



Standards Oversight Council (SOC)

Supporting Technical Standards for Soil and Water Conservation

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DRAFT PERMEABLE PAVEMENT MEETING NOTES

December 16, 2013 || 9:00am – 3:30pm

Room 121A, Dane County LCD Office, 1 Fen Oak Ct., Madison, WI 53718

Attendees: Josh Harder, Chris Homburg, Bob Roehrig, Tim Troester, Pete Wood, Laura Fenley, Bob Givens, Kate Gleason, Gini Knight, Roger Bannerman.

Welcome / Team Member Updates

Research Plot Update

The USGS/WDNR/County Materials research site needed to be relocated due to site conditions, mainly high ground water. The research group is now investigating the Sycamore Landfill/Dog Park employee asphalt parking lot for site location. The park gets a lot of use all year round and is controlled by the Engineering Department by the City of Madison. So far they have been good to work with, so the site looks promising. The target construction date is April 2014, depending on weather. The permitting will go through Tim Troester.

Review broad review comments

The team reviewed all of the comments from the broad review and developed responses to comments in order of the comments. We started with key concerns from team members, then move through the entire standard. All of the comments and responses are listed at the end of this document.

Next Steps / Action Items:

- Pete to make draft revisions to the standard based on the meeting discussion.
- Gini/Pete to work on crafting responses to broad review comments based on team discussion.
- Josh will draft a forward or intro to provide at the beginning of the Tech Note to describe general intent of standard, research, etc
- Roger will 1) find references to alternate infiltration rate testing, 2) Check on rain file data in SLAMM; and create an example for the Tech Note
- Gini, Pete, and David will continue to work on outreach/training plan
- All team members to review and respond to revised draft standard and Tech Note by mid January

Broad Review Comments for WDNR standard 1008, Permeable Pavement

Nov 5 – Nov 27, 2013

Comments are listed in the order of the standard. Responses are in bold and begin with 'R:'.

General

- We felt that the standard as a whole is overly verbose and sometimes unclear.
 - The specification for filtering pavement is presented no less than three times.
 - Section V.E.4.a was noted. *This comment was inserted later in this document, under V.E.4 section.*
 - Section V.J.3, for example, could be condensed to say "...pipes shall have an open-graded aggregate bedding layer no less than 4 inches in thickness on all sides."

R: The infiltration pretreatment and underdrain sections will be revised as suggested.



- The Technical Standard needs to be written as generic as possible to allow for the flexibility of emerging and current technologies. A one size fits all standard does not incentivize public and private entities to use permeable technologies. Especially new technology that far exceeds existing infiltration rates of brick and permeable paver technology.

R: The permeable pavement technical standard will establish minimum criteria that must be met by all permeable pavement systems that will be designed and installed for regulatory purposes. This approach is consistent with the technical standards that have been developed for other storm water control practices. It's understood that there are differences between the various permeable pavement systems. However, it's unclear at this time how these differences, including surface infiltration rate, impact storm water pollutant removal. The technical standard will be revised in the future if research suggests that the variability in pollutant removal associated with these differences is significant.

- A study funded by the U.S. Environmental Protection Agency and researched in conjunction with the University of Louisville in partnership with the Louisville Metropolitan Water Reclamation District is currently underway. It is studying the effects of non-filled joints of Permeable Articulating Concrete Block/Mat (P-ACB/M) systems. The initial study was only supposed to last 12 calendar months. However, due to advancements in maintenance of P-ACB/M's the study continued for an additional 12 months. The final report by Kasra Kazemi, Graduate Research Assistant, Civil and Environmental Engineering from the University of Louisville is not expected to be finished until late March of 2014. Even though I.C.P.I. personnel like to show the picture below to potential customers they are only getting half of the story. *Initial reports are still showing between a 30- 60% INFILTRATION rate even when visually clogged.*

Moving forward with this technical standard without this information would be foolish.

R: Technical standards are guidance documents that are routinely reviewed and updated based on new information. The team has been involved in the planning process for an intensive permeable pavement monitoring project that will be conducted in the Madison area in the near future. In addition, the team is committed to tracking permeable pavement research and meeting on an annual basis to review available information and revise the technical standard as necessary.

- Spancrete has been innovating the precast industry for almost 70 years. Designing precast products, perfecting production processes, engineering hollowcore systems and authoring the standards for research, design, production, installation and safety in the precast industry. Spancrete is a leader in precast pervious concrete and the first precaster worldwide to utilize hollowcore technology for pervious concrete.

Spancrete acknowledges that the intent of the specification is to guide future permeable pavement projects and that the specification is written to include all available techniques/technologies for building with permeable surfaces. However, we feel the infiltration rates of 100 in/hr at the time of new construction and a minimum of 10 in/hr over time are too low. For the record, Spancrete recommends an initial minimum infiltration rate of 250 in/hr as anything less creates nuisance maintenance. Long term maintenance based on a percentage decrease in infiltration (for example 50%). Beyond noting our concern, we will not be requesting a change to the infiltration rates.

Land Cover	Infiltration Rates in./hr (mm/hr)	Curve Number CN	Runoff Co-efficient, C
Permeable Interlocking Concrete Pavement	Up to 50 in./hr (1270 mm/hr) with maintenance 3-4 in./hr (75-100 mm/hr) with no maintenance	45 - 80	0.00 - 0.30
Impervious Asphalt or Concrete Pavement	0 in./hr (0 mm/hr)	95 - 98	0.90 - 0.95

Fundamentally, we would like to clearly note in several specific sections that although the parameters are based off infiltration rates of 100 in/hr or 10 in/hr (depending on the context), that there are products available which exceed those rates. We also would like to note each instance where Tables, equations, examples, etc. are based off 100 in/hour (not just a one-time mention in the Technical Note II-2 "Initial Surface Infiltration Rate"). The statement in Technical note II-2 in regards to 100 in/hr as conservative is inaccurate as it assumes all permeable surfaces are equal; paver systems rarely exceed 100 in/hr (see below, or PICP Fact Sheet PDF page 3) while pervious concrete systems can easily exceed 1000 in/hr.

These rates are critical to the size and scope of the project as well as the long term maintenance and we are requesting that this distinction be acknowledged.

R: The team believes that there are a significant number of permeable pavement surfaces that can achieve an initial surface infiltration rate of 100 in/hr. The pavement surface infiltration properties section will be revised to indicate that there are permeable pavement surfaces that can exceed an initial surface infiltration rate of 100 in/hr.

- The Technical Standards have become a regulatory tool that is integrated into the WRAPP permit application. The draft technical standard related to permeable pavers appears to be more specific to brick paver blocks, which is only one of many permeable pavement systems available on the market. Utilizing other technologies that might be superior to brick pavers would be problematic from a technical standards perspective and would not be acceptable to regulators even though those technologies might/will outperform the brick pavers that the technical standard appears to be based upon. The Technical Standard needs to be written as generic as possible to allow for the flexibility needed for emerging and current technologies. This is not a one size fits all standard and the consequences of adopting this standard as it now stands will not incentivize public and private entities to use alternative paver/pavement systems that may exceed brick paver performance now and in the future.

R: The team does not believe that the technical standard is specific to brick paver blocks or that other technologies will not be acceptable to regulators. As previously indicated, the technical standard establishes minimum criteria for all permeable pavement systems. The technical standard is not a "product acceptability list" and only general terms are used, such as pervious concrete, porous asphalt and permeable pavers/blocks. The infiltration pretreatment and underdrain discharge credit sections include criteria that is specific to the joints associated with permeable paver/block systems. However, this is necessary because water flows through the joints rather than through a pavement matrix.

- Shouldn't there be a limit on surface or aggregate storage reservoir slope? In theory you could get full credit on a steep slope the way the standard is written.

R: The aggregate storage reservoir section will be revised to include subgrade slope criteria as suggested.

- Great job team...this is a great standard!

R: Thanks!

III. Conditions Where Practice Applies

- It is stated that permeable pavement can be used in areas where infiltration is prohibited “when appropriate liners and subsurface drainage mechanisms are installed where needed”. I think it would clearer if the term “subsurface drainage mechanisms” would be qualified with “which inhibit infiltration” or similar language.

R: The liner language will be revised as suggested.

V.A. Site Criteria

- The Site Evaluation for Stormwater Infiltration (1002) does not include a permeable pavement device under Table 1 to define evaluation requirements. Is a permeable pavement device considered a surface infiltration basin and if so should this be mentioned in the permeable pavement technical standard? Or should the Tech Standard 1008 simply address this for a permeable pavement.

R: The site criteria section indicates that the requirements for “Subsurface Dispersal Systems” found in Technical Standard 1002 – Table 1 should be used for permeable pavement systems. Permeable pavement systems will be added to Table 1 when Technical Standard 1002 is revised in the future.

- V.A.3. Should there be a required 100-foot well setback, per NR 812.08(4)(d)6?

R: Required separation distances to wells and other features are identified in s. NR 151.124, Wis. Adm. Code, which is referenced in the conditions where practice applies section.

- V.A.3.b. Would there be a problem with being closer than 10-feet for buildings with no basements or slab on grade construction? If so, shouldn't the separation apply to more than just buildings (i.e. utility boxes, poles, other pavement systems...)?
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R: This language is essentially the same as the language found in the technical standards for other infiltration practices. The team believes that potential problems associated with other structures are less common.

V. B. Pavement Surface Design

- Under section 1008 V.B. pervious concrete, porous asphalt, and permeable pavers/blocks are listed as the 3 pavement surface designs. Under the Definition in 1008 I., pavement systems include these 3 but also allows for a “similar surface that allows movement of stormwater through the pavement...”. I think it would be beneficial to include a more generic option under section V.B. to allow for different technologies like the Definitions section does. Suggested wording would be: “4. Other types of permeable pavements shall comply with manufacturer’s recommended installation methods and meet the requirements of this Standard.” One permeable pavement which does not fit within the 3 types of pavements included in the draft standard is Filterpave by Presto which uses recycled glass and is bound by epoxy-resin glue.
- V.B. Pavement Surfaces Design: This should allow Invisible Structures, Inc.’s Gravelpave2 and Grasspave2 both of which are permeable. Gravelpave2 should be considered a pavement versus Grasspave2 more for parking areas that are used infrequently or for emergency access. The list eliminates these options and maybe Flexi-pave and it should not. The options by Invisible Structures and Flexi-pave are great for emergency access and recreation trails. Add another section V.B.4. stating, “Other Proprietary Products – Comply with manufactures specifications and standards.”

R: The pavement surface design section will be revised to include “Other Pavement Surfaces”.

V.C. Pavement Surface Infiltration Design

- Some guidance in the Technical Note on how to calculate the infiltration rate after clogging has occurred would be helpful.

R: The technical note will be revised to provide more clarification.

- Modeling the practice for its entire expected life-span seems excessive. Are there other BMP's that have this requirement? In any event is there any penalty exacted for having a shorter expected life?

R: The team believes that permeable pavement systems are more susceptible to reductions in performance over time than other practices. The anticipated life of the pavement will be determined on a case by case basis by the designer. Ultimately, the permeable pavement is considered "failed" if the in service surface infiltration rate drops below 10 in/hr. At that time, the permeable pavement surface must be repaired or replaced similar to other failed practices.

- Products on the market with higher infiltration rates may be substituted in the design provided third party test results per ASTM C1701 or ASTM C1781 document a rate higher than 100 in/hr. *(The intention is to convey that qualified tests per recognized testing methods should allowed to modify the design criteria, and that those reading this standard understand this option)*
- Please change sentence to: "An initial surface infiltration rate of *at least* 100 in/hr."
 - Reasoning: To assume all pavements have the max of 100 in/hr will discourage advancing technology and eliminate the market for those who can do better.

R: Based on preliminary modeling results, the use of 100 in/hr as the initial surface infiltration rate for design should not significantly limit anticipated pavement life as long as the minimum surface cleaning frequency is included in the design analysis. The use of higher initial surface infiltration rates for design based on third party testing may be considered in the future. However, the relationship between surface infiltration rate and pollutant removal must be considered.

- What is the "anticipated pavement life" of the different products?

R: It has been suggested that the anticipated pavement life for permeable pavements is similar to conventional pavements. For the purpose of this technical standard, the anticipated pavement life will be determined by the designer for site-specific conditions.

V.C.1. Should the rainfall file used be the average annual rainfall file for the location run over continuous years or some set period of historical rainfall?

R: A rainfall file that includes a period of historical rainfall data equivalent to the anticipated pavement life should be used. Details regarding rainfall files are found in the Technical Note.

- V.C. and V.D. :100 inches per hour seems to be a very high initial rate. The note in section V.D. says "Initial and in service surface infiltration rate testing is not mandatory per this technical standard." However, said sections say the infiltration rate "shall be". This is a conflict and the "shall be" should be changes to "desired to be".

R: The team believes that the 100 in/hr initial surface infiltration rate for design and installation is appropriate based on literature review, discussions with industry experts and preliminary modeling results. The minimum 100 in/hr surface infiltration rate upon completion of the installation is essentially "self-certification". The note suggests that field testing may be required if there are questions regarding the surface infiltration rate for a specific installation.

V.C.3.

- Please add to the end of the sentence “A surface clogging capacity of 0.4 pounds per square foot (lbs/sf) of permeable pavement surface area, *unless otherwise indicated by proprietary product manufacturer.*”
 - Reasoning: Some products may collect a greater volume of solids at the surface.

R: The surface clogging capacity was determined by correlating modeling results with monitoring data. Details regarding surface clogging capacity are provided in the Technical Note. The use of a different surface clogging capacity based on third party testing may be considered in the future.

V.C.4.

- Please add to the end of the sentence “A restoration of 50% of the surface infiltration rate reduction that occurs between cleaning events, *unless otherwise indicated by proprietary product manufacturer.*”
 - Reasoning: At least one product on the market has the tightest pore openings at the surface, which acts as a sieve and stops the larger particles at the surface. Particles that pass the first layer flow through the pavement to the storage zone below the pavement section. If the surface can be vacuumed or power washed, the blockages are probably closer to 90% removed.

R: 50% is considered a conservative value for surface infiltration rate restoration. Details regarding surface infiltration rate restoration are provided in the Technical Note. The use of a different surface infiltration rate restoration percentage based on third party testing may be considered in the future.

- I think is worded poorly. I had to really look into the tech note before I figured out what that paragraph was talking about.

R: The language regarding surface infiltration rate restoration will be revised.

V.D. Pavement Surface Infiltration Properties

- The surface infiltration rate upon completion of the installation shall be at least 100 in/hr, *however a variety of permeable pavement systems exceed this rate.*
 - *Note: (Spancrete requests the DNR reconsider the standard’s lack of mandatory testing of newly installed permeable pavement, the goal of any permeable pavement is to manage stormwater runoff in which the end user typically pays a premium compared to the cost of impermeable surfaces. It is Spancrete’s intention that the installer and the system be held accountable to the rated infiltration and performance as protection for the end user and our natural resources).*

R: The suggested language will be added to the pavement surface infiltration properties section. At this time, the team believes that 100 in/hr is a relatively low value that many permeable pavement installations will be able to achieve without the need for confirmation by mandatory testing.

- V.D.2. I think is worded poorly. I had to really look into the tech note before I figured out what that paragraph was talking about.

R: The language regarding the in service surface infiltration rate will be revised.

V. E.2. Pavement Surface Run-on

- We request rewording item E. 2. to state: “To minimize potential for pavement surface clogging, the ratio of run-on area to permeable pavement surface area shall be in accordance with Table 1, *or as designed using proprietary product manufacturer recommendations.*”
 - Reasoning: If particular product infiltration rates are substantially higher than 100 inches/hour, and clogging factors are less than you are showing, or better surface infiltration rate restorations are potential, a higher run-on to permeable ratio could be allowed. The professional designer should be allowed to provide all calculations for volume and quality, based upon manufacturer

recommendations. We are concerned that making all products equal will eliminate technology from advancing on this subject. If a better technology provides more treatment capability, they may also be more expensive than the 100 in/hr technology. The regulation should not prohibit product advancement.

R: The pavement surface run-on criteria were established independent of the pavement surface infiltration design parameters. Permeable pavement technical standards published by other states recommend using caution with regards to run-on ratios and source areas. Other states limit run-on ratios to no more than 2:1. The team believes that allowing greater flexibility regarding run-on is important to facilitate the use of permeable pavement in Wisconsin. However, Table 1 represents the maximum level of flexibility that the team is willing to consider at this time.

Table 1.

- The Run-on Ratio table is going to raise some eyebrows because it does not match what many practitioners have learned about stormwater. More explanation may be needed. It is curious that the lowest run-on ratio is for landscaped areas, which in SLAMM typically produces lower TSS loadings than parking lots or roads. Also curious is that rooftops and parking lots have the same run-on ratio, and roof tops are considered to have much cleaner runoff than parking lots. Given the unknowns about some of the assumptions of the pavement performance in the standard, it may be prudent to use a more conservative run-on ratio for parking lots, especially in light of the fact that other states that have permeable pavement standards do not go as high as 5:1.

R: Previous drafts of the technical standard included a maximum 5:1 run-on ratio regardless of source area type. Based on initial review comments, the technical standard was revised to identify prohibited run-on source areas and provide some distinction between allowable run-on source areas. Table 1 is intended to maintain the 5:1 ratio for as many source areas as possible, including parking lots. The highest pollutant loading source area (roads) was reduced from 5:1 to 3:1. Landscape areas was reduced from 5:1 to 1:1 due to the type of pollutants (e.g., mulch and soil particles) that potentially discharge to permeable pavement surfaces.

- Table 1 uses a 3:1 ratio for run on from roads and 5:1 for parking lots. E.4. uses a carte blanche 3:1, should it be prorated between 3:1 and 5:1 to be consistent?

R: The effective infiltration area language will be revised.

- I agree that Landscape Areas tend to have more particulate matter in its runoff that could lead toward clogging of pervious pavement. However, it seems unlikely that landscaped areas would approach a 1:1 ratio. Having a 1:1 ratio implies that it is fine to have up to 1:1 runoff from landscaped areas. Instead, I suggest removing the landscaping 1:1 category and direct that landscaped areas should be directed away from pervious pavement to the extent feasible. Landscaped areas tend to have more particulate matter in its runoff that can lead to clogging from a combination of issues including elevated landscape areas, loss of mulch, non-vegetated areas, disturbed earthen areas from vehicle and pedestrian traffic driving over edges of landscaping, soil disturbance associated with replanting.
- Table 1 should include additional source areas such as woods, prairies, meadows and agricultural lands. Clarification should be given for whether the source areas should be the existing or a planned condition.

R: The pavement surface run-on section, including Table 1, will be revised as suggested.

- Table 1 based off infiltration rates of 100 in/hr, products exceeding 100 in/hr will have higher run-on ratios. (*The intention is to convey that higher infiltration rates will change the ratios as those systems can accept more water*)

R: As previously indicated, the run-on ratios identified in Table 1 were not established based on surface infiltration rates.

- Should “landscape areas” be “landscape areas other than turf grass”? I think this would limit confusion over what constitutes a landscape area.

R: The pavement surface run-on section will be revised regarding landscape areas.

V.E.3. Instead of using a pro-rating formula, wouldn't it be better to just defer to the limiting run-on ratio? If order for the pro-rating to be correct, it would have to account for the location of the source areas. If the landscape area is adjacent to the pavement versus being separated by turf grass you would expect a different clogging rate.

R: The team believes that Equation 1 is adequate regardless of the relationship of individual source areas to the permeable pavement surface. To be conservative, designers have the option of using the limiting run-on ratio. As suggested in the considerations section, runoff from run-on source areas should be distributed as evenly as possible across the permeable pavement surface area.

V.E.4.a. ii.

- In regards to a comment about the standard being unclear... In another instance, our staff spent a half hour arguing about whether section V.E.4.a is intended to describe the use of pavement itself as pre-treatment or to some other pre-treatment BMP, because the text is unclear (to some people, at least), doesn't define what pre-treatment means in this context, or what the “pavement system” is.

R: The infiltration pretreatment language will be removed from the pavement surface run-on section and a new infiltration pretreatment section will be created.

- The aggregate used between paver blocks is specified as ASTM No. 8, 89 or 9. I don't believe these are the full specifications. It would be beneficial to use the full specifications. It appears that it should be ASTM C-33 No. 8, ASTM D448 No. 89 and I don't know what No. 9 is. I can't verify because I don't have access to the ASTM standards. This same issue is present in section 1008 V.K.3.b, and in Figure 1.

R: The aggregate specifications will be modified as suggested.

- We are concerned that the requirement of aggregate filled joints will discourage the use of our paving system known as PaveDrain® which does NOT require the use of an aggregate between the joints in order to function properly. Owners, engineers, architects and contractors all complain about filling the joints between permeable pavers with a small aggregate (i.e. #8's or #9's).
 - a. The smaller aggregate gets stuck to shoes and tracked INTO existing buildings.
 - b. Maintenance Expense – The joints must be filled with small stone in order to stay in place. However, these joints become clogged with debris, rendering them mostly *impermeable*. In order to get them functioning again, the joints must be vacuum cleaned and then re-filled with aggregate in order to remain in place. This costly repetitive step is a constant complaint.
 - c. Another aggregate to manage on site.
 - d. Infiltration rate, although fast, is not fast enough, especially once it begins to clog.
 - e. Re-filling of joints whether clogged or not is a necessary evil.

Maintenance of the aggregate depth between the joints of a permeable paver varies from one square foot area to the next in virtually every job. For *THIS* to be **THE** defining item of a technical paper such as this renders it a JOKE of a standard. The Interlocking Concrete Paving Institute (I.C.P.I.) wants to

identify the stone filled joint as being a filtration media. However, the consistency of the depth of rock on a permeable paver installation varies following ONE (1) rain event following installation.

We find it ironic that this committee which consists of several members of the permeable paver world, focused on the one big item that differentiates the PaveDrain system from permeable pavers; rock filled joints.

Almost 100,000 square feet of the PaveDrain system was installed in the Wisconsin area in 2013. Owners, engineers and contractors alike are removing permeable pavers from their plans and inserting the PaveDrain system into them. Precedence is being set at this very moment. The incorporation of a larger unit that does NOT have to have its joints filled with aggregate is being readily accepted in the market place.

R: Pretreatment of runoff prior to infiltration into the soil subgrade is required by State law (see s. NR 151.124(7), Wis. Adm. Code). The technical standards for infiltration practices, including permeable pavement, must include specific criteria intended to meet the regulatory pretreatment requirement. According to existing DNR policy, no run-on to permeable pavement surfaces is allowed under the assumption that permeable pavement does not provide pretreatment. The permeable pavement technical standard will replace this policy with a more flexible approach to run-on and pre-treatment. The technical standard assumes that appropriate pretreatment is provided by filtration through the permeable pavement matrix and aggregate storage reservoir. For paver/block systems with joints, the small aggregate is essentially the pavement matrix or filter. However, the team agrees that the small aggregate doesn't need to be installed within the joints. The infiltration pretreatment language will be revised to indicate that the small aggregate can be installed within the joints (filled joints) and/or below the pavement (open joints).

V.E.4.b.

- If properly understood, this item touches on the key to allowing for designer discretion using manufacturer specifications. If this is the intention, this statement should be more of a guiding principal than an underlying "note".
 - **Reasoning:** If effective infiltration area is described as the "area of infiltration system that is used to infiltrate runoff to the native soil", then by way of creating a deeper stone storage zone, the ratio can be greatly varied. Our designs to date have shown that the area of permeable pavement can be somewhat small (say 10:1 run-on area to permeable) because the infiltration rates of the pavement are so much greater than the exfiltration or discharge rate of the underdrain, so that if the area of storage zone below the pavement is increased, we are able to treat much more area with less permeable pavement. This keeps costs lower, still achieves the intent and encourages that future development may actually see positive steps toward infiltration, reducing TSS, phosphorus, thermal pollution, etc. which is the overall common goal!
- I find V.E.4.b. to be somewhat lacking per guidance in Table 1 regarding parking lots.

R: The effective infiltration area language will be revised.

V.F. Pavement Surface Cleaning

- Is it the expectation that conventional street sweepers or the regenerative air or vacuum sweeper be adequate for cleaning this pavement since it won't be in a curb line?

R: Yes

- Cleaning of the pavement surface shall be conducted at least twice per year using industry recommended methods. *(Spancrete recommends power washing to clean our pervious precast hollowcore, which is not an acceptable method for some products— we request the elimination of any cleaning examples)*

R: The team prefers to keep the examples in the technical standard.

V.H. Pavement System Drainage

- Include “evaporation” as a method of drainage method as up to 2 in/day of water can be evaporated.

R: The team has discussed evaporation and will consider adding evaporation criteria to the technical standard in the future.

- V.H.3. How deep should observation wells be?

R: The observation well language will be revised to specify that observation wells should be installed to the aggregate storage reservoir/soil subgrade interface.

V.I. Soil Design Infiltration Rate

- The paragraph seems to mandate that the 1002 Table 1 infiltration rates be used, even if there is infiltrometer data. Could add a statement that measured and corrected infiltration rates from infiltrometer testing may be used if available. If there is no dead storage, and water is flowing to an underdrain, it may be more appropriate to use the dynamic infiltration rate, instead.

R: Design infiltration rates can be determined by field infiltration testing per Technical Standard 1002. The default design infiltration rates are found in Table 2 of Technical Standard 1002. Table 1 identifies the number of soil borings or pits that are required to identify site-specific soil and groundwater conditions.

V.J. Underdrains

- This section is confusing. It reads like you can exceed 72 hours of ponding if you put in an underdrain. It should read that you may need to install an underdrain in order to get the ponding time below 72 hours. Suggested verbiage: “Perforated underdrain piping or an equivalent drainage mechanism may be necessary to reduce the storage drain down time below 72 hours. The underdrain shall meet the following by design:”

R: The underdrain language will be revised as suggested.

- Initially the discharge of the pavement is alkaline if it is concrete and so treatment should be considered for the first year or so. This should be an issue if the discharge has little treatment downstream and the water resource has high ecological value.
 - <http://www.wgr-sw.com/SW-newsletters/RainEventsNewsletter-June2010-CA.pdf>
 - Page 16 of <http://water.epa.gov/polwaste/green/upload/stormwater2streettrees.pdf>

R: The team does not believe that this concern needs to be addressed in the technical standard at this time.

V.J.1.

- As the perforated pipe size increases the area of opening per circumference usually decreases. Most designers will not know this and will not check it. This is not an issue for 4” and 6” perforated pipe, but when the increase to 8” and larger the perforation area could be less than a 4” and so the collection capacity decreases. WinSLAMM may not consider in the analyses as it just asks for diameter and not length. WinSLAMM needs to consider the length of the underdrains for pavement and biofilters. V.J.2. does not provide criteria to size the perforations, like C=6, definition of design capacity. WinSLAMM does not provide design capacity so clarification needs to be provided.

R: The team believes that the designer is responsible for using appropriate computation methods for underdrain sizing.

- What is the reasoning for a minimum pipe diameter of 4-inches? I would think that 3-inch pipe would be adequate to prevent clogging.

R: The team believes that 4-inch perforated pipe is commonly used for permeable pavement systems. A 3-inch perforated pipe could be proposed if justification is provided.

V.J.3.

- Regarding pipe protection- is there a standard elsewhere that can be referenced? I am not sure that the methods listed will adequately protect pipes from crushing by vehicles.

R: The technical standard is not intended to directly address structural design concerns. It's assumed that permeable pavement systems will be designed to prevent pipe crushing.

V.K. Pollutant Removal Credit

- Are WinSLAMM calculations are incorrect and so Table 2 must be used? Yet, section L. says to use WinSLAMM.

R: Table 2 establishes the level of treatment that can be applied to the volume of runoff that discharges from permeable pavement systems through an underdrain. WinSLAMM is identified as an example of a model that can be used to perform the calculations but the use of WinSLAMM is not required. WinSLAMM can calculate the volume of runoff discharged through an underdrain. However, the values from Table 2 may need to be applied to this volume by hand calculation depending on the model version.

V.K.3.a.

- Does limiting the surface void ratio to less than 25% actually increase pollutant removal? How does the resulting average pore size in the pavement compare with the typical particle size of the pollutants? In the NURP distribution, our understanding is that the bulk of the TSS is less than 50 microns. Dissolved pollutants, such as dissolved phosphorus, nitrogen, and chlorides, will presumably flow right through regardless.

R: The percent voids criteria was selected based on information suggesting that permeable pavement surfaces are typically less than 25% percent voids. The fact that frequent surface cleaning is critical for restoration of surface infiltration rates suggests that significant pollutant accumulation occurs at and/or just below the pavement surface. The permeable pavement monitoring project in Madison will quantify the pollutant removal efficiency of various permeable pavement surfaces. The underdrain discharge credit may need to be revised based on the results of this monitoring project.

• V.K.3.b.

- The aggregate used between paver blocks is specified as ASTM No. 8, 89 or 9. I don't believe these are the full specifications. It would be beneficial to use the full specifications. It appears that it should be ASTM C-33 No. 8, ASTM D448 No. 89 and I don't know what No. 9 is. I can't verify because I don't have access to the ASTM standards. This same issue is present in section 1008 V.K.3.b, and in Figure 1.

R: The aggregate specification will be revised as suggested.

- We are concerned that the requirement of aggregate filled joints will discourage the use of alternate paving blocks that are designed to function without aggregate in the joints, but are just as capable of infiltrating stormwater and improving water quality.

R: The infiltration pretreatment and underdrain discharge credit language will be revised to allow the small aggregate to be installed below the pavement for open joint paver/block systems.

- The following pictures were taken at the Milwaukee County Sports Complex. Figure 1 typifies approximately 80% of the parking lot. The aggregate between the joints is not full depth, due to the loss of the joint aggregate, as required by the technical standard (Figure 2). This lot has only been in service for just under 2 years. Because maintenance of the depth of stone in the joints can be highly variable from site to site, the pretreatment capability of the joint stone, or lack thereof, can be questioned. We don't believe that a technical standard should be based upon something as highly variable as the stone depth in the joints and the ongoing and expensive maintenance to maintain a full depth scenario. (maintenance will not be done if the financial resources are not available and/or if there is no ongoing regulatory oversight of the installation)



Figure 1

Figure 2

R: The infiltration pretreatment and underdrain discharge credit language will be revised to allow the small aggregate to be installed within the joints and/or below the joints. Some depth of small aggregate will likely be required under the pavers/blocks even if the joints are filled. Systems with filled joints are specifically addressed in the operations and maintenance section.

V.K.3.c.

- What difference does the depth of the aggregate stone reservoir make if there is an underdrain at the bottom of the storage layer? It seems like pollutants would simply be carried through the stone to the underdrain and out. Is the implication that some gravity sedimentation occurs when the reservoir has a certain thickness?

R: The specific function of the aggregate storage reservoir in the filtration process is unknown at this time. It's assumed that the combination of the pavement/small aggregate matrix and the aggregate storage reservoir stone provides filtration prior to the underdrain.

- The WAPA website's (http://www.wispave.org/downloads/WAPA_Porous_Pavement.pdf) calls out a reservoir depth of 4' in our area (to get below potential frost), but the standard only calls out a minimum of 12". My concern is someone may claim they do not have to have an underdrain system because the drain down time will exceed 72 hours, but then only have a reservoir depth of 12" = subjecting the subgrade to freezing. The 12" minimum does not seem to match the industry standards (as mentioned on page 2, item B). I can use my judgement to insist on the drain, but not all plans are properly reviewed.

R: The team doesn't believe that subgrade freezing is a major concern. The subgrade would not be expected to be saturated during the time of year that freezing can be expected. In addition, it has been reported that some level of infiltration will continue to occur through a frozen subgrade.

V. N. Thermal Mitigation

- (What are the accepted computational methods used to determine stormwater temperature? Example software needs to be listed or software criteria need to be provided in the standard.

R: At this time, accepted computational methods for thermal mitigation have not been established. The use of permeable pavement systems for storm water temperature control will be evaluated on a case by case basis. Temperature sensors will be installed as part of the Madison monitoring project.

V.O. Construction Practices

- When construction is complete, inspect the permeable pavement surface and, if necessary, clean the surface using industry recommended standards. (*Spancrete recommends power washing to clean our pervious precast hollowcore, which is not an acceptable method for some products – we request the elimination of any cleaning examples*)

R: See previous response.

- V.O.3. Why not include the same items in Section 1004 V.B.9. of the DNR Bioretention standard? I believe these are good requirements. The backhoe or loader bucket used to excavate the subsoil interface will tend to create a compacted layer. It improves infiltration to break this up. Maybe there are some pavement settling issues by doing this?
- V.O.3. While this makes complete sense from an infiltration standpoint, has the subsoil compaction issue been discussed with the pavement industry? Is there any way to grade a permeable pavement area without compacting it in the process? From the perspective of contractors and developers, we would think they would be extremely reluctant to put expensive pavement on “soft” subsoil. Is compaction mitigation a realistic requirement that will be implemented? Or are the builders comfortable with just compacting the overlying stone?

R: The construction practice section was developed with input from members of the team with construction experience and representatives of the permeable pavement industry. It’s understood that the term “compaction” can be confusion in regards to permeable pavement installations. The language in this section will be revised to indicate that a reduction in porosity and permeability below the design parameters is the concern.

VI. Considerations

VI.A. This should be moved to V.E. or referenced in V.E.

R: The run-on section will be revised as suggested.

VI.B. VI.B. through VI.D. should be referenced in V.E.

R: The run-on section will be revised as suggested.

VI. F.

- This section talks about having aggregate berms on sloped soil subgrade (> 2%) so that water doesn’t seep out of the downslope pavement. This actually exposes a concern regarding the design infiltration volume and water quality treatment. If the soil subgrade is on a slope, the effective infiltration area will be less than the soil subgrade is in plan view. As water percolates through the stone storage layer it reaches the soil subgrade and then surface flows along the slope until it reaches the lowest spot and pools there. The soil subgrade infiltration rate is usually so low that very little water infiltrates in as it flows along the top surface. Remember when modeling swales we use a dynamic infiltration rate which is half of the static infiltration rate. I have seen this problem with infiltration basins which have a slight slope on the bottom. Water tends to pool at the low end but infrequently inundates the entire basin bottom, therefore rendering the effective

infiltration area to be much less than what was designed. The low area becomes overloaded and then can become prone to clogging. I have also seen berms going across the bottoms of sloped infiltration basins but again, the area which pools and infiltrates is significantly less than the total bottom area.

- I think it should be recommended if not required to make the soil subgrade flat. A good method to accommodate changes in grade is to terrace the subgrade in steps. Each terrace is flat and has a small berm or lip at the edge of the step to promote pooling on each terrace. I have seen long bioretention systems built along a slope and they are built with multiple cells, each one being flat but at varying elevations to accommodate the change in grade. These work quite well. If for some reason the soil subgrade has to be sloped, I suggest two methods to accommodate that. A) Model and take credit for an effective infiltration area which is less than the total subgrade area, based on the slope and some selected pooling depth which seems reasonable (2-3" ?). B) Make the soil subgrade design infiltration rate a "dynamic" infiltration rate such as what is used for swales.

R: The aggregate storage reservoir section will be revised as suggested.

VI.J.

- Item J mentions that the use of geotextile filter fabrics may be considered where appropriate, and item B on page 2 states the installation shall be in accordance with industry standards, with B(2) calling out the Wisconsin Asphalt Pavement Association (WAPA). On WAPA's website (http://www.wispave.org/downloads/WAPA_Porous_Pavement.pdf) they appear to require the use of a geotextile non-woven fabric and a filter layer. It appears some people like the fabric, and some do not because it could be a confining layer.

R: The requirement to follow industry standards is specific to the permeable pavement surface. The geotextile identified in the WAPA document appears to be located at the aggregate storage reservoir/soil subgrade interface and would not be considered part of the pavement surface installation.

VI.K. Should also consider seasonal and temperature limitations to installation.

R: The team believes that seasonal and temperature related concerns are generally covered in the construction and considerations sections.

VI.N.

- We recommend that the effects of sodium on the native soils (SAR effect) be discussed. As permeable pavement is likely to go in locations where road salt is liberally applied, maybe a cap should be placed on the clay content of the underlying soils, if any infiltration is expected. Limiting the use of road salt is a great idea, but then there is the reality of snow removal contractors.

R: The team agrees that SAR is a potential concern for systems that will infiltrate to the soil subgrade. However, a cap on clay content is not being considered at this time. The application of sodium chloride and SAR will be addressed during training and outreach events.

VI.O.

- While this makes complete sense from an infiltration standpoint, has the subsoil compaction issue been discussed with the pavement industry? Is there any way to grade a permeable pavement area without compacting it in the process? From the perspective of contractors and developers, we would think they would be extremely reluctant to put expensive pavement on "soft" subsoil. Is compaction mitigation a realistic requirement that will be implemented? Or are the builders comfortable with just compacting the overlying stone?

R: See previous response.

VIII. Operations and Maintenance

VIII.C.3 Inspections should be conducted after 72 hours of a rainfall event to verify that the storage area is draining down effectively.

R: This language will be revised as suggested.

VIII.D. Clean the pavement surface using the industry recommended methods, at least twice per year. *(Spancrete recommends power washing to clean our pervious precast hollowcore, which is not an acceptable method for some products – we request the elimination of any cleaning examples)*

R: See previous response.

VIII.E. The word “shall” should be changed to “may,” as this is not an ordinance.

R: The pavement surface infiltration properties section will be revised to indicate that permeable pavement systems with measured surface infiltration rates of less than 10 in/hr are considered failed. Failed practices must be repaired or replaced.

Add to this statement that testing permeable pavement must be done by any recognized standard for infiltration, as in ASTM C1701 or ASTM C1781.

R: This language will be revised as suggested.

X. Definitions

- The definition of Seasonal High Ground Water should include observed soil saturation and redoximorphic features. It should also consider soil textures that are not prone to reduction and oxidation due to the lack of iron or manganese.

R: The definition will be revised as suggested.

- Design Infiltration Rate- minor typo; size and infiltration

R: Thanks for the edit.

- Finally, could a definition of “Open” graded be added?

R: The definition will be added for open graded aggregate.

Figure 1.

- The aggregate used between paver blocks is specified as ASTM No. 8, 89 or 9. I don't believe these are the full specifications. It would be beneficial to use the full specifications. It appears that it should be ASTM C-33 No. 8, ASTM D448 No. 89 and I don't know what No. 9 is. I can't verify because I don't have access to the ASTM standards. This same issue is present in section 1008 V.K.3.b, and in Figure 1.

R: Figure 1 will be revised as suggested.

- Should the second layer on the right half of the right figure have a label?

R: Figure 1 will be revised to use one symbol to represent asphalt.

- Also, under Notes, Item 4, what is a Choker?

R: Figure 1 will be revised to eliminate the term choker.

- In Figure 1 of the Technical Standard, the joint aggregate is shown to be integral with the aggregate bedding layer. Since the joint stone is so variable due to stone loss and maintenance, and the aggregate bedding stone will not lose stone or require annual replacement once it is in place, it is recommended that the aggregate bedding stone be considered the basis for pretreatment and used as the required standard and not the full depth joint stone. This will provide the generic flexibility to all pavers and blocks currently available on the market and those that have yet to be developed.

R: Figure 1 will be revised to show an open joint alternative.

Technical Note:

- Technical Note is great but I think it would be even more useful if it were a case study rather than just marching through the method.

R: The technical note will be revised to provide a case study.

- The combined standard and note are ambiguous on how permeable pavement is intended to work. The two unit operations for pollutant removal (which are not discussed) appear to be:
 - Filtration in the pavement itself and perhaps the underlying media, and
 - Filtration where pollutants are left on the surface of the native soil after the water infiltrates. Some gravity sedimentation on the native soil interface may also occur when water flows laterally through the media to an underdrain.

The standard seems to view these processes to a certain extent as bad things, because in either case clogging of a filter occurs, leading to long-term problems. In particular, clogging of the native soil is undesirable because no restorative maintenance is possible, and there is natural process to maintain macropores. Some sort of up-front discussion of processes and objectives may be a good idea. Topics could include:

- Life-expectancy of a porous pavement system, given consistent maintenance
- How much sedimentation can be tolerated in the subsurface
- Pavement pore size versus pollutant particle size distribution

R: A companion document will be developed to address these issues.

- Page 1. I. Introduction. This introduction leads us to believe that the actual we are designing of the actual surface infiltration, anticipated pavement life and other actual specifications as dictated by the manufacturer. We understand the minimum rates of 100 in/hr and no less than 10in/hr at the end of the life, but other locations in the draft documents say “shall” use the values of 100 in/hr, etc. Please add a final sentence “If, due to manufacturer’s specifications, the pavement life, surface infiltration rate, surface clogging capacity or surface infiltration rate restoration is different than values shown herein, the designer may adjust these values per the manufacturer’s recommendations. This may allow for a greater run-on ratio than values shown herein.

R: This may be considered in the future if third party testing is provided.

- Some minor edits to the Technical Note: add a date; in section II.1. fifth line insert a “d” after anticipate; in section II.2. line 2 insert “upon” before literature; the Site Description field in the SLAMM screen shot on page 4 should read “Perm Pave with cleaning and no underdrain”.

R: Thanks for the edits.

- Section II. 2. Initial Surface Infiltration Rate. The assumption that the pavement will clog and need replacement within 10 years may be a good assumption for standard pervious pavement (asphalt or

concrete), but new products are being developed that may be pre-cast and may have design characteristics that would provide a much longer useful life. A general comment that by assuming all pavements to have a 100 in/hour starting point, greatly reduces an innovative manufacturer from developing a pavement product that can provide greater rates with less clogging, etc. Two of these products on the market today are PaveDrain® and Spancrete® Pervious. Limiting the potential run-on to well below what calculations show should be attainable, using a much lower infiltration rate than what their ASTM tests prove they achieve, along with a clogging factor and infiltration rate restoration that proves the product to have an end of useful life after 10 years, all lead the product costs to being prohibitive. We believe we are not alone that in this industry, we are hoping to see more pervious/porous pavements that work, but these factors will work against these new great products.

R: The anticipated life for permeable pavement surfaces that are cleaned at the minimum required frequency (i.e., twice per year) should exceed 10 years even when the required model input parameters are used. However, the team is interested in third party testing result that can be used to help refine these parameters. It's unclear if higher surface infiltration rates have a positive or negative effect on pollutant removal. The monitoring project in Madison will attempt to answer this question and others.

- In the Technical Note under Section III, the WinSLAMM version should be designated as v 10.0.2, not 10.0. I tried modeling the example in v. 10.0.0 and get erroneous surface infiltration rate results. I don't know if this was fixed in version 10.0.1 or 10.0.2.

R: The technical note will be revised to address the limitations of WinSLAMM.

- Currently there is no way to model treatment of water which would flow through the permeable pavement and out the underdrain. Apparently there are plans to add this ability to WinSLAMM so maybe there is no need to address this, but if this is going to take a while perhaps a work around should be discussed in the Technical Note (take the underdrain flow volume from detailed output and calculate the total treatment efficiency outside the model).

R: The technical note will be revised to address pollutant removal calculations.

- Currently in WinSLAMM the permeable pavement area and the soil subgrade area are entered as one and the same area. In some cases they will not be the same – especially with the run on ratio disparities for pavement (as shown in Table 1 of Standard 1008) and the effective infiltration area in 1008.V.E.4.b. It would be best if the model had the ability to differentiate these areas but if this is not added in the near future it may be good to describe some modeling tricks in the Technical Note which address this (prorating the reservoir porosity and subgrade infiltration rates by the area ratio). This may not be necessary if the run on ratios are made to align.
- I have modeling comments I would like to share with you. I created a model in WinSLAMM 10.0.0 using the same parameters shown in the Technical Note example. I have attached this model. I got goofy surface infiltration rate (the rate through the pavement) results. The surface seepage rate is supposed to slowly decline over time (governed by the surface clogging capacity) and then be partially restored after cleaning. This infiltration restoration as defined in the draft Standard 1008 V.C.4 is 50% of the surface infiltration rate reduction that occurs between cleaning events. One would expect a slow, stepped decline in the surface infiltration rate. WinSLAMM does not model this. The parameter that is entered into the Porous Pavement Device screen in WinSLAMM is called “Percent of Original Infiltration Rate Upon Cleaning”. The original or initial infiltration rate is 100 in/hr as defined by draft Standard 1008 V.C.2. By this definition, if the “Percent of Original Infiltration Rate Upon Cleaning” is 50%, after the initial cleaning the infiltration rate would be reduced to 50 in/hr, and after each cleaning the rate would be 50 in/hr. But my example WinSLAMM model does not do this either. Let me explain below what happened according to my interpretation of the detailed output (also attached). I focus on the results in the “Maximum Seepage Rate” in column M which appears to be the Surface Infiltration rate.

1. The max seepage rate starts at 100 in/hr and does not start declining until the end of March. This is because this is the end of the winter season. I am assuming this is desired.

2. The infiltration rate slowly declines to 96.22 in/hr and then drops to approximately half that at 48.03 in/hr after the first cleaning. So WinSLAMM does not reduce the rate to half the initial infiltration rate but to half of what the rate is prior to the cleaning.
 3. After the first cleaning the infiltration rate continues to decline at what appears to be a fairly constant rate. This decline does not appear to be affected with the cleaning after the first cleaning.
 4. The model shows that the surface infiltration rate goes to zero at the end of July, 1969 (the time series starts in 1962). The Technical Note results table shows that the surface seepage rate was 20.67 in/hr at the end of 1982. I am not sure why our modeling results are so dissimilar.
 5. To be a more effective tool it appears that WinSLAMM needs to be updated so that it models the infiltration rate restoration due to cleaning as defined in the draft Standard 1008.
- There are also a couple of other improvements which should be considered for WinSLAMM. Currently it appears that there is no way to model treatment of water which would flow through the permeable pavement and out the underdrain. I ran a permeable pavement model with an underdrain and it appear that the TSS removal is coming solely from the infiltration out of the system (the TSS removal rate equals the infiltration rate in the output summary). The biofilter control practice allows the user to enter a treatment efficiency for water being filtered and going out the underdrain. The permeable pavement control practice should have this same option. The other possible improvement would be to add the ability to enter the permeable pavement area and the native soil interface area independent of each other. In some cases they will not be the same – especially with the run on ratio disparities for pavement (as shown in Table 1 of Standard 1008) and the effective infiltration area in 1008.V.E.4.b. There are modeling tricks to address this (prorating the porosity and infiltration rates) but it is not intuitive and would be best done in the model. The biofilter control practice has the same issue.

According to John V. there are some additional changes which need to be done in order for it to model porous pavement cleaning properly. He is basically re-doing the code to reflect sediment storage in the pavement layer (that which can be cleaned) and sediment storage in the subsurface layers, which can't. He might have it cleaned up soon, though he and Bob decided to account for subsurface clogging in addition to sediment storage, so it might take a bit longer. I am going to wait to update my WinSLAMM until his v. 10.0.3 is out. I'm hoping in the next week but we shall see.

R: As previously indicated, the technical note will be revised to address the limitation of WinSLAMM and pollutant removal calculations.