Report of the Stormwater Infiltration Task Force of the Dane County Lakes and Watershed Commission

Executive Summary

July 6, 2006

Dane County's Chapter 14 infiltration standards are aimed at protecting surface water and groundwater resources and must comply with Wisconsin NR 151. These standards require, to the maximum extent practicable, a high percentage of predevelopment average annual infiltration during development. Like the state-wide NR 151 standards, the County Ch 14 ordinance provides "caps" on the land required for infiltration devices (1% of site for residential developments, 2% for non-residential). The County ordinance, however, provides a one-year sunset clause for these caps, in order to allow time for further study of their usefulness. On one hand, there are concerns about the potential impact of the absence of caps on the economic viability of high density development; on the other hand, there are concerns that caps can result in suboptimal infiltration practices, as there is not a way to ensure that infiltration practices done within the minimal (1-2%) land area reflect best management options.

The Dane County Stormwater Infiltration Task Force (SITF) was created to further evaluate stormwater infiltration requirements, including caps on the area required to be devoted to infiltration as well as other approaches, and to make recommendations for possible changes in these standards. The 16-member SITF met 10 times between September 2005 and May 2006. In addition, subgroups met several times to focus on specific issues and conduct technical analyses. As a result of this work, the SITF agreed unanimously on a number of recommendations for improving infiltration standards and practices in Dane County. These recommendations fall under five categories:

1. **Chapter 14 infiltration standards**: amend ordinance language to provide an option for developers to meet specific groundwater recharge goals in lieu of exceeding caps on the percentage of land required for infiltration devices. If a development would require more than 1% (residential) or 2% (non-residential) of the site to meet NR 151 infiltration standards, developers may choose to satisfy the Dane County infiltration standard by designing infiltration practices that (in addition to meeting minimum NR 151 standards) meet a recharge rate of 7.6 inches/year, which is the estimated county-wide predevelopment groundwater annual recharge rate. This option also requires mitigation of the effects of compaction on disturbed open areas.
2. **Information and enforcement**: provide guidelines for the use of computer models for infiltration calculations that are part of the approval process; work with stakeholders to provide short courses, workshops, and other programs for installers of infiltration devices, to ensure effective practices; require and enforce "as-built certification" of installed infiltration devices.
3. **Monitoring effectiveness of infiltration practices**: place a high priority on testing the effectiveness of installed infiltration practices to determine what works and what does not work, and why.
4. **Hydrological research and management**: establish appropriate groups to make recommendations about the status of, and future needs for, hydrological research and management in Dane County.
5. **Resource needs**: provide funds for research and for additional staff for training, permit review, monitoring effectiveness of installations, and on-going review of infiltration standards.

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Background

In November 2005, Dane County amended its Chapter 14 stormwater ordinance in order to comply with Wisconsin NR 151 state-wide infiltration standards. Both Wisconsin and Dane County standards are aimed at a maintaining, to the maximum extent practicable, a high percentage of predevelopment average annual infiltration (90% of for residential sites, 60% for non-residential) during developments and redevelopments that meet particular criteria (of size, etc.).

Like the state-wide NR 151 standards, the amended County Ch 14 ordinance provides "caps" on the land required for infiltration devices. The County ordinance, however, provides a one-year sunset clause for these caps, in order to allow time for further study of their usefulness. The caps provide for a maximum area of developments (1% of disturbed land for residential sites, 2% for commercial) that are required to be set aside for engineered infiltration devices.

In addition to the sunset provision on the caps, Dane County infiltration standards are different than required by NR 151 in that the County standards: 1) do not contain an exception for infill developments, 2) apply to developments with greater than 20,000 sq ft of cumulative impervious surface since Aug 2001 (compared to 1 acre of disturbed land, or 43,500 sq ft, under NR 151), 3) rely on a more restrictive Dane County definition of "redevelopment" that reduces exemptions, 4) excludes the use of the TR-55 model for estimating infiltration, and 5) consider the entire site, rather than just impervious area, for effective infiltration area calculation on non-residential sites.

The present Dane County Stormwater Infiltration Task Force was created in response to concerns about the implications of not retaining the land area caps that are part of NR 151. In particular, the City of Madison and area developers expressed concern about the potential impact of any infiltration standards that would not include caps on the economic viability of high density development, where it is often more difficult to allocate sufficient land area to meet the required percentage of predevelopment infiltration. On the other hand, support for the lack of caps arises largely from the concern that such caps can result in suboptimal infiltration practices, as there is not a way to ensure that infiltration practices done within the minimal (1-2%) land area reflect best management options.

Charge to Task Force

The Task Force is charged with evaluating the current approach to stormwater infiltration requirements found in Dane County ordinances, which reflect the state runoff rule requirements of NR 151, and include a cap on the land area that can be devoted to infiltration practices. The Task Force is to evaluate and compare the merits of the infiltration cap and other approaches (including no caps), and recommend possible changes to the county infiltration standards.

Approach

Identification of Issues

As a first step in addressing its charge, the Task Force identified the scope of issues that we considered relevant. These issues (listed fully in Attachment 3) can be grouped in four categories: 1) infiltration standards in the context of larger development planning, 2) resource protection goals of infiltration standards, 3) interpretation of infiltration standards, and 4) research needs.

Site Analysis Subgroup (Details in Attachment 4)
This subgroup used computer modeling to analyze the impact of different standards on specific development site scenarios. Initial modeling focused on infiltration predictions from two different models (SLAMM and RECARGA), where "infiltration" is actually calculated as the amount of water that that does not run off the site. Since this calculation includes evaporation and evapotranspiration as well as groundwater recharge (water that soaks into the soil and helps replenish groundwater), it might more accurately be called "stay-on" water. During discussion of initial results brought by the Site Analysis Subgroup to the entire Task Force, it became apparent that while the NR 151 focuses on runoff retention to meet water quality goals, groundwater recharge is also of specific concern in Dane County. In fact, "infiltration" practices designed to minimize run-off (maximize stay-on) can actually encourage evaporation and evapotranspiration at the expense of recharge. Subsequent computer modeling by the Site Analysis Subgroup, therefore, focused on estimating recharge rates instead of stay-on.

Resource Approach Subgroup
This subgroup approached long-term infiltration issues from a "resource-based" perspective, starting with the following questions:

- What would it take for us to develop infiltration standards based on solid understanding of resource needs (groundwater and surface water quality and quantity) under various projected development scenarios?
- What is the status of research efforts that can help with the above question?
- Can we and should we support refinements of the current Dane County Regional Groundwater Model, or other modeling efforts, to help address this?
- What needs are there for on-going data collection as part of new development that will allow us to revise and improve infiltration standards?
- Besides the question of the appropriateness of "caps" on land required to be devoted to infiltration, are there other issues that should be considered for addition or revision to the infiltration standards?

Discussion of these questions by the Resource Approach Subgroup led to recommendations from the entire Task Force.

Consideration of Recommendations
The Infiltration Task Force met as a whole to consider information and potential recommendations that came out of the two subgroups. Several categories of recommendations (see below) were discussed and approved besides the ordinance language dealing with "caps," including education and enforcement, monitoring of effectiveness of infiltration practices, hydrological research and management, staffing needs, and considerations for possible future revisions to standards. The recommendations included in this report were accepted unanimously by the Task Force members at its final meeting of May 18, 2006.

Findings

- Computer modeling showed that the infiltration requirement for non-residential sites (60% of pre-development infiltration volume) can normally be met with less than 2% of land devoted to infiltration practices, even on poor soil. (Attachment 4 contains detailed results and analyses.)

- For high density (4 - 5,000 sq ft lots) residential sites, modeling shows that they often cannot meet NR 151 infiltration requirements within a 1% cap on land area devoted to effective infiltration areas on poorer (silt loam) soils.

- Published scientific studies indicate that the average recharge rate for Dane County is in the range of approximately 5 – 8 in/yr (see memo, Attachment 5). An average recharge estimate of 7.6 in/yr was derived using the 1981 rainfall record, which is typically prescribed for use in design analyses submitted for DNR and County approval (Attachment 4). The committee agreed that 7.6 in/yr is a reasonable target for site stormwater design because it falls within the range of existing recharge rates indicated by the literature. A value near the upper end of the range is appropriate as a recharge target for developing designs intended to restore recharge rates to those nearer pre-development conditions.

- Modeling indicates that effective infiltration practices will generally provide 7.6 in/yr recharge using considerably less land area than would be required to meet the percentage "stay-on" (water not leaving the site by runoff) stipulated in NR 151.

Recommendations

Infiltration Standards

- Proposed approach: require that developers first prepare a plan to attempt to meet NR 151 infiltration requirements by creating effective infiltration areas (practices) that require up to the 1% (residential) and 2% (non-residential) caps. This would use the DNR "stay-on" approach (stay-on here refers to any water that does not run off the site, and includes evaporation and evapotranspiration as well as recharge).
- If when designing infiltration systems, developers would need to devote more than 1% (residential) or 2% (non-residential) of the site to meet NR 151 infiltration standards, they would have the option of going through a recharge calculation. If they can demonstrate that infiltration practices meet the estimated average county recharge rate goal (7.6 inches/year), then that would satisfy the county infiltration standard, provided that land area devoted to infiltration facilities is at least 1% (residential) or 2% (non-residential) of the site.
- If developers pursue the option of going through the recharge calculation, they would be required to mitigate the effects of compaction on disturbed open areas.
- Because the recharge approach results in meeting or exceeding the NR 151 requirement of a 1% or 2% cap on land area devoted to infiltration practices, this proposed Dane County approach complies with state requirements.

Proposed Ordinance Language:

1. *Residential development.* For residential developments, design practices to infiltrate sufficient runoff volume so that post-development infiltration volume shall be at least 90% of the pre-development infiltration volume, based upon average annual rainfall. If when designing appropriate infiltration systems, more than one percent (1%) of the site is required to be used as effective infiltration area, the applicant may alternatively design infiltration systems and pervious surfaces to meet or exceed the estimated average predevelopment annual recharge rate (7.6 inches per year). If this alternative design approach is taken, at least 1% of the site must be used for infiltration.

2. *Nonresidential development.* For nonresidential development, including commercial, industrial and institutional development, design practices to infiltrate sufficient runoff volume so that post development infiltration volume shall be at least 60% of the pre-development infiltration volume, based on average annual rainfall. If when designing appropriate infiltration systems, more than two percent (2%) of the site is required to be used as effective infiltration area, the applicant may alternatively design infiltration systems and pervious surfaces to meet or exceed the estimated average predevelopment annual recharge rate (7.6 inches per year). If this alternative design approach is taken, at least 2% of the site must be used for infiltration.

Information and Enforcement

1. Included with this report (Attachment 6, "Infiltration Modeling Guidance") are standard guidelines for the use of computer models (SLAMM, RECARGA) for infiltration calculations that are part of the approval process. The Infiltration Task Force recommends that these guidelines be included in the Dane County Erosion Control and Stormwater Management Manual, and that training be provided for designers of systems.
2. Dane County, working with Madison Area Builders Association, City of Madison, and other municipalities should provide short courses, workshops, and other programs for installers of infiltration devices, to ensure effective practices. Audiences should include landscapers and installers. Note that this cannot be done without additional staff.
3. Require and enforce "as-built certification" of installed infiltration devices (e.g., letters of credit cannot be released until certification is provided).

Monitoring Effectiveness of Infiltration Practices

1. Place a high priority on testing the effectiveness of installed infiltration practices to determine what works and what does not work, and why. As a first step, the County should establish a system for inventorying installations using a simple observational monitoring protocol aimed at acquiring information useful for adaptive management (Attachment 7). (Implementing this system will require additional County staff resources.) Municipalities should also encouraged to conduct such inventories.

Hydrological Research and Management

The County should establish appropriate groups to make recommendations about the status of, and future needs for, hydrological research and management in Dane County. Among the potential needs which these groups should consider are:

1. Maintenance and updating of existing Dane County hydrologic models.
2. Protocols for testing the infiltration effectiveness of different practices (infiltration trenches, bioretention, etc.).
3. Coordination of a database (using well logs) of shallow wells, to provide important data (e.g., depth to bedrock) for locating retrofit infiltration devices and for refining existing hydrological models.
4. Identification of exceptional resources (e.g., cold water fisheries; springs) that may require "sustainable standards" different from those applied more generally.
5. Piloting a rigorous "resource-based" approach on a particular sub-watershed. This would mean establishing new wells and refining the current county-wide groundwater model based on new data at a more detailed local level. One possible area is the Odana Pond subwatershed of the Lake Wingra watershed. Such a pilot might support studies associated with the MG&E

infiltration project (and associated concerns about possible road salt contamination of groundwater) and a possible pilot of road salt reduction practices by the City of Madison.

6. Evaluation of the impact of possible future designation of Dane County as a regional groundwater management unit under the Wisconsin groundwater management legislation.

Resource Needs

1. Additional county staff to provide training, permit review, monitoring effectiveness of installations, and on-going review of infiltration standards. Recommend municipalities also assess staffing needs and adjust as needed.
2. Up-front costs for data-gathering, modeling, and other research needed to ensure our future natural resource needs are being met by infiltration standards and practices (thus preventing costly future failures of infiltration devices), and for maintaining and updating existing Dane County hydrologic models. Explore finding these funds through a uniform fee that does not unfairly burden developers.

Attachment 1

Dane County Lakes and Watershed Commission
Stormwater Infiltration Task Force Members
September 2005 - June 2006

Members
Jeremy Balousek Dane County Land & Water Resources Department
Randy Christianson Caldwell Banker Sveum
Ann Dansart (Scott Taylor represented this group until April) Friends of Starkweather Creek
Kent Disch Madison Area Builders Association
Don Esposito Veridian Homes
Steve Fix Upper Sugar River Watershed Association
Greg Fries City of Madison Engineering
Deb Hatfield Mayo Corporation
Ken Johnson Wisconsin Department of Natural Resources
Nathan Lockwood D'Onofrio Kottke
Jim Lorman, Chair Dane County Lakes & Watershed Commission
Birl Lowery UW-Madison Soils
Kamran Mesbah Dane County Community Analysis & Planning Division
Rob Montgomery Montgomery & Associates
Ken Potter UW-Madison Civil & Environmental Engineering
Jon Radloff Vierbicher Associates

Staff
Sue Jones Dane County Department of Land and Water Resources Josh Harder Dane County Department of Land and Water Resources

Attachment 2

Schedule of Meetings

Entire Task Force: Sept 29, 2005; Oct 14, 2005; Jan 20, 2006; Feb 10, 2006; Feb 23, 2006; March 7, 2006; April 7, 2006; April 14, 2006; April 28, 2006; May 18, 2006

Resource Subgroup: Nov 17, 2005; Dec 19, 2005

Site Analysis Subgroup: Nov 8, 2005, Nov 28, 2005; Dec 3, 2005; Dec 22, 2005; March 3, 2006

Attachment 3

List of Identified Issues

1. Infiltration standards in the context of larger development planning
   a. How does infiltration fit into all of the stormwater management considerations that need to be addressed during development planning? Projects also need to consider controls on peak runoff, sediment erosion, thermal pollution, wetland loss, floodplain impact, etc. In addition, developers need to plan for density, open space, lot sizes, connectivity, topography, zoning, and economic factors.
   b. Municipalities have specific community standards (e.g., widths for sidewalk, curb & gutter, and terraces; building densities; new urbanism with alleys) that may limit stormwater management options. How should these standards affect requirements for infiltration in developments?
   c. How do we best deal with the perception that a lack of "caps" on the area required for infiltration conflicts with the economic needs of development, and to what extent is that perception based on solid information?
2. Resource protection goals of infiltration standards
   a. To what extent are standards based on what is needed to protect specific resource qualities (water quality, groundwater supply, flood protection, etc.)? To what extent are such resource-based standards possible given the current state of research?
   b. To the extent neither NR 151 nor Dane County standards are "resource based," what criteria should be used to establish standards?
   c. Should infiltration goals (and standards) be different in watersheds that have different resource quality needs (e.g., cold water streams that are heavily dependent on groundwater to sustain their value)?
   d. To what extent can we document that the resource/environmental benefits resulting from the implementation of infiltration standards exceed any additional costs incurred?
3. Interpretation of infiltration standards
   a. How might the application of standards to a particular development be made simpler? Developers are faced with different standards developed at different governmental levels, differences between guidelines and technical design standards even at a single governmental level, and different interpretations of standards by different reviewing agencies. This complicates the design process and tends to encourage developers to choose simpler "cap" approaches.
   b. How can creative designs by developers be encouraged within the complex and changing regulatory environment? Since infiltration standards and design guidelines are fairly new and complex, the design community has not had time to become comfortable with appropriate modeling methods to produce creative designs.
   c. Do SOC (Standards Oversight Council, http://www.socwisconsin.org/) standards apply if Dane County's infiltration standards exceed those of NR 151?

4. Research needs
    a. What additional information do we need to do a reasonable cost/benefit analysis of infiltration standards?
    b. To what extent can existing models, or extensions of existing models, provide additional information that would allow us to better understand i) the effectiveness of particular development practices with respect to infiltration, and ii) the long-term impact of particular standards on resource quality?
    c. Do we need to plan for on-site monitoring of infiltration devices to learn how different devices actually perform under specific conditions of soil, etc.?

Attachment 4

Infiltration Task Force Site Analysis Subgroup Summary
5/18/06

The Site Analysis Subcommittee of the Infiltration Task Force was formed to analyze and model the potential effects of modifying or removing the caps on the maximum size of infiltration practices. The subcommittee was comprised of six engineers that were also members of the full task force. Subcommittee members included:

Jeremy Balousek, Dane County Land and Water Resources Department
Greg Fries, City of Madison Engineering Division
Jon Radloff, Vierbicher Associates, Inc.
Nathan Lockwood, D'Onofrio Kottke and Associates, Inc.
Deborah Hatfield, Mayo Corporation
Rob Montgomery, Montgomery Associates: Resource Solutions, LLC

The subcommittee met four times to discuss findings and make recommendations to the full task force.

The first analysis the task force completed was evaluating the difference in modeling results between the two available infiltration models, SLAMM and RECARGA. In order to complete the analysis, several model inputs were examined, including the following:

1. Disconnection of impervious surfaces (connected vs. disconnected)

2. Soil texture class (sandy loam vs. silt loam)

3. Pervious runoff curve number (58 vs. 68)

Each subcommittee member independently modeled the same commercial development using both infiltration models and varied model inputs with each run. The initial goal of the analysis was to produce a side-by-side comparison of the of the two models' outputs. When the group convened to discuss their individual results, it was quickly evident that due to the complexity and required assumptions of the infiltration models, each member had run the models differently. The disparity in model inputs and assumptions made it difficult to compare the two models. The group then concentrated on developing a set of uniform criteria to be used when performing infiltration calculations. By using the same set of assumptions and variables, it was hoped that meaningful results could be obtained. The following assumptions were agreed upon:

1. For an area to be disconnected, it must be separated by at least 30 feet of pervious surface from any treatment device or conveyance system.

2. No side discharge from infiltration or bioretention basins. [Need to add additional clarification based on 5/18 discussion.]

3. The maximum depressional depth for an infiltration basin is 24-inches and the maximum depressional depth for a bioretention basin is 12-inches.

4. The pervious area runoff curve number should be 68, unless justified by existing or proposed vegetation (i.e. 58 for prairie vegetation).

5. All treatment areas must be removed from the tributary areas for calculation purposes and not double counted as pervious surfaces.

6. The SOC standard *"Site Evaluation for Stormwater Infiltration"* will be used for determining design infiltration rates.

7. For RECARGA, the maximum ponded time is 96 hours. (Note: Other requirements may apply in specific situations such as airports.)

The subcommittee then decided to model several different types of development to determine which land uses would have difficulty in meeting the infiltration goals without exceeding the 1% cap for residential land uses and the 2% cap for non-residential land uses, using bioretention devices. In addition, results of the two infiltration models would then be compared to see if large discrepancies exist. The results of the analysis are shown in the table below.

Rock Depth (ft.)	Root Depth (ft.)	Pond Depth (ft.)	Land Use	Analysis Program	Connectivity	Regulatory Cap		Area Required to Meet Goal		Infiltration Rate (in./hr.)	Project Impervious Percentage	
0	3	1	MDR	SLAMM	NO	1%	6,300	6,000	<1%	0.13	40%	
0	3	1		SLAMM	YES	1%	6,300	32,000	5.1%	0.13	40%	
2.5	3.5	0.5	HDR	SLAMM	YES	1%	16,770	55,000	3.2%	0.13	65%	(Perv. + Imp.)
2.5	3.5	0.5		SLAMM	YES	1%	16,770	12,500	0.7%	3.6	65%	(Perv. + Imp.)
2.5	3.5	0.5		SLAMM	YES	1%	16,770	28,000	1.7%	0.5	65%	(Perv. + Imp.)
3	3	1	LARGE COMMERCIAL	SLAMM / REC.	YES	2%	3,120	624	0.4%	0.5	37%	(Imp. Only)
3	3	0.5		SLAMM / REC.	YES	2%	3,120	2,340	1.5%	0.13	37%	(Imp. Only)
3	2	0.5	MIXED (FITCHBURG CENTER)	RECARGA	YES	2%	2,082	2,675	2.6%	0.13	60%	(Imp. Only)
3	2	0.5		SLAMM	YES	2%	2,082	3,275	3.2%	0.13	60%	(Imp. Only)
3	2	0.5		SLAMM	YES	2%	2,082	450	0.3%	0.13	60%	(Perv. + Imp.)
2	3	1	LDR	SLAMM	NO	1%	8,700	0	0%	0.5		(Perv. + Imp.)
2	3	1		SLAMM	YES	1%	8,700	2,000	0.2%	0.5		(Perv. + Imp.)
2	3	1		RECARGA	YES	1%	8,700	4,000	0.5%	0.5		(Perv. + Imp.)
2	3	1	COMM (OFFICE)	SLAMM	YES	2%	3,020	630	0.4%	0.5	84%	(Imp. Only)
				RECARGA	YES	2%	3,020	1,300	0.9%	0.5	84%	(Imp. Only)
2	3	0.25		SLAMM	YES	2%	3,020	1,812	1.2%	0.13	84%	(Imp. Only)
				RECARGA	YES	2%	3,020	2,500	1.7%	0.13	84%	(Imp. Only)

The following conclusions were reached as part of this analysis:

1. RECARGA generally requires larger infiltration facilities than SLAMM to meet infiltration stay on goals.

2. Bioretention subsurface storage volume greatly influences the required facility area. As underground storage increases ("Rock Depth" in the above table), the required facility area decreases.

3. Medium and high-density residential (MDR and HDR) land uses generally exceed the cap for silt loam soils. This is partially due to not being able to feasibly disconnect impervious areas.

4. Commercial developments do not need to exceed the cap due to a lower goal and a higher cap percentage (2%).

Since it is generally accepted that infiltration basins designed for the same requirements would have to be larger, but less expensive to construct, the subcommittee decided that future model runs should also include infiltration basin calculations.

The question of what the maximum allowable design ponding depth should be was discussed. The issue is complicated by "multiple use" or "hybrid" stormwater practices that combine detention with infiltration. It was noted that the DNR standards state the maximum allowable depth for specific practices, but it was recognized that the maximum depth would be greater for the hybrid devices.

Other issues that were raised included density classifications and the total dedicated area for stormwater management. The group agreed that the definitions of "high" and "medium" density varied greatly amongst municipalities and that a term such as "higher density" should be used. The total area being dedicated to stormwater management is also an issue since infiltration areas are only part of the total area that must be dedicated. The group recognized that the use of hybrid devices would play an important role in total area required.

It was concluded that more modeling was needed to determine why the HDR & MDR sites were exceeding the cap with silt loam soils. The subcommittee chose to estimate the incremental increase in area dedicated to stormwater management when infiltration requirements were added, not just area dedicated to infiltration. The group decided that "pre-October, 2004" developments (not originally subject to NR151 infiltration requirements) would be reevaluated with the addition of infiltration devices (both bioretention and infiltration basins).

The modeling of the infiltration basins with RECARGA used the following criteria: the storage layer will be zero and the root zone will be one inch thick with an infiltration rate of 0.13 inches per hour (native silt loam). The group decided that the terms MDR and HDR were not appropriate due to the wide range of interpretation. Instead, sites with lots greater than 6,500 square feet were analyzed as one group and sites with lots less than 6,500 square feet were analyzed as another group.

Four of the "smaller" lot size developments and three of the "larger" lot size developments were modeled. An issue that was encountered was the depth of depressions in bioretention devices (due to its effect on the maximum hours ponded). One member used six inches and kept the pond retention time under 96 hours in the model results. Others used three inches based on draw down calculations using the soil type and the 24-hour draw down time. The group agreed that the draw down calculation approach (rate = 0.13in/hr and 24hr max = 3in) was appropriate for the infiltration basins, but did not reach a consensus on this approach for bioretention devices. The other significant result was the difference between the models. SLAMM required much more of the site to meet the goals. One reason for the discrepancy might be the hydrology that each model uses to determine the predevelopment runoff/stay-on ("small storm" vs. CN).

The infiltration basins required between 2 and 3 times more area than the hybrid bioretention devices for "smaller lot" higher density developments. It was pointed out that this is good evidence why many hybrid devices are being proposed. One drawback to this approach is that using hybrid devices eliminates the inclusion of a permanently wet pond, which many developers like for aesthetic reasons and is also results in better sediment trapping. Several group members questioned whether hybrid bioretention devices are a long-term, sustainable practice. The group also concluded that the modeling results indicate that the nonresidential goals were met quite easily without dedicating additional area to stormwater management.

The SLAMM analysis of a "larger lot" high-density residential development (6,500-10,000 square feet) did not require any additional infiltration practices to be installed due to the amount of pervious area present in the drainage area and the impervious area being modeled as "disconnected". There was some debate as to the validity of modeling the impervious as disconnected. The group felt that at least a portion of the site should have been connected. RECARGA modeling, which doesn't allow for disconnecting impervious surfaces, showed that a bioretention device with a facility area of about 5% of the site would be necessary, while the infiltration basin would need to be about three times that size. It was also noted that the practice of curve number "bumping" for detention had effected the change in total area dedicated to stormwater management.

The subcommittee discussed the question of how often the scenario modeled (small lot, high density residential, entirely contained on silt loam soils) would occur in practice. The group strongly doubted there was a reliable way of determining how often this scenario would occur. The general consensus was that this type of "worst case" scenario would occur infrequently, however the group did concur that it was a real possibility that merited consideration.

The site analysis subcommittee did not formally meet again, but additional modeling was performed based on questions from the full task force. The task force suggested that instead of targeting "stay on" as NR151 does for infiltration calculations, it might be worthwhile to analyze recharge as well. "Stay on" is made up of several components including evaporation, transpiration, and groundwater recharge. Since the group was most interested in infiltrating runoff back into the ground, it was suggested that modeling goals that address recharge might be a better option. In addition, since higher density developments produce more runoff, there is more runoff available to overcome evapotranspiration (ET) in the infiltration facilities. Ken Potter noted that through his research the optimum size to achieve recharge in an infiltration basin was found to be 15% of the impervious area. As facilities begin to exceed this size, more of the runoff becomes ET than recharge.

Jon Radloff performed an analysis of recharge rates using SLAMM and RECARGA for both bioretention devices and infiltration basins by modeling a 40-acre residential site. Model runs were completed varying the impervious area from 40 to 65 percent and included calculations for 1% and 2% of the site area along with 15% of the impervious area.

It was quickly apparent that results from the two models varied significantly. RECARGA had much lower recharge rates than SLAMM. The main reason for this discrepancy is that SLAMM does not account for ET in the facility, but simply assumes that runoff into the basin is infiltrated, while RECARGA attempts to model the effects of ET. It was difficult to draw any significant conclusions from the model results as neither model accurately predicts the recharge that occurs on the pervious areas in the pre and post development conditions.

Through discussions with Ken Potter (Civil and Environmental Engineering) and John Norman (Soil Science) at the University of Wisconsin, an approach to calculating recharge rates on pervious surfaces was derived. Included below are the assumptions and proposed calculation techniques.

Assumptions/Notes:

1. Detailed and accurate models exist to calculate recharge rates on pervious surfaces, however these models are complicated, require numerous variable inputs, and lack intuitive user interfaces. There are current projects at the University to simplify these models, but the time scale is such that they won't be available in time for the task force to utilize them.

2. It is possible to estimate recharge rates without the use of models. Variables such as soil and vegetation type may be assumed to be negligible, while precipitation during periods of the year with high recharge rates must be considered.

3. It should be assumed no recharge occurs in the fall even though there is very little ET. The soil moisture levels are typically so low from summer heat that all infiltration goes to filling soil pore space.

4. An assumption may be made that all frozen precipitation and rainfall that occurs from December 2nd to May 31st becomes 100% recharge due to the lack of ET and moist soil conditions. Using the 1981 Madison rainfall file, precipitation during this period equals 7.6 inches.

5. Predevelopment infiltration rates on pervious surfaces would then be assumed to be 7.6 inches per year.

6. At this time, the only model that has the ability to calculate recharge rates in an infiltration facility is RECARGA.

Calculation of Recharge for Post Development Conditions:

post development recharge (inches) = calculated facility recharge + (% pervious x 7.6)

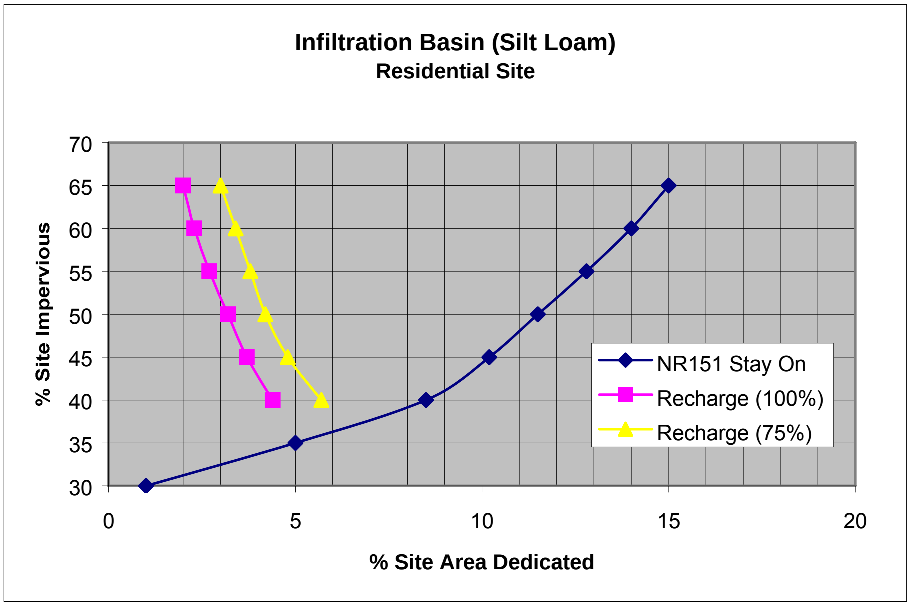
Note: This assumes that entire area drains to the facility. This rate would need to be prorated if only a portion of the site drains to the infiltration practice.

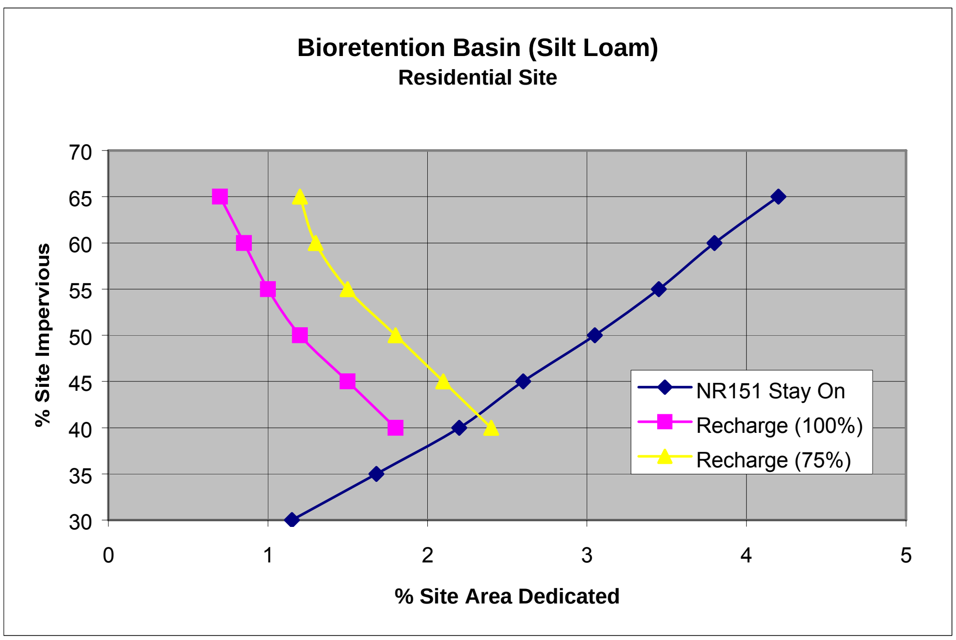
Example:

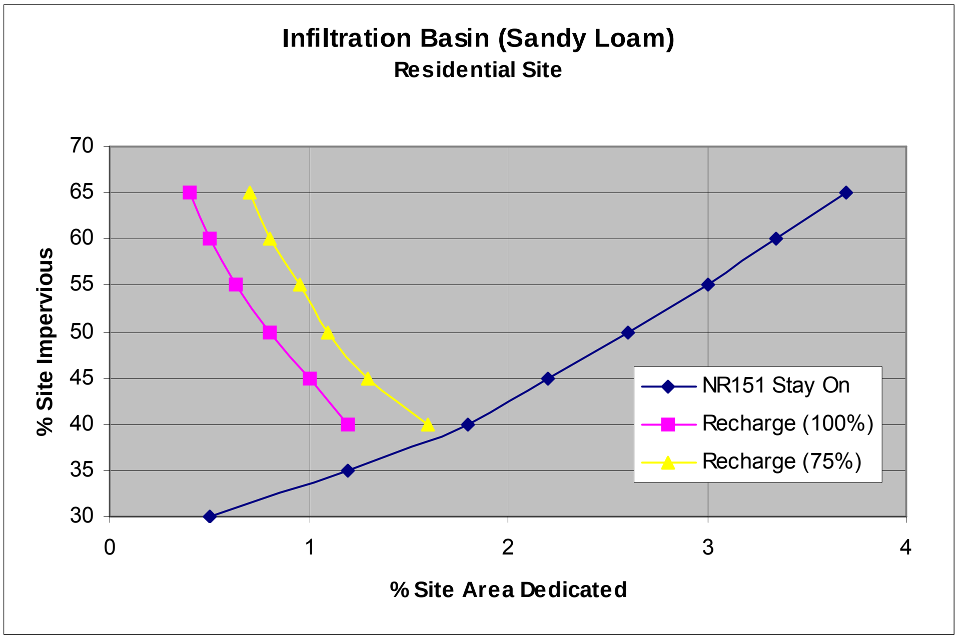
1-acre residential development, 50% impervious, entire site drains to a bioretention device. RECARGA gives a recharge depth of 5.0 inches. Then:

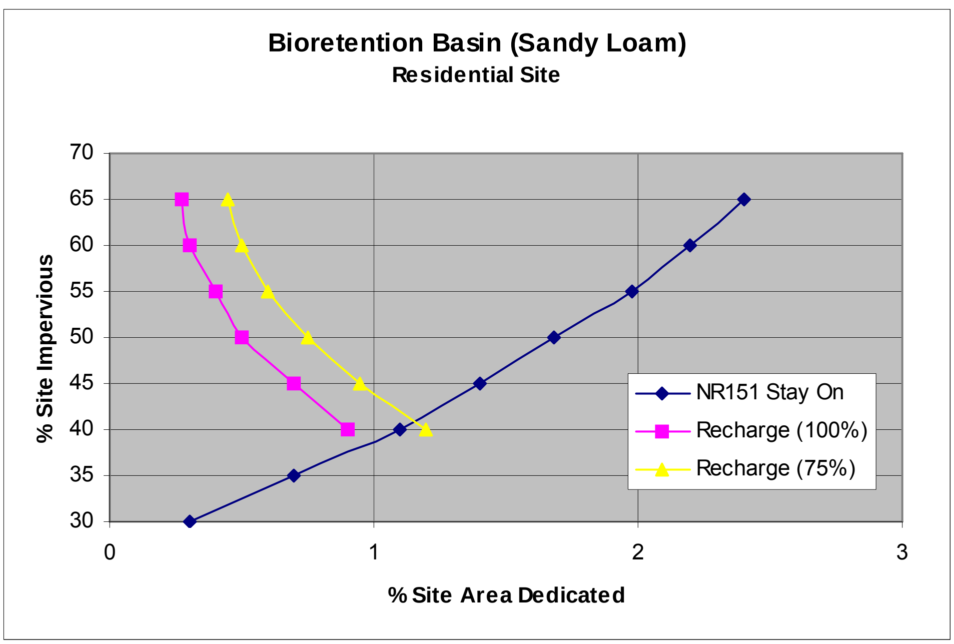
5.0 + (.50 x 7.6) = 8.8 inches of recharge

The task force questioned whether or not developers should get full credit for pervious areas in a post development condition. Some members suggested reducing the post development recharge rate and giving only 75% of the predevelopment value, while others suggested requiring developers to mitigate the effects of compaction on their sites and using 100% of the predevelopment recharge rate. In the end it was decided to repeat the recharge calculations that were previously conducted, incorporating the calculation of pervious area recharge both for 100% and 75% of the predevelopment rate. Results of this analysis are shown in the charts below.


Infiltration Basin (Silt Loam)
Residential Site
% Site Impervious
70
65
60
55
50
45
40
35
30
0
5
10
15
20
% Site Area Dedicated
NR151 Stay On
Recharge (100%)
Recharge (75%)


Bioretention Basin (Silt Loam)
Residential Site
% Site Impervious
70
65
60
55
50
45
40
35
30
0
1
2
3
4
5
% Site Area Dedicated
NR151 Stay On
Recharge (100%)
Recharge (75%)





This analysis shows that the maximum required size of an infiltration basin on silt loam soil is approximately 5% of the site area and 2% for a bioretention facility. With other soils, such as sandy loam, the site area required is significantly less.

The site analysis subcommittee did not make formal recommendations to the full task force, but rather made suggestions and recommendations for consideration during the task force meetings. This allowed the entire task force to be involved in the decision making process. A document was also prepared entitled *"Infiltration Modeling Guidance"* that can be found in Attachment 6. This document provides guidance for selection of appropriate variable inputs and model schematics for SLAMM and RECARGA and serves to summarize the consensus that has been reached in the subcommittee on these model inputs.

Attachment 5

Memorandum

To: Dane Co Infiltration Task Force Members

From: Rob Montgomery, Steve Gaffield and Linda Severson

Date: June 30, 2006

Re: Review of estimates of groundwater recharge in Dane County

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Purpose

Dane County is in the process of revising its stormwater ordinance (Ch 14) to replace the caps on maximum land area required for infiltration devices with a new approach focusing on maintaining the predevelopment groundwater recharge. This requires identifying a target recharge rate (or rates) for application in the ordinance. Groundwater recharge rates are very difficult to measure directly or to estimate accurately. Furthermore, recharge rates vary spatially with geologic conditions and land use, and they change through time in response to changes in precipitation. The purpose of this memo is to summarize and compare estimates of groundwater recharge rates in Dane County from a variety of sources.

Dane County Recharge Estimates

Groundwater recharge can be estimated by several methods, including analysis of data representing indirect measurements of recharge (i.e. streamflow), recharge values determined from the calibration of computer models of groundwater or watershed hydrology, and analytical calculations that rely upon simplifying assumptions. In general, we believe the most reliable estimates to be those based upon direct analysis of data and the least reliable to be the simple analytical calculations.

Direct Analysis of Data

1) A study of streamflow in Wisconsin by the USGS[1] uses gaging station records throughout Wisconsin to estimate groundwater recharge in the contributing watersheds and to develop empirical relationships between watershed properties and groundwater recharge. The period analyzed was from 1970 – 1999. At the river basin scale, recharge estimates for the Upper Rock River Basin, the Lower Rock River Basin, and the Lower Wisconsin River Basin are **5.4 in/yr**, **5.9 in/yr**, and **7.6 in/yr**, respectively. The study also analyzed data from smaller river basins, several of which are partially or entirely in Dane County. For the larger basins that cover substantial parts of Dane County, recharge rates range from **2.7 – 9.5 in/yr**. The results presented do not show obvious trends in recharge rates from one part of the county to another.

   A disadvantage to this study is that it covers only parts of Dane County. In addition, some uncertainty in the results arises from the possibility that groundwater divides are not in the same location as the

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[1] Gebert, WA and MJ Lange, EJ Considine and JL Kennedy, in press. Use of Streamflow Data to Estimate Baseflow/Ground-Water Recharge for Wisconsin. Journal of the American Water Resources Association.

surface drainage basin divides. This is especially true for very small basins; however it is less likely to be a major source of error at the scale of the larger basins discussed above. The USGS has measured stream baseflow at many more sites in Dane County than are presented in this study, and these measurements could be used in the future to refine recharge estimates for the county.

Calibrated Models

2) The Dane County Regional Groundwater Model[2] uses recharge rate as an input parameter that is calibrated to match water levels measured in wells and observed streamflows. The authors note that different values for recharge are obtained depending on which set of targets – water levels or streamflows – are given more importance in the calibration process. We consider streamflow to be the more relevant target for estimating recharge. The model produced the best match to measured streamflows with an average recharge rate of **5 in/yr**. (The average recharge rate obtained by matching the model to water level records is considerably lower.) It is important to note that this recharge rate is an average over the entire county and includes areas with little or no recharge, such as groundwater discharge areas and heavily urbanized areas (Ken Bradbury, personal communication, June, 2006).

3) In a UW-Madison dissertation project, Sue Swanson constructed a groundwater model of the Nine Springs area by refining the regional groundwater model for that part of the county[3]. The model uses a uniform recharge rate, and it is calibrated to both water levels in wells and measured streamflows. The best fit between the model and the observations was produced with a recharge rate of **8 in/yr**.

4) The USGS has conducted detailed studies of the Pheasant Branch Creek watershed using both a groundwater model and a watershed hydrologic model. The groundwater model is another refinement of the regional model, and it includes the Pheasant Branch watershed and some of the surrounding area.[4] The calibrated model uses spatially variable recharge ranging from **2.2 – 9.5 in/yr**, with an average of **8.0 in/yr**. In a related study, the Precipitation Runoff Modeling System (PRMS) was used to simulate surface water flows in the watershed, and it was calibrated with recharge rates ranging from 2.3 in/yr in a highly impervious subwatershed to **9.7 in/yr** in the undeveloped North Fork basins, with a watershed-wide average of **8.1 in/yr**.

5) Kristin Anderson refined the Pheasant Branch groundwater model in a UW-Madison graduate thesis[5]. This model also uses **8.1 in/yr** for recharge, with the exception of an urbanized area in Middleton, which was assigned a recharge of **6.2 in/y**r.

6) The USGS has constructed a groundwater model for northwestern Dane County for a study of Fish, Mud and Crystal Lakes[6]. The model, also based upon the regional model, was run in transient mode for the

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[2] Krohelski, JT, KR Bradbury, RJ Hunt and SK Swanson, 2000. Numerical Simulation of Groundwater Flow in Dane County, Wisconsin. Wisconsin Geological and Natural History Survey Bulletin 98.

[3] Swanson, SK, 2000. Hydrogeologic Controls on Spring Flow near Madison, Wisconsin. University of Wisconsin-Madison Ph.D. Dissertation (Geology).

[4] Hunt, RJ and JJ Steuer, 2000. Simulation of the Recharge Area for Frederick Springs, Dane County, Wisconsin. United States Geological Survey Water-Resources Investigations Report 00-4172.

[5] Anderson, KM, 2002. Hydrogeologic Controls on Flow to Frederick Springs in the Pheasant Branch Watershed, Middleton, Wisconsin. University of Wisconsin-Madison M.S. Thesis (Geology).

period from 1966-1998. The calibrated recharge rate varies from year to year reflecting climatic variations, ranging from **4.6 - 9.7 in/yr**.

Analytical Estimate

7) At the April 7, 2007 Infiltration Task Force meeting, Jeremy Balousek of the Dane County Land and Water Resources Department presented a simple calculation to estimate local groundwater recharge. This estimate makes the assumptions that all frozen precipitation and all rainfall between December 2 and May 31 becomes recharge, and that no recharge occurs during other times of year due to either evapotranspiration losses or infiltrated water filling pore spaces in very dry soil in the fall. In 1981, rainfall in Madison during this period was 7.6 in, yielding a recharge estimate of **7.6 in/yr**. As noted by Jeremy, the assumptions required by this method reflect broad generalizations. It is widely accepted that recharge events are common during the fall, and runoff from snowmelt and rainfalls before May 31 are very common. While this method provides a useful check on the estimates developed in other studies, it should be regarded as a very approximate estimate of recharge rate.

Conclusions and Recommendations

These studies indicate that the average recharge rate for Dane County is in the range of approximately 5 – 8 in/yr. Given the intent to promote recharge and the likelihood that the lower values reported in the literature are influenced by human impacts, such as development and poor agricultural practices, specifying a value near the upper end of this range as the recharge goal in the revised County ordinance is appropriate.

The Infiltration Task Force gave some consideration to developing different target recharge rates for different parts of the county. Although there are sound reasons for considering this approach, it appears that available scientific information is insufficient to justify applying different standards in different areas at this time. The USGS streamflow study has potential for this purpose, however not all parts of the county are included, and the issue is complicated by the possibility of interbasin groundwater transfers. It may eventually be possible to accurately estimate recharge rates at a site-specific scale based upon soil, topographic and climatic data, however current methods are probably better suited for estimating relative differences in recharge potential from one location to another than they are for predicting a precise recharge rate.

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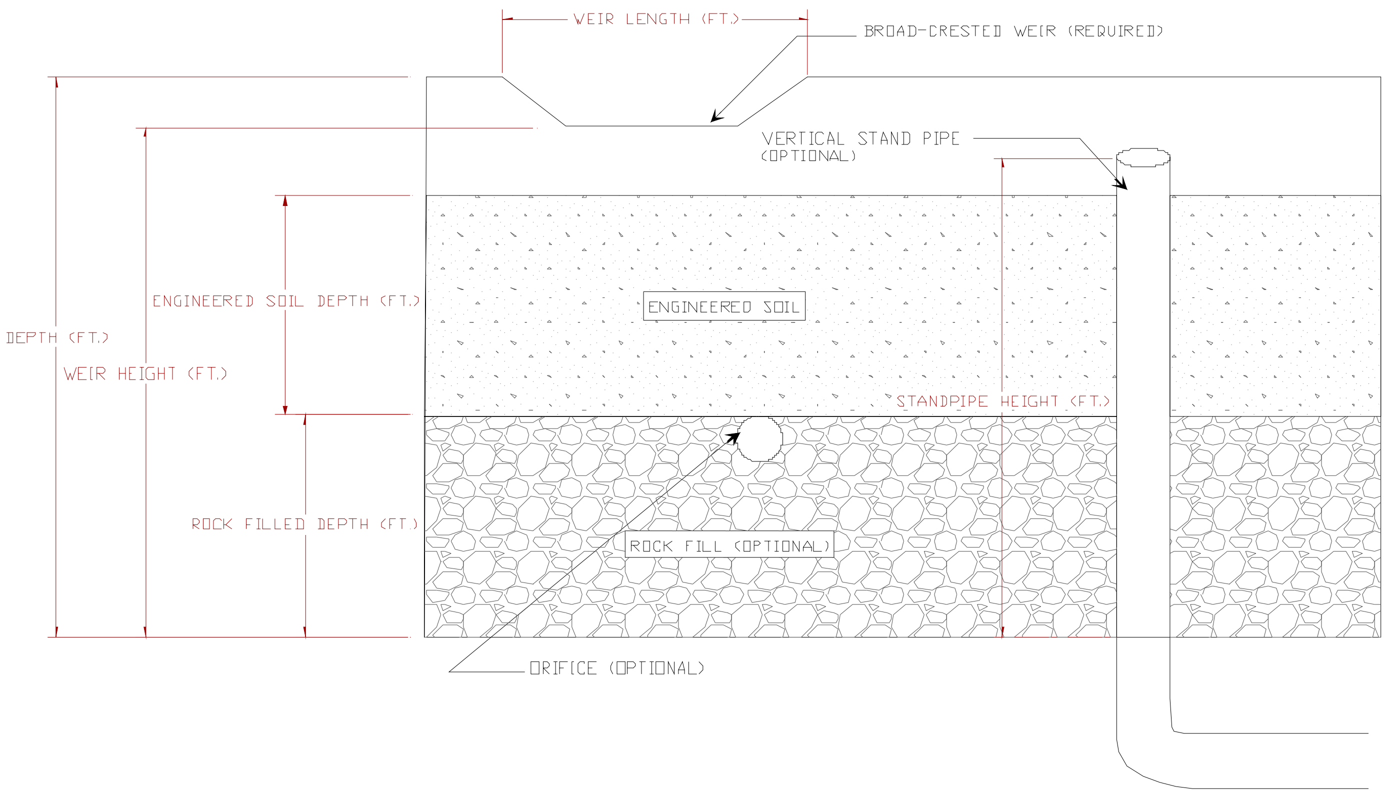
[6] Krohelski, JT, YF Lin, WJ Rose and RJ Hunt, 2002. Simulation of Fish, Mud, and Crystal Lakes and the Shallow Ground-Water System, Dane County, Wisconsin. United States Geological Survey Water-Resources Investigations Report 02-4014.

Attachment 6

Infiltration Modeling Guidance

SLAMM:

Bioretention Dimension Diagram
(for use with SLAMM)



1. The Datum (Elevation Zero) is the bottom of the facility (bottom of rock fill in diagram above).
2. Depth is the entire vertical dimension of the facility, including to the top of the overflow weir.
3. The fraction as voids for engineered soil is 0.27 and the fraction as voids for the rock fill is 0.33.
4. WinSLAMM versions 9.1 and earlier….Depth of BioFilter that is Rock Filled = both the depth of engineered soil and stone storage. In addition, the fraction as voids is a combination of the two materials.
5. No seepage rate out the side is allowed (must be set to 0).

Additional Guidance for Using WinSLAMM:

1. Winter precipitation must be removed from the calculations. According to NR151, precipitation from 12/2 to 3/12 should not be included when using the Madison 1981 rain file. These dates are entered on the current file data page.

2. In order for an area to be considered "disconnected", it must sheet drain over at least 30 feet of pervious surface. Concentrated flow areas, conveyances, and stormwater management facilities are not considered sheet flow.

RECARGA:

1. The infiltration rate for engineered soil is 3.94 in./hr.

2. The maximum ponded time must not exceed 96 hours.

3. The pervious area runoff curve number should be 68, unless justified by existing or proposed vegetation (i.e. 58 for prairie vegetation).

4. When using RECARGA for modeling an infiltration basin, the rooting zone depth should be assumed to be 1-inch and the storage zone should be set to zero.

Other Modeling Notes:

8. The maximum depressional depth for an infiltration basin is 24-inches and the maximum depressional depth for a bioretention basin is 12-inches.

9. All treatment areas must be removed from the tributary areas for calculation purposes and not double counted as pervious surfaces.

10. The SOC standard *"Site Evaluation for Stormwater Infiltration"* must be used for determining design infiltration rates.

Attachment 7: Draft Inspection Form

Inspected By: ______________________________________ Date ____________

Affiliation: ____ Time: ____________

Location

Postal Address

____

____

____

PLSS

Township (N): _______ Range (E): _______

Section: _____ Quarter/Quarter: ________

Weather Conditions

Recent Precipitation (in)

7 days _______ 72 hr _______ 48 hr _______ 24 hr _______

Site/Practice Characteristics

Practice Type: ☐ *Basin* ☐ *Rain Garden* ☐ *Bioretention* Design Standard: ___________________

Tributary Area (acres) _______ Tributary land use ☐ *Residential* ☐ *Non Residential*

Tributary Land Cover Percentage: *Pavement* _______ *Roof* _______ *Pervious* _______

Pretreatment: ☐ *Basin* ☐ *Buffer* ☐ *None;* Calculated sediment trapping efficiency _________

Practice Conditions

Condition of Pretreatment Device: ☐ *Good* ☐ *Fair* ☐ *Poor* ☐ *Not Applicable*

☐ *Ponded Water* - Percent ponded _____ Average depth _____ Depth in observation well _____

☐ *Dead Vegetation* - Type:_____________ ☐ *Side slope* (_____%) ☐ *Bottom* (_____%)

☐ *Sedimentation* - Percent of bottom covered _____ Average depth of sediment _____

☐ *Scour* – Location: ☐ *Inlet:* mild / severe ☐ *Outlet:* mild / severe

Comments: ____

____

____

Attachment 8

Possible Future Revisions to Standards Identified by Task Force Members

Below are ideas for potential changes in infiltration standards that members of the Task Force suggested for possible future consideration. They were not discussed at length by the entire Task Force, and therefore do not represent group agreements. Some members, however, felt these are ideas that merit recording here for possible consideration at some later time.

1. Develop site-specific sustainable, resource-based standards in instances where hydrological information is adequate to establish them.
2. Reduce or remove exceptions for sites with poor soils, since these areas may be critical as recharge areas despite low infiltration rates. (The reduction in exceptions could be accompanied by additional language in the standards aimed at preserving the viability of high density development.)
3. Increase the required percentage of predevelopment average annual infiltration for commercial sites.
4. Consider requirements for infiltrating wastewater and/or greywater.
5. Provide an option for "fees in lieu of" meeting infiltration standards, with the fees used for mitigation in other appropriate sites (as long as such fees are in response to a standard that exceeds standards established by the Dane County Stormwater Ordinance.)