Welcome to ……

Hydraulics for
Stormwater Quality Design (continued)

INAFSM Annual Conference
September 2022

INAFSM
INDIANA ASSOCIATION FOR FLOODPLAIN AND STORMWATER MANAGEMENT

BANNING ENGINEERING

Introduction

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- University of Illinois
  BS Agricultural Engr., 1978
- Wright State University,
  Groundwater Hydrology, 1988
- Soil Conservation / NRCS, 1976-1996
- Banning Engineering, PC, 1996 – present
- Retiring 1/6/2023 (for real)

Program Overview

- Discuss / Evaluate Soil Infiltration and Percolation
- Evaluate / Design Multi-stage Pond Outlets
- Evaluate / Design Best Management Practices
- Evaluate Hydraulic Impact of Structural BMP's
- Evaluate / Design Flow Through Vegetated Swales

Program Overview

- Discuss / Evaluate Soil Infiltration and Percolation and Flow Through Porous Media
- Evaluate / Design Multi-stage Pond Outlets
- Evaluate / Design Best Management Practices
- Evaluate Hydraulic Impact of Structural BMP's
- Evaluate / Design Flow Through Vegetated Swales

Predicting Soil Infiltration / Permeability

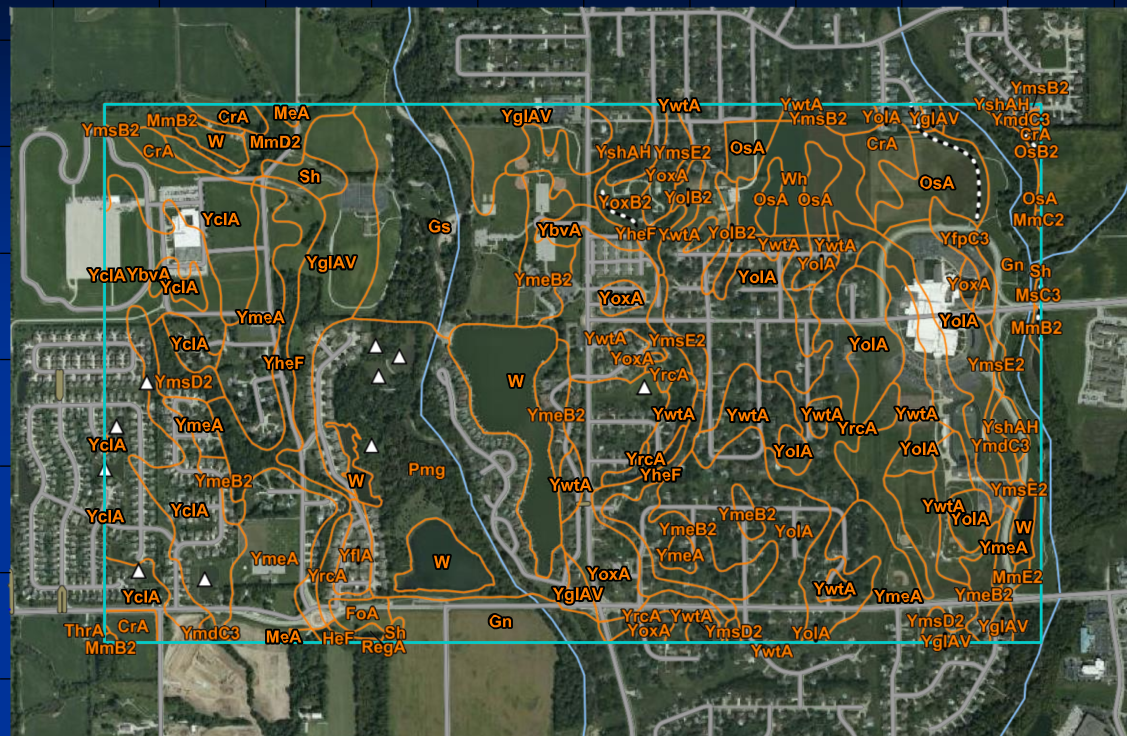
Soil Map—Hendricks County, Indiana

86° 24' 32'' W

86° 22' 18'' W

39° 41' 23'' N

39° 40' 16'' N



86° 24' 32'' W

86° 22' 18'' W

Map Scale: 1:14,600 if printed on A landscape (11" x 8.5") sheet.

N

Meters: 0, 200, 400, 800, 1200

Feet: 0, 500, 1000, 2000, 3000

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 16N WGS84

Appendix A Hydrologic Soil Groups

Soils are classified into hydrologic soil groups (HSG's) to indicate the minimum rate of infiltration obtained for bare soil after prolonged wetting. The HSG's, which are A, B, C, and D, are one element used in determining runoff curve numbers (see chapter 2). For the convenience of TR-55 users, exhibit A-1 lists the HSG classification of United States soils.

The infiltration rate is the rate at which water enters the soil at the soil surface. It is controlled by surface conditions. HSG also indicates the transmission rate—the rate at which the water moves within the soil. This rate is controlled by the soil profile. Approximate numerical ranges for transmission rates shown in the HSG definitions were first published by Musgrave (USDA 1955). The four groups are defined by SCS soil scientists as follows:

Group A soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sand or gravel and have a high rate of water transmission (greater than 0.30 in/hr).

Group B soils have moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15-0.30 in/hr).

Group C soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine texture. These soils have a low rate of water transmission (0.05-0.15 in/hr).

Group D soils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0-0.05 in/hr).

In exhibit A-1, some of the listed soils have an added modifier; for example, "Abrazo, gravelly." This refers to a gravelly phase of the Abrazo series that is found in SCS soil map legends.

Disturbed soil profiles

As a result of urbanization, the soil profile may be considerably altered and the listed group classification may no longer apply. In these circumstances, use the following to determine HSG according to the texture of the new surface soil, provided that significant compaction has not occurred (Brakensiek and Rawls 1983).

HSG	*Soil textures*
A	Sand, loamy sand, or sandy loam
B	Silt loam or loam
C	Sandy clay loam
D	Clay loam, silty clay loam, sandy clay, silty clay, or clay

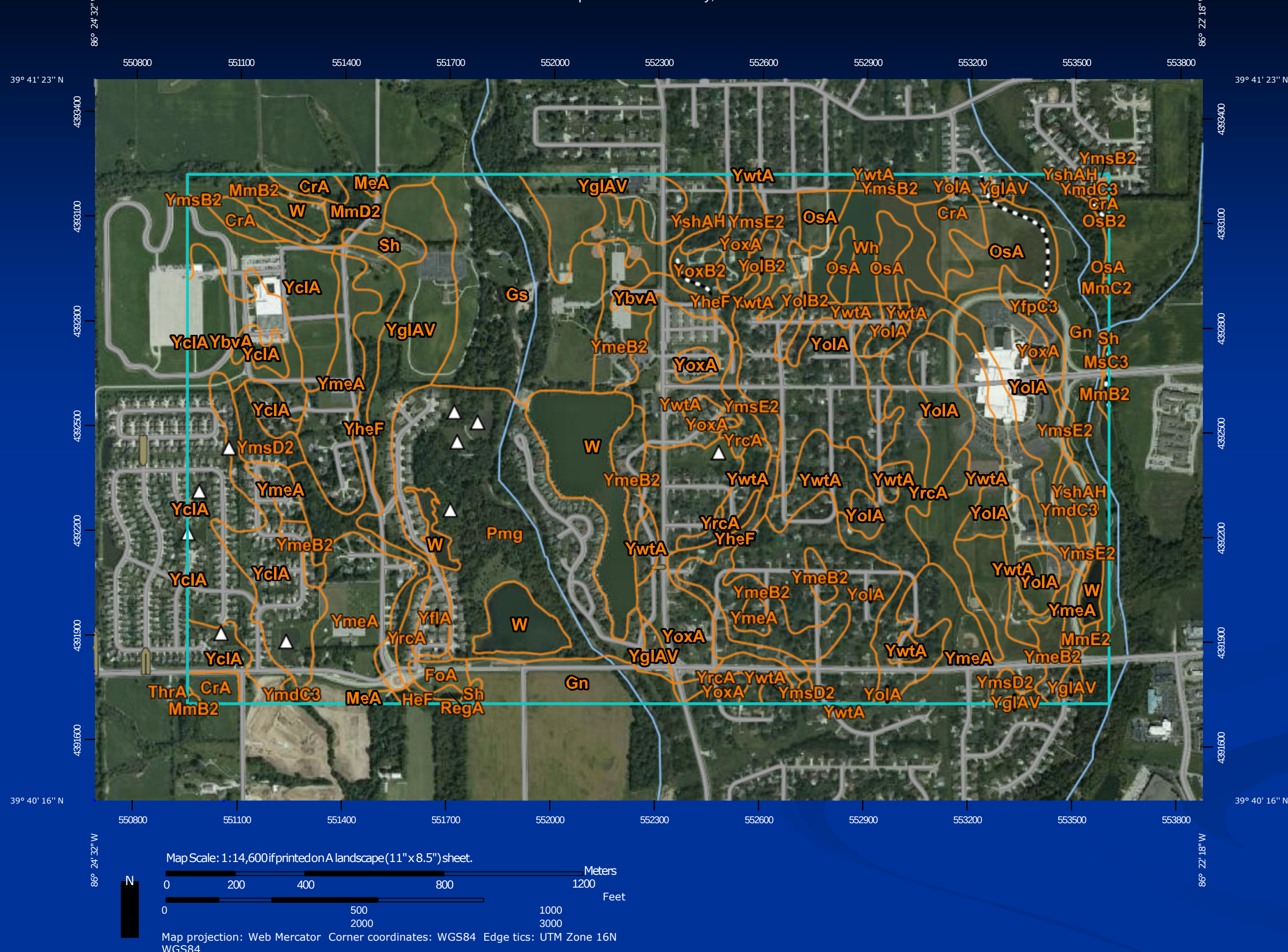
Drainage and group D soils

Some soils in the list are in group D because of a high water table that creates a drainage problem. Once these soils are effectively drained, they are placed in a different group. For example, Ackerman soil is classified as A/D. This indicates that the drained Ackerman soil is in group A and the undrained soil is in group D.

What Affects Soil Infiltration?

- Season / Surface Condition
- Debris
- Soil Saturation

Soil Map—Hendricks County, Indiana



Soil Map—Hendricks County, Indiana

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
CrA	Crosby silt loam, fine-loamy subsoil, 0 to 2 percent slopes	16.9	1.7%
FoA	Fox loam, 0 to 2 percent slopes	3.2	0.3%
Gn	Genesee silt loam, 0 to 2 percent slopes, frequently flooded, very brief duration	53.3	5.3%
Gs	Genesee sandy loam, sandy substratum	56.3	5.6%
HeF	Hennepin loam, 25 to 50 percent slopes	1.0	0.1%
MeA	Martinsville loam, 0 to 2 percent slopes	1.5	0.2%
MmB2	Miami silt loam, 2 to 6 percent slopes, eroded	7.2	0.7%
MmC2	Miami silt loam, 6 to 12 percent slopes, eroded	0.2	0.0%
MmD2	Miami silt loam, 12 to 18 percent slopes, eroded	9.2	0.9%
MmE2	Miami silt loam, 18 to 25 percent slopes, eroded	0.9	0.1%
MsC3	Miami clay loam, 6 to 12 percent slopes, severely eroded	0.4	0.0%

Soil Map—Hendricks County, Indiana

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
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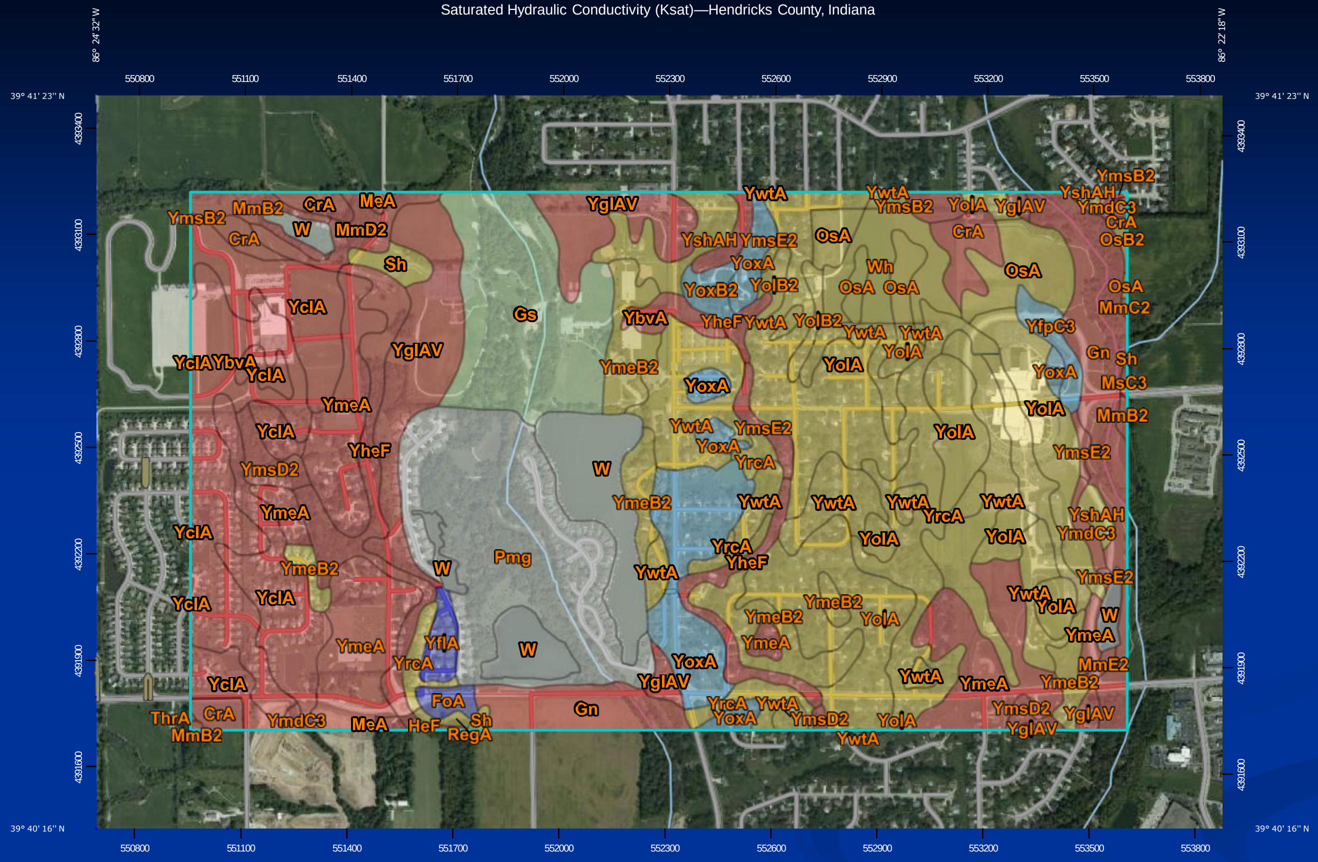
Gn	Genesee silt loam, 0 to 2 percent slopes, frequently flooded, very brief duration	53.3	5.3%
Gs	Genesee sandy loam, sandy substratum	56.3	5.6%
HeF	Hennepin loam, 25 to 50 percent slopes	1.0	0.1%
MeA	Martinsville loam, 0 to 2 percent slopes	1.5	0.2%

Map Unit Legend

Saturated Hydraulic Conductivity (Ksat)—Hendricks County, Indiana



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Saturated Hydraulic Conductivity (Ksat)—Hendricks County, Indiana

Map unit symbol	Map unit name	Rating (micrometers per second)	Acres in AOI	Percent of AOI
CrA	Crosby silt loam, fine- loamy subsoil, 0 to 2 percent slopes	3.5476	16.9	1.7%
FoA	Fox loam, 0 to 2 percent slopes	167.5738	3.2	0.3%
Gn	Genesee silt loam, 0 to 2 percent slopes, frequently flooded, very brief duration	9.1700	53.3	5.3%
Gs	Genesee sandy loam, sandy substratum	56.9737	56.3	5.6%
HeF	Hennepin loam, 25 to 50 percent slopes	3.2100	1.0	0.1%
MeA	Martinsville loam, 0 to 2 percent slopes	10.7492	1.5	0.2%
MmB2	Miami silt loam, 2 to 6 percent slopes, eroded	3.9091	7.2	0.7%

Saturated Hydraulic Conductivity (Ksat)—Hendricks County, Indiana

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HeF	Hennepin loam, 25 to 50 percent slopes	3.2100	1.0	0.1%
MeA	Martinsville loam, 0 to 2 percent slopes	10.7492	1.5	0.2%
MmB2	Miami silt loam, 2 to 6 percent slopes,	3.9091	7.2	0.7%

USDA

Saturated Hydraulic Conductivity (Ksat)

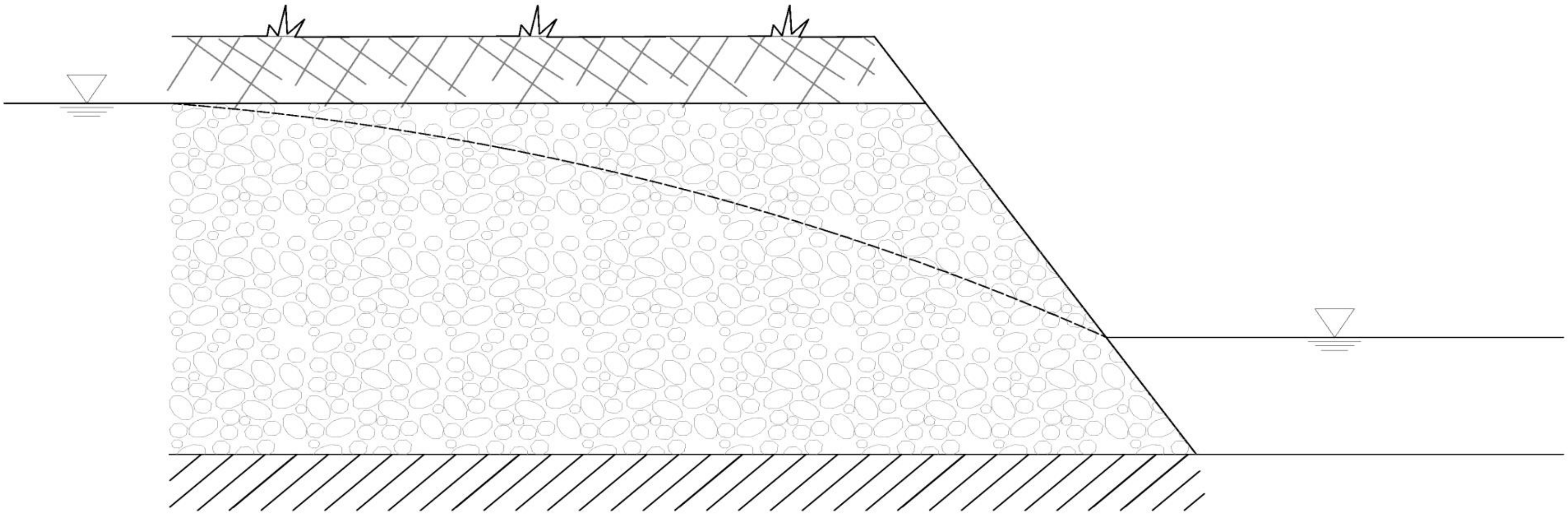
1 in/hr = 7.05556 micrometers / sec

So what about your site?

- Use mapped values?
- Granular soils – field testing
- Fine-grained soils – Shelby tubes and lab falling head permeameter (ASTM D5084)

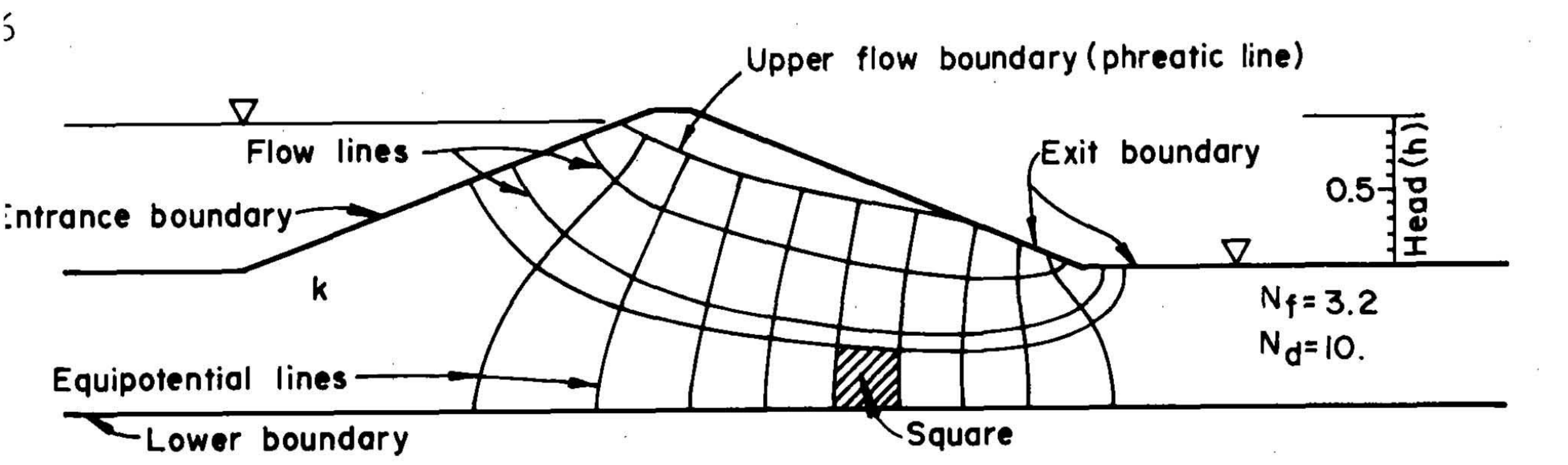
Darcy's Law
(Flow through Porous Media)

$$q = k\,i\,a$$



$i = h / l$

Flow Net



Upper flow boundary (phreatic line)
Flow lines
Exit boundary
Entrance boundary
0.5
Head (h)
k
$N_f = 3.2$
$N_d = 10.$
Equipotential lines
Lower boundary
Square

Darcy’s Law

(Flow through Porous Media)

$$q = k\, i\, a$$

Form SCS 130
5-65

MATERIALS TESTING REPORT

U.S. DEPARTMENT of AGRICULTURE
SOIL CONSERVATION SERVICE

DRAIN MATERIALS

PROJECT and STATE: Project Study No. 101

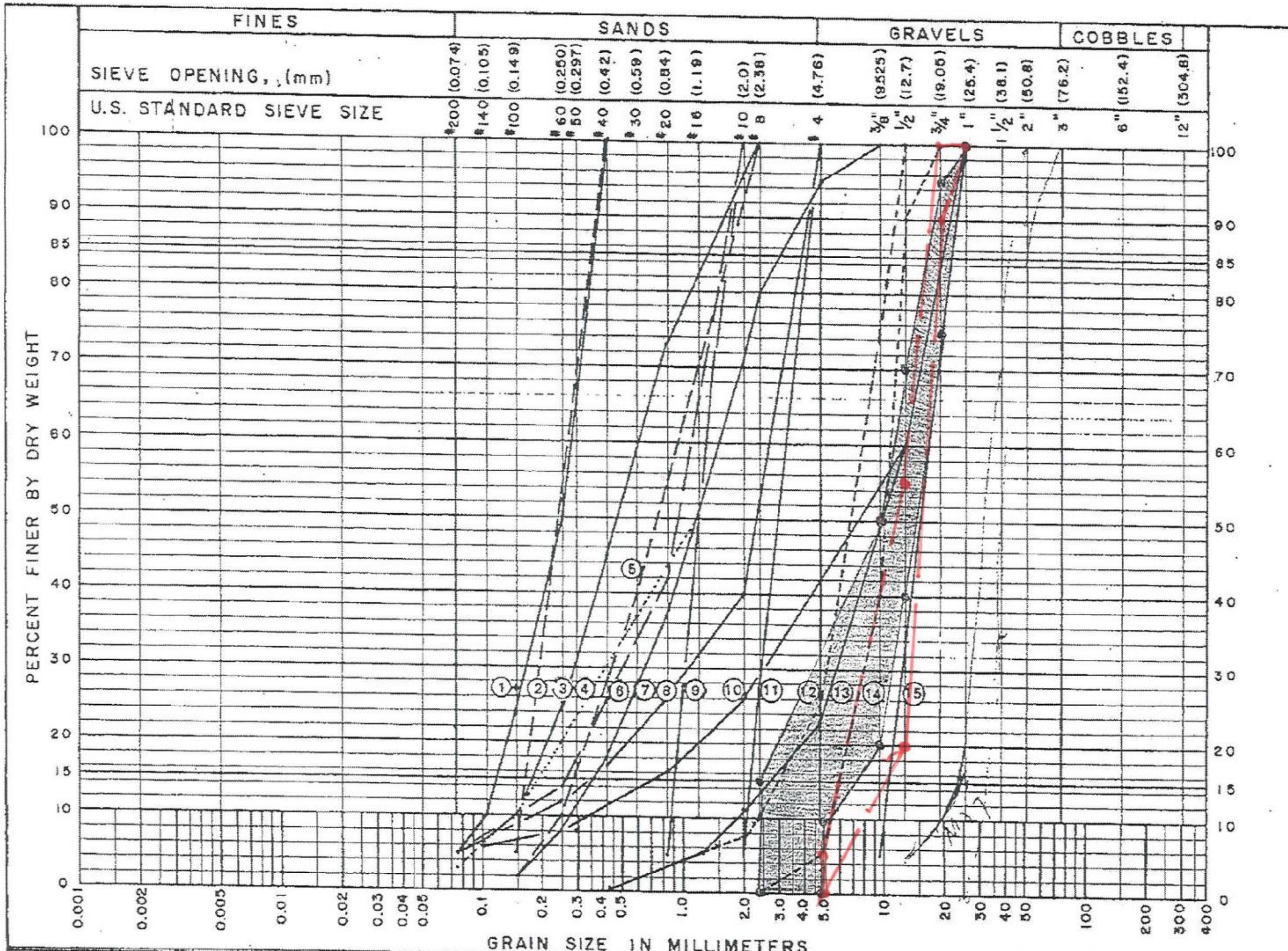
DESIGNED AT

BY: SML

DATE

INDOT SIEVE SIZE 8

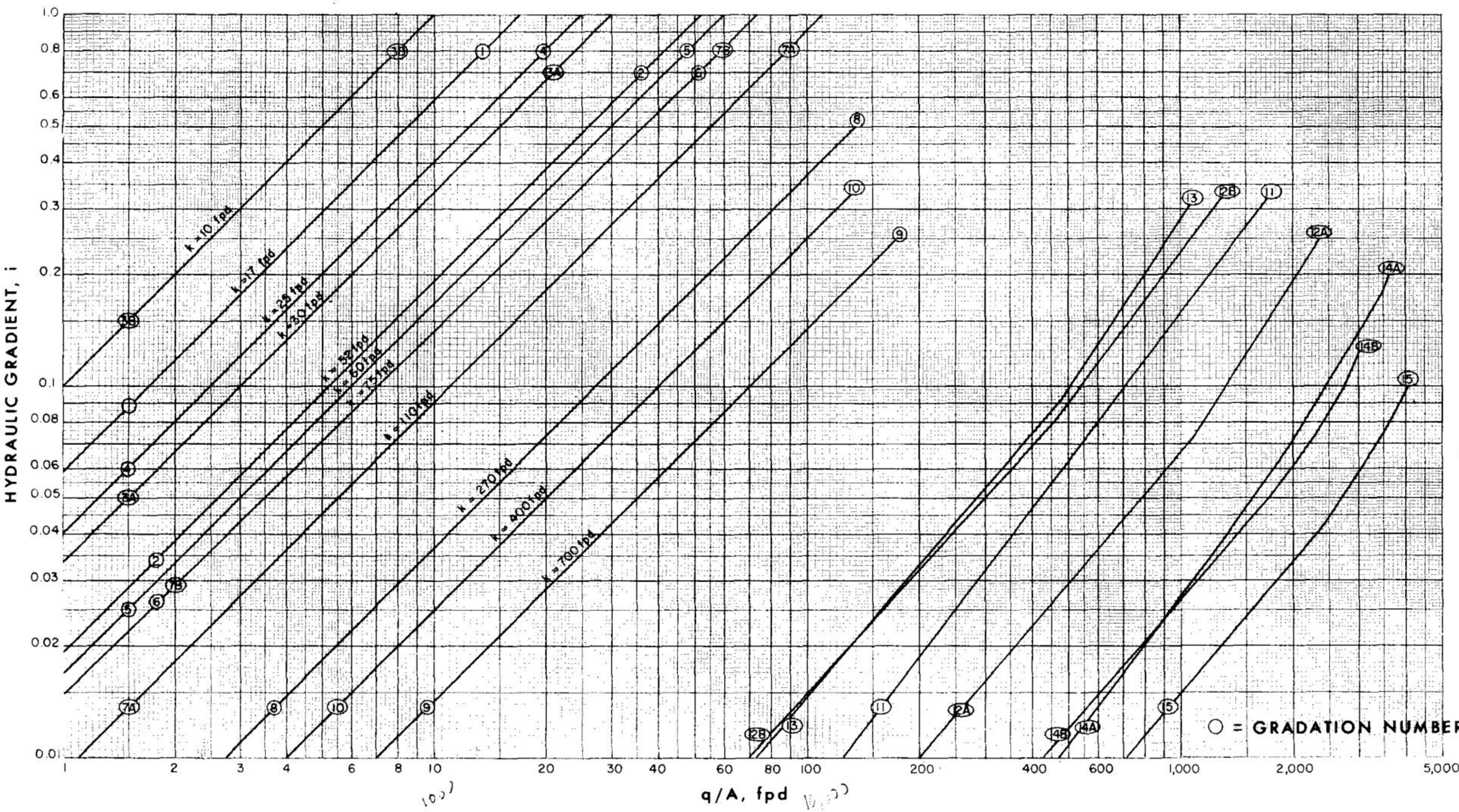
D448 #6



REMARKS 1. Gradations No. 3 and 7 represent the fine and coarse limits of fine aggregate sand (ASTM Designation C33).

2. Gradations No. 12 and 14 represent the fine and coarse limits of gravel size No. 78 (ASTM Designation D448).

Figure 1. Gradations of sands and gravels tested



RELATIVE DENSITY ≈ 70%

Figure 2. RELATIONSHIP BETWEEN i AND q/A FOR 15 GRADATIONS OF CLEAN SANDS AND GRAVELS

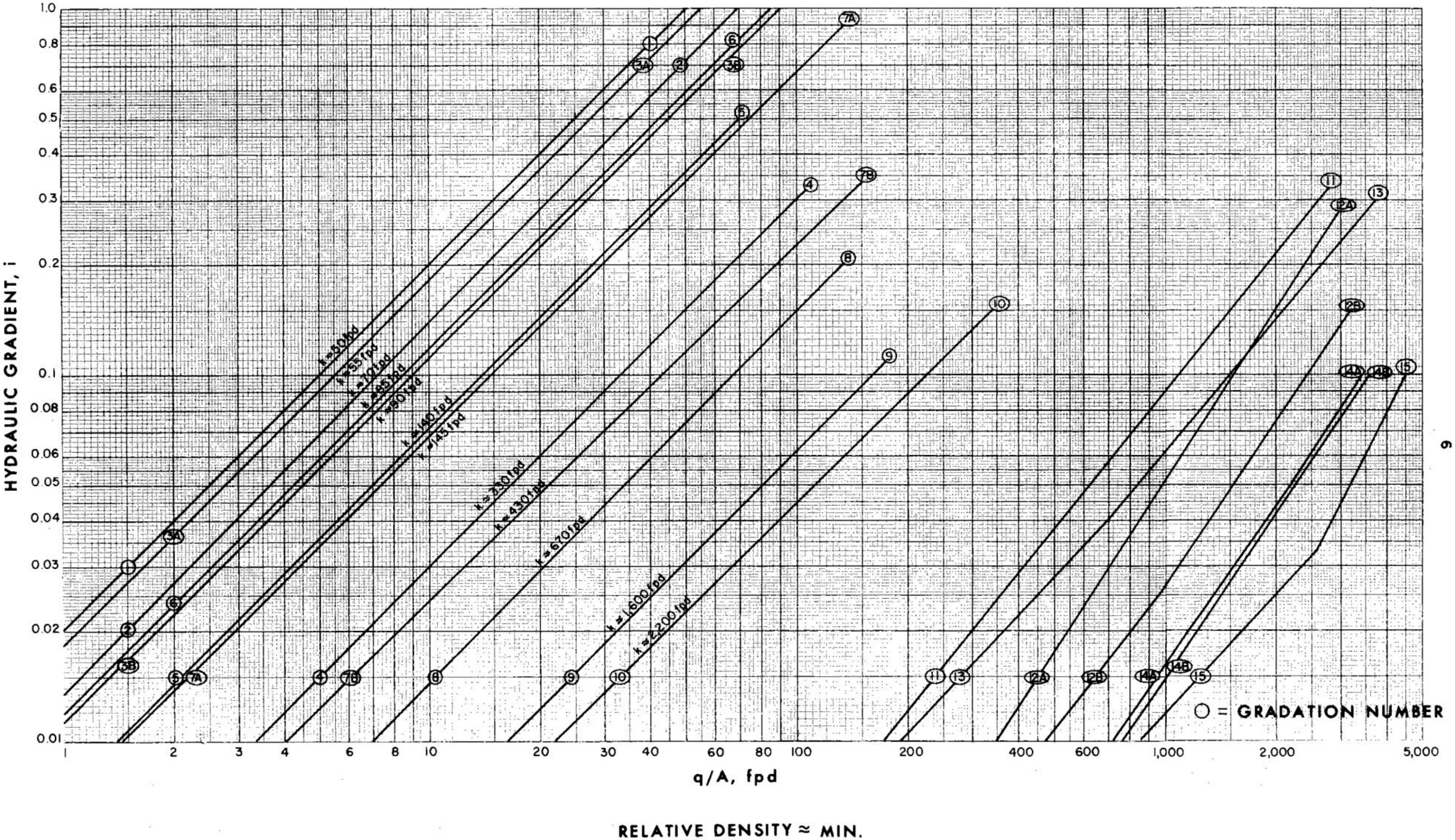
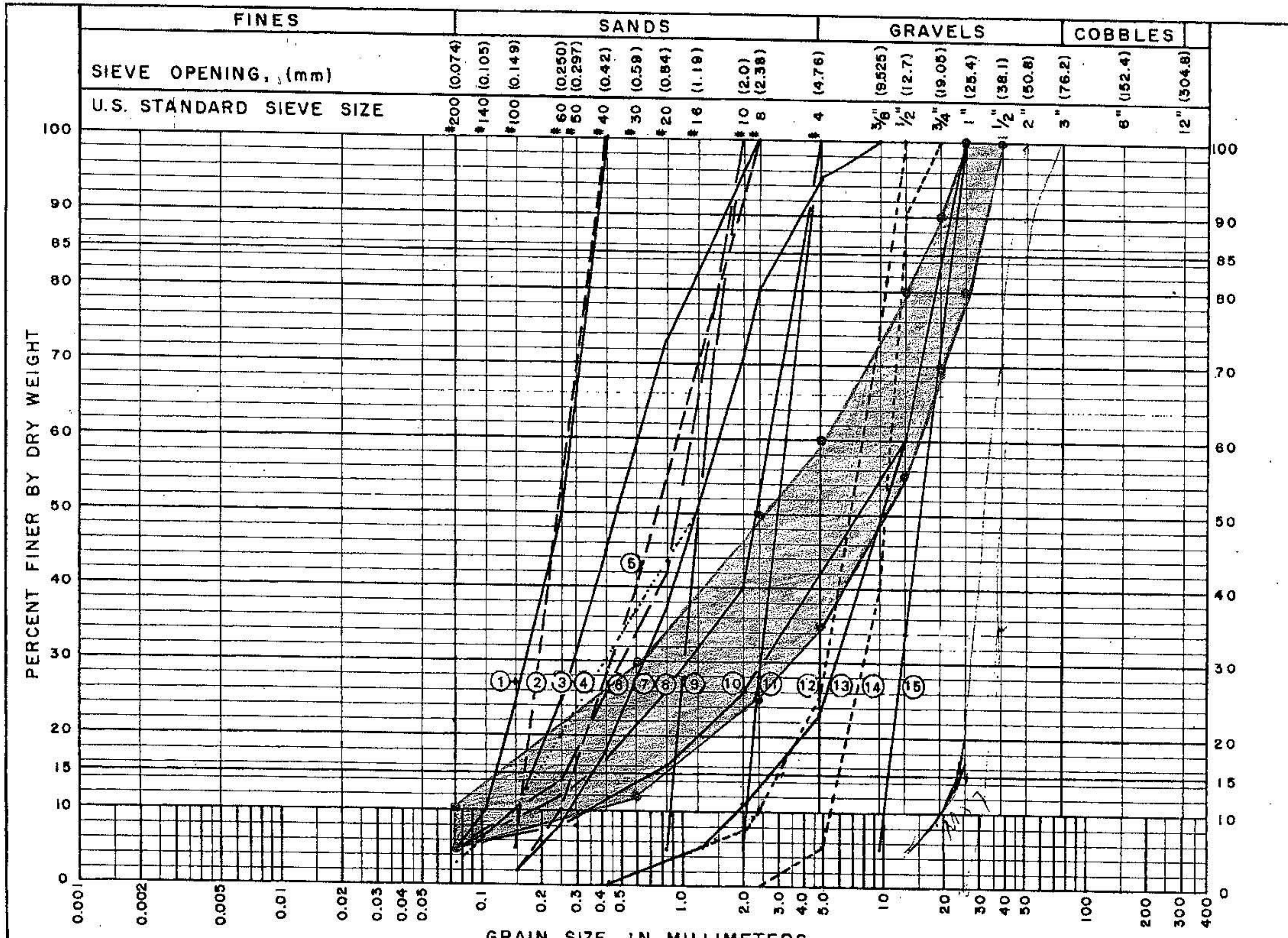


Figure 3. RELATIONSHIP BETWEEN i AND q/A FOR 15 GRADATIONS OF CLEAN SANDS AND GRAVELS



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DESIGNED AT | BY SML | DATE

PROJECT and STATE Project Study No. 101

Form SCS 130 5-65

MATERIALS TESTING REPORT

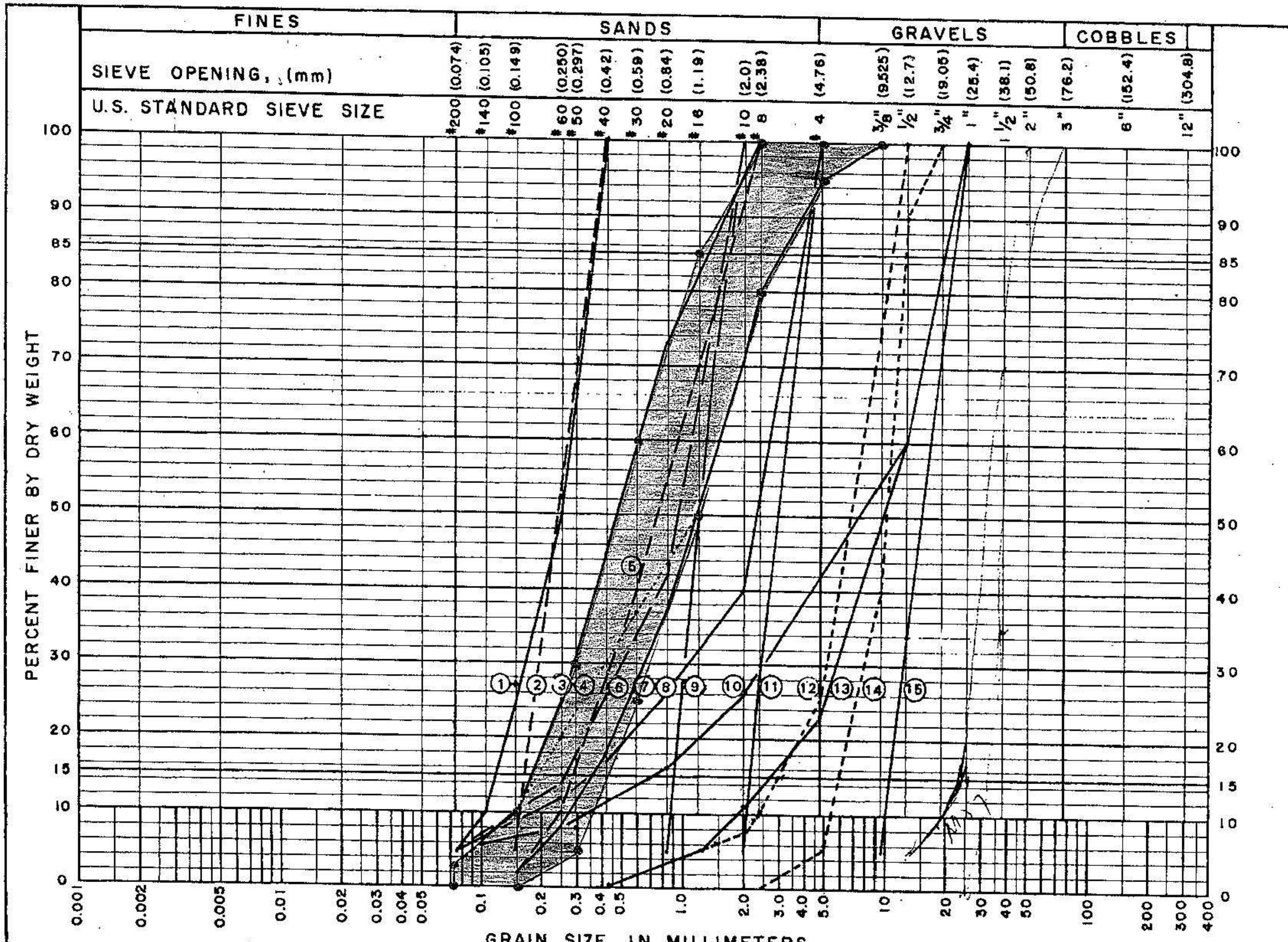
U.S. DEPARTMENT of AGRICULTURE SOIL CONSERVATION SERVICE

DRAIN MATERIALS

SIEVE SIZE 53

4

Figure 1. Gradations of sands and gravels tested



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DESIGNED AT

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MATERIALS TESTING REPORT

U.S. DEPARTMENT of AGRICULTURE SOIL CONSERVATION SERVICE

DRAIN MATERIALS

Form SCS 130 5-65

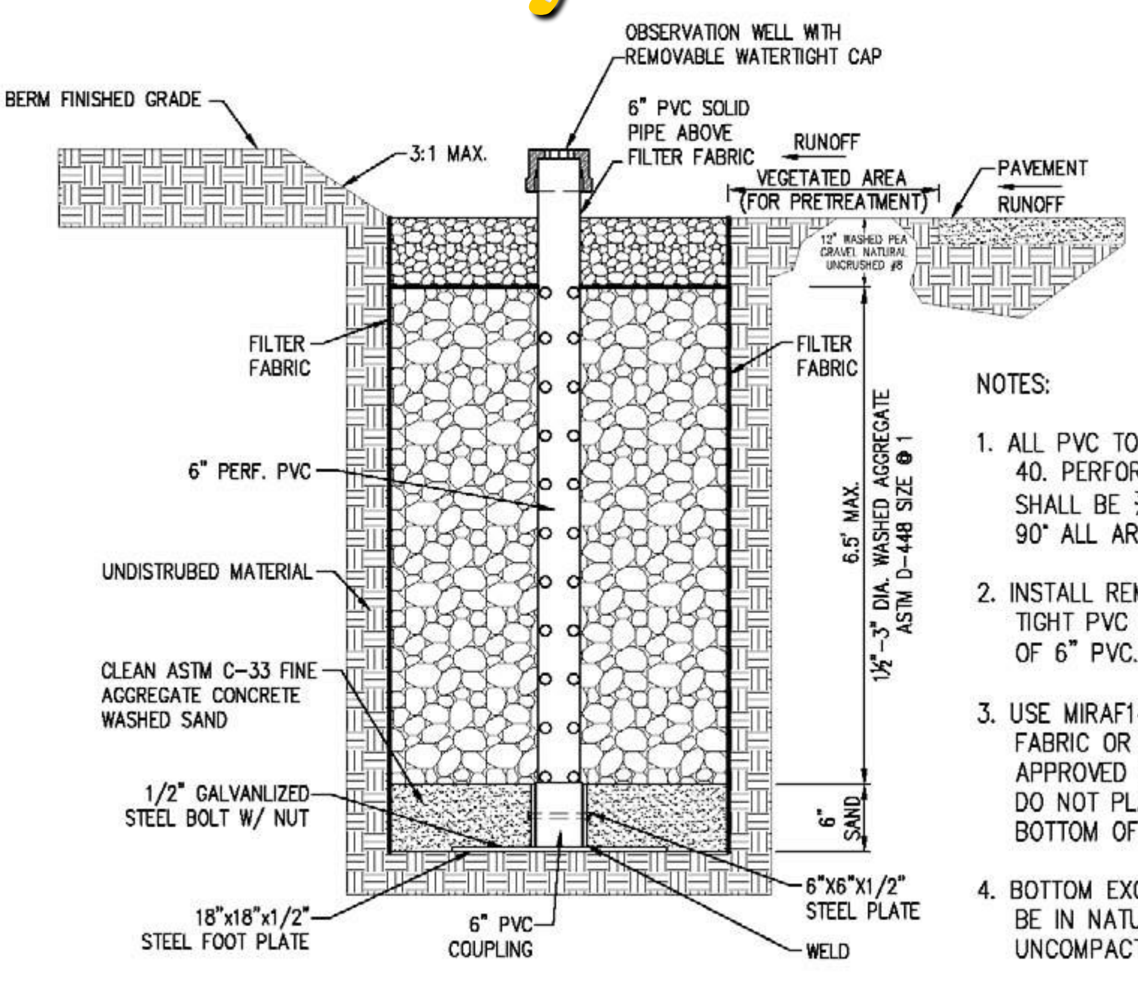
SIEVE SIZE 23

Darcy's Law

(Flow through Porous Media)

$$q = k\,i\,a$$

Boundary Conditions



NOTES:

1. ALL PVC TO BE SCHEDULE 40. PERFORATIONS SHALL BE ⅜"ø @ 4" O/C 90° ALL AROUND PIPE.
2. INSTALL REMOVABLE WATER TIGHT PVC CAP ON TOP OF 6" PVC.
3. USE MIRAF140-N FILTER FABRIC OR MCDPS APPROVED EQUIVALENT. DO NOT PLACE FABRIC ON BOTTOM OF TRENCH.
4. BOTTOM EXCAVATION IS TO BE IN NATURAL UNCOMPACTED EARTH.

INFILTRATION TRENCH DETAIL

Not To Scale

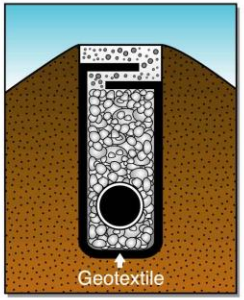
US 160NW

3904 Virginia Ave • Cincinnati, Ohio 45227 • Phone (513) 271-6000 • Fax (513) 271-4420

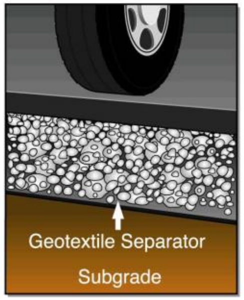
Nonwoven Geotextile

A 6.0 oz/sy nonwoven needlepunched geotextile made of 100% polypropylene staple filaments. This product can be used under riprap, in drainage applications, or can be used for separation under roads, driveways or parking areas. US 160NW will satisfy the requirements as outline in AASHTO M-288 96/00 for Class 2 applications.

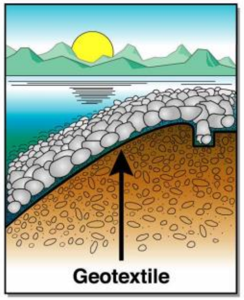
Drainage



With a Geotextile Separator



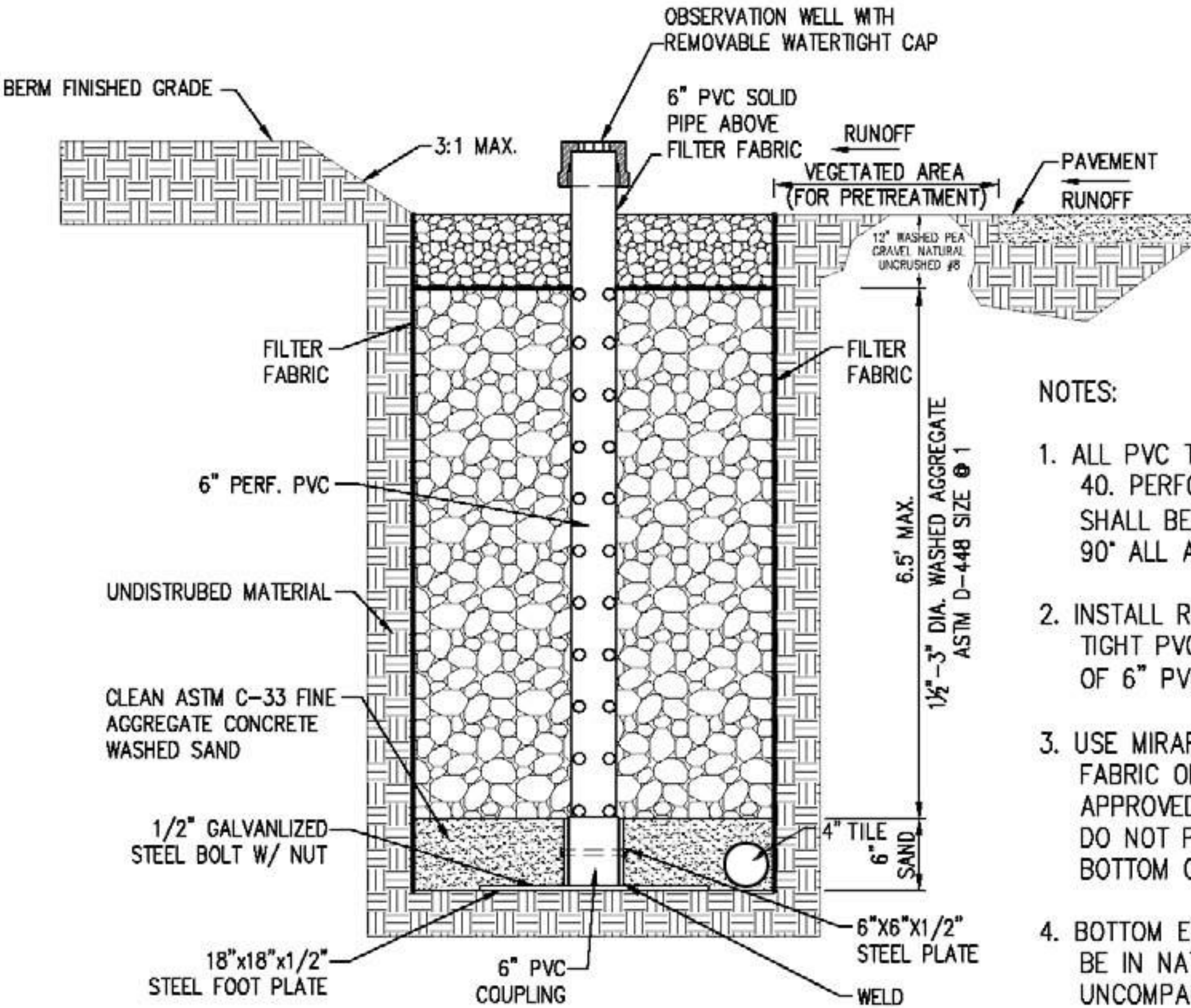
Riprap



PROPERTY	TEST METHOD	ENGLISH	METRIC
Tensile Strength	**ASTM D-4632**	**160 lbs**	**711 N**
Elongation @ Break	**ASTM D-4632**	**50 %**	**50 %**
Mullen Burst	**ASTM D-3786**	**315 psi**	**2170 kPa**
Puncture Strength	**ASTM D-4833**	**90 lbs**	**400 N**
Trapezoidal Tear	**ASTM D-4533**	**65 lbs**	**289 N**
Apparent Opening Size	**ASTM D-4751**	**70 US Sieve**	**0.212 mm**
Permittivity	**ASTM D-4491**	**1.60 Sec^{-1}**	**1.60 Sec^{-1}**
UV Resistance, % Retained	**ASTM D-4355**	**70 %**	**70 %**
Flow Rate	**ASTM D-4491**	**110 gal/min/sf**	**4480 1/min.m^{2}**

1 gal./min./SF = 0.0022 cfs/SF

110 gal./min./SF = 0.25 cfs/SF



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4. BOTTOM EXCAVATION IS TO BE IN NATURAL UNCOMPACTED EARTH.

INFILTRATION TRENCH DETAIL

Not To Scale

FRATCO....Tubing Specifications

Fratco tubing and fittings comply with the applicable requirements specified in:

- ASTM F-405
- AASHTO M-252
- ASTM F-667
- AASHTO M-294
- and/or SCS Code 606

Click the link below for INDOT's "approved pipe supplier" list.
(Then click on "Plastic Pipe Sources" to view the

I.D.*	O.D.*	Pitch	Corr. Per Ft	Rows of Perf.	Perf. Per Ft	Slot Length*	Slot Width*	Hole Dia.*	Sq In Inlet/Ft	Single Wall Wt/ft (lbs)	Smooth-Corr Wt/ft (lbs)
3	3.65	.66	18	8	72	.65	.045	-	2.1	.210	-
4	4.75	.66	18	8	72	.65	.045	-	2.1	.330	.485
5	5.75	.66	18	8	72	.65	.045	-	2.1	.474	-
6	6.90	.66	18	8	72	.65	.045	-	2.1	.694	.98
4+	4.75	.66	18	3	9	-	-	1/2	1.8	.330	-
5+	5.75	.66	18	3	9	-	-	5/8	2.8	.474	-
6+	6.90	.66	18	3	9	-	-	5/8	2.8	.694	-
8+	9.3	1	12	3	9	-	-	5/8	2.8	1.10	-
8	9.3	1	12	8	96	.65	.045	-	2.7	1.10	1.52
10	11.7	1.5	8	8	64	.80	.060	-	3.0	1.76	2.55
12	14.6	2	6	8	48	.80	.060	-	2.3	2.53	3.60
15	18.3	2.4	5	8	40	-	-	1/4	2.0	3.88	5.5
18	21.3	3	4	8	32	-	-	1/4	1.6	5.0	7.0
24	27.7	3	4	8	32	-	-	1/4	1.6	10.5	11.0
30	34.8	4	3	8	24	-	-	1/4	1.2	-	16.0
36	41	4	3	-	-	-	-	-	-	-	19.5
42	48.1	6	2	-	-	-	-	-	-	-	27
48	54.4	6	2	[illegible]	[illegible]	-	-	-	-	-	32

\+ Drilled for Septic or Muck Tubing
* Inches

Design Resource

USDA – NRCS

Part 633 NEH

Chapter 26 Gradation Design of Sand and Gravel Filters

Pervious Pavement (thoughts)

- More than one-half of all rain falls in storms with less than ½-inch rainfall depth
- Pervious Pavement provides runoff coefficient as good as sod.
- Pervious Concrete Pavement passes water at 3-5 gal/min/SF [5 gal = 8 inches; 100% effective]
- Installation is the key
  (Source: T. Fansler III, President, Smock Fansler)
- How do you maintain this practice?

Thanks for Your Participation!

Questions?

INAFSM
INDIANA ASSOCIATION FOR FLOODPLAIN AND STORMWATER MANAGEMENT

BANNING ENGINEERING