Effectiveness of FieldTurf Artificial Turf for Management of Stormwater

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A. INTRODUCTION

The Maryland Stormwater Management Act of 2007 has created a new paradigm for the management of stormwater in Maryland. The primary goal of the Act is to mimic, after development or redevelopment, pre-development runoff characteristics, to the extent that it is possible. Traditional designs for stormwater management are less likely to mimic predevelopment conditions because they focus on managing large volumes of polluted stormwater rather than treating runoff closer to the source.

The comprehensive design strategy for maintaining predevelopment runoff conditions is referred to as Environmental Site Design (ESD). ESD relies on integrating site design, natural hydrology, and smaller controls to capture and treat runoff. The objective of ESD is to replicate the hydrology and water quality of forested systems. Each ESD practice is intended to incrementally reduce the volume of stormwater on its way to the stream, thereby reducing the amount of conventional stormwater infrastructure. ESD measures are further defined as those that can minimize the use of impervious surfaces and slow down runoff and increase infiltration and evapotranspiration.

The most recent version of the Maryland Stormwater Design Manual identifies various ESD practices that may be used in commercial areas and urban watersheds. While artificial turf is not specifically mentioned, it appears that products such as FieldTurf should be considered as a potential ESD practice in numerous situations. Use of products such as FieldTurf to achieve stormwater targets would be desirable to counties in Maryland who are tasked with meeting draconian stormwater management requirements. However, the infiltration characteristics of artificial turf products such as FieldTurf would need to be identified to determine how they compare to natural turf and perhaps other developed ESD practices (e.g., permeable pavements). This report will provide a preliminary assessment of the suitability and potential use of FieldTurf as an ESD practice.

B. MARYLAND’S CURRENT STORMWATER REGULATIONS

As described above, MDE updated the current stormwater regulations in 2009. As stated in these regulations:

> The criteria for sizing ESD practices are based on capturing and retaining enough rainfall so that the runoff leaving a site is reduced to a level equivalent to a wooded site in good condition as determined using United States Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) methods (e.g., TR-55). The basic principle is that a reduced runoff curve number (RCN) may be applied to post-development conditions when ESD practices are used. The goal is to provide enough treatment sing ESD practices to address CP_v requirements [i.e., the 24-hour extended of a post-developed 1-year, 24-hour storm event] by replicating an RCN for woods in good condition for the 1-year rainfall event. This eliminates the need for structural practices… If the design rainfall captured and treated using ESD is short of the target rainfall, a reduced RCN may be applied to post development conditions when addressing stormwater management requirements. (MDE 2009)

MDE (2009) set four performance standards for ESD:

- the standard for characterizing predevelopment runoff characteristics for new development projects shall be woods in good hydrologic condition;
- ESD shall be implemented to the [maximum extent practicable] to mimic predevelopment conditions;
- as a minimum, ESD shall be used to address both Re_v [the volume of groundwater recharge that must be maintained] and WQ_v [storage needed to capture and treat the runoff from 90% of the average annual rainfall] requirements; and
- channel protection obligations are met when ESD practices are designed according to the Reduced [RCN] Method…

In order to comply with Maryland's stormwater regulations, an ESD practice must treat the runoff from one inch of rainfall (i.e., P_e = 1 inch) and ESD practices must address the 24-hour extended detention of a post-developed 1-year, 24-hour storm event (i.e., CP_v). If the reduced RCN for a drainage area reflects woods in good condition, then the CP_v has been satisfied. Structural practices must be used to treat any targeted rainfall that is not met by ESD.

For those readers who wish to more fully understand MDE's requirements, and some of the key underlying terms/concepts such as WQ_v, Re_v, and P_e, the following sections titled Water Quality Volume, Recharge Volume Requirement and Volumetric Runoff Coefficient are presented below. Other readers may wish to skip directly to the section titled Runoff Curve Numbers on Page 4.

WATER QUALITY VOLUME

Water quality volume, or WQ_v, is the storage needed to capture and treat the runoff from 90% of the average annual rainfall. WQ_v is measured in acre-feet. WQ_v can be calculated using the following formula:

$$WQ_v = \frac{P_e * R_v * A}{12}$$

where:

WQ_v = water quality volume, in acre feet

Pe = rainfall target used to determine ESD goals and size practices, in inches

R_v = volumetric runoff coefficient

A = site area, in square feet or acres

RECHARGE VOLUME REQUIREMENT

The recharge volume requirement, or Re_v, is the volume of groundwater recharge that must be maintained at a development or redevelopment site. According to MDE (2009):

> This helps to preserve existing water table elevations thereby maintaining the hydrology of streams and wetlands during dry weather. The volume of recharge that occurs on a site depends on slope, soil type, vegetative cover, precipitation and evapo-transpiration. Sites with natural ground cover, such as forest and meadow, have higher recharge rates, less runoff, and greater transpiration losses under most conditions.

Re_v is a fraction of WQ_v, depending on the pre-development soil hydrologic group. Therefore, Re_v and WQ_v are inclusive.

There are two formulas that can be used to calculate Re_v in acre-feet, the percent volume method and the percent area method:

$$Re_v = \frac{S * R_v * A}{12}$$

and

$$Re_v = S * A_i$$

where:

A = site area in acres;

A_i = the measured impervious cover;

S = the soil specific recharge factor (found in Chapter 2 of MDE 2009); and

R_v = the volumetric runoff coefficient.

VOLUMETRIC RUNOFF COEFFICIENT

Volumetric runoff coefficient, or R_v, is used to calculate the water quality volume. It can be calculated using the formula:

$$R_v = 0.05 + 0.009 * I$$

where:

I = the percent impervious cover.

RUNOFF CURVE NUMBERS

Runoff curve numbers (RCN)[1] are used to predict total runoff of a storm event for a given rainfall event. Higher RCNs indicate that less infiltration will occur and that greater volumes of runoff will be produced. There are eight major factors that influence RCN values: hydrologic soil group (HSG); cover type; treatment; hydrologic condition; antecedent runoff condition; urban impervious area modifications; connected impervious areas; and unconnected impervious areas (NRC 1986).

NRC (1986) solves the runoff equations and presents a series of curves and tables that can be used to identify the appropriate value(s) for RCN for a given set of conditions. MDE's 2009 stormwater regulations rely on these curves and tables to identify the target RCN for woodlands (see Table 1, below).

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[1] United States Department of Agriculture, Department of Natural Resources Conservation Service (NRC) and other state agencies commonly use the acronym "CN" to represent the runoff curve number. To maintain consistency with MDE and the current stormwater regulations, the acronym RCN is being used throughout this document.

It is quite clear that the soil characteristics exert a very strong influence on the degree of infiltration and runoff. Table 1 indicates that hydrologic soil type A, which typically consists of 90% sand or gravel and less than 10% clay, has excellent infiltration characteristics (RCN = 30). This can be contrasted with soil type D, which typically consists of greater than 40% clay and therefore has a much higher runoff curve number (RCN = 77).

Table 1
RCN Values for Woods

Hydrologic Condition	Hydrologic Soil Group			
	A	**B**	**C**	**D**
Woods	30	55	70	77
Sources: NRC 1986				

NRC (1986) also presents hydrologic curve numbers for open spaces (e.g., lawns, parks, golf courses, cemeteries). This is the type of landuse that artificial turf could be expected to replace. The RCN values for open spaces, depending on the hydrologic condition and hydrologic soil type, range from 39 to 89. Table 2, below, presents the RCN values for this "natural turf."

Table 2
RCN Values for Natural Turf

Hydrologic Condition	Hydrologic Soil Group			
	A	**B**	**C**	**D**
Poor condition (grass cover < 50%)	68	79	86	89
Fair condition (grass cover 50% to 75%)	49	69	79	84
Good condition (grass cover > 75%)	39	61	74	80
Notes: RCN values originally presented for open space/pasture – here defined as "natural turf"				
Sources: NRC 1986				

As can be seen from a comparison of the RCN values presented in Tables 1 and 2, natural turf does not provide the same level of natural stormwater runoff control as does wooded property (i.e., RCN values for natural turf are considerably higher than for woods, for a given landuse). This means that more water runs off of a natural turf site than is allowed under current MDE stormwater regulations for the development (or redevelopment) of a site.

C. FIELDTURF

DESCRIPTION OF PRODUCT

FieldTurf, like other synthetic turf products, consists of four main components: the fiber, (or grass like material), the backing to which the fiber is tied, the infill, and the prepared subsurface. FieldTurf offers a number of different product lines, each with different variations of nylon or polyethylene fibers. FieldTurf's backing is 40% porous; it has a coating applied only along the fiber rows, allowing the remainder of the backing to drain. The infill is a combination of cryogenic rubber and silica sand (FieldTurf Tarkett Undated a).

While FieldTurf's unique coating allows for water to quickly pass through the turf system, overall drainage depends heavily on the quality of the underlying base. In most instances, the turf system will drain anywhere from 5 to 10 times faster than the base; therefore, the most critical component in a field's drainage performance revolves around the design of the base and the quality of its materials and construction (FieldTurf Tarkett Undated b).

TYPICAL INSTALLATION

The Field Turf system is typically installed to be slightly higher in the center, sloping gradually at 0.5% towards the field's edges. The fibers are underlain with 1 to 2 inches of No. 8 and finishing stone. A free draining gravel subbase consisting of No. 57 stone is installed beneath the No. 8 stone layer. The depth of the No. 57 stone treatment is typically 4-5 inches at the center and gradually thickens to 8 to 9 inches towards the edges of the field. Therefore, the total subsurface depth of stone treatment for FieldTurf typically ranges from 6 to 11 inches. Underdrain systems are provided to enhance drainage and may serve to detain runoff.

D. LITERATURE REVIEW

Effective stormwater management involves addressing both water quality and water quantity concerns to prevent a range undesirable outcomes including biological impairment of surface waters, public health concerns, stream erosion, and downstream flooding. AKRF was tasked with compiling and reviewing existing literature to assess the relative efficacy of natural turf and synthetic turf systems in providing stormwater management.

WATER QUALITY

The effects of turf systems on water quality include both the ability of the turf system to remove pollutants associated with rainwater or incoming stormwater and the potential for pollutants to be generated by turf systems through processes such as erosion or leaching.

Several studies have looked at the potential for water quality impacts associated with artificial turf fields. Generally, these studies have focused on the potential for leaching of heavy metals and lead. The conclusions of most studies has been that the primary water quality concern associated with artificial turf fields is the potential for zinc leaching from crumb rubber. Yet the findings of these studies are certainly not conclusive with respect to toxicity. For instance, a study performed by the New York State Department of Environmental Conservation and New York State Department of Health (2009) concluded that leaching from crumb rubber did not pose a significant risk of groundwater contamination, but found that zinc leaching from crumb rubber made from truck tires could pose a threat to aquatic life. The same study concluded that leaching from crumb rubber made from mixed tires posed an insignificant risk for aquatic life.

A study of four artificial turf fields in Connecticut (Connecticut Department of Environmental Protection, 2010) found that zinc leaching from artificial turf fields was a potential risk to surface waters, but in evaluating the potential risks of stormwater runoff the study goes on to state that, *"Since the mean concentration of zinc in the stormwater samples is below surface water protection criteria, the discharge from the artificial turf fields to groundwater is intermittent, and zinc is immobilized in soils by adsorption, absorption and precipitation, the potential for impacts to surface waters being recharged by this groundwater is minimal."* A recent Montgomery County, Maryland report (Montgomery County Staff Work Group, 2011) reported that samples obtained from an on-going San Francisco Pubic Utilities synthetic turf monitoring study showed total zinc levels above the Maryland Toxic Substances Criteria for Ambient Surface Waters (120 µg/l) standard but showed dissolved zinc levels below the acute toxicity level.

In the same study, a review of literature found that many previous studies have shown that artificial turf fields are generally unlikely to generate pollutant at concentrations above water quality limits, although some studies do indicate that toxic compounds can be released from used tires, which are used to produce the rubber infill material associated with many synthetic turf products, during leachate studies (Montgomery County Staff Work Group 2011). Additionally, one study reported that artificial turf systems have been shown to support lower levels of bacteria than natural turf fields (California Department of Resources Recycling and Recovery 2010).

In summary, there is a perception based on limited studies that zinc can be an issue for aquatic life depending on the type of tires and crumb rubber used. Because the results of the previous studies are neither conclusive nor product specific, we plan on investigating the relationship between FieldTurf and zinc concentrations in stormwater runoff during a second phase field testing project.

Natural turf systems could potentially give rise to a number of water quality concerns including leaching of fertilizer, herbicides, or pesticides and through surface erosion, although these effects can be reduced to varying extents through the use of best management practices. There are also potential environmental risks from spills associated with lawnmower use, which is needed for managing turf systems. We did not locate any studies that quantified these potential impacts.

THERMAL IMPACTS

Increases in water temperature can pose a threat to certain types of aquatic life, particularly cold water fish. Several studies have shown that artificial turf surfaces have significantly higher ambient temperatures than natural turf areas (e.g., NYSDEC/NYSDOH 2009), although these effects can be mitigated by washing down the turf surface. As a result of elevated ground temperatures, surface runoff coming in contact with artificial surfaces could be subjected to higher levels of thermal loading than runoff coming in contact with natural turf, but the amount of temperature increase would be strongly influenced by the contact time between the runoff and turf surface. Also, thermal impacts may be mitigated by the increased potential for infiltration associated with artificial turf surfaces. We did not find any study that specifically compared stormwater runoff temperature between artificial and natural turf surfaces.

INFILTRATION

Infiltrating stormwater into the ground is an effective means for mitigating many of the negative impacts associated with stormwater runoff and has emerged as the stormwater management strategy of choice throughout much of the U.S. The potential for precipitation to infiltrate into the ground is generally a function of the permeability of the ground surface and subsoils.

Infiltration rates associated with natural turf systems vary with a host of factors including the type and density of turf grass, root development, maintenance, compaction and soil characteristics. However, we found few studies that systematically looked at how these characteristics influence infiltration rates. One study by Hamilton and Waddington (1999), who measured infiltration rates associated with 15 residential lawns in central Pennsylvania, provides some insight into the potential range of infiltration rates associated with grass/soil complexes. The study showed that most lawns had infiltration rates less than 1.18 in/hr and that soil characteristics or maintenance were not correlated with infiltration rates.

Logically, engineered natural turf systems (e.g., turf over sand or other engineered media, etc.) may produce much higher infiltration rates than conventional natural turf (e.g., in residential lawns, etc). For instance, Davis (1981) reported compacted infiltration rates for sand samples obtained from nine sports fields in California and found that most infiltrates rates exceeded 20 in/hr.

Laboratory testing provided by FieldTurf reported permeability rates of 139.2 in/hr, suggesting that precipitation moves very rapidly through the turf surface and to the subsurface gravel bed. A study by James and McLeod (2010) looking at the effect of maintenance on the performance of sand filled synthetic turf showed that infiltration rates declined significantly (approximately 18 in/hr at installation to between approximately 2-4 in/hr) as the infill became contaminated by fine material. It is unclear to what extent this effect would be present for rubber filled turf systems or for natural turf.

E. POTENTIAL USE OF FIELDTURF UNDER MARYLAND REGULATIONS

POTENTIAL FOR USE AS AN ESD PRACTICE

Very high surface infiltration rates (up to 139.2 in/hr; TSI 2010) suggest that FieldTurf effectively conveys stormwater from the ground surface to subsurface soils similar to other approved ESD porous alternative surfaces, such as permeable pavements. In fact, the measured infiltration rate associated with FieldTurf appears to be one to two orders of magnitude higher that the 8 in/hr required of permeable pavement in the MDE Stormwater Design Manual. This comparison suggests that FieldTurf is highly porous and will not impede conveyance of stormwater even during high intensity precipitation events.

Given its high infiltration rate, FieldTurf applications offer the potential to infiltrate stormwater to a greater extent than from natural turf fields, provided sufficient subsurface storage (i.e., gravel media) is provided beneath the turf. While typical installation of FieldTurf is not currently identical to the installation of permeable pavements, the installation could be readily adapted to match or be similar to the guidelines set forth by MDE (2009) for permeable pavements (e.g., depth and drainage characteristics of subsurface media, required infiltration rates for subsoils etc.). ESD design guidelines for permanent pavements are presented in Attachment A.

The high surface infiltration rate associated with FieldTurf suggests that it would be appropriate to, at a minimum, apply the RCN values provided in the MDE Stormwater Design Manual for permeable pavers to FieldTurf applications, provided that the installation of the subsurface bed beneath the FieldTurf met, or was similar to, MDE requirements for permeable pavements. A comparison between RCN values associated with natural turf and permeable pavements is presented in Table 3. As is shown, the RCN associated with permeable pavements is a direct function of the hydrologic soil group and the depth of the gravel subbase. Assuming RCN values for permeable pavements could be applied to FieldTurf and comparing those RCN values to RCN values for natural turf, replacing natural turf with FieldTurf systems *could* provide the ability to lower the RCN, particularly if the existing natural turf is in fair or poor condition and if a 12”, or possibly a 9” subbase is used beneath the FieldTurf. However, in other situations (e.g., good condition turf converted to FieldTurf using a shallower gravel bed, etc.) the RCN may be significantly increased when converting from natural turf to FieldTurf, at least according to the RCN values provided in the MDE Stormwater Design Manual.

Based on the typical construction details provided to AKRF, the typical FieldTurf installation consists of a roughly 6 to 11 inch stone layer beneath the FieldTurf system. If we assume that RCNs for FieldTurf would be similar to those presented the MDE Stormwater Design Manual for permeable pavements, in most cases the depth of the gravel layer would need to be increased to provide a substantial reduction in RCN. According to Table 3, providing a 12 in. subbase beneath the FieldTurf system would provide RCN values roughly equaling those provided for a “woods in good condition” target, thus eliminating the need to provide additional treatment for runoff generated by the FieldTurf installation.

Table 3
Comparison Between RCN Values for Natural Turf and Permeable Pavements for Various Hydrologic Condition, Depth of Subbase, and Hydrologic Soil Group (HSG) as Reported in the MDE Stormwater Design Manual

Natural turf					Permeable Pavements					Difference in RCN			
Hydrologic Condition	HSG				Depth of Subbase	HSG				HSG			
	A	B	C	D		A	B	C	D	A	B	C	D
Poor condition (grass cover < 50%)	68	79	86	89	6”	76	84	93	N/A	-8	-5	-7	N/A
	68	79	86	89	9”	62	65	77	N/A	6	14	9	N/A
	68	79	86	89	12”	40	55	70	N/A	28	24	16	N/A
Fair condition (grass cover 50% to 75%)	49	69	79	84	6”	76	84	93	N/A	-27	-15	-14	N/A
	49	69	79	84	9”	62	65	77	N/A	-13	4	2	N/A
	49	69	79	84	12”	40	55	70	N/A	9	14	9	N/A
Good condition (grass cover > 75%)	39	61	74	80	6”	76	84	93	N/A	-37	-23	-19	N/A
	39	61	74	80	9”	62	65	77	N/A	-23	-4	-3	N/A
	39	61	74	80	12”	40	55	70	N/A	-1	6	4	N/A

HYDROLOGIC MODELING OF RCN VALUE FOR FIELDTURF

To further characterize the runoff characteristics associated with FieldTurf applications, AKRF performed a hydrologic modeling study of an existing FieldTurf installation, which had been previously studied by ELA Group, Inc. (2007) (Project No: 103-070, January 9, 2007). The project site is a 6.33 acre watershed located at Coatesville High School in Coatesville, Pennsylvania. This watershed contains a 2.09 acre synthetic turf field that is the subject of this analysis. The approach of this study is to model the hydrologic response of the project site to actual precipitation events and to compare and attempt to match these results to measured runoff data previously collected by ELA Group, Inc. by varying synthetic turf RCN inputs.

AKRF’s modeling study utilizes the U.S. Army Corps of Engineers Hydrologic Modeling System (HEC-HMS) and is based on data provided in the report titled Field Test Data Study for the Stormwater Runoff From Synthetic Turf Fields at Coatesville High School, prepared by ELA Group, Inc. (2007). ELA’s study included measured runoff from the project site for several precipitation events before and after the conversion of an existing natural turf field to a FieldTurf field. Data utilized from this report for AKRF’s modeling study include post development drainage area cover descriptions and rational method runoff coefficients, time of concentration, field recorded post development peak flow rates and runoff volumes for seven storm events from 9/2006 to 11/2006, and 24 hour rainfall volumes from the Coatesville 2W rain gage (NOAA Station ID: PA361591), which is located 3.68 miles from the project site. These data were supplemented with 15 minute rain gage data from the Glenmoore rain gage (NOAA Station ID: PA363321), located 7.18 miles from the project site. It should be noted that the Post Development Watershed Map that accompanies ELA Group's report was not provided for the analysis.

The project site contains four defined post development land cover classifications, which include impervious modular classrooms, an impervious track, a pervious grass area, and the pervious synthetic turf field. To develop a hydrologic model using NRCS methodology, RCNs were assumed for each land cover based upon soil data and the provided cover descriptions and rational runoff coefficients. The project site lies predominately over Conestoga silt loam (CtB) soil, which is in the 'B' hydrologic soil group. All impervious areas were assumed to have a RCN of 98, and the pervious grass area was assumed to be in good condition based on aerial imagery. The watershed land cover and assumed RCNs used in the hydrologic model are summarized in Table 4. Synthetic turf RCN was isolated and varied as it is the main focus of this hydrologic study.

Table 4
Watershed Land Cover Summary

Land Cover	Area (acres)	RCN
Modular Classrooms	0.83	98
Grass	0.74	61
Impervious Track	2.67	98
Synthetic Turf	2.09	---

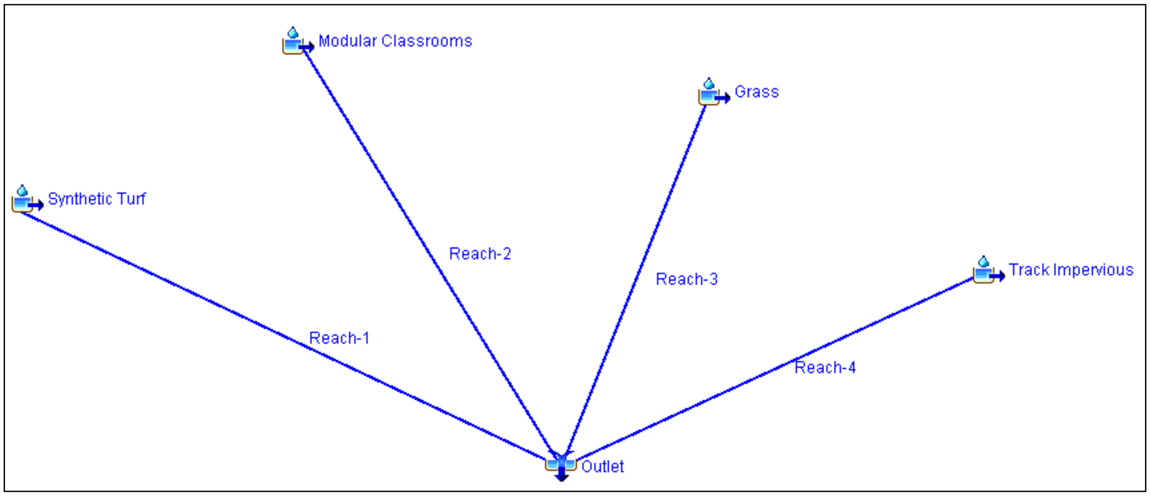
Glenmoore rain gage (NOAA Station ID: PA363321) 15 minute rainfall data were used as the precipitation input for hydrologic modeling. Although the Coatesville 2W rain gage is located closer to the project site, only daily rainfall totals are provided for this rain gage. It is understood that actual rainfall patterns and intensities would more accurately model field recorded peak flow rates than synthetic rainfall distributions based only on daily rainfall totals. Despite the close proximity of both rain gages, differences in total rainfall volumes were observed for the seven rainfall events examined. The rainfall records for these rain gages are summarized in Table 5. Based on the available data, Event #4 (10/17/2006 to 10/18/2006) and Event #6 (10/27/2006 to 10/29/2006) were selected as the events to focus modeling efforts. Event #4 was selected due to the size of the event and the close correlation of total precipitation volumes between both rain gages. Event #6 was chosen because it was the largest event in the provided data set.

Table 5
Rainfall Gage Records

Event Number	Date	Total Recorded Precip. (inches)	
		Coatesville	Glenmoore
1	9/28 to 9/29/2006	0.86	0.6
2	10/1/2006	0.1	0.1
3	10/6 to 10/7/2006	0.56	0.4
4	**10/17 to 10/18/2006**	**0.79**	**0.8**
5	10/19 to 10/21/2006	1.01	0.6
6	**10/27 to 10/29/2006**	**1.74**	**1.9**
7	11/2/2006	0.55	0.4

A schematic of the hydrologic model is shown in Figure 1. All watershed land covers were modeled as individual subareas and assumed to flow directly to the watershed outlet. This assumption was necessary due to the lack of provided information about the physical layout of the watershed and information about the location of the flow recording instrumentation. A time of concentration of 5 minutes was applied to all subareas, as specified in ELA Group's report. A lag time of 1 minute was assumed for each reach.

Figure 1. Hydrologic model schematic



The RCN input for the synthetic turf subarea was varied from a range of 50 to 90. Model results and field recorded data are summarized for total runoff volume in Table 6 and for peak flow in Table 7.

Table 6
Hydrologic Model Runoff Volume Results Summary

Event Number	4	6
Glenmoore Gage Recorded Precipitation Volume (in)	0.8	1.9
Field Recorded Runoff Volume (in)	**0.12**	**0.57**
Model Total Runoff Volume (in)		
Turf RCN=50	0.33	0.93
Turf RCN=60	0.33	0.94
Turf RCN=65	0.33	0.96
Turf RCN=70	0.33	1.00
Turf RCN=75	0.33	1.04
Turf RCN=80	0.34	1.09
Turf RCN=85	0.36	1.17
Turf RCN=90	0.39	1.26
Model Runoff Volume from Impervious Areas (in)	0.33	0.93

Table 7
Hydrologic Model Peak Flow Results Summary

Event Number	4	6
Glenmoore Gage Recorded Precipitation Volume (in)	0.8	1.9
Recorded Peak Flow (cfs)	**0.20**	**1.21**
Model Peak Flow (cfs)		
Turf RCN=50	1.3	1.4
Turf RCN=60	1.3	1.5
Turf RCN=65	1.3	1.6
Turf RCN=70	1.3	1.7
Turf RCN=75	1.3	1.8
Turf RCN=80	1.5	1.9
Turf RCN=85	1.6	2.0
Turf RCN=90	1.8	2.1

The hydrologic model results consistently predict higher observed runoff volumes for both Event #4 and for Event #6. In fact, the predicted runoff volume from the impervious areas alone (modular classrooms and impervious track) is greater than the actual observed runoff for both events. Peak flow rates are also over predicted for both events.

These results led to the conclusion that the difference between the modeled runoff volume and observed runoff volume has been stored or infiltrated by the pervious watershed areas, which include the grass area and the synthetic turf. This infiltrated volume could potentially be as great as 0.21 inches for Event #4 and 0.36 inches for Event #6. The difference in peak flow rate may also be a result of this removed runoff volume. While there is strong evidence to support these conclusions, further watershed information is necessary to begin to isolate the stormwater management benefits of the synthetic turf from those of the natural grass area. The Post Development Watershed Map that accompanies ELA Group's report, site survey data if available, and a detailed site inspection may offer further insight. If watershed mapping confirms that newly constructed impervious areas drain to the FieldTurf area, **the study may**

suggest that the effective RCN for the FieldTurf installation is actually much lower than reported RCN values for porous pavement provided in the MDE manual.

It is the recommendation of AKRF that an additional field study is necessary to conclusively assess and relate the stormwater management performance and benefits of FieldTurf's synthetic turf system to the NRCS RCN methodology. Ideal study conditions would consist of an isolated synthetic turf system specifically designed for observation, and outfitted with instrumentation to record and log onsite precipitation, inflow, and outflow.

F. ADVANTAGES OF USING FIELDTURF

Field Turf offers many advantages to natural turf and is more consistent with sustainability initiatives being implemented both in Maryland and on the national level. Maintenance costs are substantially lower for artificial turf products and far fewer days are lost in terms of usage due to field conditions. Furthermore, FieldTurf does not require labor associated with frequent mowing or striping of natural turf athletic fields. The use of gas powered mowers on natural systems also results in air emissions of metals and hydrocarbon breakdown products.

In addition, there are a number of stormwater management advantages to the use of artificial turf, specifically FieldTurf. These include:

WATER QUANTITY IMPROVEMENTS

DRAINAGE

Artificial turf has superior water drainage characteristics, when compared to natural turf. It was designed to drain water to limit the periods of time that an athletic field is unavailable for play due to a storm event. This capability to drain rainfall is also beneficial when considering ways to manage stormwater, increasing infiltration and limiting the amount of runoff that leaves the field/site.

REDUCTION IN PEAK STORMWATER FLOW

Stormwater that falls on artificial turf must travel through the different components of the artificial turf product before entering a natural waterway, including the infill turf, infill, backing, and subsurface. This results in a reduction in the peak stormwater flow to the waterway, which can have positive effects, such as a reduction in erosion.

WATER QUALITY IMPROVEMENTS

DECREASE IN FERTILIZER AND PESTICIDE USE

Artificial turf (e.g., FieldTurf) does not require the traditional lawn supplements that are necessary to maintain healthy natural turf. Among other inputs, this includes fertilizers and pesticides. Fertilizers and pesticides can and do wash off of natural turf in a rain event, degrading downstream water quality. The use of artificial turf can improve the quality of any stormwater that does leave the site and minimize the requirements for stormwater quality controls.

FILTRATION

Artificial turf can act as a filter, capturing solid material suspended in stormwater that flows over and/or through the surface. This filtering action can reduce the phosphorus and sediment load carried by the stormwater that ultimately reaches natural waterways, thereby improving water quality.

G. EXPERIMENTAL DESIGN AND STUDY PLAN FOR A FIELD TESTING PROGRAM – RELATIVE EFFICIENCY OF FIELDTURF VS. NATURAL TURF FOR MANAGING STORMWATER

Further experimental testing could help to refine appropriate RCNs for FieldTurf applications. As is reflected in the RCN values provided in the MDE Stormwater Design Manual for porous pavement, RCNs for Field Turf applications are likely to be a function of both the depth of the underlying subsurface gravel bed and the Hydrologic Soil Group associated with the subgrade material.

Given these parameters, an effective experimental design to develop RCNs for FieldTurf applications would systematically vary both Hydrologic Soil Group (i.e., A, B ,C) and Gravel depth (i.e., 6 in., 9 in., and 12 in.) Thus, nine (9) experimental plots would be required to fully capture the range of possible hydrologic soil groups and gravel depth combinations. Ideally, each plot would be replicated, yielding a total of 18 plots.

Individual plots should be identical in size and slope and should be located in a similar geographic area to permit the use of directly comparable precipitation data. Plots should be located on mildly sloping ground (no more than 5% slope) and should be at least 50 ft. x 50 ft. in size. Plots should be located on open ground with no overhanging cover.

To measure surface runoff from the site, the drainage area associated with each field plot must be isolated. If possible, plots should be located at or near a natural drainage divide to avoid the necessity of rerouting upstream flow around the plots. However, if needed, small earthen berms can be constructed at the upstream extents of the plots to redirect upstream flows.

Surface runoff from the each plot should be collected into a downslope piping system or earthen channel. Since the plots are small, a relatively modest channel or piping network will suffice. AKRF would develop a flow rating curve for the conveyance channel or pipe using manual velocity measurements. Flow stage within the pipe or channel would then be measured continuously using pressure transduction and converted to discharge measures using the aforementioned rating curve. Alternatively, flow could be conveyed to a weir structure and discharge could be calculated using standard equations for weir flow by measuring the flow stage at the weir.

In addition to flow monitoring, the FieldTurf test plots could be used to evaluate the effects of FieldTurf on water quality, both for surface water and water that is infiltrated through the turf system. Evaluation of surface water quality would involve collection of flow-weighted water samples using an ISCO sampler or similar automated sampling device. Typical constituents of interest would include nitrate, nitrate, ammonia, dissolved phosphorus, total phosphorus, total suspended solids, and toxic metals. Measured concentrations could be either compared with rainwater samples collected near the test plots, or alternatively with surface runoff collected from a nearby control plot (i.e., a similarly sized plot covered with natural turf). Collection of water quality samples to characterize infiltrated rainwater would involve the collection of infiltrated water via an underdrain system located beneath the porous gravel bed.

The final experimental design will depend on further coordination with FieldTurf representatives. We do note that the experiment design described above represents an ideal configuration. However, less intensive studies may yield useful, although perhaps not as widely applicable results. Accordingly, the experimental design can be simplified/reduced as needed to accommodate available resources. For instance, a smaller experimental design could be developed using only Hydrologic Soil Groups A and C and gravel depths of 6” and 12”. We would also need to coordinate with FieldTurf to determine whether any of their existing installations could be useful or modified for incorporation into our experimental design.

Once an experimental design is developed and agreed upon, we may wish to coordinate with MDE prior to conducting additional field studies.

H. COMPARISON WITH OTHER PRODUCT

AKRF compared permeability rates associated with FieldTurf to another leading synthetic turf product (AstroTurf Gameday Grass). It appears that FieldTurf had much higher permeability rates (139.2 in./hr vs. >30 in/hr) than AstroTurf using the same test (ASTM F1551-03)**.** Even if AstroTurf’s permeability rate were doubled to 60 in/hr, it would still be less than half of that for FieldTurf. Therefore, if both products used the same subsurface treatment, it is reasonable to assume that FieldTurf would exhibit substantially better infiltration characteristics for stormwater management purposes. Both products have infiltration rates that are significantly higher than the 8.0 in/hr required for permeable pavement by the MDE Stormwater Design Manual.

I. CONCLUSION

A number of approaches were developed that suggest FieldTurf has considerable promise as an ESD practice under the Maryland Stormwater regulations. FieldTurf’s infiltration potential appears to be as good or superior to that of permeable pavements, which is an accepted ESD practice. Results of a hydrologic model applied to field data from the Coatesville High School study further support these findings and suggest that RCNs for FieldTurf may be lower than those for permeable pavements. However, additional experimental testing to refine the appropriate runoff curve numbers for FieldTurf applications is needed before a case for ESD can be made to the Maryland Department of the Environment.

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Attachment A

A-2. Permeable Pavements

Permeable pavements are alternatives that may be used to reduce imperviousness. While there are many different materials commercially available, permeable pavements may be divided into three basic types: porous bituminous asphalt, pervious concrete, and permeable interlocking concrete pavements. Permeable pavements typically consist of a porous surface course and open graded stone base/subbase or sand drainage system. Stormwater drains through the surface course, is captured in the drainage system, and infiltrates into the surrounding soils. Permeable pavements significantly reduce the amount of impervious cover, provide water quality and groundwater recharge benefits, and may help mitigate temperature increases.

Applications:

Permeable pavements are effective for reducing imperviousness in pedestrian pavements, parking lots, driveways, plazas, and access roads. They may be used in both new and redevelopment applications in residential, commercial, and industrial projects. Permeable pavements are particularly useful in high-density areas where space is limited.

Performance:

When designed according to the guidance provided below, areas covered by permeable pavements will have runoff characteristics more closely resembling vegetated areas. The capacity of permeable pavements to capture and detain runoff is governed by the storage capacity, compaction of the soil subgrade, and in-situ soil properties. Consequently, RCN's applied to these systems vary with individual design characteristics. The effective RCN's shown in Table 5.5 are used when addressing the ESD Sizing Criteria.

Constraints:

The following constraints are critical when considering the use of permeable pavements to capture and treat stormwater runoff:

- **Space:** The size and distribution of paved surfaces within a project must be considered early during planning and design. Permeable pavements should not be used in areas where there are risks for foundation damage, basement flooding, interference with subsurface sewage disposal systems, or detrimental impacts to other underground structures.

- **Topography:** Runoff should sheetflow across permeable pavements. Pavement surfaces should be gradual ($\leq 5\%$) to prevent ponding of water on the surface and within the subbase.

- **Soils:** Sandy and silty soils are critical to successful application of permeable pavements. The HSG should be A, B or C.

Subsurface water conditions (e.g., water table) will help determine the stone reservoir thickness used. The probability of practice failure increases if the reservoir intercepts groundwater. Therefore, subbase inverts should be above local groundwater tables.

- **Drainage Area:** Permeable pavements are an at-source practice for reducing the effects of impervious cover and addressing ESD criteria. As the impervious area draining to each practice increases, practice effectiveness weakens. Therefore, runoff from adjacent areas (or "run-on") should be limited.

- **Hotspot Runoff:** Permeable pavements should not be used to treat hotspots that generate higher concentrations of hydrocarbons, trace metals, or toxicants than are found in typical stormwater runoff and may contaminate groundwater.

- **Structure:** Most permeable alternatives have a lower load bearing capacity than conventional pavements. Therefore, applications should be limited to locations that do not receive heavy vehicle traffic and where sub soils are not compacted.

- **Operation:** Permeable pavements are highly susceptible to clogging and subject to owner neglect. Individual owners need to be educated to ensure that proper maintenance and winter operation activities will allow the system to function properly.

Design Guidance:

The following conditions should be considered when designing permeable pavements:

- **Conveyance:** *Runoff shall flow through and exit permeable pavements in a safe and non-erosive manner.* Permeable pavements should be designed off-line whenever possible. Runoff from adjacent areas should be diverted to a stable conveyance system. If bypassing these areas is impractical, then runoff should sheetflow onto permeable pavements.

  Pavement surfaces shall have a permeability of eight inches per hour or greater to convey water into the subbase rapidly. The slope of the permeable pavement shall be no greater than 5%. Any grade adjustments requiring fill should be accomplished using the subbase material. Permeable pavements may be placed in sloped areas by terracing levels along existing contours.

  Pavement systems should include an alternate mode for runoff to enter the subbase reservoir. In curbless designs, this may consist of a two-foot wide stone edge drain. Raised inlets may be required in curbed applications.

  The bottom of the subbase shall be level to enhance distribution and reduce ponding within the reservoir. A network of perforated pipes may be used to uniformly distribute runoff over the bed bottom. Perforated pipes may also be used to connect structures (e.g., cleanouts, inlets) located within the permeable pavement section.

All permeable pavements shall be designed to ensure that water surface elevations for the 10-year 24 hour design storm do not rise into the pavement to prevent freeze/thaw damage to the surface. Designs should include overflow structures like overdrains, inlets, edge drains, or similar devices that will convey excess runoff safely to a stable outfall.

- **Treatment:** All permeable pavement systems shall meet the following conditions:
  - *Applications that exceed 10,000* ft^2 *shall be designed as infiltration practices using the design methods outlined in Appendix D.13 for infiltration trenches. A porosity (n) of 30% and an effective area of the trench (*A_t*) equal to 30% of the pavement surface area shall be used.*
  - *A subbase layer of a clean, open graded, washed aggregate with a porosity (n) of 30% (1.5" to 2" stone is preferred) shall be used below the pavement surface.* The subbase may be 6", 9" or 12" thick.
  - *Filter cloth shall not be used between the subbase and soil subgrade.* If needed, a 12" layer of washed concrete sand or pea gravel (⅛" to ⅜" stone) may be used to act as a bridging layer between the subbase reservoir and subsurface soils.

Table 5.5 Effective RCNs for Permeable Pavements

Subbase	**Hydrologic Soil Group**			
	A	**B**	**C**	**D**
6"	76[1]	84[1]	93[2]	—
9"	62[3]	65[3]	77[3]	—
12"	40	55	70	—

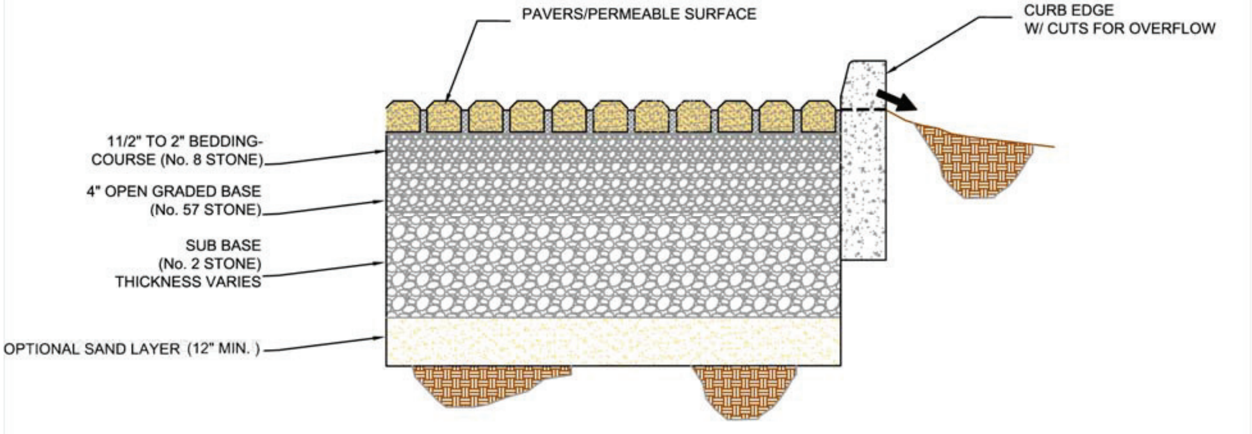
[1] Design shall include 1 - 2" min. overdrain (inv. 2" below pavement base) per 750 s.f. of pavement area.

[2] Design shall include 1 - 2" min. overdrain (inv. 2" below pavement base) per 600 s.f. of pavement area

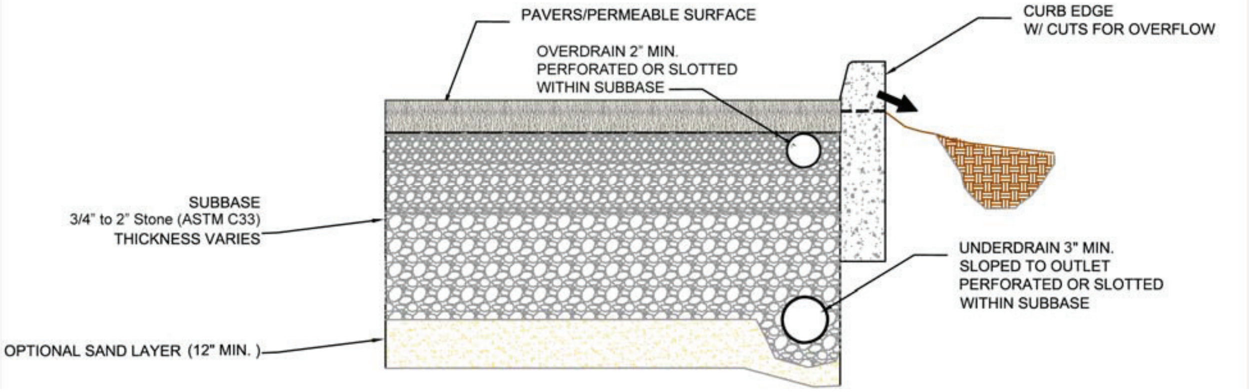
[3] Design shall include 1 - 3" min. overdrain (inv. 3" below pavement base) and a ½" underdrain at subbase invert.

- **Soils:**
  - *Permeable pavements shall not be installed in HSG D or on areas of compacted fill. Underlying soil types and condition shall be field-verified prior to final design.*
  - *For applications that exceed 10,000* ft^2*, underlying soils shall have an infiltration rate (f) of 0.52 in/hr or greater.* This rate may be initially determined from NRCS soil textural classification and subsequently confirmed by geotechnical tests in the field as required in Chapter 3.3.1.
  - *The invert of the subbase reservoir shall be at least four feet above (two feet on the lower Eastern Shore) the seasonal high water table.*

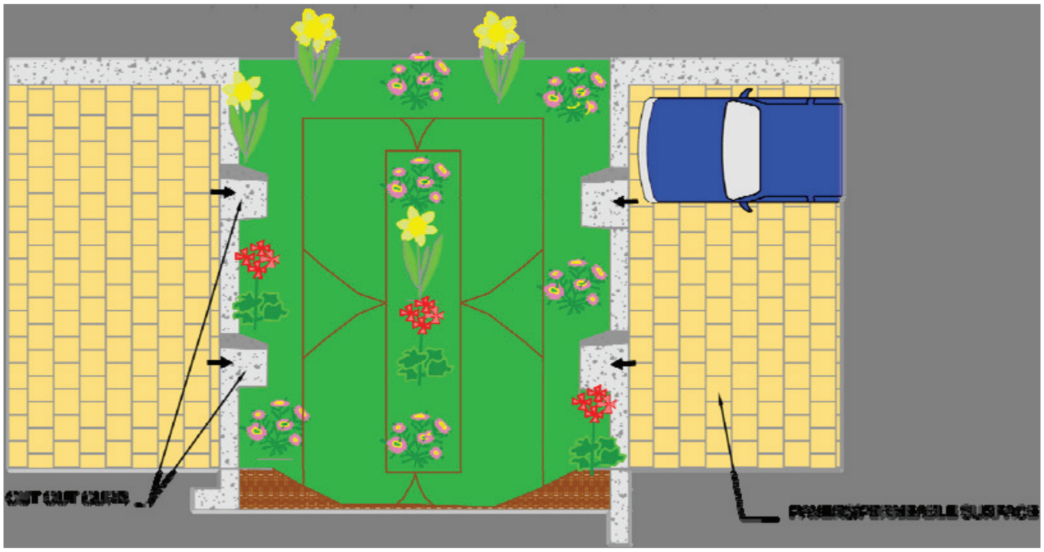
Figure 5.3 Examples of Permeable Pavements



Typical Section



Typical Section w/Overdrain & Underdrain



Permeable Pavement w/Micro-Bioretention - Plan View

- **Setbacks:**
    - *Permeable pavements shall be located down gradient of building structures and be setback at least 10 feet from buildings, 50 feet from confined water supply wells, 100 feet from unconfined water supply wells, and 25 feet from septic systems.*
    - Permeable pavements should also be sized and located to meet minimum local requirements for underground utility clearance.

- **Structure:** *All permeable pavement systems shall be capable of bearing the anticipated vehicle and traffic loads.* Pavement systems conforming to the specifications found in Appendix B.4 should be structurally stable for typical (e.g., light duty) applications.

- **Landscaping:** *Permeable pavement shall be identified on landscaping plans.* Trees and shrubs should not be located adjacent to asphalt and concrete if damage by root penetration and clogging from leaves is a concern.

Construction Criteria:

The following items should be addressed during construction of projects with permeable pavement:

- **Erosion and Sediment Control:** Final grading for installation should not take place until the surrounding site is stabilized. *If this cannot be accomplished, runoff from disturbed areas shall be diverted around proposed pavement locations.*

- **Soil Compaction:** *Sub soils shall not be compacted.* Construction should be performed with lightweight, wide tracked equipment to minimize compaction. Excavated materials should be placed in a contained area.

- **Distribution Systems:** *Overdrain, underdrain, and distribution pipes shall be checked to ensure that both the material and perforations meet specifications (see Appendix B.4). The upstream ends of pipes should be capped prior to installation.* All underdrain or distribution pipes used should be installed flat along the bed bottom.

- **Subbase Installation:** *Subbase aggregate shall be clean and free of fines. The subbase shall be placed in lifts and lightly rolled according to the specifications (see Appendix B.4).*