Standards Oversight Council *(SOC)*
Supporting Technical Standards for Urban and Rural Soil and Water Conservation

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# DRAFT PERMEABLE PAVEMENT MEETING NOTES

October 9, 2013 || 9:30am – 3:30pm
Conference Room A/B, Dane County LCD Office, 5201 Fen Oak Dr., Madison, WI 53718

Attendees: John McCarthy, Roger Bannerman, Tim Troester, Chris Homburg, Josh Harder, Bob Givens, Scot Schwandt, Kate Gleason, Pete Wood, Bob Roehrig, Michelle Reynolds, Laura Fenley, Gini Knight.

**Welcome / Team Member Updates**

**Research Plot Update** (Bob R., John, Roger)
Due to the federal government shutdown, the permeable pavement installation for the research project has been stalled because it is contracted by the USGS. Federal contracts have been ordered to cease operations. Final permits are being received, and the project will commence when the government reopens.

**Review & Respond to initial review comments** (Pete, Gini)
The team decided to develop responses to initial review comments in order of review. All responses will be documented and the entire document with comments and responses will be sent to all of the initial reviewers.

The team reviewed and considered each comment provided from ten initial reviewers. Accepted comments were incorporated and drafted into the standard language. The team provided an explanation if the comments were not incorporated into the draft standard. All of the comments and the responses are at the end of the document.

**Next steps.** (Gini)
Pete will work on revising the standard based on the team's discussion and decisions from today's meeting. Roger will select a few references regarding water quality impacts and run-on ratio to include in the reference section of the standard. Pete and Gini will work on revising the responses to the comments. The team will have the opportunity to review the responses one more time before the responses get sent to the initial reviewers.

The team will also be able to review the newly revised draft standard and provide additional feedback before the standard is released for broad review. We are currently scheduled to release the draft standard for broad review comments from Tuesday, Nov 5 to Wednesday, Nov 27th at www.socwisconsin.org. The broad review comments will be compiled and sent to the team by 3rd. The team will meet to review these comments on Wednesday, December 11th.

**Timeline:**

- Oct 11 – Send revised responses to team for review
- Oct 17 – Send responses to initial reviewers; Send revised standard to team
- Nov 1 – Deadline to incorporate any changes into draft standard before being released for broad review
- Nov 5 to Nov 27 – Open for broad review comments
- Dec 3 – Send compiled comments to the team
- Dec 11 – Team meets to review comments

**WDNR Permeable Pavement Standard – Initial Review Comments**
Comments from initial reviewers are listed by section of the draft standard. Any text in red is additional language suggested by the initial reviewers. ***The responses from the team to the comments are documented after the comments in bold and italic***.

General Comments:

- Regardless of my comments, I can tell that a lot of thought went into this. Nice work!

**I. Definition**
Please delete permeable articulating concrete block/mat from this paragraph and from this document.
There are articulated concrete mats on the market that are attempting to be permeable unit paving. PaveDrain is one of them. There may be others. Rationale for elimination of this product/product group from this document follows:

Materials
Articulated concrete block/mat material specifications fall under ASTM D6684 *Standard Specification for Materials and Manufacture of Articulating Concrete Block (ACB) Revetment Systems*. This ASTM standard provides requirements for freeze-thaw durability of the paving units, plus minimum compressive strength and maximum absorption.

Specifically, freeze-thaw durability testing is at the project owner's discretion using one of three ASTM test methods listed in D6684. The owner also determines acceptance criteria. This places the responsibility of knowing which test method to use and interpretation of results on the owner. This should be the *manufacturer's* responsibility. Most project owners are not familiar with freeze-thaw durability test methods or interpretation of results from each, and likely would need to hire outside expertise. This is not the case with other concrete and clay materials used in permeable pavements.

Regarding compressive strength, the minimum required in ASTM D6684 is 4,000 psi. Higher compressive strengths may be required to with higher densities and cement contents to achieve freeze thaw durability and resistance to the eroding effects of deicers.

The minimum concrete density in ASTM D6684 is 130 lbs/cf. Most dry cast concrete paving units need higher minimum densities (and low absorption) to survive winter conditions. ACBs material specifications may not be appropriate for pavements subject to constant traffic and deicing materials. I would be interested to receive long-term field testing reports of ACB that demonstrate winter durability against freeze-thaw and deicers in a pavement application. Such studies exist for PICP and other permeable pavements and these can be provided upon request.

One ACB product, PaveDrain, has arched paving units. The arch is a means to save weight, material and transportation costs. The absence of material inside the arch does not contribute to unit strength. Contrary to PaveDrain guidance, the arch void space should **not** be used for water storage as water at that elevation in the pavement risks surface instability under vehicular traffic due to pore pressures within the aggregate. The base and underdrain system are designed for water storage, infiltration and removal; that is not the role of the paving and bedding layers.

Design
ACB manufacturer's literature provides no information on structural design (base thicknesses) or references, nor is that provided in that attached literature published by the National Concrete Masonry Association. Some SCM product manufacturers used under vehicular loads (such as PaveDrain) reference AASHTO H-20 loads. This is *incorrect*. H-20/HS-20 loads are for bridge design and are not used per se in pavement design. AASHTO flexible pavement design procedures (using the 18,000 lb ESAL or equivalent single axle load concept) should be used.

ACBs may use no jointing stone which, if present, might lend some load distribution. Cabling (if used) appears to not distribute applied loads and is only a construction expedient for lifting and placing mats. If jointing stone were used with arched paving units, it would migrate into the arched void space under the paving units and likely would not remain in the joints. The rectangular mat layout of cabled ACBs presents less design flexibility for accommodating curves or irregular edges. This likely translates into increased construction time and costs for cutting and adjustments.

Construction

Installation (compaction in particular) and performance of the base/subbase is critical to the long-term success of a permeable pavement surface. There is almost no guidance from ACB manufacturers or from the National Concrete Masonry Association on construction for permeable pavement use; i.e., no information on the quality of aggregate base materials, base compaction methods or acceptance criteria.

Maintenance
Power washing is a non-starter for municipal uses. This cleaning method will very likely not happen in reality due to the excessive cost. Furthermore, such perceptions of high maintenance costs run a substantial risk of municipal officials casting aspersions on the use of all permeable pavements, thereby eliminating them as an option for stormwater management. I don't believe this risk is in the interests of WDNR. In addition, power washing loosens sediment/pollutants and it often enters the nearest storm drain. I don't believe that outcome is in the interests of WDNR as well.

If there are no stone jointing materials in some ACBs, how does one visually inspect the (deep) joints to see if they require cleaning? A critical aspect for inspection—sediment deposition in the joints—seems obscured. Other surfaces in this document have joints completely filled with permeable stones such as ASTM No. 8, 89 or 9 stone so that sediment is trapped at the top and is available for removal by vacuum equipment.

Since some ACB surfaces (e.g., PaveDrain) are cabled, reinstatement after surface or subsurface repairs means cutting the cable(s). How are cables mended? What if one or two pavers crack or break? How are they repaired? How long does it take and how much does it cost?

Finally, the US EPA has written and presented technical papers on the performance of PaveDrain in street side parking lane application in Louisville, Kentucky installed for CSO mitigation. This project was presented at the recent LID Symposium in St Paul, MN by Dr. Robert Brown (contact email Brown.Robert-A@epamail.epa.gov) with the EPA labs in Edison, NJ. While the presentation was more about the use of time domain reflectometers to monitor surface infiltration, the project clearly demonstrated clogging of the joints and bedding layer due to an absence of jointing stone materials and the presence of spaces formed by arches. Granted, the almost 18 to 1 impervious to permeable surface ratio accelerated joint and bedding clogging of the ACB surface. But the remediation cost of cleaning clogged joints with power washing would be unacceptable to most municipalities as previously noted.

In addition, there is a Ph.D. dissertation being completed that includes comparison of the surface infiltration performance of PaveDrain to PICP surfaces. The dissertation was done by Amir Ehsaei who is based at the EPA laboratories in Edison, NJ. He presented his studies at the recent LID Symposium as well and demonstrated the numeric advantages of stone-filled joints. This paper should be available soon. His contact email is amir.eh@gmail.com.

***The technical standard is not intended to be a product acceptability list. The definition section will be revised to identify general permeable pavement categories (e.g., pervious concrete, porous asphalt, permeable pavers). Any products, including articulating concrete blocks/mats, could potentially be used as long as the technical standard criteria are met. However, articulating concrete blocks/mats would not be eligible for the underdrain discharge credit or run-on from roads or parking lots unless the joints are filled with aggregrate.***

**II. Purpose**

**III. Conditions Where Practice Applies**
I think you need to include something along the lines of "in commercial settings where watershed management is included, a professional engineer must be retained"

***The team does not feel the inclusion of this requirement is necessary. We assume that an engineer will be involved in the design of permeable pavement systems for new development and redevelopment projects that require state and local permits.***

**V. Criteria**
A. Site Criteria

1. Consider adding: For purposes of determining the number of required pits or borings and evaluating mounding potential, permeable pavement systems are classified as a "Subsurface Dispersal System" in Table 1 of Code 1002.

***This section will be revised to include the proposed language.***

2. In areas of highly permeable soil (sand) and high groundwater, permeable pavement systems may not provide the anticipated water quality and quantity benefits. The groundwater table may permanently fill a portion the aggregate storage reservoir. Consider adding additional criteria to address this water balance issue, not just a consideration. The computer models assume groundwater is not seeping into the aggregate storage reservoir.

***The team agrees with this concern. The term "seasonal high groundwater" will be added to this section. For systems that will not be lined, separation distance between the bottom of the aggregate storage reservoir and seasonal high groundwater is required and addressed by reference to NR 151.124 and NR 151.241 in the "Conditions Where Practice Applies" section.***

3. c. - It may be appropriate to establish more detailed criteria for when a slope stability analysis is needed. For example, is a slope stability analysis always good engineering for permeable pavement systems located within 2, 10, or 50 feet of a top of sandy slope (> 4:1)?

   - Should specify what sufficient distance and steep slopes are.

   Add bullet point d.: A sufficient distance (need to also specify as above) away from disturbed areas with loose fines.

   ***The team agrees with this concern. However, we are not able to establish specific criteria at this time. With this in mind, the criteria will be moved to the "Considerations" section until such time that specific criteria can be developed.***

B. Pavement Surface Design

1. –
2. Not sure that these agree. Maybe use "or" *Agreed.* ***This section will be revised to include "or".***
3. –
4. –
5. Delete the following: ~~B.5 Comply with recommendations from the National Concrete Masonry Association~~.
   The subject association provides little information on design, construction and maintenance of ACBs as permeable pavement. Evidence: There is a paucity of information in a 2011 NCMA technical bulletin (see attached). Salient text in it is highlighted. The two references cited are incorrect as they have nothing to do with design or performance of ACBs. They are papers on PICP!

   ***This section will be revised to be consistent with the revised "Definition" section.***

C. Pavement Surface Infiltration Design

- Please consider clarifying the 100 in/hr and 10 in/hr criteria. How do you want the designer to calculate and verify that the 10 in/hr criteria is satisfied over the anticipated pavement life? The 100 in/hr criteria seems straight forward.

- This seems confusing. It has to have a performance of 10 in/hr, but an initial rate of 100 in/hr and restoration of 50%? That means 50 in/hr after cleaning, 5 times higher than the stated minimum. Maybe I am reading it wrong, but it seems confusing.

  ***The team agrees that this section is confusing. This section is intended to identify required input parameters for modeling purposes to verify that at least 10 in/hr will be maintained over the anticipated pavement. The language in this section will be revised to clarify. A technical note will be developed to further explain the modeling input parameters and provide a sample calculation.***

1. Is this section needed? I don't understand the relevance of rainfall data to the design infiltration rate of the pavement.

   ***This section requires continuous simulation modeling to verify that at least 10 in/hr will be maintained over the anticipated pavement life. Continuous simulation modeling uses actual rainfall data over a specified period of time. The WDNR will identify rainfall files that should be used for continuous simulation modeling.***

2. Please add the following to this section:
   C.2. An initial surface infiltration rate of 100 in./hr per ASTM C1701 or ASTM C1781.
   C1701 is useful for measuring the infiltration rate of pervious concrete. C1781 was recently approved by ASTM for use on unit paving. The test methods are almost identical making the results comparable. See these attached ASTM test methods for reference.

   ***The 100 in/hr value in this section is intended to be an input parameter for modeling purposes only. At least 100 in/hr is required "upon completion of the installation" in the "Pavement Surface Infiltration Properties" section. However, the technical standard will not require infiltration rate verification by field testing for all permeable pavement installations. The technical standard will include references to ASTM C1701 and ASTM C1781 in cases where infiltration rate field testing is required by the administering authority.***

3. If the initial surface infiltration rate is required to be 100 in/hr, please clarify how the 0.4 lbs/sf is used by the designer, particularly as it relates to the computer model, 10 in/hr criteria for the life of the pavement system, and how the surface maintenance activities help reestablish the surface infiltration rate.

   ***The team agrees that the modeling input parameters, including 0.4 lbs/sf for surface clogging capacity, need more explanation. This will be addressed in a technical note and sample calculation.***

   What is the basis of Clause V (C) (3) where it states "A surface clogging capacity of 0.4 pounds per square foot of permeable pavement surface area". Note the definition on page 10, the Surface clogging capacity is the "capacity to accumulate pollutants to the point where void spaces are full and surface infiltration can no longer occur". I am wondering if this number is going to preclude most PICP products. Refer to the following details:
   1. Using 90 lbs/cubic foot for lose dry sand, 0.4 pounds per square foot works out to 7.68 cubic inches of debris per square foot of coverage. (0.4/90*12^3).
   2. For PICP, how deep does the debris have to accumulate within the joints before the system is clogged? Say we assume that once the top 1" of jointing material is full then the system is clogged; under this assumption, the joint material porosity (measure of the voids compared to the entire volume - use 30% for #8 stone) within the open space of one square foot of surface area needs to be able to hold 7.68 cubic inches of debris. The required open space for the pavers would need to be a minimum of 17.7 percent, which nothing but Turfstone meets.
   3. However, we also know from the FGCU study that the larger particulate of the debris actually gets trapped on the surface; it is only the medium sized particulate that accumulates in the joints, while the smaller particulate passes through the joints. How does the particulate size factor into the clogging capacity?

   I would ask for clarification on how this number is going to be applied before we allow it to be adopted.

   ***The surface clogging capacity is intended to be a modeling input parameter only. The 0.4 lbs/sf value was established based on literature review and tested by continuous simulation modeling. Model runs were conducted for several permeable pavement surface void ratios, including ratios typical for PICP products. Based on these model runs, the 0.4 lbs/sf value did not generate a rapid decline to the 10 in/hr surface infiltrate rate threshold as long as routine surface cleaning was conducted.***

4. The other major item that should be done is distinguishing between cleaning and remediating. According to Clause V (C) (4), cleaning is only capable of partially restoring the infiltration rate, which is true if all that is being done is using regenerative air or a sweeping; however, when remediation is done using a vacuum truck, which involves extracting the built up debris and jointing material in the joints, and replacing with clean jointing material, then the effective restoration is much higher. Cleaning with regenerative air or a sweeper should be done as outlined in V (F), while remediation should be done when the infiltration rate is at or below 10"/hour or surface ponding is noted (see VIII(D)(2)).

   ***The team agrees with this comment. However, the "restoration of 50% of the surface infiltration rate reduction" is an input parameter intended for modeling purposes only. For model purposes, only surface cleaning is assumed for all permeable pavements. The term "surface cleaning" is included in the "Definitions" section. The term "remediation" will be added to the "Operations and Maintenance" section for permeable paver products.***

   This may not be clear. Perhaps add an example?

***The team agrees with this comment. A technical note and sample calculation will be developed to help explain this criteria and the other model input parameters in this section.***

E. Pavement Surface Run-on

I would think that routing rooftop runoff directly into the storage layer would be acceptable and be identified as such.

***The team acknowledges the validity of this comment. However, routing rooftop runoff directly to the aggregate storage reservoir would not be considered "run-on". It is a stormwater management option that could be considered assuming it is not prohibited by state or local plumbing codes.***

Agree on the fueling part, but not the loading areas. Water quality impact is low if something is leading but could limit the use as a disqualifier.

***It is understood that all industrial loading areas are not equal relative to potential for surface clogging and/or groundwater contamination. We are not able to address this variability in the technical standard. However, the intent of this requirement is to avoid surface clogging and/or groundwater contamination from "dirty" source areas. With this in mind, this requirement could be discussed with the administering authority on a case by case basis.***

Table 1.

Perhaps the only real concern that we have is regarding the "run-on" ratio. Please see the attached spreadsheet that shows the capacity of systems and the rate at which they become overburdened. This is most evident when considering a 5:1 ratio. Note at the bottom of the spreadsheet that only a 1" per hour rainfall event on a 5:1 application can exceed the base storage capacity resulting in all additional water being sent right back into the sewers untreated. If the goal is to treat the most water effectively, the run-on ratios really should be lessened. With zero run-on being the ideal, a 1:1 or even 2:1 is already encroaching on what a 1-2" rainfall can effectively handle/treat. Exceeding these ratios will likely cause premature clogging and lessen the effectiveness of slowing the first flush and properly treating the storm water.

These systems are installed with the thought that it will last. We have a life expectancy of 40+ years with our pavement and the goal for the storm water management should match. I also know that typically the first concern of the ultimate owners is maintenance. If we tax the system to the limit it will increase the need for maintenance which will in turn require more regulation and/or inspection and more work for the owner.

We do realize that by dropping the acceptable run-on levels it might make it less attractive to use for some projects. We would gladly have less projects installed if it means that they will work better, last longer and require less maintenance.

***The team appreciates the spreadsheet that was provided. The run-on ratios in Table 1 were tested using continuous simulation modeling. This modeling considered infiltration and/or underdrain discharges that are expected to drain permeable pavement systems during and after rain events. It doesn't appear that the spreadsheet considers infiltration and/or underdrain discharges from the permeable pavement systems.***

***The team agrees that higher run-on ratios will increase the risk for surface clogging and reduce the anticipated pavement life. This was discussed at length and the team attempted to balance the risk with a desire to allow permeable pavement systems to be used in as many applications as possible. For example, the team believes that a run-on ratio of 3:1 is potentially important for use of permeable pavement for municipal road applications. Table 1 considers the risk associated with different run-on source areas rather than using a single run-on ratio for all source areas. The first four items in the "Considerations" section also address run-on concerns.***

I would say the run on ratios are okay, except for the 5:1. I think 3:1 makes more sense, but the definition on "lawn" needs to be more clearly defined. Just seems to be a bit ambiguous and it could be a problem down the road. This is a connection to the structural performance, but I understand that is not what this is for. However, it still impacts the infiltration capacity of the system, hence the water quality impact.

***See above for a discussion regarding the run-on ratios. The team agrees with the comment regarding the term "lawn". Definitions will be developed for "lawns" and "landscape areas".***

Define run-on ratio, eg, ratio of surfaces contributing runoff to the porous pavement to the area of the porous pavement. Does the first value include the porous pavement surface? Not clear.

***The team agrees with this comment. A definition for "Run-on Ratio" will be developed. The first value in the ratio does not include the permeable pavement surface area.***

1. –
2. –
    a. This provision does not allow for a newly repaved parking lot to have a mixture of permeable and standard pavement where the standard pavement flows onto the permeable pavement unless the permeable pavement meets the criteria in Section V.K.3., even if there is no pollutant removal credit desired. There could be a situation where the permeable pavement has no underdrain, so the provisions of Section V.K.3 would not apply to the parking lot except that there is a bit of impermeable pavement that drains onto the permeable pavement. This is too restrictive.

    ***This requirement is associated with the infiltration pretreatment requirement found in s. NR 151.124(7), Wis. Adm. Code. Essentially, pretreatment is required by code for all permeable pavement systems that will have run-on AND will infiltrate to the subsoils. The reference to the underdrain discharge credit criteria in Section V.K.3. is only intended to establish what would be considered adequate pretreatment prior to infiltration. The language in this section will be revised to provide more clarification.***

    Also exclude permeable systems for industrial storage and loading areas and vehicle fueling and maintenance areas, regardless of whether they are from run-on or not.

    ***The team agrees with this comment. Language will be added to the "Conditions Where Practice Applies" section to address this.***

    b. Insert "surface" between "run-on" and "area"

    ***This proposed addition will be incorporated.***

F. Pavement Surface Cleaning

- This may be an area to keep the ratios as they are with a more frequent cleaning cycle.

- Use of vacuum sweepers or power washers to clean the surfaces of permeable concrete blocks is not recommended as this may cause significant loss of the aggregate between the blocks, requiring immediate replenishment of aggregate. It is recommended to use a light power hose at medium pressure for these systems.

***The language in this section will be revised to indicate that manufacturer or industry recommendations should be followed regarding the methods and equipment that should be used for surface cleaning.***

- It is highly recommended to increase the cleaning frequency indicated. At least three times a year for number 1 and four times a year for number 2.

***The team agrees that surface cleaning is critical. The cleaning frequency will be increased to at least twice per year for all conditions. However, the team believes that a minimum cleaning frequency of twice per year will be sufficient. Language will be added recommending higher cleaning frequencies be considered.***

- The differentiation of run-on ratios in items 1 and 2 below is superfluous and needs simplification to address all run-on and adjacent vegetation conditions. Example: there could be no run-on onto a permeable parking

lot surrounded by overhanging trees. The flowers, leaves, needles and seeds might need to be vacuumed in the spring. In addition, there may be a need to vacuum sand applied in the winter for traction, as well as to remove defoliated, crushed leaves in the fall. Please revise this section by deleting 2 and revising 1 as follows:

1. **Pavement *Surface Cleaning* –** Cleaning shall be conducted using a regenerative air or vacuum sweeper at least twice per year, typically in the spring and the fall after tree defoliation.

***This section will be revised as proposed.***

- Consider excluding power washers, as I expect they might force fine debris further into the pavement or push it off the pavement so that when the next rain comes, it just washes back on again.

***The specific reference to power washers will be removed from this section. However, power washers could potentially be used if recommended by the manufacturer or industry associated with a particular permeable pavement product.***

G. Aggregate Storage Reservoir

1. a.
    - Under V(G)(1)(a), the fines content should be less than 2%. Also, choking analysis should be done between the bedding and base materials, and the base and reservoir aggregates, where different materials are used, to verify compliance. See Page 41 of the PICP Design Manual for the formulas.

    - Please revise as indicated below. 5% passing the No. 200 sieve can produce an unacceptable amount of solids/fines that increase the risk of subgrade clogging. Example: if base/subbase is 24 inches thick and is 120 lbs/cf, at 5% passing the No. 200 sieve, the total "suspendable" solids/fines is 12 lbs/sf. 2% passing is achievable with washing at quarries. There will *always* be fines generated from handling and placing aggregates. That cannot be controlled beyond washing.

        a. Use open-graded base consisting of crushed stone or crushed gravel with no greater than ~~5~~2% passing the No. 200 sieve.

    ***The team agrees that aggregate with less than 2% fines is preferred. However, the team is also concerned with availability of this aggregate in Wisconsin. Aggregate with less than 5% fines is readily available in Wisconsin. It is understood that some additional fines will potentially be released from the aggregate using the less than 5% fines criteria. A recommendation regarding use of aggregate with a less than 2% fine content where possible will be added to the "Considerations" section.***

    ***The choking analysis appears to be an industry specific requirement that will not be directly addressed in this technical standard.***

H. Pavement System Drainage

Please revise the time frame as indicated below. The soil should be saturated for the shortest time possible to not become unduly weakened while still allowing some time for infiltration. In that light, 72 hours should be the maximum time allowed for drainage should includes the rainstorm since the water begins infiltrating the soil subgrade at the start of each rainstorm**.**

1. - Please add "**By design,** water should be retained in the system, including…"
   - Please revise as follows: Water shall be retained in the system, including the aggregate storage reservoir, for no longer than 72 hours ~~following cessation of a rain event~~ including the rain event.

   ***The proposed "by design" language will be added to this section. However, the "following cessation of a rain event" language is consistent with criteria found in other DNR technical standards and available modeling techniques.***

2. –

3. I would suggest “per 10,000 sq/ft, not to exceed 1 per acre

***The language in this section will be revised to clarify that at least one observation well is required regardless of permeable pavement surface area size.***

J. Underdrains

If a suitable outlet is not available, permeable pavement probably is not the correct BMP for the site. If the drain time is not met, the water quality and quantity benefits of the facility will not be available for the next rainfall event. If my memory is correct, we typically have a rainfall event every 3 to 5 days in Wisconsin, on average.

***The team agrees with this comment. The last phrase, “unless there is not suitable or available outlet location”, will be removed from this section.***

Explicitly exclude fabric or geotextile around an underdrain.

***The team could not arrive at a consensus regarding the use of fabric or geotextiles. It was decided to mention the possible use of fabric or geotextiles in the consideration section and allow designers to make this decision.***

1. –
2. –
3. Please delete “granular material” and insert “open-graded aggregate”
    a. Please delete “granular material” and insert “open-graded aggregate”
    b. Please delete “ a granular” and insert “an open-graded aggregate”

***The language in this section will be revised as proposed.***

Please keep in mind that most permeable pavements with underdrains only need such drains at or near the outlet(s). In most designs, underdrains do not need to stretch over the entire soil subgrade surface or within the aggregate base due to the ability of the open-graded aggregate to move the water as fast horizontally as water flowing through the underdrain pipes. ICPI will be updating its literature to reflect this reality.
***Thanks for providing this information.***

K. Pollutant Removal Credit

3. –
    a. I don’t understand why the pavement surface void ratio needs to be less than 25% for pollutant removal credit. I had thought that pavement surface void ratios were greater than that.

    ***A pavement surface void ratio of 25% is the upper limit for typical permeable pavements. This criteria is associated with the underdrain discharge credit and assumes that the pavement surface provides filtration. The team believes that higher surface void ratios would not provide adequate filtration.***

    b. Consider specifying a minimum thickness for water quality purposes. For example, is a ¼ inch thickness sufficient?

    ***The team agrees with this comment. The language in this section will be revised to indicate that the joints must be filled with aggregate to the full joint depth.***

Table 2. –

- How were these percent TSS and TP reductions determined?
- The values in table 2 seem arbitrary to me because they don’t account for particle size distribution. I suggest lower numbers until the values can be verified by research.

***The values indicated in Table 2 were selected based on literature review. To be conservative, Table 2 represents the low end of the range of values presented in the literature.***

L. Infiltration Volume and Pollutant Load Reduction
For your information, the WinSLAMM program currently removes TSS only by infiltration (K.2.). We are making modifications in the program to do the following:

a. No pollutant removal for runoff that does not enter the pavement (follows this standard)
b. 100% pollutant removal for runoff that infiltrates into native soil (follows this standard)
c. TSS entering the pavement is assumed to be stored in the pavement until the surface clogging load rate (0.4 lb/sf in this standard and user-defined in WinSLAMM) is met. The surface infiltration rate is reduced as a linear function of surface clogging (including run-on), reaching zero when the surface clogging load rate is reached. At that point, no pollutants are retained by the pavement for subsequent events and no infiltration occurs. (this is different than the 55% reduction in this standard)
d. If the device is completely clogged (ie, reaches the 0.4 lb/sf clogging value), it cannot be cleaned and has failed. (I am not sure if this is in this standard)
e. We are discussing making the removal rate a function of particle size. We will be using Bob Pitt's lab testing analyses to characterize particle reductions in the surface in the following particle size ranges: <60u, 0% removal; 60-120u, 25% removal; 120-250u, 50% removal; >250u, 100% removal (these will likely be revised as we complete the data analyses). We will assume settling in the storage layer below the drain tile, adjusting the area based upon the porosity and using the underdrain plus the infiltration rates as the total discharge rate. The pore storage volume available will be calculated based upon the accumulative trapped material consuming storage for each event. This storage layer, of course, cannot be cleaned, and retention of sediment up to the underdrain depth would cause complete failure of the system.

***Thanks for providing this information. Will WinSLAMM consider water loss due to wetting of the aggregate and evaporation?***

M. Peak Discharge Rate Control
Should list the accepted stormwater hydrologic and hydraulic computational method(s) and/or describe how a method is approved.

***The team believes that this is beyond the scope of this technical standard.***

N. Thermal Mitigation
Should list the accepted thermal computational method(s) and/or describe how a method is approved.

***The availability of thermal computational methods is a concern that the team will continue to discuss.***

O. Construction Practices
Explicitly state that no surface pollutants may enter the porous pavement system during construction.

***The team agrees with this comment. However, it may be difficult to achieve this level of control on every site.***

1. It is recommended these be constructed late in the construction schedule when possible.

   ***The team agrees with this comment. This language will be added in the "Considerations" section.***

2. –
   a. –
   b. This is somewhat critical to reduce run on and contaminated water sources from clogging systems.

      ***The team agrees with this comment.***

      The only way to <u>prevent</u> sediment and pollutants from entering the subgrade that is carried by runoff from construction sites is to divert the runoff. All other methods will only serve to <u>limit</u> sediment and pollutants from entering. This provision can be interpreted as an absolute prohibition of all potential pollutants carried by construction site runoff, which is too restrictive.

      ***The team agrees with this comment. The language in this section will be revised to indicate that sediment and pollutant inputs should be prevented to the maximum extent practicable.***

3. - Under V(O)(3), there are Permeable pavement designs (roadways for example) where subgrade compaction will be required, even though it results in a reduction in infiltration rates. The paragraph should be adjusted to state that refracturing or tilling would take place if the design compaction rate (which may be the initial compaction rate in some cases) is exceeded.

   - This one needs some clarification: Rip the soil and do not till it (in the agricultural sense) as ripping provides a better result. The reader needs to be notified that ripping the soil increases the risk of surface settlement and that additional materials and additional compaction of them may be necessary. Please revise to read as follows:

   If infiltration is a component of the permeable pavement system, protect the native soil subgrade from *compaction* by construction equipment. If the soil is compacted during construction, refracture or ~~till~~ rip the native soil subgrade to a depth of 12 inches. Additional base/subbase aggregate may be needed as well as additional compaction of these materials to reduce the risk of surface settlement and to render a stable structure for supporting vehicular traffic.

   ***The team agrees with these comments. The last sentence regarding compaction mitigation methods will be removed from this section and moved to the "Considerations" section.***

   - I would go 20 inches, because they could have some pretty heavy duty equipment that could do a wonderful job of compacting the soil.

   ***This suggestion will be included in the "Considerations" section.***

4. –
5. –
6. - Again, power washer isn't the best solution for cleaning PICP or clay as the jointing stone materials can be converted to bee-bees. Please use the proposed wording below as it leaves open other cleaning options.

   Suggested revision: When construction is complete, inspect the permeable pavement surface and, if necessary, clean the surface using a regenerative air, ~~or~~ vacuum sweeper or by other means ~~power washer~~.

   - Skip the power washer (see my comment F.)

   ***The language will be modified as suggested and include a reference to manufacture and industry recommendations.***

7. Section O.7 (new provision)
   Landscaping materials nor equipment shall not be permitted to operate on permeable pavement, pavement base, or storage layer, unless the surface is protected from contamination by landscaping materials and compaction by landscaping equipment.

   ***The team agrees with this comment. A new section will be added regarding the operation of equipment and storage of material in the permeable pavement construction area.***

P. Add requirement that the devices must be cleaned to get credit, and that there must be a legally enforceable maintenance agreement in place. Otherwise, why bother?

***Development and implementation of long-term maintenance plans and agreements for permeable pavement systems are required under state and local regulations. Permeable pavement cleaning frequencies will be established and required under the regulatory process.***

**VI. Considerations**

Within the Consideration section should "road salt" use within the area draining to the pervious pavement be discussed. Should limit its use to that only necessary due to potential for SAR limiting infiltration at the native soil layer?

***The team agrees that the use of road salt is a potential concern. Language will be added to the "Considerations" section regarding this issue.***

Use of a geotextile between the base and subgrade should be added.

***The "Considerations" section will include language regarding the use of geotextiles.***

B. Please use more emphatic language as indicated below:

The susceptibility of permeable pavement surfaces to clogging can increase with increasing run-on ratios. Run-on source areas should be carefully considered when the run-on ratio will exceed 2:1. A higher ~~more aggressive~~ cleaning frequency may be required ~~appropriate~~ based on the site-specific run-on ratio and source area characteristics.

***The language in this section will be revised as proposed.***

C.

D. –

E. I think this should be a requirement. Otherwise, you could potentially loose a lot of storage and infiltration capacity because the device is sloped. WinSLAMM would not account for the reduced infiltration rate, and I doubt any other model would.

***The team agrees with this concern. However, the team was not able to develop specific criteria at this time.***

F. Please revise the following to include ASTM C1781 as noted:

If verification of in place pavement surface infiltration rates is necessary, consider conducting pavement surface infiltration rate testing per ASTM C1701 Standard Test Method for Infiltration Rate of In Place Pervious Concrete or ASTM C1781 Standard Test Method for Surface Infiltration Rate of Permeable Unit Pavement Systems. ASTM C1701 can be used to measure surface infiltration of pervious concrete and porous asphalt and C1781 can be used on permeable unit pavements. The result from these test methods are comparible.

***The language in this section will be revised as proposed.***

G. Remove the filter sock reference. We are just asking for premature failure by clogging with them.

***This language will be removed as proposed.***

H. Add ASTM C1781, Standard Test Method for Surface Infiltration Rate of Permeable Unit Paving Systems. It is the paver equivalent to ASTM C1701.

***The language in this section will be revised as proposed.***

I. A filter sock should not be used around perforated pipe as this significantly increases the risk of clogging the pipe.

***This language will be removed as proposed.***

J. PE opinion. I don't think you should use any system with ground water within 12" of the finished grade without a liner or significant barrier to retard vertical water creep.

***The team agrees with this comment. Consideration H will be removed because groundwater inflows to the aggregate storage reservoir should not occur if regulatory separation distances to seasonal high groundwater are followed.***

**VII. Plans and Specs**

A. –

1. –
2. c. The high-water table should also be noted.

***The language in this section will be revised as proposed.***

3. –
4. c. Please add an “s” to the end of the last word in this sentence.

***Done.***

5. –

a. Request to insert the following in red: This can include, but is not limited to, pervious pavement technician by the National Ready Mix Concrete Association or a certificate for a permeable interlocking concrete pavement technician from the Interlocking Concrete Pavement Institute.

***The team believes the proposed additional language is redundant.***

b. –
c. Weekly erosion control inspections to check that sediment will not reach the pavement prior to site stabilization.

***At least weekly erosion control inspections are required under state and local regulations and permits.***

**VIII. Operations & Maintenance**

A. –
B. 3. Application of sand and salt for deicing. (These devices are a direct conduit to groundwater, and I would think we would not want to add still more salt to the groundwater).

***Language regarding salt usage will be added to the “Considerations” section. However, the team is concerned about potential issues regarding public safety if the application of sand and salt are prohibited.***

C. –
D. –

1. - Please revise the following to be consistent with previous edits:
Clean the pavement surface using a regenerative air, ~~or~~ vacuum sweeper or other means ~~power washer~~ at least ~~once or~~ twice per year in accordance with Section V.F.

- Remove the power washer.

***The language in this section will be revised as proposed.***

6. Industry associations generally do not publish standards. They publish recommendations unless they are accredited by ANSI or some other national accrediting organization for standard-making. Neither ICPI nor BIA is accredited to create standards.

Revised Suggestion: For permeable interlocking concrete and clay pavers, replenish the joint aggregate in accordance with industry recommendations ~~standards~~.

***The language in this section will be revised as proposed***.

7. Please consider small grammatical upgrade to last sentence:
The 10% threshold may only be exceeded if design calculations confirm that the system can accept the full loading for which it was originally designed after repairs. ~~as that it was originally designed for after repairs.~~

***The language in this section will be revised as proposed.***

**IX. Resources**

A minor edit is needed on the last item:
Smith, D.R., *Permeable Interlocking Concrete Pavements: Selection, Design, Construction, Maintenance*, 4th edition, Interlocking Concrete Pavement Institute, Herndon, Virginia, 2011 ~~2010~~

***Done.***

**XI. Definitions**

If low permeability liners have in fact low permeability, they shouldn't be used if the intention is to create an impermeable liner. In rare instances, a decrease in permeability may be needed in very high infiltration soil subgrades. If so, that can be achieved less expensively with double wrapping geotextile or choking the subgrade with fines. Landfill technology using clay liners is not needed or effective here.

Also, clay liners are not used in permeable pavements as they cannot be placed vertically on the sides of pavement section. Further, the durability of clay liners under the force of compacted aggregates is also suspect. Please delete clay liners completely from this document. As an aside, the names of the liners below are not proper nouns so they don't require initial caps. Impermeable liners are also called geomembranes.

~~*Low Permeability*~~ *Impermeable Liners* (III): Liners made of ~~appropriate clay material,~~ high density polyethylene (HDPE), polyvinyl chloride (PVC), or EPDM (ethylene propylene diene monomer) ~~or Geosynthetic Clay Liners (GCL) that will minimize the migration~~ that prevent infiltration of water into the subgrade.

***Some revisions to the language in this section will be made as proposed. However, the team believes that clay can be used as a liner in some situations.***

Please do not suggest that ACBs can be used as permeable pavements as previously explained. Please delete this definition from this document:
~~*Permeable Articulating Concrete Block/Mat* (I): Concrete blocks bound into mats by the use of revetment cables that allows water to drain through the joints.~~

Please add the following text to clarify these two surfaces:
*Permeable Interlocking Clay Brick Pavers* (I): Clay units when assembled into a pattern allow water to drain through the joints filled with highly permeable aggregates.
*Permeable Interlocking Concrete Pavers* (I): Concrete units when assembled into a pattern allow water to drain through the joints filled with highly permeable aggregates.

***These definitions will be eliminated or revised based on changes made to the "Definition" section.***

**Figure 1.**

For Figure 1, it should be noted that the bedding layer below pavers should not be considered part of the 12-in minimum.

***Figure 1 will be modified as proposed.***

Please delete Figure 1 on the last page as it is a bit vague and confusing. There are numerous solutions to permeable pavement drainage depending on soils, base depths, and nearby drainage outlet structures. The variations in solutions can easily fill several additional pages and such details appear to be outside the scope of this document. As an aside, perforated pipes are generally placed on or in the soil subgrade for construction expediency and not within the aggregate base as shown on the drawing. If retention is required, a raised outlet is generally used or an orifice in the underdrain(s), or both.

***Figure 1 is associated with the aggregate storage reservoir depth requirement in Section V.K.3. The figure will be revised to be more generic.***