Unit #2	3.670	3.198	7.647	7.69
9/7/2010	Unit #3	3.656	3.206	7.661	7.67
	Average	3.657	3.205	7.648	7.69

Compression Specimens

		Avg. Width (in.)	Avg. Height (in.)	Avg. Length (in.)	Sample Weight (lb)	Aspect Ratio	After Capping Height (in.)	Average Cap Thickness (in.)	Total Load (lb)	Net * Area ($in.^2$)	Net Area Compressive Strength (psi)
	Unit #1	3.644	3.212	7.636	7.73	0.88	3.272	0.030	322000	27.82	11570
Date Tested:	Unit #2	3.670	3.198	7.647	7.69	0.87	3.254	0.028	321130	28.06	11440
9/9/2010	Unit #3	3.656	3.206	7.661	7.67	0.88	3.268	0.030	310020	28.00	11070
	Average	3.657	3.205	7.648	7.69	0.88	3.264	0.029	317720	27.96	11360

* Net area determined as the product of the length and width of the unit.

Absorption Specimens

		Received Weight W_R (lb)	Immersed Weight W_I (lb)	SSD Weight W_S (lb)	Oven-Dry Weight W_D (lb)	Absorption (%)	Density (pcf)	Net Volume (ft^3)
Date Tested:	Unit #4	7.83	4.58	7.90	7.63	3.5	143.4	0.0532
9/7/2010	Unit #5	7.64	4.49	7.77	7.47	4.0	142.2	0.0525
to	Unit #6	7.63	4.44	7.72	7.44	3.7	141.9	0.0525
9/13/2010	Average	7.70	4.50	7.79	7.51	3.7	142.5	0.0527

Comments: These units meet or exceed the compressive strength, absorption, and dimensional requirements of ASTM C936/C936M-09.

Nicholas R. Lang
Manager, Research & Development Laboratory

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NATIONAL CONCRETE MASONRY ASSOCIATION
Sustainable Concrete Products for Structures and Hardscapes

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ASTM C1645/C1645M-09 Test Report
Freeze-Thaw and De-icing Salt Durability of
Solid Concrete Interlocking Paving Units

Job No: 10-523B
Report Date: 11/23/2010

Client: Interlocking Concrete Pavement Institute
13921 Park Center Road, Suite 270
Herndon, VA 20171

Testing Agency: National Concrete Masonry Assoc.
Research and Development Laboratory
Address: 13750 Sunrise Valley Drive
Herndon VA, 20171-4662

Unit Specification: ASTM C936/C936M-09

Sampling Party: Interlocking Concrete Pavement Institute

Name/Description of Unit:
Concrete Paver

Date Samples Received: 9/1/2010

Specified Height (mm): 80.00

Summary of Test Results

	Required	Actual	
Surface Area	****	0.08	m^2
7 Cycle Mass Loss	****	0.00	g/m^2
28 Cycle Mass Loss	225 max	16.51	g/m^2

Test Solution: Saline

Individual Unit Test Results

		Avg. Width (in.)	Avg. Height (in.)	Avg. Length (in.)	Surface Area (in^2)	Surface Area (m^2)
	Unit #1	3.66	3.19	7.63	127.73	0.08
	Unit #2	3.66	3.22	7.62	128.46	0.08
Date Tested:	Unit #3	3.62	3.21	7.63	127.35	0.08
9/7/2010	Average	3.64	3.21	7.62	127.84	0.08

		7 Cycle Mass Loss (g)	7 Cycle Mass Loss (g/m^2)	28 Cycle Mass Loss (g)	28 Cycle Mass Loss (g/m^2)
Date Tested:	Unit #1	0.00	0.00	1.13	13.76
10/16/2010	Unit #2	0.00	0.00	1.13	13.69
to	Unit #3	0.00	0.00	1.81	22.09
11/23/2010	Average	0.00	0.00	1.36	16.51

Comments: These units comply with the resistance to freezing and thawing requirements of ASTM C936/C936M-09.

Nicholas R. Lang
Manager, Research & Development Laboratory

APPENDIX I: Memo from UNH Facilities.

Below is the feedback from Tom Byron, UNH Manager of Grounds and Events in response to question regarding standard practices and effectiveness of winter plowing and anti-icing/de-icing management of the PICP.

From: Byron, Thomas
Sent: Monday, March 25, 2013 7:09 AM
To: Geuther, Mark
Cc: Fortin, Robert; VanDessel, Larry; Howard, Dave
Subject: RE: Hood House Drive Questions

1. What type of equipment was use to remove snow? It's a 1 ton truck that plows that area with a steel cutting edge. The small areas it can be shovels or snow blowers we have had no problems.
2. Did Hood House Drive receive deicing materials? What type? Rock salt was used just like the rest of the campus I don't think there was any less or more used.
3. Did snow on Hood House Drive melt faster, the same, or slower than snow and ice on asphalt pavements? As far as melting I would say it's slower just because of the drainage. When applying salt as it melts it makes a brine that helps with melting and because of the drainage it doesn't spread out as well.