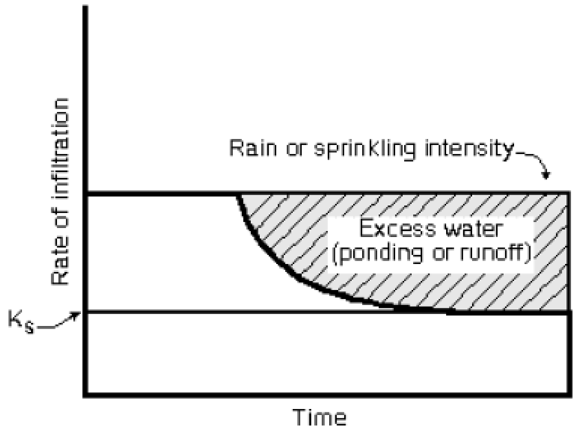
Memorandum

To: MIDS Work Group
From: Barr Engineering Company
Subject: Regional Hydrologic Metrics – Infiltration (Item 4, Work Order 1)
Date: December 22, 2010
Project: 23/62 1050 MIDS

Stormwater runoff volume reduction Best Management Practices (BMPs) are focused on retaining stormwater runoff onsite. Runoff retention can be achieved by several main methods, including infiltration of stormwater into the ground surface, evapotranspiration of stormwater into the atmosphere, or storage and reuse of the stormwater (for example, for irrigation purposes). When site conditions permit, the most common stormwater runoff volume reduction BMP is infiltration.

Infiltration can be defined as the flow of water from the land surface into the soil. The rate at which the stormwater infiltrates into the soil is dependent on several factors, including the rate and duration of stormwater supply, physical properties of the soil, such as its porosity and hydraulic conductivity, vegetation, slope of the land, and the current moisture content of the soil. The maximum rate at which water can infiltrate into the soil under a given set of conditions is called the infiltration capacity. In general, the rate of infiltration in soils is higher in the beginning of a storm, decreases rapidly, and then slowly decreases over time until it approaches a constant rate (saturated hydraulic conductivity). This process is shown below in Figure 1 (Hillel, 1982).



Source: Hillel, 1982

Figure 1. Infiltration Process

Estimating Infiltration Rates

Hydrologic Soil Group (HSG)

The Natural Resources Conservation Service (NRCS) has grouped soils throughout the nation into several categories (A, B, C, D) based on their hydrologic characteristics and runoff potential under similar storm and vegetation conditions. Soil properties that influence runoff potential are those that influence the minimum rate of infiltration for a

bare soil after prolonged wetting and when not frozen, including depth to a seasonally high water table, saturated hydraulic conductivity after prolonged wetting, and depth to a layer with a very slow water transmission rate. The four hydrologic soil groups are defined below:

> **Hydrologic Soil Group A** (Low runoff potential): The soils have a high infiltration rate even when thoroughly wetted. They chiefly consist of deep, well drained to excessively drained sands or gravels.
>
> **Hydrologic Soil Group B:** The soils have a moderate infiltration rate when thoroughly wetted. They mainly are moderately deep to deep, moderately well drained to well drained soils that have moderately fine to moderately coarse textures.
>
> **Hydrologic Soil Group C:** The soils have a slow infiltration rate when thoroughly wetted. They chiefly have a layer that impedes downward movement of water or have moderately fine to fine texture.
>
> **Hydrologic Soil Group D** (High runoff potential): The soils have a very slow infiltration rate when thoroughly wetted. They chiefly consist of clay soils that have high swelling potential, soils that have a permanent high water table, soils that have a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material.

Dual hydrologic groups, A/D, B/D, and C/D, are identified for certain wet soils that can be adequately drained. The first letter applies to the drained condition, the second to the undrained. Only soils that are rated D in their natural condition are assigned to dual classes. Soils may be assigned to dual groups if drainage is feasible and practical. Generally, for the purposes of estimating infiltration rates, soils with dual hydrologic groups should be considered D soils. This is certainly the case if trying to estimate infiltration rates from native soil conditions.

An approximate estimation of infiltration rates can be made based on the hydrologic soil group. However, it must be noted that there can be significant variation in infiltration rates among soils within each hydrologic soil group. The Minnesota Stormwater Manual provides guidance on infiltration rates for designing infiltration BMPs based on hydrologic soil group (Appendix A - Attached). As stated in the manual, these infiltration rates represent the long-term infiltration capacity of a constructed infiltration practice and are not meant to exhibit the capacity of the soils in the natural state.

Soil Texture

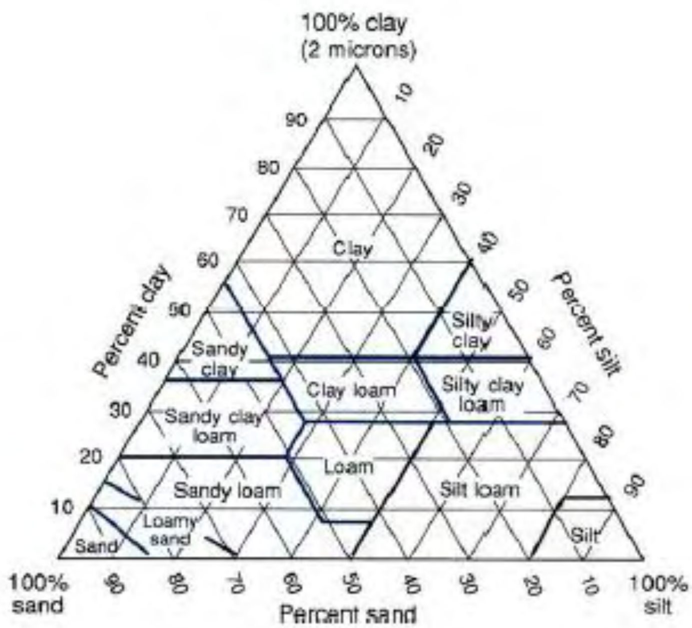


Figure 2. USDA Textural Classification (USDA 2010)

Soil texture is a term commonly used to describe the varying proportions of soil particles of different size groups in a soil (excluding organic matter). The U.S. Department of Agriculture (USDA) has developed a Soil Textural Triangle, which is presented in Figure 2, to help identify soil texture based on the proportions of sand, silt, and clay in a soil. Soil texture influences the saturated hydraulic conductivity (minimum infiltration rate) as well as other engineering properties such as bearing strength, compressibility, shrink-swell potential, and compaction. Soil texture also influences plant growth by its effects on aeration, water intake rate, available water capacity, the cation-exchange capacity, saturated hydraulic conductivity, erodibility and workability.

Considerable work has been conducted to characterize infiltration rates based on USDA soil texture. In 1982, Rawls et al presented mean saturated hydraulic conductivity values for eleven USDA soil texture classes, based on a limited survey of literature (Rawls, 1982). Later, Rawls et al assembled a national database of observed saturated hydraulic conductivities (nearly 1,000 values) and summarized the mean and range of saturated hydraulic conductivities for fourteen USDA soil texture classes (Rawls, 1998). This data is presented in Table 1. These studies are referenced in the Minnesota Stormwater Manual guidance on design infiltration rates for BMPs (Appendix A - Attached). It is important to note that although the infiltration values identified in the Stormwater Manual are based in part on these commonly cited references, the Stormwater Manual guidance combines numerous soil textures into a limited number of categories (two categories each for A and B soils and one category each for C and D soils) and generally identifies infiltration rates that represent the limiting saturated hydraulic conductivity within each category. For example, a loamy sand and sandy loam are both classified as HSG A in Appendix A, with a corresponding infiltration rate of 0.8 inches per hour (in/hr), but the mean saturated hydraulic conductivity identified in Rawls et al (1998) for these two soil textures are 2.6 in/hr to 0.9 in/hr,

respectively. The Stormwater Manual guidance also does not reflect the wide range of documented infiltration rates within each texture class (see Table 1).

Table 1. Saturated Hydraulic Conductivity classified by USDA Soil Texture (Rawls, 1998)

USDA Soil Class	Texture	Saturated Hydraulic Conductivity[1] (K_s) (in/hr)	Range Saturated Hydraulic Conductivity[2] (K_s) (in/hr)
Sand		5.3	10.3 - 3.6
Fine	Sand	4.8	8.7 – 4.2
Loamy	Sand	2.6	5.6 – 1.4
Loamy Sand	Fine	2.3	4.8 - 1.4
Sandy	Loam	0.9	2.7 - 0.4
Fine Loam	Sandy	0.5	1.1 - 0.2
Loam		0.2	0.8 - 0.11
Silt	Loam	0.3	0.9 - 0.14
Sandy Loam	Clay	0.14	0.6 - 0.04
Clay	Loam	0.05	0.28 - 0.01
Silty Clay	Loam	0.17	0.5 - 0.09
Sandy	Clay	0.04	0.12 - 0.01
Silty	Clay	0.06	0.28 - 0.02
Clay		0.07	0.27 - 0.03

[1] Geometric mean value from Ks database
[2] 25% and 75% percentile values from Ks database

Unified Soil Classification System (USCS)

Soils are often classified using the Unified Soil Classification System, a system used in the engineering field to describe the grain size distribution and other properties such as plasticity and liquid limit. Soils are classified into USCS groups with a group symbol containing two letters. The first letter indicates the most prevalent soil particle size fraction (G = gravel, S = sand, M = silt, C = clay, O = organic). The second letter is a descriptive modifier. For course-grained soils (more than 50% of material is larger than Number 200 sieve size), the following modifiers are used: P = poorly graded, W = well graded, M = silty, C = clayey. For fine-grained soils (less than 50% of material is larger than Number 200 sieve size), the following modifiers are used: H = high plasticity, L = low plasticity. A summary of USCS groups and symbols prepared by the Virginia Department of Transportation is included in Appendix B.

The USCS is significantly different than the USDA's system for determining soil texture. One difference is that the classification among different particle sizes varies between the two methods (for example, the USCS defines a silt as particles between the sizes 0.005 mm and 0.08 mm, whereas the USDA system defines silt as particles between 0.002 mm and 0.05 mm). Another difference is that the USDA system is entirely dependent on soil particle size, whereas the USCS also reflects properties such as liquid limit and plasticity. Due to the inherent differences in these two classification systems, there is unfortunately no way to directly translate between the two. For example, a silty sand (SM) in the USCS system could be a sandy loam, fine sandy loam, loamy sand, fine sand or sand in the USDA textural classification system. This can make it difficult to estimate an expected infiltration rate when a soil is identified by USCS soil group (as is typical in soil boring logs), as most literature values for infiltration rates are based on USDA soil texture. Appendix C can be used as a guide to translate between the USDA textural classification and USCS classification. Another method to assist in identifying a probable soil texture classification for a given soil is to conduct a grain size analysis, which will determine the percentages of gravel, sand, silt, and clay for application to the USDA soil textural triangle (Figure 2).

Soil Density and Compaction

The infiltration capacity of soil is also influenced by the density of the soil and the degree of compaction. Soil bulk density is a measurement of soil volume, which includes the volume of soil particles and volume of pores among the soil particles. The bulk density is inherently determined by soil texture, densities of the soil minerals (sand, silt, and clay) and organic matter, and the soil structure. Loose, porous soils and those rich in organic matter typically have a lower bulk density. Sandy soils have a relatively high bulk density due to the relatively small amount of pore space in comparison with silt or clay soils. In general, bulk density increases with soil depth, as a result of compression by overlying soils and reduced organic matter and root penetration.

Soil compaction can alter the soil bulk density from its natural state. As heavy equipment moves over the land surface, solid particles are forced into pore spaces previously occupied by water or air, resulting in a higher density. High bulk density can cause restricted root growth and penetration and poor movement of water and air through the soil. For all soil textures, higher bulk densities can result in significant decreases in infiltration rate. Rawls et al (1992) documented that bulk density has a significant effect on saturated hydraulic conductivity, and Rawls et al (1998) presented mean saturated hydraulic conductivity values according to soil texture and bulk density classes. For nearly all soil textures, the mean saturated hydraulic conductivities for high density samples were lower than that of the lower density samples, ranging from 10 to 83 percent lower (Rawls, 1998). The NRCS National Soil Survey Handbook contains guidance on estimating the impact of density on infiltration rates for various soil textures (see Figure 2).

Assessing Soils for Infiltration Feasibility

When evaluating the feasibility of soils for infiltration BMPs, the hydrologic soil group listed in the county's soil survey is often used as a preliminary screening tool. However, soil borings or test pits are recommended and sometimes required to verify soil types and infiltration potential. During the on-site soil investigation, the soil profile descriptions are recorded for each soil horizon or layer. These descriptions usually include the soil horizon thickness, color, USCS soil classification, and occurrences of mottling, saturated soil, impermeable layers/lenses, groundwater, and bedrock.

As previously stated, studies have been conducted to characterize infiltration rates based on USDA soil texture rather than the USCS. At the same time, soil investigations use the USCS method to classify the soil. Because there is no way to translate USCS classified soils directly to USDA soil texture categories, determining soil infiltration rates from references is difficult. For that reason, on-site infiltration tests are always preferred.

The soil boring log typically also includes results of the standard penetration test by listing the number of blow counts (the number of blows it takes a slide hammer with a weight of 63.5 kg (140 lb) to fall a distance of 760 mm (30 in)), which is a measure of the soil's looseness. Reviewing the blow counts throughout the soil profile provides a cursory assessment of soil density, which can help determine if soils are conducive to infiltration and whether soils will need to be loosened to promote infiltration. Table 2 provides guidance on interpreting the blow counts (N-value) with respect to soil density for course grained soils). For fine grained soils, the standard penetration test can be an indicator of soil stiffness. Table 3 provides guidance on interpreting the blow counts (N-value) with respect to relative soil stiffness for fine grained soils (Midwest Geosciences Group Field Guide for Soil and Stratigraphic Analysis 2007). As a general rule of thumb, loosening of the soils at an infiltration BMP site should be considered if the standard penetration test indentifies an N-value in exceedance of 10 blow counts per foot.

Table 2. Guidance on Interpretation of Standard Penetration Test Results with Regard to Density of Course Grained Soils (Midwest Geosciences Group 2007)

# of Blow Counts (N-Value)	Density Indicator
0 – 4	Very Loose
5 – 10	Loose
11 – 29	Medium Density
30 – 49	Dense
>50	Very Dense

Table 3. Guidance on Interpretation of Standard Penetration Test Results with Regard to Relative Stiffness of Fine Grained Soils (Midwest Geosciences Group 2007)

# of Blow Counts (N-Value)	Description
0 – 2	Very Soft
3 – 4	Soft
5 – 8	Medium
9 – 15	Stiff
16 - 30	Very Stiff
>30	Hard

Infiltration BMPs

Stormwater volume reduction can be achieved through implementation of numerous infiltration-based BMPs, including bioretention basins (rainwater gardens) without underlying drain tiles[1], infiltration basins, infiltration trenches, rapid sand filters, underground infiltration systems, porous pavement or other practices such as vegetated swales, native landscaping, and disconnection of impervious surfaces. How

[1] Bioretention basins with underlying drain tiles provide extended detention and filtration, but likely do not significantly reduce stormwater runoff volumes. A future MIDS task will seek to define the amount of stormwater volume reduction associated with bioretention basins with underlying drain tiles. Bioretention basins with underlying drain tiles also have reduced pollutant removal effectiveness. However, limited research is available to quantify the pollutant removal achieved through these systems at this time.

much stormwater volume is reduced by any of these BMPs is dependent on a variety of factors. Through a future MIDS task, stormwater volume reduction credits will be defined in more detail. Stormwater volume reduction BMPs do not necessarily address flood control needs, runoff from higher intensity storm events, and runoff from back to back storms.

Infiltration BMPs can be split into two categories: Infiltration BMPs with plants (bioretention basins, infiltration basins, vegetated swales, native landscaping, disconnected impervious surfaces, etc.) and infiltration BMPs without plants (infiltration trenches, rapid sand filters, underground infiltration systems, and porous pavement). The presence or absence of plants can affect the overall amount of volume retention and the long-term infiltration capacity of the soils.

Infiltration BMPs with Plants

Plant-based infiltration BMPs utilize vegetation to improve the onsite retention of stormwater runoff. When stormwater infiltrates into the soil, the water is either stored in the soil and returned to the atmosphere via plant transpiration and evaporation or is conducted to lower soil levels and ultimately groundwater. Although difficult to quantify, the volume of water stored in the soil and utilized by plants can be considerable. The increase in volume reduction from plant transpiration and evaporation relative to soils without plants varies between soil types/textures and is difficult to quantify.

The long-term infiltration capacity of vegetated infiltration BMPs can vary based on several key factors. The suitability of the soil for infiltration is the primary factor that will control long term infiltration capacity, regardless of the presence of vegetation, as some soil textures are more conducive to clogging or reduced infiltration over time. However, the presence of plants can improve the long-term infiltration capacity of soils, as the root structures of plants promote healthy soil structure and help to maintain or increase infiltration rates over time. Long term infiltration capacity will also be dependent on the tributary drainage area to the BMP, as a greater amount of runoff directed to the BMP will result in a greater sediment load. In some cases, formation of a soil crust has been shown to cause a major decrease in infiltration rates within the surface soil layer (Rawls, 1990) of vegetated soils. This crust is typically formed by raindrop compaction and by washing of fine particles into the soil matrix. The formation and thickness of the soil crust can vary based on factors such as soil texture and organic matter. The thickness of the layer has been reported to vary from 1 to 5 mm on vegetated soils (Rawls, 1990), but may be greater for infiltration BMPs. Periodic maintenance of the surface soils of vegetated BMPs may be necessary to break up the soil crust and reinstate infiltration rates.

When plants are utilized in infiltration BMPs such as bioretention or infiltration basins, the depth of ponding must be limited to prevent extended inundation of plants. The Minnesota Stormwater Manual recommends that bioretention basins be completely drained with 48 hours of a storm event. This drainage

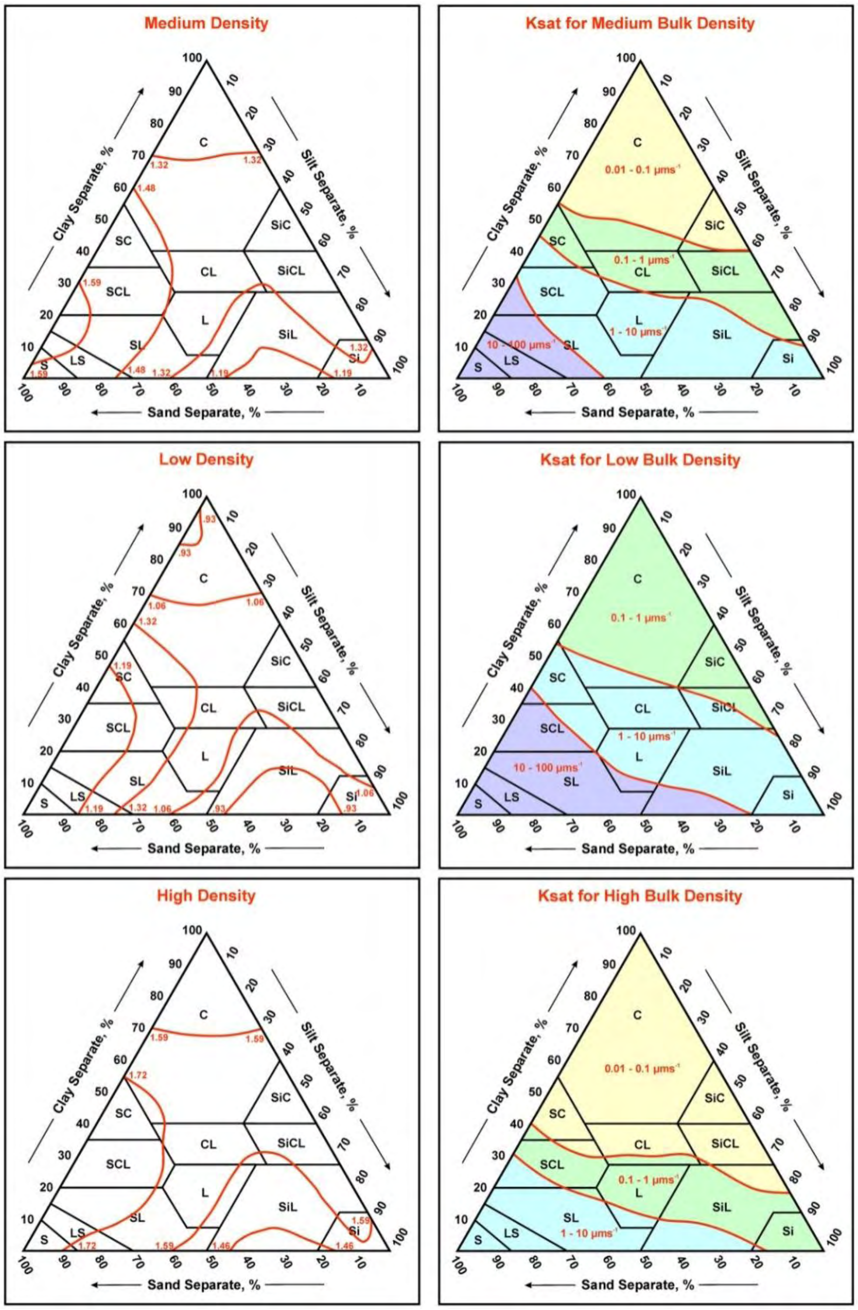
requirement ensures that the stress on plants from inundation will be limited in duration. This requirement also provides reasonable assurance that the basin will be empty by the next storm event.

Infiltration BMPs without Plants

Infiltration BMPs without plants rely solely on the infiltration capacity of the soil to retain runoff. Examples of such BMPs include infiltration trenches, rapid sand filters, underground infiltration systems, and porous pavement systems. One advantage to the infiltration BMPs without plants is that the basin/trench can be deeper, as inundation of plants is not a concern. However, maintaining the long term infiltration capacity of these systems is a challenge. Infiltration rates are likely to decrease over time due to clogging of the infiltration substrate from fine silt particles. Active maintenance will likely be required to main the long term infiltration capacity; however, many of these systems are underground, which makes maintenance extremely challenging and expensive.

Engineered Wet Detention Basins

Wet detention basins and constructed stormwater wetlands are designed to hold a permanent pool of water. If designed properly, these BMPs can remove significant loads of suspended pollutants, such as metals, nutrients, sediments, and organics through sedimentation. Constructed stormwater wetlands also promote the growth of microbial populations that can extract soluble carbon and nutrients and potentially reduce biological oxygen demand (BOD) and fecal coliform concentrations. While these BMPs are valuable in providing stormwater treatment and can be used for flood control proposes, they do not specifically provide stormwater volume control. Many wet detention basins are constructed with clay liners on the bottom to prevent infiltration for a variety of reasons. Basins without liners may infiltrate, but the infiltration rates can become greatly reduced over time due to clogging of the pore space and other factors. Infiltration shelves can be designed as a part of wet detention basins. However, designing and constructing such shelves to provide long-term infiltration is challenging and not widely accepted. Concerns include sometimes complicated water level controls in and out of the shelves to achieve required draw-down times and reduce stress on plants, infiltration possibly only occurring while water is discharging from the basin, the high water table of the basin relative the infiltration shelves, and the potential for the shelves to see reduced infiltration over time due to water weight, sediment, and plant decay.



Note: Estimate saturated hydraulic conductivity (K_{sat}) from soil texture by first selecting the bulk density class of medium, low or high. Then use the corresponding textural triangle to select the range of saturated hydraulic conductivity in mms-1.

Figure 3. Guide for Estimating Saturated Hydraulic Conductivity (K_{sat}) from Soil Properties (USDA, 2010)

References

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Appendix A:

Design Infiltration Rates

(MPCA 2005)

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and steep slopes. The stormwater management implications of shallow bedrock affect infiltration, ponding depths, and the use of underground practices.

Figure 2.14 illustrates just one example of shallow bedrock along the North Shore. Again, details can be obtained from the MGS or a reliable local source, such as the county or a local well driller.

Table 2.4 Design Infiltration Rates

Hydrologic Soil Group	Infiltration Rate [inches/ hour]	Soil Textures	Corresponding Unified Soil Classification
A	1.6*	Gravel, sandy gravel and silty gravels	**GW** - Well-graded gravels, sandy gravels **GP** – Gap-graded or uniform gravels, sandy gravels **GM** - Silty gravels, silty sandy gravels **SW** - Well-graded, gravelly sands
	0.8	Sand, loamy sand or sandy loam	**SP** - Gap-graded or uniform sands, gravelly sands
B	0.6	Silt loam	**SM** - Silty sands, silty gravelly sands
	0.3	Loam	**MH** – Micaceous silts, diatomaceous silts, volcanic ash
C	0.2	Sandy clay loam	**ML** - Silts, very fine sands, silty or clayey fine sands
D	< 0.2	Clay loam, silty clay loam, sandy clay, silty clay or clay	**GC** – Clayey gravels, clayey sandy gravels **SC** – Clayey sands, clayey gravelly sands **CL** – Low plasticity clays, sandy or silty clays **OL** – Organic silts and clays of low plasticity **CH** – Highly plastic clays and sandy clays **OH** – Organic silts and clays of high plasticity

* This rate is consistent with the infiltration rate provided for the lower end of the Hydrologic Soil Group A soils in the Wisconsin Department of Natural Resources Conservation Practice Standard: Site Evaluation for Stormwater Infiltration.

Source: Thirty guidance manuals and many other stormwater references were reviewed to compile recommended infiltration rates. All of these sources use the following studies as the basis for their recommended infiltration rates: (1) Rawls, Brakensiek and Saxton (1982); (2) Rawls, Gimenez and Grossman (1998); (3) Bouwer and Rice (1984); and (4) Urban Hydrology for Small Watersheds (NRCS). SWWD, 2005, provides field documented data that supports the proposed infiltration rates.

Appendix B:

Unified Soil Classification System

(Virginia DOT)

UNIFIED SOIL CLASSIFICATION SYSTEM

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)		
	Clean Gravels (Less than 5% fines)	
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
	GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	
	GM	Silty gravels, gravel-sand-silt mixtures
	GC	Clayey gravels, gravel-sand-clay mixtures
	Clean Sands (Less than 5% fines)	
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	SW	Well-graded sands, gravelly sands, little or no fines
	SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	
	SM	Silty sands, sand-silt mixtures
	SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)		
SILTS AND CLAYS Liquid limit less than 50%	ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
	OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
	CH	Inorganic clays of high plasticity, fat clays
	OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS	PT	Peat and other highly organic soils

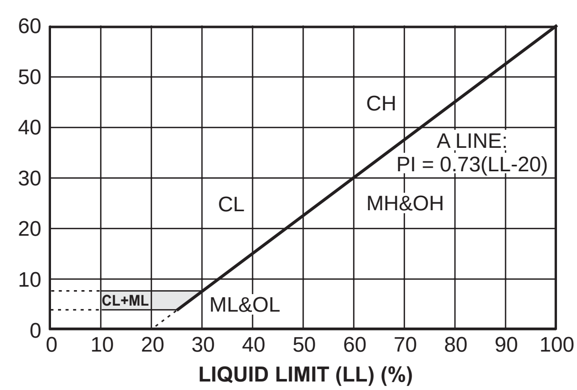
LABORATORY CLASSIFICATION CRITERIA

GW	$C_u = \frac{D_{60}}{D_{10}}$ greater than 4; $C_c = \frac{D_{30}}{D_{10} \times D_{60}}$ between 1 and 3	
GP	Not meeting all gradation requirements for GW	
GM	Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are borderline cases requiring use of dual symbols
GC	Atterberg limits above "A" line with P.I. greater than 7	
SW	$C_u = \frac{D_{60}}{D_{10}}$ greater than 4; $C_c = \frac{D_{30}}{D_{10} \times D_{60}}$ between 1 and 3	
SP	Not meeting all gradation requirements for GW	
SM	Atterberg limits below "A" line or P.I. less than 4	Limits plotting in shaded zone with P.I. between 4 and 7 are borderline cases requiring use of dual symbols.
SC	Atterberg limits above "A" line with P.I. greater than 7	

Determine percentages of sand and gravel from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows:

Less than 5 percent .... GW, GP, SW, SP
More than 12 percent .... GM, GC, SM, SC
5 to 12 percent .... Borderline cases requiring dual symbols

PLASTICITY CHART



Appendix C:

USDA and USCS Correlation

NORMAL PERCENT OF MATERIAL SMALLER THAN SPECIFIC SIZES 1/

USDA TEXTURE	#4 (5.0mm)	#10 (2.0mm)	#40 (0.4mm)	#200 (0.74mm)	POSSIBLE PASSING #200	PROBABLE UNIFIED CLASSIFICATION 2/	PROBABLE AASHO CLASSIFICATION 2/
c	100	100	90 – 100	75 – 95	55 – 100	CH, MH, CL	A–7
sic	100	100	95 – 100	90 – 95	80 – 100	CH, MH, CL	A–7
sicl	100	100	95 – 100	85 – 95	80 – 100	CL, CL–ML, CH, MH	A–7, A–6
cl	100	100	90 – 100	70 – 80	55 – 85 3/	CL, CL–ML, CH, MH	A–6, A–7
l	100	100	85 – 95	60 – 75	50 – 80 3/	ML, CL, CL–ML	A–4, A–6
sil	100	100	90 – 100	70 – 90	50 – 100	ML, CL, CL–ML	A–4, A–6
si	100	100	100	90 – 100	80 – 100	ML	A–4
sc	100	100	85 – 95	45 – 60	35 – 60 3/	CL, SC, CH	A–7
scl	100	100	80 – 90	35 – 55	20 – 60 3/	SC, CL	A–6, A–2–6
sl	100	100	60 – 70	30 – 40	15 – 70 4/	SM	A–2–4, A–4
fsl	100	100	70 – 85	40 – 55	15 – 70 4/	SM, ML, CL–ML	A–4, A–2–4
vfsl	100	100	85 – 95	50 – 65	15 – 70 4/	ML, CL–ML, SM	A–4, A–2–4
lvfs	100	100	90 – 95	40 – 60	10 – 80 5/	SM, ML	A–4, A–2–4
ls	100	100	50 – 75	15 – 30	10 – 55 6/	SM, ML	A–2–4, A–4
fs	100	100	65 – 80	20 – 35	0 – 40 6/	SM, SP, SW, SP–SM, SW–SM	A–3, A–2–4
s	100	100	50 – 70	5 – 15	0 – 40 6/	SM, SP, SW, SP–SM, SW–SM	A–3, A–2–4, A–1
vfs	100	100	75 – 90	35 – 55	0 – 65 5/	SM, ML	A–4, A–2–4

1/ In determining textural class, material larger than #10 Sieve is removed. Thus, these figures must be reduced if soil contains material larger than #10 sieve. Multiply by % passing #10 sieve, and round off.

2/ May not apply to gravelly soils or to soils high in organic matter

3/ Assuming up to about 5% of material is vfs of a size that might pass #200 sieve.

4/ Assuming up to about 15% of material is vfs of a size that might pass #200 sieve.

5/ Assuming up to about 50% of material is vfs of a size that might pass #200 sieve.

6/ Assuming up to about 25% of material is vfs of a size that might pass #200 sieve.

From South Dakota SIR Guide