United States
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**Soil
Conservation
Service**

St. Paul,
Minnesota

Minnesota Drainage Guide

MINNESOTA DRAINAGE GUIDE

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PREFACE

Drainage is an important component of many successful resource management systems in Minnesota. In combination with other conservation practices, drainage helps improve soil conditions and reduces energy required for crop production. It is an essential component of the soil-water-plant relationship needed for crop production on wet soils. In addition, good drainage is necessary to assure success of reduced tillage systems on the wet soils.

This Drainage Guide presents information, data, and recommendations for drainage of Minnesota soils. Professional judgment must be used when applying these recommendations to specific cases.

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CHAPTER 1

INTRODUCTION

INTRODUCTION

This guide is for engineers and engineering specialists, drainage contractors and others interested in the design and construction of drainage systems. While this guide primarily addresses agricultural drainage, many of the same principles and values are applicable to recreational areas, parks, roads and urban areas as well. This guide does not condone the drainage of wetlands. It is important that each case be assessed on an individual basis to weigh significant long term environmental and economic impacts. Professional judgement and the policies, regulations, and rules of the local, state and federal governments should be observed.

Research data is limited for recommendations about drain depth and spacing; therefore, recommendations made are historical in nature and intended to serve as guidelines. They do not eliminate the necessity of making further inquiries into such subjects as soils, crops grown, soil and water table conditions, or economics. Modifications may be needed to adapt them to local conditions. Recommendations contained herein are based on the best available data, long experience, judgement and observations of drainage systems.

CHAPTER 2

LEGAL REQUIREMENTS

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LEGAL REQUIREMENTS

HISTORICAL BACKGROUND

In 1858, Minnesota become the 32nd state to enter the federal system of the United States. In that year, the Legislature passed "an act to regulate and encourage the drainage of lands."

The topography in Minnesota resulted from glacier movements, glacial outwash and glacial lakes. This left a large portion of the land needing drainage in order that agricultural crops could be produced.

King[1/] suggests that drainage has occurred primarily in three periods: 1858-1920, 1920-1950 and 1960-1979. Most of the existing public drainage was constructed or initiated between 1900 and 1920. During the period 1920 to 1950, the attitudes toward water and drainage changed with the state government being given more of an active role. By the end of the dust bowls of the 30's, water was not a "common enemy" anymore, but a resource that needed to be conserved and managed and the state had been given authority over public waters. "Public waters" was originally defined as "all water in lakes and streams that provide substantial beneficial public use." In the 1970's, environmental issues were addressed in the drainage law and wetlands were included in the definition of public waters. Today, protected waters and waters of the state are generally defined as any waters, surface or underground, except those surface waters which are not confined but are spread and diffused over the land.

PROCEDURES

Drainage work done on private land which does not involve protected waters (including wetlands), does not require a State of Minnesota permit. Private land located in a legal watershed district will normally require a permit from that district. Some local units of government are now requiring an owner to obtain a local permit for drainage. The owner should check with respective districts and units of governments as to their requirements before proceeding. If private drainage systems affect wetlands or other protected waters, a permit is needed under Chapter 105, Minnesota Statutes and Protected Water Permits rules, 6 MCAR 1.5020.

Public drainage systems can be carried out under Chapter 106 of the Minnesota Statutes (Drainage law), Chapter 40 of the Minnesota Statutes (Soil and Water Conservation law), or Chapter 112 of the Minnesota Statutes (Watershed law). Under Chapters 40 and 112, the approving authority is the Soil and Water Conservation District or the Watershed District, respectively. Under Chapter 106, the approving authority is the county board. Under Chapters 40 and 112, the planned improvements are also reviewed by the Minnesota Water Resources Board to determine if the improvements are consistent with state water policy.

1/ King, K. Elton A History of Drainage Law in Minnesota with Special Emphasis on the Legal Status of Wetlands. WRRC Bulletin 106, University of Minnesota. Nov. 1980.

The provisions of Chapter 106 are referenced in Chapters 40 and 112 law and are essentially followed in the planning and development or improvement of a drainage system.

To obtain a permit for drainage, the procedure outlined in Chapter 106 of the Minnesota Statutes (Drainage law) should be followed. If the drainage system might effect protected waters, a permit from the Minnesota Department of Natural Resources, (MDNR), may be needed. For more information and transmittal forms, contact your local MDNR representative or the state MDNR office at the below address.

State of Minnesota
Department of Natural Resources
Division of Waters
3rd Floor, DNR Building
500 Lafayette Road
St. Paul, MN 55146
telephone: (612) 296-0521

The Commissioner of MDNR will then determine if the proposed drainage work will substantially affect any natural watercourse or any lake basin which serves a beneficial public purpose (Chapter 105, Section 105.42, and Section 105.301, Minnesota Statutes) and if a permit will be needed under the Protected Waters Permits rules, 6 MCAR 1.5020.

A permit may be required from the Corps of Engineers when dredging out of or filling into the waters of the United States. Under Section 404 of the Federal Water Pollution Control Act, interstate waters and their tributaries, including adjacent wetlands, isolated wetlands and lakes, intermittent streams, and prairie potholes, are considered "waters of the United States". For further information and permits contact:

The District Engineer
U.S. Army Engineering District
1421 U.S. Post Office &
Custom House
St. Paul, MN 55101-9808

Telephone: (612) 220-0376
(612) 220-0302

CHAPTER 3

DESIGN DATE AND RECOMMENDATIONS

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DESIGN DATA AND RECOMMENDATIONS

GENERAL

This section contains soil charateristics data and drainage recommendations for all known soils in Minnesota. The soil data, from which the drainage recommendations were developed, can be used to determine the need for filters around subsurface drains and the corrosion potential of a soil.

This information is also valuable in determining spacings on a soil which has not been classified or mapped by comparing this soil's properties and profiles with known soils.

For more information on soils, refer to the published Soil Survey for your area, if available, or the Soil Interpretation Record (SCS-SOI-5) for the soil in question, or consult a soil scientist.

NEED FOR FILTERS

The Unified Soil Classification is given in Table 3-1 so that need for filters can be determined by comparing the classification of the given soil with the recommendations shown in Table 4-5, in Chapter 4, Subsurface Drainage.

CORROSION POTENTIAL

The pH range of the soil should be considered when selecting the type of materials to be used in a drainage system. Corrosion and deterioration rates vary with the pH of the soil and other factors, depending on the type of material in question.

The risk of corrosion is classified as low, moderate, and high on the SCS-SOI-5 for two types of materials: steel and concrete.

Corrosion of steel materials used in tiles and structures correlates poorly with soil reaction (pH range). There are some significant exceptions. (1) A pH of 4 or less, almost without exception, indicates a high soil corrosion potential. (2) Sulfate-reducing bacteria can significantly increase the corrosion rate of iron. The bacteria reduce sulfates in water to sulfides in the presence of hydrogen or organic matter, and are most active in anaerobic conditions. Iron aids in this process, and in turn rust or ferrous sulfide is formed. The most favorable pH for sulfate-reducing bacteria is 7; increasingly higher or lower pH values are less and less favorable. In wet or moist soils with anaerobic conditions, especially in clays that contain some organic matter and sulfur, a pH of about 7 indicates a high corrosion potential.

Ratings, based on a single soil property or quality, that place soils in relative corrosivity classes must be tempered by knowledge of other properties and qualities that affect corrosion. A study of soil properties in relation to local experiences with soil corrosivity helps engineers in making corrosion potential interpretations.

The estimation of corrosivity for untreated steel shown on the SCS-SOI-5 is commonly based on (1) resistance to flow of electrical current, (2) total acidity, (3) soil drainage, (4) soil texture, and (5) conductivity of saturated soil.

The probability of corrosion is greater for extensive installations that intersect soil boundaries or soil horizons than for installations that remain in one kind of soil or in one soil horizon.

Using soil corrosivity interpretations found on the SCS-SOI-5 without considering the size of the metallic structure or the effects of using different metals may lead to wrong conclusions. Construction paving, fill and compaction, surface additions, etc., that alter the soil, increase the probability of corrosion. Mechanical agitation or excavation that results in aeration and in nonuniform mixing of soil horizons, such as excavation and backfilling of tile trenches, also increase the probability of corrosion.

Corrosion of concrete materials can be related to the pH of the soil. Special cements and methods of manufacturing may be used to reduce the rate of deterioration in soils of high corrosivity. The rate of deterioration is related to (1) the amount of sulfates and (2) soil texture and acidity. The corrosivity classes used by the Soil Conservation Service to indicate corrosion potential for concrete are:

Low. Generally includes (1) coarse-textured and moderately coarse textured soils and organic soils that have pH greater than 6.5, or medium- and fine-textured soils that have a pH greater than 6.0, and (2) soils that contain less than 1,000 parts per million of watersoluble sulfate (as SO_4).

Moderate. Generally includes (1) coarse-textured and moderately coarse textured soils and organic soils that have a pH of 5.5 to 6.5, and medium- and fine-textured soils that have a pH of 5.0 to 6.0, and (2) soils that contain 1,000 to 7,000 parts per million of watersoluble sulfate (as SO_4).

High. Generally includes (1) coarse-textured and moderately coarse textured soils and organic soils that have a pH of 5.5 or less, and medium- and fine-textured soils that have a pH of 5.0 or less, and (2) soils that contain more than 7,000 parts per million of watersoluble sulfate (as SO_4).

These ratings are shown on the SCS-SOI-5; however, these must be tempered with engineering judgement and knowledge of local experience.

DESIGN GROUPS

Table 3-1 shows a Design Group number in the fourth column. The Design Groups are groups of soils that have similar problems and need similar treatments, such as erosion control and drainage. The Design Group number suggests items that should be considered by the planner and designer. However, each field has its own unique characteristics of

soil, topography, crop history, and management, and the planned treatment and final design should vary accordingly. Usually, the best treatment for a field will include erosion and runoff control practices, as well as drainage. On some fields with heavy soils, conservation tillage practices are not practical unless subsurface drainage is installed.

Many of the soils fall into more than one Design Group. For example, a particular soil may be mapped on slopes ranging from 0 to 12%. By the definitions that follow, the same soil can be in two, or even three, different design groups. The planner or designer must decide if drainage and/or other treatments are necessary, based on the field's characteristics and the landowner's needs.

The Design Groups are described below. Soils in Groups 1 - 6 are generally "wet" soils, or have a seasonal water table less than 30 inches from the ground surface. Soils in Groups 1 - 6 normally need some form of drainage, while soils in Groups 7 and 8 normally do not need drainage.

Group 1: Soils in pothole-type topography. Treatments to be considered include random field ditches and/or surface inlets to subsurface drainage systems to remove ponded water. Subsurface drainage systems may be needed on the larger depressional areas. All soils in Design Group 1 have also been analyzed as a group 3, 4, or 5 soil, as appropriate, for drain spacing recommendations.

Group 2: Soils on slopes greater than 5%. Treatments to be considered include interceptor-type drains to control seepage, and diversions, terraces, waterways, etc. to control erosion and runoff which overflows the area. Except for interceptor drains, subsurface drainage is usually not needed. Most soils in Design Group 2 are also included in Design Group 3, 4 or 5, because these soils are also mapped on slopes less than 5%.

Group 3: Soils on slopes less than 5% which frequently or occasionally flood. Subsurface drainage should be considered for these soils. Drainage systems may need water control structures, pumping plants, flap gates, etc. to get drainage water to an outlet. Treatments to be considered, in addition to subsurface drainage, include levees, field ditches, land shaping, grade control structures, etc. to control or dispose of surface waters.

Group 4: Soils on slopes less than 5% that do <u>not</u> occasionally flood but do receive runoff or seepage from adjacent slopes. Wetness is usually a problem on these soils. Diversions or interceptor drains may adequately treat the drainage problem; however, if subsurface drainage is also needed, a balance between surface flow diversion, seepage interception and normal subsurface systems should be evaluated.

Group 5: Soils on slopes less than 5% with no overflow runoff contributing to the area. Subsurface drainage measures are usually

needed, and some minor supplemental surface drainage, land shaping, and runoff control measures may be needed to control or dispose of surface waters.

Group 6: Soils having a restricting layer (permeability less than 0.06 inch/hours) or bedrock at less than 15 inches depth. Usually, subsurface drainage is not recommended on these soils. Field ditches, bedding, land shaping, diversions, open interceptor drains, etc. are recommended for drainage practices. Some sites may need erosion control measures.

Group 7: Soils with water tables deeper than 30 inches and with no restricting layer (restricting means permeability is less than 0.06 inch/hour). These soils have at least one layer with permeability less than 6.0 inches/hour. Drainage practices are usually not needed. Treatment on these soils is generally for erosion control, including practices such as terraces, diversions, grassed waterways, grade control structures, etc.

Group 8: Soils with water tables deeper than 30 inches and with soil permeabilities greater than 6 inches per hour throughout the entire profile. Drainage and erosion control practices are usually not needed.

DRAIN DEPTH AND SPACING

Table 3-1 contains recommended drain depths and spacings for various drainage coefficients. The designer must judge if the recommended spacings are appropriate or whether different spacings can be justified. Spacings wider than 1.1 times the recommended spacings must be based on site conditions and soils and appropriately documented.

The Hooghoudt formula was used to determine the spacings on all of the soils that need drainage. The formula used is:

$$S = \sqrt{\frac{8k_b d_e h + 4k_a h^2}{q}}$$

where $d_e = \dfrac{S}{\frac{S}{d} + a}$

and $a = 2.55 \ln \frac{d}{r_e} - 3.52$

where:

S = drain spacing, feet
h = head above the drain at the midpoint between the drains, feet
d = distance between the drain and barrier, feet

q = water removal rate (drainage coefficient), inches per day

k_a = weighted lateral hydraulic conductivity above the drain, inches per day.

k_b = weighted lateral hydraulic conductivity below the drain and to the effective drainage barrier, inches per day.

d_e = distance between drain and the effective drainage barrier, feet.

r_e = effective radius of the drainage tubing, feet.

For Table 3-1, drain (tile) depth is given as 36 and 48 inches. If the depth to a barrier is less than 36 or 48 inches, the drain depth is set at the barrier. Bedrock and soil layers with permeability less than 0.06 inches per hour are considered to be barriers. If depth to barrier is greater than 60 inches, the barrier depth is arbitrarily set at 10 feet.

Midpoint drawdown values are set at 12 inches or one-half the drain depth, whichever is less. Accordingly, the value of "h" in the Hooghoudt equation is computed by subtracting the midpoint drawdown from the drain depth.

The lateral hydraulic conductivity is calculated as the average of the permeability range for each layer as shown on Table 3-1. These averages are weighted according to layer thickness to determine k_a and k_b. Only the soil profile below the drawdown depth is used in computing the lateral hydraulic conductivity. "A" horizons (topsoils) with different permeabilities are analyzed separately only if the "A" horizon depths exceed the drawdown depth. If the recommended spacings are significantly different for the different "A" horizons, the spacings are listed by the "A" horizon texture class.

Four-inch diameter drainage tubing was assumed for determining the spacing recommendations in Table 3-1. The effective radius, r_e, of four-inch CPT is 0.2008 inches.

NOTE: The user of this guide must note that the drainage recommendations given in Table 3-1 are based on typical characteristics of the soil series, and should not be considered rigid criteria but a guide. No attempt has been made to evaluate the economics of the recommendations. For very close spacing recommendations (e.g. Fargo soil needs drains at 25' spacing and 48" depth to remove 3/8" water per day) tile installation is probably not economically justified for most fields and crops. On some sandy soils, subsurface drainage without provisions to control the water table can damage crops by leaving the root zone too dry in low rainfall periods. (See Chapter 9.) Each situation should be analyzed for technical and economic feasibility. A qualified drainage engineer must be consulted when difficult or unusual situations are encountered.

Example 1

Use Table 3-1 to find design data for a Glencoe series soil (I.D. no. MN0026):

The data for Glencoe soil shows that it is in Design Groups 1 and 5. This means that the soil is in pothole topography, and that surface drainage and/or surface inlets to subsurface drain lines are needed to remove ponded surface water. Subsurface drainage is needed on the larger depressional areas, with depth and spacing recommendations as shown for Design Group 5. If the field needs drainage, the drain lines should be spaced at about 73 feet for a 36-inch depth or 98 feet for 48-inch depth, assuming a 3/8" drainage coefficient.

The Unified Soil Classification is CL or ML, so a filter (See Table 4-6) may be needed. Soils should be monitored closely during construction, so that filters can be installed if needed. The pH range is near 7, so corrosivity for concrete is probably low, but corrosivity for steel needs further investigation because of the pH range, organic matter in topsoil (OL and OH), and the CL (clay) subsoil. A check of the SCS-SOI-5 for Glencoe series soil shows a corrosivity rating of HIGH for steel, and LOW for concrete. Steel would probably corrode rapidly in this soil.

Table 3-1 shows that the depth to water table is "+1-1.0", which means the seasonal high water table is from one foot above ground (ponding) to one foot below ground. This is typical of pothole topography.

Depth to bedrock is greater than 60 inches, so no problems are anticipated in that regard.

Example 2

Use Table 3-1 to find design data for a Bluffton series soil (I.D. No. MN0184):

Bluffton soil is in Design Groups 1 and 5, which means the soil is in pothole topography. The larger depressional areas need subsurface drainage, with the drains spaced as shown for Design Group 5.

Note that this soil has two topsoil phases: the first phase has texture classes L (loam) and SIL (silt loam) with a permeability of 0.6 - 2.0 inches per hour; the second phase has texture classes SL (sandy loam) and SCL (sandy clay loam) with a permeability of 0.6 - 6.0 inches per hour.

The lower permeability of the first topsoil phase results in narrower spacing recommendations than for the second phase. For a 3/8" drainage coefficient and 48" drain depth, the spacing recommendation is 60 feet for the first phase and 68 feet for the second phase.

The designer must determine which topsoil phase is present at the site being drained, so that the drain system can be designed properly.

The Unified Soil Classification shows that ML, SM, and SC classes may be present below 22 inches. See Table 4-6. A filter may be needed, depending on site conditions.

The average pH range for the soil profile is near 7, so corrosivity for concrete is probably low; but corrosivity for steel may be high because of the neutral pH, clay (CL) in the soil, and relatively high organic matter content typical of potholes. The SCS-SOI-5 for Bluffton series soil shows a corrosivity rating of HIGH for steel, and MODERATE for concrete. Steel would probably corrode rapidly in this soil, and Extra Quality should be specified if concrete tile is used.

Example 3

Use Table 3-1 to find design data for a Brookings series, nonflooded soil (I.D. No. SD0282):

Brookings nonflooded soil is in Design Group 7. Drainage is generally not needed on this soil. Erosion control practices should be applied as necessary.

This soil also has two different topsoil phases. But since the differences in topsoils do not affect drainage recommendations, and both topsoil phases are in Design Group 7, no entry is made in the COMMENTS column. The recommendations apply to all phases.

TABLE 3-1 DRAINAGE GUIDE DATA FOR MINNESOTA

Table 3-1 gives drain design recommendations and soil characteristic data for Minnesota soils. The column headings are explained below:

SOIL NAME	The first column gives the name of the soil, the kind of soil unit, and other modifiers that identify the soil.
ID NO.	The second column gives the soil identification number, by which the soil data can be obtained from computer storage.
COMMENTS	This column gives the texture class of the different "A" horizon phases of a soil when the different phases result in different design groups or spacing recommendations, and the appropriate design group or spacings are listed accordingly. If no texture class is given in this column, the design group number and spacings apply to all phases of the soil. See Appendix III for explanations of the texture class abbreviations.
DSN GRP	The Design Group, or Groups, of which the soil is a member. The definitions of the Design Groups are found earlier in this chapter.
DRAIN DEPTH	This column gives the design depth for drains, in inches. For most soils, the depths are 36 and 48 inches.
SPACINGS, FT.	These 4 columns give the recommended drain spacings, in feet, for the drainage coefficient shown in each column header and the depth shown in the DRAIN DEPTH column. See Chapter 4 for appropriate drainage coefficient.
HORIZ DEPTH	The depth, in inches, of the horizons (layers) of the soil profile. Information about the layers is in the next three columns. Some soil series have more than one type of "A" horizon (topsoil layer).
UNIFIED SOIL CLASSIFICATION	This column gives the classification by the Unified System of the soil layer defined in HORIZ DEPTH. Definitions of the Unified Classification system can be found in Appendix III. This information is valuable in determining the need for filters.

PERMEABILITY	This column gives the permeability range, in inches per hour, of the soil layer defined in HORIZ DEPTH. For some soils, the ranges shown are slightly different from the standard ranges found on SCS-SOI-5, so that spacing recommendations coincide better with good drainage practice.
pH RANGE	This gives the pH range of the soil layer defined in HORIZ DEPTH. The pH range is useful in determining corrosion potential.
DEPTH TO WATER TABLE	This column gives depth to the seasonal high water table, in feet. Plus (+) values indicate water surface above ground (ponding).
DEPTH TO BEDROCK	This column gives the normal range of depth to bed rock, in inches. Subsurface drainage may be impossible on shallow-to-bedrock soils.

DRAINAGE GUIDE DATA FOR MINNESOTA

SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	HORIZ DEPTH In.	SOIL CHARACTERISTICS UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BED-ROCK In.
AASTAD SERIES NONFLOODED, PE>44	MN0186		7						0-19	CL	0.2-0.6	6.6-7.8	3.0-6.0	>60
									0-19	ML,CL	0.6-2.0	6.6-7.8		
									19-32	CL	0.2-0.6	6.6-7.8		
									32-60	CL	0.2-0.6	7.4-8.4		
AAZDAHL SERIES	MN0001		5	36	49	37	31	24	0-14	CL	0.6-2.0	6.6-7.3	3.0-6.0	>60
			5	48	65	51	43	34	14-20	CL	0.2-0.6	6.6-7.8		
									20-60	CL	0.2-0.6	7.4-8.4		
ABSCOTA VARIANT	MN0407	Computer	7						0-3	SM,SP-SM	2.0-20	6.6-7.8	3.0-6.0	>60
									3-60	SM,SP-SM	2.0-20	6.6-7.8		
ADOLPH SERIES	MN0489		1						0-13	ML,CL	0.6-2.0	5.6-7.3	0.5-2.0	>60
			5	36	60	47	40	32	13-32	ML,CL-ML	0.6-2.0	6.1-7.3		
			5	48	78	62	53	42	32-60	SM,SM-SC	0.2-0.6	6.6-7.8		
ADOLPH SERIES PONDED	MN0188		5	36	60	47	40	32	0-13	ML,CL	0.6-2.0	5.6-7.3	+1-1.0	>60
			5	48	78	62	53	42	13-32	ML,CL-ML	0.6-2.0	6.1-7.3		
									32-60	SM	0.2-0.6	6.6-7.8		
ADOLPH VARIANT	MN0447		5	36	24	18	15	12	0-10	CL,CL-ML	0.2-0.6	6.6-7.8	+1-3.0	>60
			5	48	34	26	22	17	10-15	CL	0.2-0.6	6.6-7.8		
									15-24	CL,CL-ML	0.06-0.2	6.6-8.4		
									24-60	ML,CL,CL-ML	0.06-0.2	7.4-8.4		
ADRIAN SERIES	MI0028		1						0-34	PT	0.2-6.0	5.1-7.8	+1-1.0	>60
			5	36	344	275	234	185	34-60	SP,SM	6.0-20	5.6-8.4		
			5	48	422	340	291	233						
ADRIAN SERIES FLOODED	MI0328		3	36	344	275	234	185	0-34	PT	0.2-6.0	5.6-7.3	+3-0.5	>60
			3	48	422	340	291	233	34-60	SP	6.0-20	6.1-7.3		
AFTON SERIES	IA0130		3	36	70	50	39	28	0-26	MH,CH	0.2-0.6	6.1-7.8	1.0-3.0	>60
			3	48	100	78	65	50	26-51	CL,CH	0.2-0.6	7.4-8.4		
									51-65	CL	0.2-2.0	7.9-8.4		
AHMEEK SERIES	MN0157		7						0-3	ML,CL-ML	0.6-2.0	4.5-6.0	6.0	>60
									0-3	SM,SM-SC	0.6-2.0	4.5-6.0		
									3-16	SM,SM-SC,ML,CL-ML	0.6-2.0	4.5-6.0		
									16-36	SM,SM-SC,SC	0.2-0.6	5.1-6.5		
									36-60	SM,SM-SC,SC	0.2-0.6	6.1-7.3		

DRAINAGE GUIDE DATA FOR MINNESOTA

SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BED-ROCK In.
ALCESTER SERIES FLOODED	SD0299		7						0-7	CL,CL-ML,ML	0.6-2.0	5.6-7.8	3.0-6.0	>60
									0-7	CL,ML	0.6-2.0	5.6-7.8		
									7-34	CL,ML	0.6-2.0	6.1-7.8		
									34-60	ML,CL	0.6-2.0	6.6-8.4		
ALCESTER SERIES MODERATELY WET	SD0391		7						0-10	CL,ML	0.6-2.0	5.6-7.8	3.0-6.0	>60
									10-43	CL,ML	0.6-2.0	6.1-7.8		
									43-60	CL,ML	0.6-2.0	6.6-8.4		
ALCESTER SERIES NONFLOODED	SD0063		7						0-7	CL,CL-ML,ML	0.6-2.0	5.6-7.8	>6.0	>60
									0-7	CL,ML	0.6-2.0	5.6-7.8		
									7-34	CL,ML	0.6-2.0	6.1-7.8		
									34-60	ML,CL	0.6-2.0	6.6-8.4		
ALGANSEE SERIES	MI0123		3	36	366	293	250	199	0-10	SM	6.0-20	5.6-7.3	1.0-2.0	>60
			3	48	448	361	310	249	0-10	SM	2.0-6.0	5.6-7.3		
									0-10	SM,SP-SM	6.0-20	5.6-7.3		
									10-60	SM,SP-SM	6.0-20	5.6-7.8		
ALGANSEE SERIES PROTECTED	MI0407		5	36	366	293	250	199	0-10	SM	6.0-20	5.6-7.3	1.0-2.0	>60
			5	48	448	361	310	249	10-60	SM,SP-SM	6.0-20	5.6-7.8		
ALLENDALE SERIES	MI0185		2						0-10	SM	6.0-20	5.1-7.3	1.0-2.0	>60
			5	36	119	97	84	68	0-10	SM,SW-SM,SP-SM	6.0-20	5.1-7.3		
			5	48	146	119	103	84	0-10	SM,ML	2.0-6.0	5.1-7.3		
									10-28	SP,SM,SP-SM	6.0-20	5.1-7.3		
									28-60	CH,MH	0.06-0.2	6.1-8.4		
ALMENA SERIES	WI0262	STONY	2						0-4	CL	0.6-2.0	4.5-6.0	1.0-2.5	>60
			5	36	64	51	43	34	4-19	CL,CL-ML	0.6-2.0	4.5-5.5		
			5	48	80	64	54	43	19-32	CL	0.2-2.0	4.5-5.5		
									32-41	CL	0.2-2.0	4.5-6.0		
									41-60	SM,SC,ML,CL	0.2-0.6	5.1-6.0		
ALSTAD SERIES	WI0218		2						0-9	CL,CL-ML,ML	0.6-2.0	5.1-7.3	1.0-3.0	>60
			5	36	70	56	47	38	0-9	ML,SM,CL-ML,SM-SC	0.6-2.0	5.1-7.3		
			5	48	85	68	58	46	9-16	ML,CL,SM,SC	0.6-2.0	5.1-7.3		
									16-23	CL,SC	0.6-2.0	5.1-7.3		
									23-44	CL,SC	0.6-2.0	5.6-7.8		
									44-60	SC,CL,SM,ML	0.2-0.6	6.1-8.4		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
ALSTAD VARIANT	MN0450		5	36	52	41	34	26	0-3	PT	0.6-2.0	4.5-6.0	+1-2.0	>60
			5	48	69	55	46	36	3-19	CL-ML,CL	0.6-2.0	4.5-6.0		
									19-45	CL	0.2-0.6	5.1-7.3		
									45-60	CL	0.2-0.6	6.6-7.8		
ALVIN SERIES	IL0090		7						0-18	SM,ML	2.0-6.0	5.1-6.5	>6.0	>60
									0-18	SM	6.0-20	5.1-6.5		
									18-44	SM,SC,CL,ML	0.6-6.0	4.5-6.0		
									44-68	SM,SP,SP-SM	2.0-6.0	5.1-7.8		
AMES SERIES	IA0195		1						0-17	CL,CL-ML	0.6-2.0	5.1-7.3	+1-1.0	>60
			5	36	65	45	30	16	17-53	CL	0.06-0.2	5.1-7.3		
			5	48	104	81	67	51	53-60	CL	0.6-2.0	6.6-8.4		
ANDRUSIA SERIES	MN0496		7						0-3	SP-SM,SM	6.0-20	6.6-7.3	>6.0	>60
									3-37	SP-SM,SM	6.0-20	6.6-7.3		
									37-47	SC,SM,SM-SC	2.0-6.0	6.6-7.3		
									47-60	SP,SW	6.0-20	7.4-8.4		
ANKENY SERIES	IA0277		7						0-30	SM,SC,SM-SC	2.0-6.0	6.1-7.3	>6.0	>60
									30-44	SM,SC,SM-SC	2.0-6.0	6.1-7.3		
									44-60	SM,SC,SM-SC,SW-SM	6.0-20	6.1-7.3		
ANKENY SERIES FLOODED	IA0194		7						0-30	SM,SC,SM-SC	2.0-6.0	6.1-7.3	>6.0	>60
									30-44	SM,SC,SM-SC	2.0-6.0	6.1-7.3		
									44-60	SM,SC,SM-SC,SW-SM	6.0-20	6.1-7.3		
ANOKA SERIES	MN0215		7						0-10	SM	6.0-20	5.6-6.5	>6.0	>60
									0-10	SM	2.0-20	5.6-6.5		
									10-56	SM	0.6-2.0	5.1-6.5		
									56-60	SM,SP-SM	2.0-20	6.1-7.3		
ANTIGO SERIES	WI0142		7						0-14	ML,CL-ML	0.6-2.0	4.5-6.5	>6.0	>60
									14-30	CL	0.6-2.0	4.5-6.5		
									30-34	SM,GM,ML,GM-GC	0.6-2.0	4.5-6.5		
									34-60	SP,SP-SM,GP,GP-GM	>6.0	5.1-6.5		
ARENZVILLE SERIES MODERATELY WET	WI0087		7						0-25	ML,CL-ML,CL	0.6-2.0	5.6-7.8	3.0-6.0	>60
									25-40	CL	0.6-2.0	5.6-7.8		
									40-60	CL,CL-ML	0.6-2.0	5.6-7.8		
ARENZVILLE SERIES WELL DRAINED	WI0314		7						0-25	ML,CL-ML,CL	0.6-2.0	5.6-7.8	>6.0	>60
									25-40	CL	0.6-2.0	5.6-7.8		
									40-60	CL,CL-ML	0.6-2.0	5.6-7.8		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	HORIZ DEPTH In.	SOIL CHARACTERISTICS: UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
ARKTON SERIES	MN0446		2						0-9	CH,CL	0.2-0.6	6.6-8.4	2.5-6.0	>60
			5	36	47	36	29	23	9-27	CH,CL	0.2-0.6	7.4-8.4		
			5	48	64	50	42	33	27-60	CL,CH	0.2-0.6	7.4-8.4		
ARVESON SERIES	MN0050		5	36	316	252	214	169	0-14	ML	2.0-6.0	7.4-8.4	1.0-2.0	>60
			5	48	388	312	267	214	0-14	SM	2.0-6.0	7.4-8.4		
									14-34	SM,SM-SC	0.6-6.0	7.4-8.4		
									34-60	SP-SM,SM,SM-SC	2.0-20	7.4-8.4		
ARVESON SERIES PONDED	MN0359		1						0-14	ML	2.0-6.0	7.4-8.4	+1-1.0	>60
			5	36	316	252	214	169	0-14	SM	2.0-6.0	7.4-8.4		
			5	48	388	312	267	214	14-34	SM,SM-SC	0.6-6.0	7.4-8.4		
									34-60	SP-SM,SM,SM-SC	2.0-20	7.4-8.4		
ARVILLA SERIES	ND0007		7						0-16	SM,SC,SM-SC	2.0-6.0	6.6-8.4	>6.0	>60
									16-60	SP-SM,GP,SP,GP-GM	>6.0	7.4-8.4		
ATHELWOLD SERIES FLOODED	SD0260		7						0-8	CL	0.6-2.0	5.6-7.3	2.5-5.0	>60
									0-8	CL,ML	0.6-2.0	5.6-7.3		
									8-17	CL,ML	0.6-2.0	5.6-7.3		
									17-30	CL	0.6-2.0	6.6-7.8		
									30-36	CL,ML	0.6-2.0	7.4-8.4		
									36-60	SW,SM,GW,GM	6.0-20	7.4-8.4		
ATHELWOLD SERIES NONFLOODED	SD0013		7						0-8	CL,ML	0.6-2.0	5.6-7.3	3.0-6.0	>60
									0-8	CL,ML	0.6-2.0	5.6-7.3		
									8-17	CL	0.6-2.0	5.6-7.3		
									17-30	CL	0.6-2.0	6.6-7.8		
									30-36	CL	0.6-2.0	7.4-8.4		
									36-60	SW,SM,GW,GM	6.0-20	7.4-8.4		
ATKINSON SERIES	IA0068		7						0-13	CL	0.6-2.0	5.6-7.3	>6.0	40-55
									13-39	CL	0.6-2.0	5.1-6.0		
									39-42	CH	0.06-0.2	6.6-7.3		
									42		-	-		
ATKINSON SERIES SOFT BEDROCK	IA0336		7						0-12	CL	0.6-2.0	5.6-7.3	>6.0	>60
									12-43	CL	0.6-2.0	5.1-6.0		
									43-45	CH	0.06-0.2	6.6-7.3		
									45-60	ML,SM	2.0-6.0	7.4-8.4		

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AUBURNDALE SERIES	WI0089		1						0-16	CL,ML,CL-ML	0.6-2.0	4.5-6.0	+1-1.0	>60
			5	36	95	74	62	48	16-38	CL	0.2-2.0	4.5-6.0		
			5	48	125	99	83	65	38-45	CL,CL-ML,SC,SM-SC	0.2-2.0	4.5-6.0		
									45-60	SM,ML,CL-ML,SM-SC	0.6-2.0	5.1-6.5		
AUBURNDALE SERIES SILTY CLAY LOAM SUBSTRAT	WI0443		1						0-18	ML,CL-ML	0.6-2.0	5.6-7.3	+1-1.0	>60
			5	36	74	59	50	40	18-36	CL	0.6-2.0	5.6-6.5		
			5	48	87	70	59	47	36-48	CL	0.6-2.0	6.1-7.3		
									48-60	CL	0.2-0.6	6.1-7.3		
AUGSBURG SERIES	MN0125		5	36	80	65	56	45	0-11	ML,CL,OL,CL-ML	0.6-6.0	7.4-8.4	1.0-3.0	>60
			5	48	100	81	70	57	11-18	ML	2.0-6.0	7.4-8.4		
									18-33	ML	2.0-6.0	7.4-8.4		
									33-62	CH	<0.2	7.4-8.4		
AUGSBURG SERIES PONDED	MN0361		1						0-11	OL,ML,CL,CL-ML	0.6-6.0	7.4-8.4	+1-1.0	>60
			5	36	80	65	56	45	11-18	ML,CL,CL-ML	2.0-6.0	7.4-8.4		
			5	48	100	81	70	57	18-33	ML,CL,CL-ML	2.0-6.0	7.4-8.4		
									33-60	CH	<0.2	7.4-8.4		
Barbert Series	MN0006		1						0-17	ML, CL-ML	0.6-2.0	5.1-6.5	+1.0-1.0	>60
			5	36	36	26	21	15	17-43	CH	0.06-0.2			
			5	48	56	43	35	27	43-60	CH, CL	0.2-0.6			
BARNES SERIES	ND0119		7						0-7	CL,CL-ML	0.6-2.0	6.1-7.8	>6.0	>60
									0-7	CL,CL-ML	0.6-2.0	6.1-7.8		
									0-7	SM,SC,SM-SC	0.6-2.0	6.1-7.8		
									7-19	CL,CL-ML	0.6-2.0	6.1-7.8		
									19-40	CL,CL-ML	0.2-0.6	7.4-8.4		
									40-60	CL,CL-ML	0.2-0.6	7.4-8.4		
BARNES SERIES MODERATE PERMEABILITY	ND0219		7						0-7	CL,CL-ML,SC,SM-SC	0.6-2.0	6.1-7.8	>6.0	>60
									0-7	SM,ML,SC,CL	2.0-6.0	6.1-7.8		
									7-19	CL,CL-ML,SC,SM-SC	0.6-2.0	6.1-7.8		
									19-60	CL,CL-ML	0.6-2.0	7.4-8.4		
BARODA SERIES	MN0007		5	36	85	66	52	39	0-16	OL,ML,CL	0.6-2.0	5.1-7.3	1.0-3.0	>60
			5	48	115	90	76	59	16-39	MH,CH	0.06-0.2	4.5-6.0		
									39-60	CL	0.6-2.0	7.9-8.4		
BARRINGTON SERIES	IL0192		7						0-12	CL	0.6-2.0	5.6-7.3	>6.0	>60
									12-31	CL	0.6-2.0	5.6-7.8		
									31-84	CL,SM-SC,SC,CL-ML	0.6-2.0	6.1-8.4		
BARRINGTON SERIES MODERATELY WET	IL0307		7						0-14	CL	0.6-2.0	5.6-7.3	3.0-6.0	>60
									14-26	CL	0.6-2.0	5.6-7.8		
									26-60	CL,SM-SC,SC,CL-ML	0.6-2.0	6.1-8.4		

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BARRONETT SERIES	WI0219		1						0-9	ML,CL,CL-ML	0.6-2.0	4.5-7.3	+1-1.0	>60
			3	36	89	69	58	45	0-9	PT	2.0-6.0	4.5-7.3		
			3	48	116	91	77	61	9-16	ML,CL,CL-ML	0.2-2.0	4.5-6.0		
									16-34	CL	0.2-2.0	4.5-6.0		
									34-60	CL	0.2-2.0	4.5-7.8		
BARRONETT SERIES SANDY SUBSTRATUM	WI0301		1						0-17	ML,CL,CL-ML	0.6-2.0	5.1-6.5	+.5-1.0	>60
			5	36	407	325	276	219	17-42	CL	0.2-2.0	5.1-6.5		
			5	48	508	409	350	281	42-60	SP,SP-SM	>20	5.1-6.5		
BARTO SERIES	MN0216		7						0-8	GM,SM	2.0-6.0	4.5-6.5	>6.0	8-20
									0-8	GM,SM	2.0-6.0	4.5-6.5		
									8-15	GM,SM	2.0-6.0	4.5-6.5		
									15		-	-		
BAUDETTE SERIES	MN0114		2						0-8	ML	0.6-2.0	5.6-7.3	3.0-6.0	>60
			5	36	98	77	64	50	0-8	SM,ML	2.0-6.0	5.6-7.3		
			5	48	127	101	85	67	8-20	ML,CL,CL-ML	0.6-2.0	5.6-7.8		
									20-60	ML	0.6-2.0	7.4-8.4		
BAYTOWN SERIES	MN0238		7						0-19	ML,CL,CL-ML	0.6-2.0	5.1-7.3	>6.0	20-40
									19-32	ML,CL	0.6-2.0	4.5-6.5		
									32-36	SM,SP-SM	6.0-20	5.1-6.5		
									36		-	-		
BEARDEN SERIES PE¶44	ND0296		2						0-7	CL,CH	0.2-0.6	7.4-8.4	2.0-4.0	>60
			5	36	86	67	56	43	0-7	CL-ML,CL	0.6-2.0	7.4-8.4		
			5	48	112	88	75	59	0-7	CL,CH	0.06-0.2	7.4-8.4		
									7-28	CL,CH	0.2-2.0	7.4-8.4		
									28-40	CL,CH	0.06-2.0	7.4-8.4		
									40-60	CL,CH	0.06-2.0	7.4-8.4		
BEARDEN SERIES SALINE	ND0126		5	36	85	66	55	42	0-8	ML,CL,CH	0.6-2.0	7.4-7.8	2.0-4.0	>60
			5	48	111	88	74	58	8-15	ML,CL,CH	0.06-2.0	7.9-8.4		
									15-60	ML,CL,CH	0.06-2.0	7.9-8.4		
BEARVILLE SERIES	MN0383		5	36	65	53	46	37	0-2	SM	6.0-20	5.1-6.5	1.0-3.0	>60
			5	48	81	66	57	46	0-2	SP-SM,SM	6.0-20	5.1-6.5		
									2-16	SM,SP-SM	6.0-20	5.1-6.5		
									16-25	SC,CL	0.2-0.6	5.6-7.3		
									25-35	CH,MH	0.06-0.2	6.6-7.8		
									35-60	CH,CL	0.06-0.2	6.6-8.4		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	HORIZ DEPTH In.	SOIL CHARACTERISTICS: UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
BEAUFORD SERIES	MN0045		5	36	33	26	22	17	0-20	CH	0.06-0.2	6.6-7.3	1.0-3.0	> 60
			5	48	40	32	27	21	20-46	CH	0.06-0.6	6.6-7.3		
									46-60	CH	0.06-0.2	7.4-7.8		
BEAVERCREEK SERIES	MN0378	STONY	7						0-5	SM	2.0-6.0	6.1-7.3	>6.0	>60
									0-5	SM	2.0-6.0	6.1-7.3		
									0-5	ML,CL-ML	2.0-6.0	6.1-7.3		
									5-12	SM	2.0-6.0	6.1-7.3		
									12-60	GM,SM	2.0-6.0	6.6-7.8		
BEAVERCREEK VARIANT	MN0435	STONY	2						0-15	SM,ML,CL-ML,SM-SC	0.6-2.0	6.1-7.3	>6.0	>50
			3	36	180	142	120	93	15-30	SM,ML,CL-ML,SM-SC	0.6-2.0	6.1-7.3		
			3	48	227	181	154	122	30-60	SM,SC,GM,GC	2.0-6.0	6.6-7.8		
BECKER SERIES	MN0233		7						0-9	ML,SM	2.0-6.0	5.6-7.3	>4.0	>60
									0-9	ML,CL-ML,CL	2.0-6.0	5.6-7.3		
									9-30	ML,SM	2.0-6.0	5.6-7.3		
									30-36	SM	6.0-20	6.1-7.8		
									36-60	SM,SP-SM	6.0-20	6.1-7.8		
BELLECHESTER SERIES	MN0217		7						0-16	SP-SM	6.0-20	6.1-8.4	>6.0	40-70
									0-16	SP-SM,SM	6.0-20	6.1-8.4		
									16-42	SP,SP-SM	6.0-20	6.6-8.4		
									42-60		-	-		
BELTRAMI SERIES	MN0136		2						0-11	SM,SM-SC	2.0-6.0	6.1-7.3	2.0-4.0	>60
			5	36	98	77	64	50	0-11	ML,CL,CL-ML	0.6-2.0	6.1-7.3		
			5	48	127	101	85	67	11-34	CL	0.6-2.0	6.1-7.8		
									34-60	CL-ML,CL,SC,SM-SC	0.6-2.0	7.4-8.4		
BEOTIA SERIES	SD0169		7						0-11	CL,ML	0.6-2.0	6.1-7.8	>6.0	>60
									11-20	ML,CL	0.6-2.0	6.6-7.8		
									20-42	ML,CL,CL-ML	0.2-2.0	7.4-8.4		
									42-60	ML,CL,CL-ML	0.2-2.0	7.4-8.4		
BERGLAND SERIES	MI0127		6						0-8	CL	0.06-0.2	5.1-7.8	+1-1.0	>60
									0-8	CH,CL	0.06-0.2	5.1-7.8		
									8-25	CH	<0.06	5.1-7.8		
									25-60	CH	<0.06	7.4-8.4		
BERTRAND SERIES	WI0096		7						0-10	CL-ML,CL	0.6-2.0	5.6-7.3	>6.0	>60
									10-44	CL	0.6-2.0	5.1-6.5		
									44-55	ML,SM,CL,SC	0.6-6.0	5.1-6.5		
									55-60	SP-SM,SM	6.0-20	5.1-6.5		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
BESEMAN	MN0189		1						0-36	PT	0.2-6.0	3.6-5.0	+2-1.0	>60
SERIES			5	36	83	67	57	46	36-60	CL,ML,SM,SC	0.2-0.6	3.6-7.3		
			5	48	105	84	72	58						
BILLETT	IL0048		7						0-8	SM,SM-SC,SC	2.0-6.0	5.6-7.3	>6.0	>60
SERIES									8-28	SM-SC,SC	2.0-6.0	5.1-6.5		
									28-47	SM,SM-SC,SC	2.0-6.0	5.6-7.3		
									47-60	SM,SM-SC,SW-SM	6.0-20	5.1-7.8		
BILLETT	IL0297		7						0-8	SM,SC,ML,CL	2.0-6.0	6.1-7.8	3.0-6.0	>60
SERIES									8-30	SM,SC,ML,CL	2.0-6.0	5.1-7.3		
MODERATELY WET									30-36	SM	2.0-6.0	5.1-7.3		
									36-60	SM	6.0-20	5.1-7.8		
BISCAY	MN0110		5	36	340	271	231	182	0-20	CL,ML	0.6-2.0	6.1-7.8	1.0-3.0	>60
SERIES			5	48	417	336	287	230	0-20	CL,ML	0.6-2.0	6.1-7.8		
									20-28	CL,ML	0.6-2.0	6.6-7.8		
									28-36	SM,SM-SC,SC	2.0-6.0	6.6-7.8		
									36-60	SP,SP-SM,GP,GP-GM	6.0-20	7.4-8.4		
BISCAY	MN0316		1						0-20	CL,ML	0.6-2.0	6.1-7.8	+1-1.0	>60
SERIES			3	36	340	271	231	182	20-28	CL,ML	0.6-2.0	6.6-7.8		
PONDED			3	48	417	336	287	230	28-36	SM,SM-SC,SC	2.0-6.0	6.6-7.8		
									36-60	SP,SP-SM,GP,GP-GM	6.0-20	6.6-8.4		
BISCAY	MN0456		2						0-17	CL,ML,CL-ML	0.6-2.0	6.1-7.8	0-2.0	>60
VARIANT			5	36	341	272	231	183	17-28	CL,ML,CL-ML	0.6-2.0	6.6-7.3		
			5	48	418	337	288	230	28-35	SM,SC,SM-SC	2.0-6.0	6.6-7.3		
									35-60	SP,SP-SM	6.0-20	7.4-7.8		
BIXBY	MN0123		7						0-9	ML	0.6-2.0	5.6-6.5	>6.0	>60
SERIES									9-36	CL,SC	0.6-2.0	4.5-6.0		
									36-60	SP	6.0-20	6.1-7.8		
BLACKHAMMER	MN0367		7						0-9	CL,ML,CL-ML	0.6-2.0	5.6-7.3	>6.0	>60
SERIES									9-26	CL-ML,CL	0.6-2.0	5.1-6.5		
									26-60	CL,SC,SM-SC	0.6-2.0	5.1-6.0		
BLACKHOOF	MN0158		1						0-11	PT	0.6-6.0	5.1-6.5	+2-1.0	>60
SERIES			5	36	47	35	29	22	11-15	CL,ML,CL-ML	<0.2	5.1-6.5		
			5	48	63	50	42	32	15-60	CL,ML,CL-ML	0.2-0.6	5.1-7.8		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEA-BILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE ft.	DEPTH TO BED-ROCK In.
BLOMFORD SERIES	MN0239		1						0-9	SM	6.0-20	5.1-7.3	0.5-1.5	>60
			5	36	143	115	98	79	0-9	SM, SP-SM	6.0-20	5.1-7.3		
			5	48	179	144	124	100	9-25	SM, SP-SM	6.0-20	5.1-7.3		
									25-39	ML, CL, SC, SM	0.6-2.0	5.1-7.3		
									39-60	ML, CL, SC, SM	0.6-2.0	6.1-8.4		
BLOOMING SERIES	MN0150		7						0-8	ML, CL, CL-ML	0.6-2.0	5.6-6.5	>6.0	>60
									8-15	CL	0.6-2.0	5.6-6.5		
									15-48	CL, CL-ML, SC, SM-SC	0.6-2.0	5.1-7.3		
									48-60	CL, CL-ML	0.6-2.0	6.6-7.8		
BLOWERS SERIES	MN0286	STONY	5	36	44	35	30	24	0-6	SM, SM-SC	0.6-2.0	5.1-6.5	2.0-3.0	>60
			5	48	56	45	38	31	6-17	SM, SM-SC	0.6-2.0	5.1-6.5		
									17-27	SM, SM-SC, SC	0.6-2.0	5.6-7.3		
									27-34	SM, SM-SC, SC	0.2-0.6	5.6-7.3		
									34-60	SM, SM-SC, SC	0.06-0.2	7.4-8.4		
BLUE EARTH SERIES	MN0064		1						0-10	PT	2.0-6.0	7.4-8.4	+2-1.0	>60
			5	36	95	74	62	49	0-10	OL, ML	0.6-2.0	7.4-8.4		
			5	48	121	96	81	64	10-60	OL, ML	0.6-2.0	7.4-8.4		
									60-70	CL, ML	0.2-2.0	7.4-8.4		
BLUE EARTH SERIES DREDGED	MN0461		5	36	98	77	64	50	0-9	OL	0.6-2.0	7.4-8.4	1.0-3.0	>60
			5	48	127	101	85	67	9-60	OL	0.6-2.0	7.4-8.4		
BLUE EARTH SERIES SLOPING	MN0439		2						0-10	OL, ML	0.2-0.6	7.4-8.4	0-1.0	>60
			4	36	47	36	29	23	10-52	OL, ML	0.2-0.6	7.4-8.4		
			4	48	64	50	42	33	52-60	CL, ML	0.2-0.6	7.4-8.4		
BLUE EARTH VARIANT	MN0177		1						0-16	OL	0.6-2.0	7.4-8.4	+1-1.0	>60
			1						16-25	ML	0.6-2.0	7.4-8.4		
			5	36	127	101	86	68	25-47	SM, SP-SM	2.0-6.0	7.4-7.8		
									47-60	CL	0.6-2.0	7.4-7.8		
BLUE EARTH VARIANT	MN0442		5	36	346	276	235	186	0-28	OL	2.0-6.0	7.4-8.4	+2-1.0	>60
			5	48	424	341	292	234	28-33	CL-ML, CL	0.6-2.0	7.4-8.4		
									33-60	SP-SM	6.0-20	6.1-8.4		
BLUFFTON SERIES	MN0184		1						0-19	CL	0.6-2.0	5.6-6.5	+2-2.0	>60
		L, SIL	5	36	58	46	39	30	0-19	SC, SM, SM-SC	0.6-6.0	5.6-6.5		
			5	48	76	60	51	40	19-22	SM, ML, CL, SC	0.6-6.0	5.6-7.3		
		SL, SCL	5	36	66	53	45	35	22-60	CL, ML, SC, SM	0.2-0.6	7.4-8.4		
			5	48	85	68	58	46						

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	DRAINAGE COEFF. In./24 Hrs. SPACINGS, Ft. 1/4	3/8	1/2	3/4	HORIZ DEPTH In.	SOIL CHARACTERISTICS: UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
BOASH SERIES	MN0396		5	36	91	71	59	43	0-7	CH,CL	0.06-0.2	6.6-7.8	1.0-3.0	>60
			5	48	119	94	79	62	7-27	CH	0.06-0.2	6.6-7.8		
									27-60	CL,CL-ML	0.6-2.0	7.4-8.4		
BOLD SERIES	IL0131		7						0-7	ML,CL,CL-ML	0.6-2.0	7.4-8.4	>6.0	>60
									7-60	ML,CL,CL-ML	0.6-2.0	7.4-8.4		
BOONE SERIES	WI0109		7						0-3	SM,SP-SM	6.0-20	4.5-6.5	>6.0	20-40
									0-3	SM,ML,SP-SM	6.0-20	4.5-6.5		
									0-3	SM,SM-SC,ML,CL-ML	2.0-6.0	4.5-6.5		
									3-36	SM,SP-SM,SP	6.0-20	4.5-6.5		
									36-60		-	-		
BOOTS SERIES	WI0045		1						0-10	PT	0.6-6.0	5.6-7.3	+1-1.0	>60
			3	36	170	134	113	89	10-60	PT	0.6-6.0	5.6-7.3		
			3	48	214	171	146	116						
BORUP SERIES	MN0051		5	36	323	258	219	174	0-14	ML	2.0-6.0	7.4-8.4	1.0-2.5	>60
			5	48	397	319	273	219	0-14	ML	0.6-2.0	7.4-8.4		
									14-26	ML	2.0-6.0	7.4-8.4		
									26-60	ML	2.0-20	7.4-8.4		
BORUP SERIES PONDED	MN0358		1						0-14	ML	2.0-6.0	7.4-8.4	+1-1.0	>60
			5	36	323	258	219	174	0-14	ML	0.6-2.0	7.4-8.4		
			5	48	397	319	273	219	14-26	ML	2.0-6.0	7.4-8.4		
									26-60	ML	2.0-20	7.4-8.4		
BORUP SERIES SALINE	MN0144		5	36	324	258	220	174	0-14	OL,ML	2.0-6.0	7.4-8.4	0-1.0	>60
			5	48	398	320	274	219	14-26	ML	2.0-6.0	7.9-8.4		
									26-60	ML,CL-ML	2.0-20	7.9-8.4		
BOWSTRING SERIES	MN0336		3	36	182	145	123	97	0-32	PT	0.2-6.0	5.6-8.4	0-2.0	>60
			3	48	221	177	151	120	32-40	SP-SM,SM	0.6-20	5.6-8.4		
									40-60	PT	0.2-6.0	5.6-8.4		
BRAHAM SERIES	MN0234		7						0-8	SM	2.0-6.0	5.6-7.3	>6.0	>60
									0-8	SP-SM,SM	6.0-20	5.6-7.3		
									8-24	SP-SM,SM	6.0-20	5.6-7.3		
									24-42	CL,ML,CL-ML	0.6-2.0	5.1-7.3		
									42-60	CL,ML,CL-ML	0.6-2.0	7.4-8.4		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	HORIZ DEPTH In.	SOIL CHARACTERISTICS: UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
BRAINERD SERIES	MN0257	STONY AREAS	2						0-6	SM	2.0-6.0	4.5-6.0	1.5-2.5	>60
			5	36	42	33	28	22	0-6	SM	2.0-6.0	4.5-6.0		
			5	48	55	43	37	29	6-11	SM	2.0-6.0	4.5-6.0		
									11-23	SM	0.6-2.0	5.1-6.5		
									23-38	SM	0.06-0.2	5.1-7.3		
									38-60	SM	<0.2	5.6-7.3		
BRICKTON SERIES	MN0258		5	36	41	31	26	20	0-10	CL-ML,ML	0.6-2.0	5.6-7.3	1.0-3.0	>60
			5	48	57	45	37	29	0-10	CL	0.6-2.0	5.6-7.3		
									0-10	SM,ML	0.6-2.0	5.6-7.3		
									10-25	CH,CL	0.06-0.6	5.1-6.5		
									25-60	CH,CL,ML,MH	0.06-0.6	7.4-8.4		
BRILL SERIES	WI0143		7						0-10	ML,CL-ML	0.6-2.0	4.5-6.5	2.5-3.5	>60
									10-15	ML,CL-ML	0.6-2.0	4.5-6.5		
									15-27	CL	0.6-2.0	4.5-6.5		
									27-36	ML,CL-ML,GM,GM-GC	0.6-6.0	4.5-6.5		
									36-60	SP,SP-SM,GP,GP-GM	>6.0	5.1-7.3		
BRODALE SERIES	MN0235		7						0-6	SM,SP-SM,SC,GM	0.6-2.0	6.6-8.4	>6.0	40-80
									0-6	SM,SP-SM,SC,GC	0.6-2.0	6.6-8.4		
									6-10	SM,SC,GM,GC	0.6-2.0	6.6-8.4		
									10-50	SM,SC,SM-SC,GM	0.6-6.0	7.9-8.4		
									50		-	-		
BROOKINGS SERIES FLOODED	SD0160		7						0-13	CL	0.6-2.0	6.1-7.3	3.0-6.0	>60
									0-13	CL,ML	0.6-2.0	6.1-7.3		
									13-23	CL	0.6-2.0	6.6-8.4		
									23-40	CL	0.6-2.0	7.4-8.4		
									40-60	CL	0.2-2.0	7.4-8.4		
BROOKINGS SERIES NONFLOODED	SD0282		7						0-13	CL	0.6-2.0	6.1-7.3	3.0-6.0	>60
									0-13	CL,ML	0.6-2.0	6.1-7.3		
									13-23	CL	0.6-2.0	6.6-8.4		
									23-40	CL	0.6-2.0	7.4-8.4		
									40-60	CL	0.2-2.0	7.4-8.4		
BROPHY SERIES	MN0259		1						0-6	PT	2.0-6.0	6.6-7.8	+1-1.5	>60
			5	36	190	150	127	100	0-6	PT	2.0-6.0	6.6-7.8		
			5	48	238	191	162	129	0-6	PT	2.0-6.0	6.6-7.8		
									6-38	PT	2.0-6.0	6.6-8.4		
									38-60	PT	2.0-6.0	6.6-8.4		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	HORIZ DEPTH In.	SOIL CHARACTERISTICS: UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BED-ROCK In.
BROWNSDALE SERIES	MN0432		5	36	57	44	37	29	0-9	CL-ML,CL	0.6-2.0	5.6-7.3	0-3.0	>60
			5	48	74	59	50	39	9-26	CL	0.6-2.0	4.5-6.5		
									26-48	CL,SC,CL-ML,SM-SC	0.2-0.6	4.5-6.0		
									48-60	CL,CL-ML,SC,SM-SC	0.2-0.6	6.6-7.8		
BROWNTON SERIES	MN0008		5	36	76	56	45	33	0-22	MH,CH	0.06-0.2	7.4-8.4	1.0-2.5	>60
			5	48	103	80	67	52	22-38	MH,CH	0.06-0.2	7.4-8.4		
									38-60	CL	0.2-2.0	7.4-8.4		
BULLWINKLE SERIES	MN0469		1						0-17	PT	2.0-6.0	5.6-7.3	+1-1.0	>60
			2						17-41	PT	2.0-6.0	5.6-7.3		
			5	36	123	98	84	67	41-45	SM,SC,ML,CL	0.6-2.0	6.6-7.8		
			5	48	149	120	103	82	45-60	SM,SC,ML,CL	0.2-2.0	6.6-7.8		
BURKHARDT SERIES	WI0050		7						0-10	SM,SM-SC	2.0-6.0	5.1-6.5	>6.0	>60
									0-10	ML,CL-ML,CL	2.0-6.0	5.1-6.5		
									0-10	SM,SM-SC	2.0-6.0	5.1-6.5		
									10-17	SM,ML,SC,CL	2.0-6.0	5.1-6.5		
									17-60	SP,SP-SM,GP,GP-GM	>6.0	5.6-6.5		
BURNSVILLE SERIES	MN0240		7						0-9	SC,SM-SC	2.0-6.0	5.6-7.3	>6.0	>60
									0-9	SC,CL,SM-SC,CL-ML	0.6-2.0	5.6-7.3		
									9-20	SM-SC,SC,CL,CL-ML	2.0-6.0	5.6-7.3		
									20-60	SP-SM	6.0-20	6.6-8.4		
BURR SERIES	MN0332		3	36	89	69	58	45	0-7	OH,CL,CH	0.2-2.0	7.4-8.4	1.0-3.0	>60
			3	48	116	91	77	61	7-30	CL,CH	0.2-2.0	7.4-8.4		
									30-60	CL,CH	0.2-2.0	7.4-8.4		
BUSE SERIES MODERATE PERMEABILITY	MN0142		7						0-7	ML,CL,CL-ML	0.6-2.0	6.6-8.4	>6.0	>60
									7-60	CL,CL-ML	0.6-2.0	7.4-8.4		
BUSE SERIES MODERATELY SLOW PERM	MN0317		7						0-7	ML,CL,CL-ML	0.2-2.0	6.6-8.4	>6.0	>60
									7-60	CL,CL-ML	0.2-0.6	7.4-8.4		
BUSE SERIES STONY	MN0310		7						0-7	ML,CL	0.6-2.0	6.6-8.4	>6.0	>60
									0-7	CL	0.6-2.0	6.6-8.4		
									7-60	CL	0.2-0.6	7.4-8.4		
CALCO SERIES	IA0075		3	36	98	77	64	50	0-16	CH,CL	0.6-2.0	7.4-8.4	1.0-3.0	>60
			3	48	127	101	85	67	0-16	CL,CL-ML	0.6-2.0	7.4-8.4		
									16-44	CL,CH	0.6-2.0	7.4-8.4		
									44-60	CL	0.6-2.0	7.4-8.4		

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CAMPIA SERIES	WI0220		7						0-12	CL-ML,CL,ML	0.6-2.0	4.5-7.3	>6.0	>60
									12-42	CL	0.6-2.0	4.5-5.5		
									42-60	CL,CL-ML,ML	0.6-2.0	5.1-7.8		
CANISTEO SERIES	MN0059		5	36	104	81	68	53	0-13	OL,CL	0.6-2.0	7.4-8.4	1.0-3.0	>50
			5	48	133	106	90	71	0-13	CL	0.6-2.0	7.4-8.4		
									13-24	CL	0.6-2.0	7.4-8.4		
									24-31	CL,ML,SM,SC	0.6-6.0	7.4-8.4		
									31-60	CL	0.6-2.0	7.4-8.4		
CANISTEO SERIES PONDED	MN0095		1						0-13	ML,CL	0.6-2.0	7.4-8.4	+1-1.0	>60
			5	36	104	81	68	53	0-13	CL	0.6-2.0	7.4-8.4		
			5	48	133	106	90	71	13-24	CL	0.6-2.0	7.4-8.4		
									24-31	CL,SM,SC,ML	0.6-6.0	7.4-8.4		
									31-60	CL	0.6-2.0	7.4-8.4		
CANISTEO SERIES SANDY SUBSTRATUM	MN0417		3	36	328	261	221	174	0-13	CL	0.6-2.0	7.4-8.4	0-1.0	>60
			3	48	409	329	281	224	13-40	CL	0.6-2.0	7.4-8.4		
									40-60	SM,SP-SM	6.0-20	7.4-8.4		
CANISTEO SERIES STONY	MN0328	STONY	5	36	98	77	64	50	0-20	OL CL	0.6-2.0	7.4-8.4	1.0-3.0	>60
			5	48	127	101	85	67	20-31	CL	0.6-2.0	7.4-8.4		
									31-60	CL	0.6-2.0	7.4-8.4		
CARLOS SERIES	MN0468		1						0-6	PT	0.2-2.0	6.6-8.4	+1-1.0	>60
			5	36	164	130	109	86	6-12	OH,MH	0.2-2.0	7.4-8.4		
			5	48	207	165	141	112	12-60	PT	0.2-6.0	6.6-8.4		
CARMI SERIES	IL0044		7						0-27	SM-SC,SC	2.0-6.0	5.1-7.8	>6.0	>60
									27-36	SM-SC,SC,GC,GM-GC	2.0-6.0	4.5-6.0		
									36-60	SP-SM,GP-GM,SM,GM	6.0-20	5.1-7.8		
CARON SERIES	MN0023		5	36	185	150	129	105	0-9	PT	2.0-6.0	5.6-7.8	+1-1.0	>60
			5	48	206	167	144	116	0-9	PT	2.0-20	5.6-7.8		
									9-46	PT	2.0-20	5.6-7.8		
									46-84	OL	0.2-0.6	6.1-7.8		
									84-96	CL	0.2-2.0	7.4-7.8		
CASHEL SERIES	ND0024		2						0-8	CH,CL	0.06-0.6	7.4-8.4	1.0-3.0	>60
			3	36	41	31	26	20	0-8	CL,CH	0.2-0.6	7.4-8.4		
			3	48	57	45	37	29	8-60	CH,CL,MH	0.06-0.6	7.4-8.4		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEA-BILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BED-ROCK In.
CATHRO	MI0392		1						0-11	PT	0.2-6.0	5.6-7.8	+1-1.0	>60
SERIES			5	36	98	77	65	51	11-23	PT	0.2-6.0	5.6-7.8		
LOW PRECIPITATION			5	48	125	100	85	67	23-60	SM,ML,SC,CL	0.2-2.0	6.6-8.4		
CATHRO	MN0451		1						0-20	PT	0.2-0.6	6.6-7.3	+1-2.0	>60
VARIANT			5	36	198	155	129	99	20-46	CL,ML,CL-ML	0.2-0.6	7.4-7.8		
			5	48	261	208	176	139	46-60	SP,GP,SP-SM,GP-GM	>6.0	7.4-7.8		
CHANNAHON	IL0106		7						0-8	CL	0.6-2.0	6.1-8.4	>6.0	10-20
SERIES									8-17	CL	0.6-2.0	6.1-8.4		
									17-60		-	-		
CHASEBURG	WI0112		7						0-4	ML,CL-ML	0.6-2.0	6.1-7.3	3.0-6.0	>60
SERIES									0-4	ML,CL-ML,SM,SM-SC	0.6-2.0	6.1-7.3		
MODERATELY WET									4-60	ML,CL-ML,CL	0.6-2.0	5.6-7.3		
CHASEBURG	WI0092		7						0-4	ML,CL-ML	0.6-2.0	6.1-7.3	>6.0	>60
SERIES									0-4	ML,CL-ML,SM,SM-SC	0.6-2.0	6.1-7.3		
WELL DRAINED									4-60	ML,CL-ML,CL	0.6-2.0	5.6-7.3		
CHASKA	MN0065		3	36	175	137	115	90	0-8	OL,CL,ML	0.6-2.0	6.6-7.8	1.0-3.0	>60
SERIES			3	48	222	177	150	119	0-8	CL,ML	0.6-2.0	6.6-7.8		
									8-38	CL,CL-ML	0.6-2.0	7.4-7.8		
									38-60	SM,ML	2.0-6.0	7.4-8.4		
CHELSEA	IA0119		8						0-4	SM,SP-SM	6.0-20	5.6-7.3	>6.0	>60
SERIES									4-70	SP,SM,SP-SM	6.0-20	5.1-5.5		
MAAT§50														
CHETEK	WI0120		7						0-13	SM,SM-SC	2.0-6.0	5.1-6.5	>6.0	>60
SERIES									0-13	ML,CL,SM,SC	2.0-6.0	5.1-6.5		
									13-18	ML,CL,SM,SC	2.0-6.0	5.1-6.5		
									18-60	SP,SP-SM	>6.0	5.1-6.5		
CHILGREN	MN0261	STONY AREAS	5	36	98	77	64	50	0-4	SM,SM-SC,ML,CL-ML	2.0-6.0	6.1-7.3	1.0-3.0	>60
SERIES			5	48	127	101	85	67	0-4	ML,CL,CL-ML	0.6-2.0	6.1-7.3		
									0-4	SM,SM-SC,SC	2.0-6.0	6.1-7.3		
									4-10	SM,ML,SM-SC,CL-ML	0.6-2.0	6.1-7.3		
									10-18	CL,ML,SM,SC	0.6-2.0	6.1-7.8		
									18-60	CL,SM,ML,SC	0.6-2.0	7.4-8.4		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	HORIZ DEPTH In.	SOIL CHARACTERISTICS: UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BED-ROCK In.
CLARION SERIES	IA0074		7						0-18	CL,CL-ML	0.6-2.0	5.6-7.3	>5.0	>60
									0-18	SM,SC,SM-SC	2.0-6.0	5.6-7.3		
									0-18	CL	0.6-2.0	5.6-7.3		
									18-36	CL,CL-ML	0.6-2.0	5.6-7.8		
									36-60	CL,CL-ML,SC,SM-SC	0.6-2.0	7.4-8.4		
CLARION VARIANT	MN0304		7						0-18	CL,CL-ML	0.6-2.0	6.1-7.3	>6.0	>60
									18-30	CL,CL-ML	0.6-2.0	5.6-7.3		
									30-60	CL,ML,CL-ML	0.2-0.6	7.4-8.4		
CLEARWATER SERIES	MN0395		5	36	22	17	14	11	0-8	CL,CH	0.06-0.2	6.6-7.8	1.0-3.0	>60
			5	48	32	25	21	16	0-8	CL	0.2-0.6	6.6-7.8		
									0-8	SM-SC,SM,ML,CL-ML	0.6-6.0	6.6-7.8		
									8-16	CL,CH	0.06-0.2	7.4-8.4		
									16-65	CH,CL	0.06-0.2	7.4-8.4		
CLONTARF SERIES	MN0262		7						0-15	SM	2.0-6.0	6.1-7.3	3.0-5.0	>60
									0-15	ML	2.0-6.0	6.1-7.3		
									15-25	SM,ML	2.0-6.0	6.1-7.8		
									25-60	SP-SM,SM	6.0-20	6.6-7.8		
CLOQUET SERIES	MN0179		7						0-8	ML	0.6-2.0	4.5-6.0	>6.0	>60
									0-8	SM,ML,CL-ML,SM-SC	0.6-6.0	4.5-6.0		
									8-14	SM	0.6-2.0	4.5-6.0		
									14-36	GW-GM,GP-GM,SP-SM	>20	5.6-6.5		
									36-60	GW,GP,SP	>20	5.6-6.5		
CLYDE SERIES	IA0046		5	36	104	82	69	54	0-23	OL,MH,ML,OH	0.6-2.0	6.1-7.3	1.0-2.5	>60
			5	48	131	104	88	69	0-23	ML,OL,CL	0.6-2.0	6.1-7.3		
									23-41	CL,ML	0.6-2.0	6.1-7.3		
									41-44	SM,SM-SC	2.0-6.0	6.1-7.3		
									44-66	CL,SC	0.6-2.0	6.6-8.4		
COGGON SERIES	IA0118		7						0-17	CL,CL-ML	0.6-2.0	5.1-7.3	>6.0	>60
									17-44	CL	0.6-2.0	4.5-6.0		
									44-80	CL	0.6-2.0	5.1-7.8		
COLAND SERIES	IA0079		3	36	156	122	102	79	0-10	CL,CH	0.6-2.0	6.1-7.3	1.0-3.0	>60
			3	48	200	159	135	106	0-10	CL	0.6-2.0	6.1-7.3		
									10-40	CL,CH	0.6-2.0	6.1-7.3		
									40-60	CL,SC,CL-ML,SM-SC	0.6-6.0	6.1-7.8		
COLLINWOOD SERIES	MN0040		2						0-15	CL,CH,ML,MH	0.2-0.6	5.6-7.3	2.0-5.0	>60
			5	36	41	32	26	20	15-33	MH,CH	0.06-0.6	5.6-7.3		
			5	48	57	45	38	29	33-60	CH,CL	0.06-0.6	7.4-8.4		

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COLO SERIES	IA0071		3	36	98	77	64	50	0-14	CL,CL-ML	0.6-2.0	5.6-7.3	1.0-3.0	>60
			3	48	127	101	85	67	0-14	CL,CH	0.6-2.0	5.6-7.3		
									14-46	CL,CH	0.6-2.0	5.6-7.3		
									46-60	CL,CH	0.6-2.0	6.1-7.3		
COLO SERIES LOW PRECIPITATION	IA0296		3	36	98	77	64	50	0-14	CL,CL-ML	0.6-2.0	5.6-7.3	1.0-3.0	>60
			3	48	127	101	85	67	0-14	CL,CH	0.6-2.0	5.6-7.3		
									14-46	CL,CH	0.6-2.0	5.6-7.3		
									46-60	CL,CH	0.6-2.0	6.1-7.3		
COLO SERIES NONFLOODED	IA0305		5	36	98	77	64	50	0-14	CL,CL-ML	0.6-2.0	5.6-7.3	1.0-3.0	>60
			5	48	127	101	85	67	0-14	CL,CH	0.6-2.0	5.6-7.3		
									14-46	CL,CH	0.6-2.0	5.6-7.3		
									46-60	CL,CH	0.6-2.0	6.1-7.3		
COLVIN SERIES PE>44	ND0295		5	36	85	66	55	42	0-10	CL	0.6-2.0	7.4-9.0	1.0-2.0	>50
			5	48	111	88	74	58	0-10	CL	0.2-0.6	7.4-9.0		
									0-10	CL,CH	0.06-0.2	7.4-9.0		
									10-30	CL	0.06-2.0	7.4-9.0		
									30-60	CL	0.06-2.0	7.4-9.0		
COLVIN SERIES SALINE	ND0181		3	36	85	66	55	42	0-10	CL	0.6-2.0	7.4-9.0	0-2.0	>60
			3	48	111	88	74	58	0-10	CL	0.2-0.6	7.4-9.0		
									10-60	CL	0.06-2.0	7.4-9.0		
COLVIN SERIES WET	ND0001		5	36	85	66	55	42	0-10	CL	0.6-2.0	7.4-9.0	+1-1.0	>60
			5	48	111	88	74	58	0-10	CL	0.2-0.6	7.4-9.0		
									0-10	CL,CH	0.06-0.2	7.4-9.0		
									10-30	CL	0.06-2.0	7.4-9.0		
									30-60	CL	0.06-2.0	7.4-9.0		
COMFREY SERIES	MN0066		3	36	98	77	64	50	0-10	OH,ML,CL,CH	0.6-2.0	6.6-7.8	0-3.0	>60
			3	48	127	101	85	67	0-10	ML,OL,CL	0.6-2.0	6.6-7.8		
									10-26	OL,OH,MH,ML	0.6-2.0	6.6-7.8		
									26-60	CL	0.6-2.0	6.6-8.4		
COMFREY SERIES SANDY SUBSTRATUM	MN0437		3	36	395	314	267	210	0-6	CL,CL-ML	0.6-2.0	6.6-7.8	+.5-1.0	>60
			3	48	501	403	345	277	0-6	CL	0.6-2.0	6.6-7.8		
									6-32	CL	0.6-2.0	6.6-7.8		
									32-46	CL	0.6-2.0	6.6-7.8		
									46-60	SP,SP-SM,SM,GP	>20	7.4-8.4		

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COMSTOCK SERIES	WI0224		5	36	61	48	41	32	0-8	CL-ML,CL,ML	0.6-2.0	5.1-7.3	1.0-3.0	>60
			5	48	79	63	53	42	8-15	CL-ML,CL,ML	0.6-2.0	4.5-6.0		
									15-34	CL	0.6-2.0	4.5-6.0		
									34-60	CL,ML,CL-ML	0.2-0.6	5.1-7.3		
CONIC SERIES	MN0190		7						0-15	SM,GM	2.0-6.0	3.6-6.0	>6.0	20-40
									15-30	SM,GM	0.06-0.2	4.5-6.0		
									30		-	-		
COPASTON SERIES	MN0058		7						0-7	SM	0.6-2.0	6.1-7.3	>6.0	12-20
									0-7	SM,ML	0.6-2.0	6.1-7.3		
									0-7	SM,ML	0.6-2.0	6.1-7.3		
									7-11	SM	0.6-6.0	5.6-7.3		
									11-18	SM	0.6-6.0	5.6-7.3		
									18		-	-		
CORDOVA SERIES	MN0024		5	36	90	70	58	43	0-14	OL,ML,MH,OH	0.2-2.0	6.1-7.3	1.0-3.0	>60
			5	48	119	93	79	61	14-35	CL	0.2-0.6	5.1-6.5		
									35-60	CL	0.6-2.0	7.4-8.4		
CORIFF SERIES	MN0393		5	36	140	112	96	76	0-10	SM-SC,SM	2.0-6.0	7.4-8.4	1.0-3.0	>60
			5	48	175	141	121	97	0-10	ML,CL,CL-ML	0.6-2.0	7.4-8.4		
									10-24	SM-SC,SM	2.0-6.0	7.4-8.4		
									24-33	SM,SP-SM	6.0-20	7.4-8.4		
									33-60	CL-ML,CL	0.6-2.0	7.4-8.4		
CORMANT SERIES	MN0002		5	36	366	293	250	199	0-6	SM,SP-SM	6.0-20	6.1-7.3	1.0-3.0	>60
			5	48	448	361	310	249	6-60	SP,SP-SM,SM	6.0-20	6.1-7.8		
CORMANT SERIES PONDED	MN0385		1						0-6	SM,SP-SM	6.0-20	6.1-7.3	+1-1.0	>60
			5	36	366	293	250	199	6-60	SP,SP-SM,SM	6.0-20	6.1-7.8		
			5	48	448	361	310	249						
CORUNNA SERIES MODERATE PERMEABILITY	MI0369		1						0-11	SM,SM-SC	0.6-6.0	6.1-7.8	1.0-2.0	>60
			5	36	115	91	77	61	0-11	ML,CL,CL-ML	0.6-2.0	6.1-7.8		
			5	48	146	117	99	79	11-36	SM,SC,SM-SC	0.6-6.0	6.1-7.8		
									36-60	CL,CL-ML	0.6-2.0	7.4-8.4		
COUNCIL SERIES MODERATELY WET	WI0331		7						0-8	ML,SM	0.6-2.0	4.5-6.5	2.5-6.0	>60
									0-8	ML,SM	0.6-2.0	4.5-6.5		
									8-52	CL,CL-ML,SC,SM-SC	0.6-2.0	4.5-6.5		
									52-60	ML,CL,SM,SC	0.6-2.0	5.1-7.3		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
COUNCIL SERIES WELL DRAINED	WI0328		7						0-8	ML,SM	0.6-2.0	4.5-6.5	>6.0	>60
									0-8	ML,SM	0.6-2.0	4.5-6.5		
									8-52	CL,CL-ML,SC,SM-SC	0.6-2.0	4.5-6.5		
									52-60	ML,CL,SM,SC	0.6-2.0	5.1-7.3		
COWHORN SERIES	MN0347		5	36	190	150	127	100	0-8	ML,SM	0.6-2.0	5.1-6.5	1.5-3.0	>60
			5	48	238	191	162	129	0-8	ML,CL-ML	0.6-2.0	5.1-6.5		
									8-51	SM,ML	2.0-6.0	5.1-6.5		
									51-60	SM,ML	2.0-6.0	6.1-8.4		
CRIPPIN SERIES	IA0177		5	36	98	77	64	50	0-16	CL	0.6-2.0	6.6-8.4	2.0-4.0	>50
			5	48	127	101	85	67	16-35	CL	0.6-2.0	7.4-8.4		
									35-60	CL	0.6-2.0	7.9-8.4		
CROCKER SERIES	IA0198		7						0-18	SC,SM,SM-SC	6.0-20	5.6-7.3	>6.0	>60
									18-60	CL,CL-ML	0.6-2.0	5.1-6.5		
CROFTON SERIES	NE0026		7						0-6	ML,CL	0.6-2.0	7.4-8.4	>6.0	>60
									6-60	CL	0.6-2.0	7.4-8.4		
CROKE SERIES	MN0473		5	36	63	51	44	36	0-9	OL,ML,CL-ML,CL	2.0-6.0	6.6-7.8	2.5-6.0	>60
			5	48	79	64	55	45	9-25	ML,CL-ML,CL	2.0-6.0	6.6-8.4		
									25-60	CH,CL	0.06-0.2	7.9-8.4		
CROMWELL SERIES	MN0191		7						0-15	SM	0.6-2.0	4.5-6.0	>6.0	>60
									15-60	SM,SP,SP-SM	6.0-20	5.1-6.5		
CRYSTAL LAKE SERIES	WI0225		7						0-12	CL-ML,CL,ML	0.6-2.0	4.5-6.5	2.5-6.0	>60
									12-32	CL	0.6-2.0	4.5-6.0		
									32-60	CL,CL-ML,ML	0.2-0.6	4.5-7.3		
CUSHING SERIES MODERATELY WET	WI0005		7						0-9	CL,ML,SC,SM	0.6-2.0	5.1-7.8	2.5-6.0	>60
									0-9	SM,SM-SC,ML,CL-ML	0.6-2.0	5.1-7.8		
									9-16	SM,SM-SC,ML,CL-ML	0.6-2.0	5.1-7.8		
									16-42	SC,CL	0.6-2.0	5.1-7.8		
									42-60	SC,CL,SM,ML	0.2-0.6	5.1-8.4		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEA-BILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BED-ROCK In.
CUSHING SERIES WELL DRAINED	WI0198		7						0-9	CL,ML,SC,SM	0.6-2.0	5.1-7.8	>6.0	>60
									0-9	SM,SM-SC,ML,CL-ML	0.6-2.0	5.1-7.8		
									0-9	SC,CL	0.6-2.0	5.1-7.8		
									9-16	SM,SM-SC,ML,CL-ML	0.6-2.0	5.1-7.8		
									16-42	SC,CL	0.6-2.0	5.1-7.8		
									42-60	SC,CL,SM,ML	0.2-0.6	5.1-8.4		
CUTAWAY SERIES	MN0346		7						0-4	SM,SP-SM	6.0-20	5.1-6.0	>6.0	>60
									4-35	SM,SP-SM	6.0-20	5.1-6.0		
									35-51	CL,ML	0.06-0.6	5.1-6.5		
									51-60	CL,ML	0.06-2.0	6.1-8.4		
CYLINDER SERIES	IA0156		5	36	438	352	300	239	0-14	CL	0.6-2.0	5.6-7.3	2.0-4.0	>60
			5	48	534	431	370	297	14-28	CL,SC	0.6-2.0	6.1-7.3		
									28-60	SP-SM,SM	>20	6.6-8.4		
CYLINDER SERIES FLOODED	IA0350		3	36	438	352	300	239	0-14	CL,ML	0.6-2.0	5.6-7.3	2.0-4.0	>60
			3	48	534	431	370	297	14-28	CL,SC	0.6-2.0	6.1-7.3		
									28-60	SP-SM,SM	>20	7.4-8.4		
DAKOTA SERIES	WI0196		7						0-14	CL	0.6-2.0	5.1-7.3	>6.0	>60
									0-14	SC,SM-SC,CL,CL-ML	0.6-2.0	5.1-7.3		
									14-27	CL	0.6-2.0	5.1-7.3		
									27-36	SM,SP-SM,GM,GP-GM	2.0-6.0	5.1-7.3		
									36-60	SP,SP-SM,GP,GP-GM	6.0-20	5.1-7.8		
DAKOTA SERIES LIMESTONE SUBSTRATUM	WI0193		7						0-15	CL	0.6-2.0	5.1-7.3	>6.0	40-60
									15-29	CL	0.6-2.0	5.1-7.3		
									29-32	SM,SP-SM,GM,GP-GM	2.0-6.0	5.1-7.3		
									32-44	SP,SP-SM,GP,GP-GM	6.0-20	5.1-7.3		
									44-60		-	-		
DAKOTA SERIES LOAMY SUBSTRATUM	WI0317		7						0-12	CL	0.6-2.0	6.1-7.3	>6.0	>60
									12-36	CL	0.6-2.0	5.1-6.5		
									36-42	SP-SM,SM	6.0-20	5.6-6.5		
									42-60	SM SC,ML,CL	0.6-2.0	5.6-6.0		
DALBO SERIES	MN0236		2						0-6	CL,ML,CL-ML	0.6-2.0	5.6-7.3	2.5-5.0	>60
			5	36	81	62	50	38	0-6	CL	0.6-2.0	5.6-7.3		
			5	48	107	84	70	55	0-6	SM,ML	2.0-6.0	5.6-7.3		
									6-35	CL,CH	0.06-0.6	5.1-7.3		
									35-60	CL,CH	0.2-2.0	7.4-8.4		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
DARFUR SERIES	MN0009		5	36	186	147	124	97	0-19	SM,ML	0.6-2.0	6.1-7.3	1.0-3.0	>60
			5	48	234	187	159	126	0-19	OL,ML	0.6-2.0	6.1-7.3		
									0-19	SM	0.6-2.0	6.1-7.3		
									19-31	SM	2.0-6.0	6.6-7.8		
									31-60	SM	2.0-6.0	6.6-8.4		
DARNEN SERIES	MN0067		7						0-24	OL,ML,CL,CL-ML	0.6-2.0	6.6-7.8	>6.0	>60
									24-34	CL,CL-ML	0.6-2.0	6.1-7.8		
									34-60	CL,CL-ML	0.6-2.0	7.4-8.4		
DARNEN SERIES MODERATELY WET	MN0364		7						0-24	OL,ML,CL,CL-ML	0.6-2.0	6.6-7.8	2.5-6.0	>60
									24-34	CL,CL-ML	0.6-2.0	6.1-7.8		
									34-60	CL,CL-ML	0.6-2.0	7.4-8.4		
DASSEL SERIES	MN0081		5	36	349	279	237	188	0-14	SM	2.0-6.0	5.6-7.3	0.5-3.0	>60
			5	48	428	345	295	236	0-14	OL,ML	2.0-6.0	5.6-7.3		
									14-31	SM	2.0-6.0	5.6-7.3		
									31-60	SM,SP-SM	6.0-20	6.1-7.8		
DASSEL SERIES PONDED	MN0386		1						0-14	SM	2.0-6.0	5.6-7.3	+1-1.0	>60
			5	36	349	279	237	188	0-14	OL,ML	2.0-6.0	5.6-7.3		
			5	48	428	345	295	236	14-31	SM	2.0-6.0	5.6-7.3		
									31-60	SM,SP-SM	6.0-20	6.1-7.8		
DAWSON SERIES	MI0134		1						0-8	PT	6.0	3.6-4.4	+1-1.0	>60
			5	36	333	266	225	178	0-8	PT	0.2-6.0	3.6-4.4		
			5	48	415	333	285	228	8-38	PT	0.2-6.0	3.6-4.4		
									38-40	ML	0.6-2.0	3.6-4.4		
									40-60	SM-SC,SM,SC,SP-SM	6.0-20	4.5-6.5		
DEBS SERIES	MN0498		7						0-4	SM,ML	0.6-6.0	6.6-7.3	>6.0	>60
									0-4	ML,CL-ML	0.6-2.0	6.6-7.3		
									4-12	ML,SM	2.0-6.0	6.6-7.3		
									12-20	ML,CL,CL-ML	0.6-2.0	6.6-7.3		
									20-60	ML,SM	0.6-2.0	7.4-8.4		
DEERWOOD SERIES	MN0018		1						0-10	PT	2.0-6.0	5.6-7.8	+1-1.0	>60
			5	36	366	293	250	199	10-12	SM,SP-SM	2.0-20	6.1-8.4		
			5	48	448	361	310	249	12-60	SM,SP,SP-SM	6.0-20	7.4-8.4		
DELFT SERIES	MN0295		4	36	80	62	49	37	0-29	CL	0.2-2.0	5.6-7.8	1.0-3.0	>60
			4	48	110	86	73	57	29-46	CL	0.2-0.6	6.6-7.8		
									46-60	CL,ML,CL-ML	0.2-2.0	7.4-8.4		

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DEMONTREVILLE SERIES	MN0242		7						0-24	SM	6.0-20	5.6-7.3	>6.0	>60
									0-24	SP,SM	6.0-20	5.6-7.3		
									24-41	SC,SM,CL,ML	0.2-0.6	5.6-6.5		
									41-60	SC,SM,SM-SC	0.2-0.6	5.6-7.3		
DEMPSTER SERIES	SD0062		7						0-10	CL,CL-ML,ML	0.6-2.0	5.6-7.3	>6.0	>60
									0-10	CL	0.6-2.0	5.6-7.3		
									10-29	CL,ML	0.6-2.0	6.1-7.3		
									29-36	CL,ML	0.6-2.0	7.4-8.4		
									36-60	SM,SW,SW-SM,GP-GM	2.0-20	7.4-8.4		
DICKEY SERIES LOAMY	ND0217		7						0-12	SM,SM-SC	2.0-6.0	6.1-7.8	>6.0	>60
									12-30	SM	6.0-20	6.1-7.8		
									30-60	CL,CL-ML	0.2-2.0	7.4-8.4		
DICKEY SERIES SANDY	ND0122		7						0-12	SM	6.0-20	6.1-7.8	>6.0	>60
									12-30	SM	6.0-20	6.1-7.8		
									30-60	CL CL-ML	0.2-2.0	7.4-8.4		
DICKEY VARIANT	MN0455		7						0-7	SM,SM-SC	2.0-6.0	6.1-7.3	>6.0	>60
									7-12	SM,SM-SC	2.0-6.0	6.1-7.3		
									12-32	SM	6.0-20	6.6-7.3		
									32-46	CL,CL-ML,ML	0.6-2.0	7.4-8.4		
									46-60	CL,CL-ML,ML	0.6-2.0	7.4-8.4		
DICKINSON SERIES MAAT<50	IA0078		7						0-9	SM,SC,SM-SC	2.0-6.0	5.6-7.3	>6.0	>60
									9-30	SM,SC,SM-SC	2.0-6.0	5.1-6.5		
									30-36	SM,SP-SM,SM-SC	6.0-20	5.1-6.5		
									36-60	SM,SP-SM	6.0-20	5.6-7.3		
DICKINSON SERIES MAP<25	IA0297		7						0-7	SM,SC,SM-SC	2.0-6.0	5.6-7.3	>6.0	>60
									7-30	SM,SC,SM-SC	2.0-6.0	5.1-6.5		
									30-50	SM,SP-SM,SM-SC	6.0-20	5.1-6.5		
									50-60	SM,SP-SM	6.0-20	5.6-6.5		
DICKINSON SERIES TILL SUBSTRATUM	IA0214		7						0-20	SM,SC,SM-SC	2.0-6.0	5.6-7.3	>6.0	>60
									20-45	SM,SP,SM-SC	6.0-20	5.1-6.0		
									45-60	CL	0.6-2.0	5.6-6.5		
DICKMAN SERIES	MN0105		7						0-11	SM,SM-SC,SC	2.0-6.0	5.6-6.5	>6.0	>60
									11-18	SM,SM-SC,SC	2.0-6.0	5.6-7.3		
									18-60	SP-SM	6.0-20	5.6-7.8		

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DICKMAN SERIES MODERATELY WET	MN0470		7						0-15	SM,SM-SC,SC	2.0-6.0	5.6-6.5	3.0-6.0	>60
									15-24	SM,SM-SC,SC	2.0-6.0	5.6-7.3		
									24-60	SP-SM	6.0-20	5.6-7.8		
DINSDALE SERIES	IA0066		7						0-15	ML,CL	0.6-2.0	5.1-7.3	>6.0	>60
									15-36	CL	0.6-2.0	5.1-6.0		
									36-73	CL	0.6-2.0	5.6-8.4		
DIVIDE SERIES	ND0011		2						0-9	CL,CL-ML	0.6-2.0	7.4-8.4	2.5-5.0	>60
			5	36	230	182	154	121	0-9	CL,SC,CL-ML,SM-SC	0.6-2.0	7.4-8.4		
			5	48	286	229	195	155	9-25	CL,CL-ML	0.6-2.0	7.9-8.4		
									25-60	GM,SM,GP-GM,SP-SM	>6.0	7.9-8.4		
DIVIDE SERIES SALINE	ND0314		2						0-9	CL,CL-ML	0.6-2.0	7.4-8.4	2.5-5.0	>60
			5	36	230	182	154	121	0-9	CL,SC,CL-ML,SM-SC	0.6-2.0	7.4-8.4		
			5	48	286	229	195	155	9-25	CL,CL-ML	0.6-2.0	7.9-8.4		
									25-60	GM,SM,GP-GM,SP-SM	>6.0	7.9-8.4		
DODGEVILLE SERIES	WI0184		7						0-13	CL	0.6-2.0	6.1-7.3	>6.0	20-40
									0-13	CL,CL-ML	0.6-2.0	6.1-7.3		
									13-18	CH,CL	0.2-2.0	5.1-6.5		
									18-31	CH	0.2-0.6	5.1-7.3		
									31-39	SM,GM	2.0-6.0	7.4-8.4		
									39		-	-		
DOLAND SERIES	MN0218		7						0-8	OL,ML	0.6-2.0	6.1-7.3	>6.0	>60
									8-22	ML,CL-ML	0.6-2.0	6.1-7.3		
									22-60	CL,CL-ML	0.6-2.0	6.6-8.4		
DONALDSON SERIES	MN0115		5	36	61	50	43	35	0-9	SM,ML	2.0-6.0	6.6-7.3	2.5-6.0	>60
			5	48	76	62	53	43	0-9	SM,ML	2.0-6.0	6.6-7.3		
									9-14	SM,ML	2.0-6.0	6.6-7.8		
									14-24	SM	2.0-6.0	6.6-8.4		
									24-60	CH	0.06-0.2	7.4-8.4		
DONNAN SERIES	IA0039		4	24	22	18	16	13	0-18	CL,ML	0.6-2.0	5.1-7.3	2.0-3.0	>60
									18-24	CL	0.6-2.0	5.1-5.5		
									24-48	CH	<0.06	5.1-6.5		
									48-60	CL	0.2-0.6	5.1-6.5		
DORA SERIES	MN0384		1						0-12	PT	0.6-6.0	4.5-7.8	+2-1.0	>50
			5	32	59	49	42	34	12-32	PT	0.6-6.0	4.5-7.8		
									32-60	CH,CL	<0.06	6.1-8.4		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
DORAN SERIES	ND0010		5	36	75	55	44	32	0-9	CL	0.2-0.6	6.6-7.3	3.0-5.0	>60
			5	48	103	80	67	52	0-9	CH,CL	0.2-0.6	6.6-7.3		
									9-20	CH,CL	0.06-0.6	6.6-7.8		
									20-40	CL	0.06-0.2	7.4-8.4		
									40-60	CL	0.2-2.0	7.4-8.4		
DORCHESTER SERIES	IA0095		7						0-31	ML,CL-ML,CL	0.6-2.0	7.9-8.4	>6.0	>60
									31-60	OL,ML,CL	0.6-2.0	6.6-7.8		
DORERTON SERIES	MN0254		7						0-10	ML	0.6-2.0	5.1-7.3	>6.0	45-70
									0-10	SM,ML	2.0-6.0	5.1-7.3		
									10-18	CL,ML	0.6-2.0	5.1-7.3		
									18-30	GM,GC,SM,SC	0.6-2.0	5.6-7.3		
									30-60	GW-GM,SP-SM,SM	2.0-6.0	7.4-8.4		
DORSET SERIES	MN0263		7						0-10	SM,SM-SC	2.0-6.0	5.6-7.3	>6.0	>60
									10-20	SM-SC,SC,CL-ML,CL	2.0-6.0	5.6-7.3		
									20-33	SP-SM,SM,SM-SC	6.0-20	5.6-7.8		
									33-60	SP,SP-SM,GP,GP-GM	6.0-20	7.4-8.4		
DOVRAY SERIES	MN0052		1						0-43	CH,MH,OH	0.06-2.0	6.1-7.8	+2-1.0	>60
			5	36	65	50	42	32	43-56	CH,MH	<0.2	6.6-7.8		
			5	48	85	67	56	44	56-60	CH,MH,CL,ML	<0.6	6.6-8.4		
DOWAGIAC SERIES	MI0006		7						0-11	ML,CL-ML,CL	0.6-2.0	5.6-6.5	>6.0	>60
									0-11	SM,SM-SC,SC	2.0-6.0	5.6-6.5		
									11-29	CL,SC	0.6-2.0	5.1-6.5		
									29-38	SM,SM-SC,SC	2.0-6.0	5.1-6.5		
									38-60	SP,SP-SM,GP,GP-GM	6.0-20	5.6-7.3		
DOWNS SERIES	IA0117		7						0-17	CL,CL-ML	0.6-2.0	5.1-7.3	>6.0	>50
									17-39	CL	0.6-2.0	4.5-6.0		
									39-60	CL	0.6-2.0	5.6-7.3		
DOWNS SERIES MODERATELY WET	IA0303		7						0-10	CL,CL-ML	2.0-6.0	5.1-7.3	4.0-6.0	>60
									10-50	CL	0.6-2.0	5.1-6.5		
									50-60	CL	0.6-2.0	5.6-6.5		
DOWNS SERIES SANDY SUBSTRATUM	IA0341		7						0-9	CL,CL-ML	0.6-2.0	5.1-7.3	>6.0	>60
									9-41	CL	0.6-2.0	4.5-6.0		
									41-48	CL	0.6-2.0	5.6-7.3		
									48-60	SP-SM,SM,SM-SC	6.0-20	5.1-7.3		

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DU PAGE	IL0206		7						0-30	CL	0.6-2.0	6.6-8.4	4.0-6.0	>60
SERIES									30-41	CL	0.6-2.0	7.4-8.4		
MODERATELY WET									41-60	CL-ML,SM-SC,CL,SC	0.6-6.0	7.9-8.4		
DU PAGE	IL0263		7						0-30	CL	0.6-2.0	6.6-8.4	>6.0	>60
SERIES									30-41	CL	0.6-2.0	7.4-8.4		
WELL DRAINED									41-60	CL-ML,CL,SC,SM-SC	0.6-6.0	7.9-8.4		
DUBUQUE	IA0098		7						0-11	CL-ML,CL	0.6-2.0	5.6-7.3	>6.0	20-30
SERIES									11-22	CL	0.6-2.0	5.6-6.0		
									22-27	CH	0.06-0.2	5.6-6.0		
									27		-	-		
DUELM	MN0192		5	36	366	293	250	199	0-11	SM,SP-SM	6.0-20	5.6-7.3	2.0-5.0	>60
SERIES			5	48	448	361	310	249	0-11	SP,SM,SP-SM	6.0-20	5.6-7.3		
									0-11	SM,SM-SC,ML,CL-ML	2.0-6.0	5.6-7.3		
									11-42	SM,SP-SM	6.0-20	5.1-7.3		
									42-60	SP,SM,SP-SM	6.0-20	5.6-7.3		
DUELM	MN0454	COBBLY SUBSOIL	5	36	149	120	102	82	0-9	SM,SM-SC	2.0-6.0	5.6-6.5	3.0-5.0	>60
VARIANT			5	48	186	150	129	104	9-21	SM	2.0-6.0	5.6-6.5		
									21-29	SM	6.0-20	5.6-6.5		
									29-34	GP,SP,SM,GM	6.0-20	5.6-6.5		
									34-60	CL,CL-ML	0.6-2.0	6.6-7.8		
DULUTH	MN0159		7						0-13	ML,CL-ML	0.6-2.0	4.5-6.0	>6.0	>60
SERIES									0-13	SM,ML	2.0-6.0	4.5-6.0		
									13-64	CL,CL-ML	0.06-0.6	5.6-7.3		
									64-72	CL,CL-ML,SC,SM-SC	0.06-0.6	6.6-7.8		
DUNBARTON	WI0185		7						0-7	CL	0.6-2.0	5.6-7.3	>6.0	12-20
SERIES									0-7	CL	0.6-2.0	5.6-7.3		
									7-12	CL,CH	0.6-2.0	5.6-7.8		
									12-18	CH	0.2-0.6	7.4-7.8		
									18-60		-	-		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	HORIZ DEPTH In.	SOIL CHARACTERISTICS UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
DUNDAS SERIES	MN0211		5	36	87	67	54	40	0-15	ML,CL	0.6-2.0	5.6-7.3	1.0-3.0	>60
			5	48	117	92	77	60	0-15	SM,ML	0.6-2.0	5.6-7.3		
									15-40	CL,CH	0.2-0.6	5.1-7.3		
									40-60	CL,SC	0.6-2.0	7.4-8.4		
DURAND SERIES	IL0261		7						0-13	CL	0.6-2.0	5.1-6.5	>6.0	>60
									13-21	CL	0.6-2.0	5.1-6.5		
									21-77	CL,SC,GC	0.6-2.0	5.1-6.5		
									77-86	SC,CL,SM-SC,CL-ML	0.6-2.0	6.1-8.4		
DUSLER SERIES	MN0160								0-15	ML	0.6-2.0	4.5-6.0	1.0-4.0	>60
									0-15	SM,ML	0.2-0.6	4.5-6.0		
			5	36	28	22	18	14	15-55	CL,ML	0.06-0.2	5.1-7.3		
			5	48	38	30	25	20	55-60	CL,ML	0.06-0.2	6.6-7.8		
ECKMAN SERIES	ND0018		7						0-8	ML	0.6-2.0	6.6-7.8	>5.0	>60
									0-8	ML	0.6-2.0	6.6-7.8		
									8-44	ML	0.6-2.0	6.6-8.4		
									44-60	ML,SM	0.6-2.0	7.4-8.4		
ECKVOLL SERIES	MN0415	STONY AREAS	5	36	111	87	74	58	0-9	SM,SM-SC	2.0-6.0	6.1-7.3	2.0-5.0	>60
			5	48	141	113	96	76	0-9	SM,SM-SC	2.0-6.0	6.1-7.3		
									9-25	SM,SP-SM	2.0-6.0	6.1-7.3		
									25-32	SC,CL	0.6-2.0	6.6-7.8		
									32-60	CL	0.6-2.0	7.4-8.4		
EDMUND SERIES	WI0183		7						0-7	CL	0.6-2.0	5.6-7.8	>6.0	12-20
									7-10	CL,SC,GC	0.6-2.0	5.6-7.8		
									10-18	CH	0.2-0.6	5.6-7.8		
									18		-	-		
EDMUND SERIES STONY	WI8034		7						0-10	CL	0.6-2.0	5.6-7.3	>6.0	12-20
									10-18	CH,CL	0.2-0.6	6.6-7.8		
									18		-	-		
EFFIE SERIES	MN0335		5	36	22	17	14	11	0-5	CL,ML,CL-ML	0.6-2.0	5.6-7.3	1.0-2.5	>60
			5	48	32	25	21	16	0-5	SC,SM,CL-ML,ML	2.0-6.0	5.6-7.3		
									5-19	CH,CL	0.06-0.2	5.6-7.8		
									19-60	CH,CL	0.06-0.2	7.9-8.4		
EGELAND SERIES	SD0140		7						0-8	CL,CL-ML	0.6-2.0	5.6-7.3	>6.0	>60
									0-8	SM,SM-SC	2.0-6.0	5.6-7.3		
									8-30	SM,SM-SC	2.0-6.0	6.1-7.8		
									30-60	SM,SP-SM,SM-SC	2.0-6.0	6.6-8.4		

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EITZEN SERIES	MN0377		7						0-25	CL,CL-ML	0.6-2.0	5.6-7.3	>6.0	>60
									25-48	CL,CL-ML	0.6-2.0	5.1-6.5		
									48-72	CL,CL-ML	0.6-2.0	5.1-6.0		
ELBAVILLE SERIES	MN0301		7						0-16	ML,CL-ML,CL	0.6-2.0	5.6-7.3	>6.0	>60
									0-16	SM	2.0-6.0	5.6-7.3		
									16-20	CL	0.2-0.6	5.1-7.3		
									20-25	CL,CH,MH,ML	0.2-0.6	5.6-7.3		
									25-36	GC,GM,SC,SM	0.6-2.0	6.6-7.8		
									36-60	GM,SM,GP-GM,SP-SM	2.0-6.0	7.4-7.8		
ELEVA SERIES	WI0011		7						0-5	SM,SM-SC,ML,CL-ML	2 0-6.0	5.1-7.3	>6.0	20-40
									0-5	ML,CL-ML	0.6-2.0	5.1-7.3		
									5-30	CL,SC,CL-ML,SM-SC	0.6-6.0	4.5-6.5		
									30-36	SM,SP-SM	2.0-20	4.5-6.5		
									36-60		-	-		
ELMVILLE SERIES	MN0366		2						0-14	ML,SM	2.0-6.0	7.4-8.4	2.5-5.0	>60
			5	36	73	59	51	41	0-14	SM	2.0-6.0	7.4-8.4		
			5	48	90	73	63	51	14-30	SM,ML	2.0-6.0	7.9-8.4		
									30-60	CH,CL	0.06-0.2	7.4-7.8		
EMMERT SERIES	MN0193		8						0-5	SM,SP,GW,GP	20	5.1-6.5	>6.0	>60
									0-5	SM,SM-SC	6.0-20	5.1-6.5		
									0-5	SM,SP-SM	6.0-20	5.1-6.5		
									5-60	GW,GP,SP,SW	>20	5.1-7.3		
ENLOE SERIES	ND0013		1						0-14	CL	0.06-0.2	5.6-7.3	+1-1.0	>60
			5	36	22	17	14	11	0-14	CH	0.06-0.2	5.6-7.3		
			5	48	32	25	21	16	14-40	CH	0.06-0.2	6.1-7.8		
									40-60	CH,CL	0.06-0.2	7.4-7.8		
ENSTROM SERIES	MN0019		2						0-8	SM,SP-SM	6.0-20	6.6-7.8	2.5-5.0	>60
			5	36	160	129	110	89	0-8	SP-SM,SM	6.0-20	6.6-7.8		
			5	48	198	160	138	111	8-33	SP-SM,SM	6.0-20	6.6-8.4		
									33-60	CL-ML,CL,SC,SM-SC	0.2-2.0	7.4-8.4		
EPOUFETTE SERIES	MI0214		1						0-8	SM	6.0-20	6.1-7.3	+1-1.0	>60
			5	36	447	359	306	244	0-8	SM,SM-SC	2.0-6.0	6.1-7.3		
			5	48	544	439	377	303	8-26	SM,SP,SP-SM	6.0-20	6.1-7.3		
									26-32	SM,SM-SC,SC	2.0-6.0	6.6-7.8		
									32-60	SP,SP-SM,GP,GP-GM	>20	7.4-8.4		

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ERIN SERIES	MN0264		7						0-12	ML,CL	0.6-2.0	5.6-7.3	>6.0	>60
									0-12	CL,ML	0.6-2.0	5.6-7.3		
									12-57	CL,CH	0.2-0.6	4.5-6.0		
									57-71	CL	0.2-2.0	6.1-7.8		
ESPELIE SERIES	MN0406		5	36	96	78	68	55	0-9	SM,ML,SC,CL	2.0-6.0	6.6-7.3	1.0-3.0	>60
			5	48	119	97	84	68	0-9	CL,ML,CL-ML	0.6-2.0	6.6-7.3		
									9-24	SM,SP-SM	2.0-20	6.6-7.8		
									24-60	CH,CL	0.06-0.2	7.4-8.4		
ESSEXVILLE SERIES	MI0230		5	36	120	97	84	68	0-11	SM,SM-SC	6.0-20	7.4-8.4	+1-1.0	>60
			5	48	149	121	104	84	0-11	SM,SP-SM	6.0-20	7.4-8.4		
									0-11	SM	2.0-6.0	7.4-8.4		
									11-26	SM,SM-SC,SP-SM	6.0-20	7.9-8.4		
									26-30	CL	0.2-0.6	7.9-8.4		
ESTELLINE SERIES	SD0206		7						0-6	CL,ML	0.6-2.0	6.1-7.3	>6.0	>60
									0-6	CL	0.6-2.0	6.1-7.3		
									6-27	CL	0.6-2.0	6.6-7.8		
									27-37	CL,ML	0.6-2.0	7.4-8.4		
									37-60	SW,SP,SW-SM,SP-SM	6.0-20	7.4-8.4		
ESTHERVILLE SERIES	MN0025		7						0-13	SM,SM-SC,SC	2.0-6.0	5.6-7.3	>6.0	>60
									0-13	CL-ML,CL	2.0-6.0	5.6-7.3		
									13-18	SM,SM-SC,SC	2.0-6.0	5.6-7.3		
									18-60	SP,SP-SM,SM,GP	>6.0	6.6-8.4		
ETTER SERIES	MN0243		7						0-8	ML,SM,CL-ML,SM-SC	2.0-6.0	5.6-7.3	>6.0	>60
									0-8	CL,CL-ML	0.6-2.0	5.6-7.3		
									8-29	ML,SM,SC,CL	0.6-2.0	4.5-6.5		
									29-32	SM,SP-SM	6.0-20	4.5-6.0		
									32-60	SP-SM,SM	6.0-20	4.5-6.0		
EVERLY SERIES	IA0161		7						0-12	CL	0.6-2.0	5.6-7.3	>6.0	>60
									12-26	CL	0.6-2.0	6.1-7.3		
									26-60	CL	0.6-2.0	7.4-8.4		
EVERLY SERIES MODERATELY SLOW PERM	IA0249		7						0-12	CL	0.6-2.0	5.6-7.3	>5.0	>60
									12-26	CL	0.6-2.0	6.1-7.3		
									26-60	CL	0.2-0.6	7.4-8.4		

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EYOTA SERIES	MN0180		7						0-10	SM,SM-SC	2.0-6.0	5.1-7.3	>6.0	>60
									0-10	SM	2.0-6.0	5.1-7.3		
									10-24	SM,ML,CL-ML,SM-SC	2.0-6.0	4.5-6.5		
									24-50	CL,CL-ML	0.6-2.0	4.5-6.5		
									50-60	ML,SM,CL-ML,SM-SC	2.0-20	6.1-7.3		
FAIRHAVEN SERIES	MN0194		7						0-14	ML,CL	0.6-2.0	6.1-7.3	>6.0	>60
									14-24	ML,CL	0.6-2.0	5.6-7.3		
									24-60	SP,SP-SM,GP,GP-GM	6.0-20	6.1-8.4		
FAIRHAVEN VARIANT	MN0457		7						0-12	CL-ML,CL	0.6-2.0	5.6-7.3	>6.0	>60
									12-44	CL-ML,CL	0.6-2.0	5.6-7.3		
									44-60	SM,SP-SM	0.6-6.0	5.6-7.3		
FARGO SERIES NONE-RARELY FLOODED	ND0020		5	36	22	17	14	11	0-8	CL	0.06-0.2	6.6-7.8	0-3.0	>60
			5	48	32	25	21	16	0-8	CH	0.06-0.2	6.6-7.8		
									0-8	CL,CL-ML	0.2-0.6	6.6-7.8		
									8-21	CH	0.06-0.2	6.6-7.8		
									21-60	CH	0.06-0.2	7.9-8.4		
FARGO SERIES PONDED	ND0201		1						0-6	CH	0.06-0.2	6.6-7.8	+.5-1.0	>60
			5	36	22	17	14	11	6-38	CH	0.06-0.2	6.6-7.8		
			5	48	32	25	21	16	38-60	CH	0.06-0.2	7.9-8.4		
FARGO SERIES SALINE	ND0111		3	36	22	17	14	11	0-8	CL	0.06-0.2	6.6-7.8	0-3.0	>60
			3	48	32	25	21	16	0-8	CH	0.06-0.2	6.6-7.8		
									8-21	CH	0.06-0.2	6.6-7.8		
									21-60	CH	0.06-0.2	7.9-8.4		
FARGO SERIES SILTY SUBSTRATUM	ND0233		5	36	78	60	47	35	0-8	CL	0.06-0.2	6.6-7.3	1.0-3.0	>60
			5	48	104	81	68	53	0-8	CH	0.06-0.2	6.6-7.3		
									8-21	CH	0.06-0.2	6.6-7.8		
									21-36	CH	0.06-0.2	7.9-8.4		
									36-60	CL	0.2-2.0	7.9-8.4		
FARGO SERIES SILTY SUBSTRATUM, PONDED	ND0235		1						0-8	CL	0.06-0.2	6.6-7.3	+1-2.0	>60
			5	36	78	60	47	35	0-8	CH	0.06-0.2	6.6-7.3		
			5	48	104	81	68	53	8-21	CH	0.06-0.2	6.6-7.8		
									21-36	CH	0.06-0.2	7.9-8.4		
									36-60	CL	0.2-2.0	7.9-8.4		
FARRAR SERIES	IA0181		7						0-14	SC,SM-SC	2.0-6.0	5.6-7.3	>6.0	>60
									14-22	SC,SM-SC	2.0-6.0	5.6-6.5		
									22-60	CL	0.6-2.0	6.1-8.4		

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FAXON	MN0082		3	36	43	35	30	25	0-15	CL	0.6-2.0	6.6-7.8	0-1.0	20-40
SERIES									0-15	ML,CL	0.6-2.0	6.6-7.8		
									15-34	CL,ML,SC,SM	0.6-2.0	6.6-7.8		
									34		-	-		
FAXON	MN0482	STONY	5	36	176	138	116	90	0-14	CL	0.6-2.0	6.6-7.8	1.0-3.0	>60
VARIANT			5	48	223	177	151	119	14-37	CL,ML	0.6-2.0	6.6-7.8		
									37-60	SM,ML	2.0-6.0	7.4-8.4		
FAYETTE	IA0082		7						0-11	CL-ML,CL	0.6-2.0	5.1-7.3	>6.0	>60
SERIES									11-47	CL	0.6-2.0	4.5-6.0		
									47-73	CL	0.6-2.0	5.1-7.8		
FAYETTE	IA0342		7						0-6	CL-ML,CL	0.6-2.0	5.1-7.3	>6.0	>60
SERIES									0-6	CL	0.6-2.0	5.1-7.3		
SANDY SUBSTRATUM									6-44	CL	0.6-2.0	4.5-6.0		
									44-50	SM-SC,SC	2.0-6.0	5.1-6.5		
									50-60	SP-SM,SM,SM-SC	6.0-20	5.1-7.3		
FAYETTE	IA0328		7						0-8	CL	0.6-2.0	5.1-7.3	>6.0	>60
SERIES									8-40	CL	0.6-2.0	4.5-6.0		
SEVERELY ERODED									40-73	CL	0.6-2.0	5.1-7.8		
FAYETTE	WI8055		7						0-11	CL-ML,CL	0.6-2.0	5.1-7.3	>6.0	>60
SERIES									11-41	CL	0.6-2.0	4.5-6.0		
STONY									41-60	CL	0.6-2.0	5.1-7.8		
FEDJI	MN0010		7						0-10	SM	6.0-20	5.6-6.5	>6.0	>60
SERIES									10-24	SM,SP-SM	6.0-20	6.1-7.3		
									24-39	CL	0.6-2.0	6.1-7.3		
									39-60	CL,CL-ML	0.6-2.0	7.4-8.4		
FESTINA	IA0096		7						0-12	CL-ML,CL	0.6-2.0	5.6-7.3	>6.0	>60
SERIES									12-47	CL	0.6-2.0	5.1-6.0		
									47-68	CL	0.6-2.0	5.1-6.5		
									68-75	SM,SC,ML,CL	2.0-6.0	6.1-7.3		
FIELDON	MN0011		5	36	180	142	119	93	0-19	CL-ML,CL,ML	0.6-2.0	7.4-8.4	1.0-3.0	>60
SERIES			5	48	227	181	154	122	0-19	SM,SM-SC	2.0-6.0	7.4-8.4		
									19-37	ML,SM	0.6-2.0	7.4-8.4		
									37-60	SM	2.0-6.0	7.4-8.4		
FINCHFORD	IA0006		8						0-18	SP-SM,SM	>6.0	6.1-7.3	>6.0	>60
SERIES									18-30	SW-SM,SP-SM	>20	5.1-6.0		
									30-60	SW,SW-SM,SP,SP-SM	>20	5.6-6.5		

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FINLAND SERIES	MN0492		7						0-4	ML,CL-ML	0.6-2.0	4.5-6.0	>6.0	>60
									0-4	SM,SM-SC,ML,CL-ML	0.6-2.0	4.5-6.0		
									4-20	SM,SM-SC,ML,CL-ML	0.6-2.0	5.1-6.0		
									20-39	SM,GM,SC,GC	0.2-0.6	5.1-6.5		
									39-60	SM,GM,SC,GC	0.2-0.6	5.6-7.3		
FLAK SERIES	MN0265		7						0-7	SM	2.0-6.0	4.5-6.5	>6.0	>60
									7-15	SM	2.0-6.0	5.1-6.5		
									15-23	SM	0.6-2.0	5.1-6.5		
									23-43	SM	0.06-0.2	5.1-6.5		
									43-60	SM	< 0.2	5.6-6.5		
FLAMING SERIES	MN0068		5	36	366	293	250	199	0-12	SM,SP-SM	6.0-20	5.6-7.3	2.5-4.0	>60
			5	48	448	361	310	249	0-12	SP-SM	6.0-20	5.6-7.3		
									12-60	SM,SP-SM	6.0-20	5.6-8.4		
FLANDREAU SERIES	SD0168		7						0-9	CL,CL-ML	0.6-2.0	5.6-7.3	>6.0	>60
									9-34	CL,ML	0.6-2.0	6.1-7.3		
									34-39	SM,SC,SM-SC	2.0-6.0	6.6-7.8		
									39-60	SM,SM-SC,SW-SM,SP-SM	6.0-20	7.4-8.4		
FLOM SERIES	MN0069		5	36	72	56	47	35	0-15	CL-ML,CL	0.2-2.0	6.1-7.8	1.0-3.0	>60
			5	48	96	75	63	50	0-15	CL	0.2-0.6	6.1-7.8		
									15-20	CL	0.2-0.6	6.6-8.4		
									20-60	CL	0.6-1.0	7.4-8.4		
FLOM SERIES PONDED	MN0388		1						0-15	CL-ML,CL,ML	0.2-2.0	6.1-7.8	+1-2.0	>60
			5	36	72	56	47	35	0-15	CL	0.2-0.6	6.1-7.8		
			5	48	96	75	63	50	15-20	CL	0.2-0.6	6.6 3.4		
									20-60	CL	0.6-1.0	7.4-8.4		
FLOYD SERIES	IA0040		4	36	111	87	74	58	0-24	OL,ML,CL	0.6-2.0	6.1-7.3	2.0-4.0	>60
			4	48	136	108	92	73	0-24	MH,OH	0.6-2.0	6.1-7.3		
									24-33	CL	0.6-2.0	6.1-7.3		
									33-41	SM,SM-SC	2.0-6.0	6.6-7.3		
									41-60	CL	0.6-2.0	6.6-8.4		
FLUVAQUENTS GREAT GROUP	MN8001		3	36	98	77	64	50	0-16	OL,ML	0.6-2.0	6.6-7.8	0-3.0	>60
			3	48	127	101	85	67	0-16	ML,SM	0.6-2.0	6.6-7.8		
									16-60	ML,CL,SM,SC	0.6-2.0	6.6-7.8		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEA-BILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BED-ROCK In.
FOLDAHL SERIES	MN0116		2						0-9	SM,SP-SM	6.0-20	6.1-7.8	2.5-4.0	>60
			5	36	146	118	101	81	0-9	SM,ML	2.0-6.0	6.1-7.8		
			5	48	182	147	126	102	9-28	SP-SM,SM	6.0-20	6.6-7.8		
									28-60	CL-ML,CL,SM-SC,SC	0.2-2.0	7.4-8.4		
FORADA SERIES	MN0070		5	36	351	280	239	189	0-16	ML	0.6-2.0	6.1-7.8	1.0-3.0	>60
			5	48	430	346	296	238	0-16	SM,SM-SC	2.0-6.0	6.1-7.8		
									16-28	ML,SM	2.0-6.0	6.1-7.8		
									28-60	SP,SM,SP-SM,GP-GM	6.0-20	6.6-8.4		
FORDVILLE SERIES	SD0178		7						0-6	ML,CL	0.6-2.0	6.1-7.3	>6.0	>60
									0-6	CL	0.6-2.0	6.1-7.3		
									6-17	CL,ML	0.6-2.0	6.1-7.8		
									17-24	CL,ML,SM,SC	0.6-6.0	6.1-7.8		
									24-60	SW,SW-SM,SM	6.0-20	7.4-8.4		
FORDVILLE SERIES STONY	SD0414		7						0-6	ML,CL	0.6-2.0	6.1-7.3	>6.0	>60
									6-17	CL,ML	0.6-2.0	6.1-7.8		
									17-24	CL,ML,SM,SC	0.6-6.0	6.1-7.8		
									24-60	SW,SW-SM,SM	6.0-20	7.4-8.4		
FORMAN SERIES	ND0137		7						0-8	CL,CL-ML	0.6-2.0	6.6-7.8	>6.0	>60
									0-8	CL,CL-ML	0.6-2.0	6.6-7.8		
									8-17	CL,CL-ML	0.6-2.0	6.6-7.8		
									17-60	CL,CL-ML	0.06-0.6	7.4-8.4		
FORMAN SERIES STONY	ND0191		7						0-6	CL,ML,CL-ML	0.6-2.0	6.6-7.3	>6.0	>60
									0-6	CL,CL-ML	0.6-2.0	6.6-7.3		
									6-16	CL,CL-ML	0.6-2.0	6.6-7.8		
									16-60	CL,CL-ML	0.06-0.6	7.9-8.4		
FORMDALE SERIES	MN0003		7						0-9	CL	0.6-2.0	6.6-7.3	>6.0	>60
									9-16	CL	0.2-0.6	6.6-7.8		
									16-60	CL	0.2-0.6	7.4-8.4		
FOSSUM SERIES	MN0102		5	36	366	293	250	199	0-13	SM,SC,SM-SC	2.0-6.0	7.4-8.4	1.0-2.5	>60
			5	48	448	361	310	249	0-13	SM,SP-SM	6.0-20	7.4-8.4		
									0-13	CL-ML,CL	2.0-6.0	7.4-8.4		
									13-21	SM,SP-SM	6.0-20	7.4-8.4		
									21-60	SP-SM,SM	6.0-20	7.4-8.4		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	HORIZ DEPTH In.	SOIL CHARACTERISTICS: UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
FOSSUM	MN0424		5	36	366	293	250	199	0-13	SM,SC,SM-SC	2.0-6.0	7.4-8.4	+1-1.0	>60
SERIES			5	48	448	361	310	249	0-13	SM,SP-SM	6.0-20	7.4-8.4		
PONDED									0-13	CL-ML,CL	2.0-6.0	7.4-8.4		
									13-21	SM,SP-SM	6.0-20	7.4-8.4		
									21-60	SP-SM,SM	6.0-20	7.4-8.4		
FOSSUM	MN0145		1						0-13	SM	2.0-6.0	7.4-8.4	+1-1.0	>60
SERIES			5	36	365	292	249	198	0-13	CL-ML,CL	2.0-6.0	7.4-8.4		
SALINE			5	48	447	360	309	248	13-21	SM,SP-SM	6.0-20	7.4-8.4		
									21-60	SM,SP-SM	6.0-20	7.4-8.4		
FOSTORIA	IA0197		5	36	98	77	64	50	0-29	CL,CL-ML	0.6-2.0	6.1-7.3	2.0-4.0	>60
SERIES			5	48	127	101	85	67	29-60	CL	0.6-2.0	7.4-8.4		
FOXHOME	MN0133		5	36	140	112	95	76	0-11	SM	2.0-6.0	6.6-7.3	2.5-6.0	>60
SERIES			5	48	174	141	120	97	0-11	ML	0.6-2.0	6.6-7.3		
									11-14	SM,SP-SM	2.0-20	6.6-7.3		
									14-24	SP,SP-SM,GP,GP-GM	6.0-20	7.4-7.8		
									24-60	ML,CL,CL-ML	0.6-2.0	7.4-8.4		
FRAM	ND0017								0-18	SM,ML	2.0-6.0	7.4-8.4	2.0-6.0	>60
SERIES									0-18	ML	0.6-2.0	7.4-8.4		
			5	36	104	82	69	54	0-18	CL-ML,CL	0.6-2.0	7.4-8.4		
			5	48	134	106	90	71	18-60	SM,ML	0.6-2.0	7.4-8.4		
FRAM	ND0199								0-18	SM,ML	2.0-6.0	7.4-8.4	2.0-4.0	>60
SERIES									0-18	ML	0.6-2.0	7.4-8.4		
SALINE			5	36	104	82	69	54	0-18	CL-ML,CL	0.6-2.0	7.4-8.4		
			5	48	134	106	90	71	18-60	SM,ML	0.6-2.0	7.4-8.4		
FRANKVILLE	IA0109		7						0-6	CL,CL-ML	0.6-2.0	6.6-7.3	>6.0	20-40
SERIES									6-23	CL	0.6-2.0	5.6-6.5		
									23-28	CH	0.06-0.2	6.1-7.3		
									28		-	-		
FREEON	WI0030		2						0-18	ML,CL,CL-ML	0.6-2.0	4.5-7.3	2.0-3.0	>60
SERIES			5	36	60	47	40	32	18-22	ML,CL,CL-ML	0.6-2.0	4.5-6.5		
			5	48	78	62	53	42	22-35	SM,SC,ML,CL	0.2-2.0	4.5-6.5		
									35-60	SM,SC,ML,CL	0.2-0.6	5.1-7.8		
FREEON	WI0148		7						0-18	ML,CL,CL-ML	0.6-2.0	5.6-6.0	3.0-5.0	>60
SERIES									18-50	CL	0.6-2.0	4.5-5.5		
HEAVY SUBSTRATUM									50-60	CL	0.2-0.6	5.6-6.0		

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FREEON SERIES STONY	WI0452	STONY	2						0-18	ML,CL,CL-ML	0.6-2.0	4.5-6.5	2.0-3.0	>60
			5	36	60	47	40	32	18-22	ML,CL,CL-ML	0.6-2.0	4.5-6.5		
			5	48	78	62	53	42	22-35	SM,SC,ML,CL	0.2-2.0	4.5-6.5		
									35-60	SM,SC,ML,CL	0.2-0.6	5.1-7.8		
FREER SERIES	MN0178		5	36	55	43	36	29	0-13	ML,CL-ML,CL	0.6-2.0	5.1-5.5	1.0-3.0	>60
			5	48	73	58	49	38	13-24	CL,ML,CL-ML	0.6-2.0	5.1-5.5		
									24-32	SM-SC,CL,SC,CL-ML	0.2-0.6	6.6-7.3		
									32-60	SM	0.2-0.6	6.6-7.3		
FRONTENAC SERIES	MN0219		7						0-12	ML,CL	0.6-2.0	5.6-7.3	>6.0	>50
									12-30	ML	0.6-2.0	5.6-7.3		
									30-60	SM,GM	2.0-6.0	6.6-7.8		
FULDA SERIES	MN0187		5	36	46	34	28	22	0-13	OH,CH,CL,MH	0.06-0.6	6.6-7.3	0-1.0	>60
			5	48	63	49	41	32	13-33	CH,CL	0.06-0.6	7.4-8.4		
									33-60	CH,CL,MH,ML	0.2-0.6	7.9-8.4		
GALCHUTT SERIES	ND0016		5	36	49	39	34	27	0-16	ML,CL,CL-ML	0.6-2.0	6.1-7.3	1.0-3.0	>60
			5	48	62	50	43	34	0-16	CL	0.6-2.0	6.1-7.3		
									0-16	SM,ML	2.0-6.0	6.1-7.3		
									16-25	ML.CL,CL-ML	0.6-2.0	6.6-7.3		
									25-60	CH	0.06-0.2	6.6-7.8		
GALE SERIES	WI0234		7						0-8	CL-ML,CL	0.6-2.0	4.5-7.3	>6.0	20-40
									8-25	CL	0.6-2.0	4.5-6.5		
									25-29	CL	0.6-2.0	4.5-6.5		
									29-36	SM,SP-SM,SM-SC	6.0-20	4.5-6.5		
									36-60		-	-		
GALE SERIES SEVERELY ERODED	WI0174		7						0-6	CL	0.6-2.0	4.5-7.3	>6.0	20-40
									6-15	CL	0.6-2.0	4.5-6.5		
									15-19	CL	0.6-2.0	4.5-6.5		
									19-26	SM,SP-SM,SM-SC	6.0-20	4.5-6.5		
									26-60		-	-		
GALE SERIES STONY	WI8070		7						0-8	CL-ML,CL	0.6-2.0	4.5-7.3	>6.0	24-40
									8-25	CL	0.6-2.0	4.5-6.5		
									25-29	CL	0.6-2.0	4.5-6.5		
									29-36	SM,SP-SM,SM-SC	6.0-20	4.5-6.5		
									36-60		-	-		

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GALVA SERIES	IA0163		7						0-11	ML,CL,MH,CH	0.6-2.0	5.6-7.3	>6.0	>60
									11-31	CL	0.6-2.0	6.1-7.3		
									31-60	CL	0.6-2.0	6.6-8.4		
									60-65	CL	0.6-2.0	7.4-8.4		
GALVA SERIES GRAVELLY SUBSTRATUM	IA0223		7						0-11	CL	0.6-2.0	5.6-7.3	>6.0	>60
									11-36	CL	0.6-2.0	6.1-7.3		
									36-50	CL	0.6-2.0	6.6-8.4		
									50-60	SP-SM,SM	>20	7.4-8.4		
GARNES SERIES	MN0117	STONY AREAS	2						0-6	ML,CL-ML	0.6-2.0	6.1-7.8	2.5-6.0	>60
			5	36	98	77	64	50	0-6	SM	2.0-6.0	6.1-7.8		
			5	48	127	101	85	67	0-6	ML,CL-ML	0.6-2.0	6.1-7.8		
									6-10	CL,SC	0.6-2.0	6.6-7.8		
									10-60	SM,ML,CL,SC	0.6-2.0	7.4-8.4		
GARWIN SERIES	IA0037		5	36	98	77	64	50	0-18	CL,CH	0.6-2.0	5.6-7.3	1.0-2.0	>60
			5	48	127	101	85	67	18-42	CH,CL	0.6-2.0	6.1-7.3		
									42-75	CL	0.6-2.0	6.6-7.8		
GARWIN SERIES SANDY SUBSTRATUM	IA0247		5	36	311	246	208	163	0-15	CL,CH	0.2-0.6	5.6-7.3	1.0-3.0	>60
			5	48	398	319	273	217	15-42	CL,CH	0.2-0.6	6.1-7.3		
									42-46	SM-SC,SC	2.0-6.0	6.1-7.3		
									46-80	SP-SM,SM,SM-SC	6.0-20	6.6-7.3		
GENESEE SERIES GRAVELLY SUBSTRATUM	IN0300		7						0-8	CL,CL-ML	0.6-2.0	6.6-7.8	3.0-6.0	>60
									0-8	SM-SC,SC,CL-ML,CL	0.6-2.0	6.6-7.8		
									8-46	CL,CL-ML	0.6-2.0	6.6-8.4		
									46-55	ML,CL,CL-ML	0.6-2.0	6.6-8.4		
									55-60	GP,GP-GM,SP,SP-SM	>20	7.4-8.4		
GENESEE SERIES MAAT<50	IN0115		7						0-8	ML,CL	0.6-2.0	6.1-7.8	>6.0	>60
									0-8	SM,SM-SC,ML,CL-ML	0.6-2.0	6.1-7.8		
									8-32	ML,CL	0.6-2.0	6.1-8.4		
									32-60	ML,CL,CL-ML	0.6-2.0	7.4-8.4		
GENESEE SERIES SANDY SUBSTRATUM	IN0180		7						0-9	ML,CL	0.6-2.0	6.1-7.8	>5.0	>60
									0-9	SM,SM-SC	0.6-2.0	6.1-7.8		
									9-40	ML,CL	0.6-2.0	6.1-8.4		
									40-49	ML,CL-ML,CL	0.6-2.0	7.4-8.4		
									49-60	SM,SP-SM	6.0-20	7.4-8.4		

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GERMANTOWN SERIES	MN0303		7						0-8	CL	0.6-2.0	5.6-6.5	>6.0	20-40
									8-27	CL	0.2-0.6	5.1-8.4		
									27-36	CL,CL-ML	0.2-0.6	7.4-8.4		
									36		-	-		
GLENCOE SERIES	MN0026		1						0-35	OL,OH,MH,ML	0.2-2.0	6.1-7.8	+1-1.0	>60
			5	36	95	73	61	46	35-48	CL	0.2-2.0	6.6-7.8		
			5	48	124	98	83	65	48-60	CL,ML	0.6-2.0	7.4-7.8		
GLENCOE SERIES PONDED	MN0444		1						0-35	OL,OH,MH,CL	0.2-2.0	6.1-7.8	+3-1.0	>60
			5	36	95	73	61	46	35-48	CL	0.2-2.0	6.6-7.8		
			5	48	124	98	83	65	48-60	CL,ML	0.6-2.0	7.4-7.8		
GLYNDON SERIES	MN0027		2						0-11	ML	0.6-2.0	7.4-9.0	2.5-6.0	>60
			5	36	188	149	125	98	0-11	CL	0.6-2.0	7.4-9.0		
			5	48	236	188	160	127	11-28	ML,CL-ML,CL	0.6-6.0	7.4-9.0		
									28-60	ML,SM,SC,CL	2.0-6.0	7.4-9.0		
GLYNDON SERIES SALINE	MN0146		5	36	325	260	221	175	0-11	ML	0.6-2.0	7.4-9.0	2.5-6.0	>60
			5	48	399	322	275	220	11-24	ML,CL-ML,CL	2.0-6.0	7.9-9.0		
									24-60	ML,CL-ML,CL	2.0-20	7.9-8.4		
GLYNDON SERIES SILTY SUBSTRATUM	MN0391		2						0-11	ML	0.6-2.0	7.4-9.0	2.5-6.0	>60
			5	36	120	95	81	64	0-11	CL	0.6-2.0	7.4-9.0		
			5	48	149	119	101	81	11-28	ML,CL-ML,CL	0.6-6.0	7.9-9.0		
									28-40	ML,CL,CL-ML	0.6-6.0	7.4-8.4		
									40-60	CL-ML,CL	0.6-2.0	7.4-8.4		
GONVICK SERIES	MN0137		5	36	98	77	64	50	0-10	ML,CL,CL-ML	0.6-2.0	6.1-7.3	2.5-6.0	>60
			5	48	127	101	85	67	10-29	CL-ML,CL,SC,SM-SC	0.6-2.0	6.6-7.3		
									29-60	CL-ML,CL,SC,SM-SC	0.6-2.0	7.4-8.4		
GOODLAND SERIES	MN0337		7						0-12	ML,CL-ML	0.6-2.0	5.1-6.5	>6.0	>60
									0-12	ML,CL-ML	0.6-2.0	5.1-6.5		
									12-28	SM,SC,CL,ML	0.6-2.0	5.1-6.5		
									28-34	SM,SP-SM,SM-SC	2.0-6.0	5.1-6.5		
									34-60	SP,SW,SP-SM	6.0-20	5.6-7.8		
GOTHAM SERIES	WI0056		7						0-9	SM	2.0-6.0	5.6-7.3	>6.0	>60
									0-9	SM,SM-SC	0.6-2.0	5.6-7.3		
									9-20	SM	6.0-20	5.1-7.3		
									20-38	SM	6.0-20	5.1-7.3		
									38-60	SM,SP-SM,SP	6.0-20	5.1-7.3		

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GOTHAM	W10450		7						0-8	SM	6.0-20	6.1-6.5	>6.0	40-60
SERIES									8-28	SM	6.0-20	6.1-6.5		
BEDROCK SUBSTRATUM									28-40	SM,SP-SM	6.0-20	6.1-6.5		
									40-60		-	-		
GOTHAM	W10189		7						0-8	SM	2.0-6.0	5.6-7.3	>6.0	>60
SERIES									0-8	SM,SM-SC	2.0-6.0	5.6-7.3		
LOAMY SUBSTRATUM									8-25	SM	6.0-20	5.6-7.3		
									25-42	SM,SP-SM	6.0-20	5.6-7.3		
									42-60	CL-ML,ML,SM-SC,SM	0.6-2.0	5.6-7.3		
GRANBY	W18077		1						0-8	SM,SC,ML,CL	2.0-6.0	5.6-7.3	+1-1.0	>60
SERIES			3	36	171	138	119	96	0-8	SM	2.0-6.0	5.6-7.8		
LOAMY SUBSTRATUM			3	48	212	172	148	119	8-17	SM	6.0-20	6.1-8.4		
									17-36	SM,SP-SM	6.0-20	5.6-8.4		
									36-60	CL,CL-ML	0.6-2.0	6.6-8.4		
GRANBY	M10029		1						0-10	SM	6.0-20	5.6-7.3	+1-1.0	>60
SERIES			5	36	366	293	250	199	0-10	SM	2.0-6.0	5.6-7.3		
MAAT<50			5	48	448	361	310	249	0-10	SP-SM,SM	6.0-20	5.6-7.3		
									10-32	SP,SP-SM,SM	6.0-20	5.6-7.8		
									32-60	SP,SP-SM	6.0-20	6.6-8.4		
GRAYCALM	M10180		8						0-3	SM,SP-SM	6.0-20	4.5-6.5	>6.0	>60
SERIES									0-3	SP-SM,SM	6.0-20	4.5-6.5		
									3-22	SP-SM,SM	6.0-20	4.5-6.5		
									22-60	SM,SP-SM	6.0-20	4.5-6.5		
									60-70	SP,SP-SM	6.0-20	5.1-8.4		
GRAYCALM	M10429		8						0-3	SM,SP-SM	6.0-20	4.5-6.5	2.5-4.5	>60
SERIES									0-3	SP-SM,SM	6.0-20	4.5-6.5		
MODERATELY WET									3-22	SP-SM,SM	6.0-20	4.5-6.5		
									22-60	SM,SP-SM	6.0-20	4.5-6.5		
									60-70	SP,SP-SM	6.0-20	5.1-8.4		
GRAYS	IL0148		7						0-11	CL	0.6-2.0	5.6-6.5	4.0-6.0	>60
SERIES									11-24	CL	0.6-2.0	5.6-6.5		
MODERATELY WET									24-60	ML,CL,SM,SC	0.6-6.0	7.4-8.4		
GRAYS	IL0271		7						0-11	CL	0.6-2.0	5.6-6.5	>6.0	>60
SERIES									11-24	CL	0.6-2.0	5.6-6.5		
WELL DRAINED									24-60	ML,CL,SM,SC	0.6-2.0	7.4-8.4		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	HORIZ DEPTH In.	SOIL CHARACTERISTICS: UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
GREENWOOD	MI0394		1						0-6	PT	>6.0	3.6-4.4	+1-1.0	>60
SERIES			5	36	170	134	113	89	0-6	PT	>6.0	3.6-4.4		
LOW PRECIPITATION			5	48	214	171	146	116	6-60	PT	0.6-6.0	3.6-4.4		
GRIMSTAD	MN0083		5	36	152	122	104	84	0-9	SM,SM-SC	2.0-6.0	7.4-8.4	2.5-4.0	>60
SERIES			5	48	189	152	131	105	0-9	ML,CL-ML	0.6-2.0	7.4-8.4		
									0-9	SM	6.0-20	7.4-8.4		
									9-28	SM,SP-SM	6.0-20	7.4-9.0		
									28-60	SC,CL,SM-SC,CL-ML	0.6-2.0	7.4-9.0		
GRIMSTAD	MN0426		5	36	113	92	80	65	0-13	SM,SM-SC	2.0-6.0	7.4-8.4	2.5-4.0	>60
VARIANT			5	48	139	113	98	80	13-23	SM,SM-SC	2.0-6.0	7.9-8.4		
									23-34	SM,SP-SM	6.0-20	7.9-8.4		
									34-60	CH	0.06-0.2	7.9-8.4		
GROGAN	MN0012		7						0-13	ML	2.0-6.0	5.6-7.3	>6.0	>60
SERIES									0-13	SM,ML	2.0-6.0	5.6-7.3		
									13-31	ML	2.0-6.0	6.1-7.8		
									31-60	ML	2.0-6.0	7.4-8.4		
GROGAN	MN0471		7						0-13	ML	2.0-6.0	5.6-7.3	3.0-6.0	>60
SERIES									13-31	ML	2.0-6.0	6.1-7.8		
MODERATELY WET									31-60	ML	2.0-6.0	7.4-8.4		
GROVECITY	MN0445		5	36	190	150	127	100	0-15	SM,SC,SM-SC	2.0-6.0	6.1-7.3	2.5-5.0	>60
SERIES			5	48	238	191	162	129	0-15	CL,ML,CL-ML	2.0-6.0	6.1-7.3		
									15-30	SM,SC,CL,ML	2.0-6.0	6.1-7.8		
									30-60	SM,SC,CL,ML	2.0-6.0	7.4-8.4		
GROWTON	MN0220		5	36	98	77	64	50	0-11	SM,SM-SC	2.0-6.0	5.1-7.3	3.0-5.0	>60
SERIES			5	48	127	101	85	67	11-37	CL,SC,SM-SC,CL-ML	0.6-2.0	5.1-7.3		
									37-60	SM,SM-SC	0.6-2.0	7.4-8.4		
GRYGLA	MN0020		5	36	149	120	103	83	0-11	SM	6.0-20	6.1-7.3	1.0-3.0	>60
SERIES			5	48	185	150	129	104	0-11	SP-SM,SM	6.0-20	6.1-7.3		
									0-11	SM,SM-SC	2.0-6.0	6.1-7.3		
									11-29	SP-SM,SM	6.0-20	6.6-7.3		
									29-60	CL-ML,CL	0.2-2.0	7.4-8.4		
GRYGLA	MN0416		1						0-11	SM	6.0-20	6.1-7.3	+.5-1.0	>60
SERIES			5	36	149	120	103	83	0-11	SP-SM,SM	6.0-20	6.1-7.3		
PONDED			5	48	185	150	129	104	0-11	SM,SM-SC	2.0-6.0	6.1-7.3		
									11-29	SP-SM,SM	6.0-20	6.6-7.3		
									29-60	CL-ML,CL	0.2-2.0	7.4-8.4		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
GRYGLA	MN0487	STONY	5	36	149	120	103	83	0-11	SM	6.0-20	6.1-7.3	1.0-3.0	>60
SERIES			5	48	185	150	129	104	0-11	SP-SM, SM	6.0-20	6.1-7.3		
STONY									0-11	SM, SM-SC	2.0-6.0	6.1-7.3		
									11-29	SP-SM, SM	6.0-20	6.6-7.3		
									29-60	CL-ML, CL	0.2-2.0	7.4-8.4		
GUCKEEN	MN0041		2						0-15	MH, ML, CL, CH	0.2-0.6	5.6-7.3	3.5-5.0	>60
SERIES			5	36	41	32	26	20	15-24	MH, ML, CL, CH	0.06-0.6	5.6-7.3		
			5	48	57	45	38	29	24-60	CL	0.06-0.6	6.6-8.4		
GUCKEEN	MN0313		5	36	41	32	26	20	0-15	ML, CL	0.2-0.6	5.6-7.3	2.0-3.5	>60
SERIES			5	48	57	45	38	29	0-15	MH, CH, ML, CL	0.2-0.6	5.6-7.3		
WET									15-24	MH, ML, CL, CH	0.06-0.6	5.6-7.3		
									24-60	CL	0.06-0.6	6.6-8.4		
HALDER	WI0090		5	36	223	177	149	117	0-10	CL, ML, SM, SC	0.6-2.0	4.5-7.3	1.0-2.5	>60
SERIES			5	48	279	223	190	151	0-10	SM, ML, SM-SC, CL-ML	0.6-2.0	4.5-7.3		
									10-31	CL, SC, SM, ML	0.6-2.0	4.5-6.5		
									31-35	SM, SM-SC, SP-SM, GM	0.6-6.0	4.5-6.5		
									35-60	SP, SM, GP, GM	>6.0	5.6-6.5		
HAMAR	SD0141		5	36	334	267	228	181	0-12	SM, SM-SC	2.0-20	6.6-7.8	0-2.0	>60
SERIES			5	48	410	330	283	227	0-12	SM, SC, ML, CL	2.0-6.0	6.6-7.8		
									12-17	SM, SM-SC	2.0-20	6.6-8.4		
									17-60	SM, SM-SC, SP-SM	2.0-20	7.4-8.4		
HAMAR	SD0422		5	36	159	129	111	90	0-12	SM, SM-SC	2.0-20	6.6-7.8	0-2.0	>60
SERIES			5	48	184	150	129	105	0-12	SM, SC, ML, CL	2.0-6.0	6.6-7.8		
CLAYEY SUBSTRATUM									12-40	SM, SM-SC	2.0-20	6.6-8.4		
									40-60	CL, MH, CH, ML	0.2-0.6	7.4-8.4		
HAMEL	MN0084		5	36	89	69	57	42	0-22	ML, CL	0.6-2.0	5.6-7.3	1.0-3.0	>60
SERIES			5	48	120	94	79	62	0-22	CL, CH	0.2-0.6	5.6-7.3		
									22-41	CH, CL	0.2-0.6	5.6-7.3		
									41-60	CL	0.6-2.0	7.4-7.8		
HAMERLY	ND0033		2						0-8	CL, CL-ML	0.6-2.0	6.6-8.4	2.0-4.0	>60
SERIES			5	36	89	70	58	45	0-8	CL, SC, SM-SC, CL-ML	0.6-2.0	6.6-8.4		
			5	48	116	92	78	61	8-18	CL, CL-ML	0.6-2.0	7.4-8.4		
									18-60	CL, CL-ML	0.2-2.0	7.4-8.4		
HAMERLY	ND0243		2						0-8	CL, CL-ML	0.6-2.0	6.6-8.4	2.5-4.0	>60
SERIES			5	36	98	77	64	50	0-8	CL, SC, SM-SC, CL-ML	0.6-2.0	6.6-8.4		
MODERATE PERMEABILITY			5	48	127	101	85	67	8-18	CL, CL-ML	0.6-2.0	7.4-8.4		
									18-60	CL, CL-ML	0.6-2.0	7.4-8.4		

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HAMERLY	ND0198		2						0-8	CL,CL-ML	0.6-2.0	7.4-8.4	2.0-4.0	>60
SERIES			5	36	89	70	58	45	0-8	CL	0.6-2.0	7.4-8.4		
SALINE			5	48	116	92	78	61	8-18	CL,CL-ML	0.6-2.0	7.4-8.4		
									18-60	CL,CL-ML	0.2-2.0	7.4-8.4		
HAMERLY	ND0310	STONY	5	36	89	70	58	45	0-8	CL,CL-ML	0.6-2.0	6.6-8.4	2.0-4.0	>60
SERIES			5	48	116	92	78	61	8-18	CL,CL-ML	0.6-2.0	7.4-8.4		
STONY									18-60	CL,CL-ML	0.2-2.0	7.4-8.4		
HAMRE	MN0418		1						0-13	PT	0.2-2.0	6.6-7.8	+2-1.0	>60
SERIES			5	36	89	69	58	45	13-18	CL,CL-ML	0.2-2.0	6.6-7.8		
			5	36	89	69	58	45	18-60	CL,CL-ML	0.2-2.0	7.4-8.4		
HAMRE	MN0418		5	48	116	91	77	61	0-13	PT	0.2-2.0	6.6-7.8	+2-1.0	>60
SERIES			5	48	116	91	77	61	13-18	CL,CL-ML	0.2-2.0	6.6-7.8		
									18-60	CL,CL-ML	0.2-2.0	7.4-8.4		
HANGAARD	MN0130		5	36	366	293	250	199	0-9	SM	2.0-20	6.6-7.8	1.0-3.0	>60
SERIES			5	48	448	361	310	249	9-13	SP-SM,SM	6.0-20	6.6-7.8		
									13-60	SP-SM,SP	6.0-20	7.4-8.4		
HANLON	IA0099		7						0-50	SM-SC,SC,SM	2.0-6.0	6.1-7.3	3.0-5.0	>60
SERIES									50-69	SM-SC,SC	2.0-6.0	5.6-7.3		
									69-80	SC,CL,SM-SC,CL-ML	2.0-6.0	5.6-7.8		
HANSKA	MN0028		5	36	353	282	240	191	0-19	ML,CL,CL-ML	2.0-6.0	6.1-7.8	1.0-3.0	>60
SERIES			5	48	432	348	298	239	0-19	SM,SM-SC	2.0-6.0	6.1-7.8		
									19-27	SM,SM-SC,SC	2.0-6.0	6.1-7.3		
									27-38	SP-SM,SM	6.0-20	6.1-7.8		
									38-60	SP-SM	6.0-20	6.6-7.8		
HANSKA	MN0463		1						0-19	ML,CL,CL-ML	2.0-6.0	6.1-7.3	+1-2.5	>60
SERIES			5	36	353	282	240	191	19-27	SM,SC,SM-SC	2.0-6.0	6.1-7.3		
DEPRESSIONAL			5	48	432	348	298	239	27-60	SP-SM	6.0-20	6.6-7.8		
HANSKA	MN0477		5	36	354	283	241	191	0-18	ML,CL,CL-ML	2.0-6.0	6.1-7.8	1.0-3.0	>60
SERIES			5	48	433	349	299	240	18-26	SM,SM-SC,SC	2.0-6.0	6.1-7.3		
GRAVELLY SUBSTRATUM									26-31	SP-SM,SM	6.0-20	6.1-7.8		
									31-60	SP-SM	6.0-20	6.6-7.8		
HANTHO	MN0266		7						0-8	ML	0.6-2.0	6.6-7.8	3.6-5.0	>60
SERIES									0-8	ML,CL-ML	2.0-6.0	6.6-7.8		
									8-24	ML	0.6-2.0	6.6-7.8		
									24-46	ML	0.6-2.0	7.4-8.4		
									46-60	ML,CL,CL-ML	0.6-2.0	7.4-8.4		

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HAPLOBOROLLS GREAT GROUP	MN8002		7						0-8	CL	0.6-2.0	6.6-7.8	>5.0	>60
									0-8	ML,SM,CL,SC	2.0-6.0	6.6-7.8		
									0-8	CH,CL	0.2-0.6	6.6-7.8		
									8-60	CL,CL-ML,SC,SM-SC	0.6-2.0	7.4-8.4		
HARPS SERIES	IA0157		5	36	98	77	64	50	0-16	CL,CH	0.6-2.0	7.9-8.4	1.0-3.0	>60
			5	48	127	101	85	67	16-42	CL,CH	0.6-2.0	7.9-8.4		
									42-60	CL	0.6-2.0	7.4-8.4		
HARPSTER SERIES	IL0147		1						0-18	CL,CH	0.6-2.0	7.4-8.4	+.5-2.0	>60
			5	36	98	77	64	50	18-36	CL,CH	0.6-2.0	7.4-8.4		
			5	48	127	101	85	67	36-41	CL,CH	0.6-2.0	7.4-8.4		
									41-60	CL,CL-ML,SC,SM-SC	0.6-2.0	7.4-8.4		
HARPSTER SERIES NONPONDED	IL0348		5	36	98	77	64	50	0-18	CL,CH	0.6-2.0	7.4-8.4	1.0-2.0	>60
			5	48	127	101	85	67	18-36	CL,CH	0.6-2.0	7.4-8.4		
									36-41	CL,CH	0.6-2.0	7.4-8.4		
									41-60	CL,CL-ML,SC,SM-SC	0.6-2.0	7.4-8.4		
HATTIE SERIES	MN0126		7						0-6	CH	0.06-0.2	7.4-8.4	>6.0	>60
									0-6	CL,CH	0.06-0.2	7.4-8.4		
									6-60	CH	0.06-0.2	7.4-8.4		
HAUG SERIES	MN0021		5	36	100	78	65	51	0-11	PT	0.6-6.0	6.6-7.8	+1-3.0	>60
			5	48	129	102	86	68	11-14	OL,ML,CL,SM	0.6-6.0	6.6-8.4		
									14-60	ML,CL,SM,SC	0.6-2.0	7.4-8.4		
HAVANA SERIES	MN0221		5	36	77	55	44	31	0-12	CL,ML	0.6-2.0	5.6-6.5	1.0-3.0	>60
			5	48	110	86	72	56	12-19	CL	0.2-0.6	5.6-6.5		
									19-50	CL	0.2-0.6	5.1-7.3		
									50-60	CL-ML,CL	0.6-2.0	7.4-8.4		
HAVERHILL SERIES	MN0255	SHALLOW BEDROCK	2						0-13	CH,OH	0.06-0.2	7.4-7.8	0-1.0	20-40
			5	32	14	12	10	8	0-13	CL,CH	0.2-0.6	7.4-7.8		
									0-13	CL,CL-ML	0.6-2.0	7.4-7.8		
									13-32	CL,CH	0.06-0.2	7.4-7.8		
									32		-	-		
HAVRELON VARIANT	ND0214		3	36	98	77	64	50	0-13	ML,CL,CL-ML	0.6-2.0	6.6-8.4	2.0-5.0	>60
			3	48	127	101	85	67	13-60	CL	0.6-2.0	7.4-8.4		

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HAWICK SERIES	MN0354	COSL,SL	7						0-11	SM	2.0-6.0	6.1-7.8	>6.0	>60
		LCOS,LS	8						0-11	SM,SP-SM	6.0-20	6.1-7.8		
									0-11	SP-SM,SM	6.0-20	6.1-7.8		
									11-21	SP-SM,SM	>6.0	6.1-7.8		
									21-60	SP,SP-SM	>20	7.4-8.4		
HAYDEN SERIES	MN0060		7						0-9	ML,CL-ML,CL	0.6-2.0	5.6-7.3	>6.0	>60
									0-9	SM,SM-SC,SC	2.0-6.0	5.6-7.3		
									0-9	CL	0.6-2.0	5.6-7.3		
									9-43	CL	0.6-2.0	5.1-7.3		
									43-60	CL,SC	0.6-2.0	7.4-8.4		
HAYFIELD SERIES	MN0124		5	36	346	277	235	186	0-13	CL-ML,CL	0.6-2.0	5.6-6.5	2.5-5.0	>60
			5	48	425	342	293	234	13-29	CL-ML,CL	0.6-2.0	5.1-6.0		
									29-80	SP,SP-SM	6.0-20	5.6-7.8		
HAYFIELD SERIES LOAMY SUBSTRATUM	MN0430		5	36	224	182	157	127	0-13	CL-ML,CL	0.6-2.0	5.6-6.5	2.5-5.0	>60
			5	48	250	203	175	142	13-29	CL-ML,CL	0.6-2.0	5.1-6.0		
									29-58	SP,SP-SM	6.0-20	5.6-7.8		
									58-70	CL	0.6-2.0	5.6-7.8		
HECLA SERIES	SD0134		2						0-6	SM,SM-SC	2.0-20	6.1-7.8	3.0-6.0	>60
			5	36	256	206	176	142	0-6	SM,SM-SC	2.0-6.0	6.1-7.8		
			5	48	302	244	209	169	6-30	SM,SM-SC	2.0-20	6.1-7.8		
									30-54	SM,SM-SC,SP-SM	2.0-20	6.1-7.8		
									54-60	SM,SM-SC	2.0-6.0	6.6-8.4		
HEGNE SERIES	MN0053		5	36	26	20	16	12	0-9	CH	0.06-0.2	7.4-8.4	1.0-2.5	>50
			5	48	39	30	25	19	0-9	CL	0.2-0.6	7.4-8.4		
									9-26	CH	0.06-0.2	7.4-8.4		
									26-38	CH	0.06-0.2	7.4-8.4		
									38-60	CH	<0.2	7.4-8.4		
HEGNE SERIES PONDED	MN0311		1						0-7	OH,CH	0.06-0.2	7.4-8.4	+2-1.0	>60
			5	36	18	15	13	10	7-43	CH	0.06-0.2	7.4-8.4		
			5	43	19	15	13	11	43-60	CH	<0.06	7.4-8.4		
HEGNE SERIES SALINE	MN0312		5	36	18	15	13	10	0-7	OH,CH	0.06-0.2	7.4-9.0	+1-2.5	>60
			5	43	19	15	13	11	7-43	CH	0.06-0.2	7.4-9.0		
									43-60	CH	<0.06	7.4-9.0		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BED-ROCK In.
HERMANTOWN SERIES	MN0491		5	36	58	45	38	30	0-10	ML,CL-ML	0.6-2.0	4.5-6.0	1.0-2.0	>60
			5	48	75	60	51	40	0-10	SM,SM-SC	0.6-2.0	4.5-6.0		
									10-15	SM,SM-SC,ML,CL-ML	0.6-2.0	4.5-6.0		
									15-28	SM-SC,SC	0.6-2.0	5.1-6.0		
									28-45	SM,SM-SC	0.2-0.6	5.1-6.5		
									45-60	SM,SM-SC	0.2-0.6	6.1-7.3		
HEYDER SERIES	MN0222		7						0-22	SM	0.6-2.0	6.1-7.3	>6.0	>60
									0-22	SM	2.0-6.0	6.1-7.3		
									22-53	SM,SC,SM-SC	0.6-2.0	5.6-6.5		
									53-60	SM,SM-SC	0.6-2.0	6.6-7.8		
HIBBING SERIES	MN0161		7						0-8	ML	0.6-2.0	3.6-6.0	>6.0	>60
									0-8	SM	2.0-6.0	3.6-6.0		
									0-8	CL	0.6-2.0	3.6-6.0		
									8-34	CL,CH	0.06-0.2	5.1-7.8		
									34-60	CL,CH	0.06-0.2	7.4-8.4		
HIDEWOOD SERIES	MN0013		5	36	89	70	58	45	0-17	CL,ML	0.6-2.0	6.1-7.8	1.0-3.0	>60
			5	48	116	92	78	61	17-37	CL ML	0.2-2.0	6.6-8.4		
									37-60	CL,ML	0.2-2.0	7.4-8.4		
HILAIRE SERIES	MN0401		5	36	139	113	98	80	0-10	SM,ML,SM-SC,CL-ML	6.0-20	6.6-7.3	2.5-6.0	>60
			5	48	170	139	120	98	0-10	SM,ML,SC,CL	2.0-6.0	6.6-7.3		
									10-15	SM,SP-SM	6.0-20	6.6-7.8		
									15-34	SM,SP-SM	6.0-20	6.6-7.8		
									34-60	CH,CL	0.06-0.2	7.4-8.4		
HILLET SERIES	MN0267		5	36	345	276	234	186	0-13	ML,CL,CL-ML	0.6-2.0	5.6-6.5	1.0-2.0	>60
			5	48	423	341	292	233	13-30	ML,CL,CL-ML	0.6-2.0	5.6-6.5		
									30-60	SP,SM,SP-SM,GP	6.0-20	6.1-6.5		
HILLET SERIES DEPRESSIONAL	MN0467		1						0-13	ML,CL,CL-ML	0.6-2.0	5.6-6.5	+1-1.0	>60
			5	36	345	276	234	186	13-30	ML,CL,CL-ML	0.6-2.0	5.6-6.5		
			5	48	423	341	292	233	30-60	SP,SM,GP,GM	6.0-20.0	6.1-6.5		
HIWOOD SERIES	MN0004		8						0-5	SP-SM,SM	6.0-20	4.5-6.0	2.0-5.0	>60
									5-37	SP-SM,SM	6.0-20	5.1-6.0		
									37-60	SP-SM,SP	6.0-20	5.6-7.8		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BED-ROCK In.
HIXTON SERIES	WI0235		7						0-12	CL, CL-ML	0.6-2.0	5.1-6.5	>6.0	20-40
									0-12	SM, SM-SC, ML, CL-ML	0.6-2.0	5.1-6.5		
									9-12	SM	2.0-6.0	5.1-6.5		
									12-25	CL, SC	0.6-2.0	5.1-6.5		
									25-35	SM, SP-SM, SP	6.0-20	5.1-6.5		
									35-60		-	-		
HIXTON SERIES LOAMY SUBSTRATUM	WI0426		7						0-12	SM, SM-SC, ML, CL-ML	0.6-2.0	6.1-7.3	>6.0	>60
									0-12	ML, CL, CL-ML	0.6-2.0	6.1-7.3		
									12-30	CL	0.6-2.0	5.6-6.5		
									30-40	SM, SP-SM, SP	6.0-20	5.6-6.0		
									40-60	SC, SM-SC, CL, CL-ML	0.6-2.0	5.6-7.3		
HIXTON SERIES STONY	WI8019		7						0-14	CL, CL-ML	0.6-2.0	5.1-6.5	>5.0	20-40
									14-25	CL, SC, CL-ML, SM-SC	0.6-2.0	5.1-6.5		
									25-35	SM, SP-SM, SP	6.0-20	5.1-6.5		
									35-60		-	-		
HOLDINGFORD SERIES	MN0042		7						0-12	SM	0.6-2.0	5.1-7.3	>6.0	>60
									12-37	SM, SC, ML, CL	0.6-2.0	5.1-7.3		
									37-60	SM, ML, CL-ML, SM-SC	0.6-2.0	7.4-8.4		
HOOPESTON SERIES	IL0080		5	36	348	278	237	188	0-18	SM	2.0-6.0	5.1-6.5	1.0-3.0	>60
			5	48	427	344	294	236	18-32	SM, SC, SM-SC	2.0-6.0	5.1-7.8		
									32-60	SP-SM, SM, SC, SM-SC	6.0-20	4.5-8.4		
HOUGHTON SERIES	MI0024		1						0-66	PT	0.2-6.0	4.5-7.8	+1-1.0	>60
			5	36	164	130	109	86						
			5	48	207	165	141	112						
HOUGHTON SERIES PONDED	MI0291		1						0-60	PT	0.2-6.0	6.6-7.3	+2-0.5	>60
			5	36	164	130	109	86						
			5	48	207	165	141	112						
HUBBARD SERIES	MN0162	SL	7						0-14	SM, ML, CL-ML, SM-SC	2.0-6.0	5.1-7.3	>6.0	>60
		LS, LCOS	8						0-14	SP-SM	6.0-20	5.1-7.3		
									0-14	SM, SP-SM	6.0-20	5.1-7.3		
									14-40	SP-SM, SW-SM	6.0-20	5.1-7.3		
									40-60	SP, SW	6.0-20	6.1-7.3		
HUBBARD SERIES LOAMY SUBSTRATUM	MN0172		7						0-17	SM	6.0-20	5.1-6.5	>6.0	>60
									17-46	SM, SP-SM	6.0-20	5.1-6.5		
									46-60	ML, CL, SM, SC	0.2-2.0	5.6-6.5		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
HUNTERSVILLE SERIES	MN0493		2						0-12	SM,SP-SM	6.0-20	5.1-7.3	2.5-5.0	>60
			5	36	106	86	74	61	0-12	ML,SM,SC,CL	2.0-6.0	5.1-7.3		
			5	48	130	106	91	74	0-12	SM,SP-SM	6.0-20	5.1-7.3		
									12-24	SM,SP-SM	6.0-20	5.1-6.5		
									24-40	SM,SM-SC,SC	0.2-0.6	5.1-7.3		
									40-72	SM,SM-SC,SC	0.06-0.2	6.6-7.8		
HUNTSVILLE SERIES	IL0054		7						0-27	CL	0.6-2.0	5.6-7.8	>6.0	>60
									27-52	CL	0.6-2.0	5.6-7.8		
									52-60	CL-ML,CL,SM-SC,SC	0.6-2.0	5.6-7.8		
HUNTSVILLE SERIES MODERATELY WET	IL0309		7						0-36	CL	0.6-2.0	6.1-7.3	4.0-6.0	>60
									36-60	CL,ML,SM,SC	0.6-2.0	6.1-7.8		
IHLEN SERIES	MN0223		7						0-8	CL,ML	0.6-2.0	6.1-7.3	>6.0	20-40
									8-24	CL	0.6-2.0	6.1-7.3		
									24-31	ML,CL	0.6-2.0	6.6-8.4		
									31		-	-		
IHLEN VARIANT	MN0480		7						0-14	ML,CL	0.6-2.0	6.1-7.3	>5.0	10-20
									14		-	-		
INDUS SERIES	MN0268		5	36	22	17	14	11	0-5	CH,CL	0.06-0.6	5.1-7.3	0.5-3.0	>60
			5	48	32	25	21	16	0-5	CL,CH	0.2-0.6	5.1-7.3		
									0-5	CL	0.6-2.0	5.1-7.3		
									5-23	CH	0.06-0.2	5.6-8.4		
									23-60	CH	0.06-0.2	7.4-8.4		
INSULA SERIES	MN0195	SHALLOW BEDROCK	6						0-15	SM,GM	2.0-6.0	4.5-6.5	>6.0	8-20
									15		-	-		
ISAN SERIES	MN0269		1						0-10	SM-SC,SM	6.0-20	5.6-6.5	+.5-2.0	>60
			5	36	366	293	250	199	0-10	SM	6.0-20	5.6-6.5		
			5	48	448	361	310	249	10-20	SM,SP-SM	6.0-20	5.1-6.5		
									20-60	SM,SP	6.0-20	5.6-7.3		
ISANTI SERIES	MN0196		5	36	366	293	250	199	0-10	SM	6.0-20	5.1-6.5	0-2.0	>60
			5	48	448	361	310	249	0-10	SM,SP-SM	6.0-20	5.1-6.5		
									0-10	SM,SP-SM	6.0-20	5.1-6.5		
									10-31	SM,SP-SM	6.0-20	5.1-6.5		
									31-60	SM,SP-SM	6.0-20	5.6-6.5		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
ISANTI VARIANT	MN0448		5	36	217	171	144	113	0-9	SM	0.6-6.0	6.1-7.3	+1-3.0	>60
			5	48	281	225	192	152	9-18	SM	0.6-6.0	6.1-7.3		
									18-32	SP-SM, SM	>6.0	6.1-7.3		
									32-47	ML, SM	0.6-2.0	6.1-7.3		
									47-60	SP-SM, SM	>6.0	6.6-7.3		
ITASCA SERIES	MN0338		7						0-9	ML, CL-ML	0.6-2.0	5.1-6.5	>6.0	>60
									0-9	ML, CL-ML	0.6-2.0	5.1-6.5		
									9-19	ML, CL-ML, SM, SM-SC	0.6-2.0	5.1-6.0		
									19-43	SM, SC, CL, ML	0.6-2.0	5.6-7.3		
									43-60	SM, SC, CL, ML	0.6-2.0	6.6-8.4		
JADIS SERIES	MN0327		2						0-9	ML, CL, CL-ML	0.6-2.0	6.1-7.8	2.5-4.0	>60
			5	36	65	53	45	37	0-9	SM, ML, SC, CL	0.6-2.0	6.1-7.8		
			5	48	73	59	51	41	9-14	CL	0.6-2.0	6.1-7.8		
									14-47	ML, CL, CL-ML	0.6-2.0	7.4-8.4		
									47-60	CH, MH	0.06-0.2	7.4-7.8		
JEFFERS SERIES	MN0296		5	36	59	46	39	31	0-16	CL	0.6-2.0	7.4-8.4	1.0-2.0	>60
			5	48	77	61	52	41	16-30	CL	0.6-2.0	7.4-8.4		
									30-60	CL	0.2-0.6	7.4-8.4		
JEFFERS VARIANT	MN0297		2						0-16	CL	0.6-2.0	7.4-7.8	1.5-3.0	>60
			5	36	58	46	39	30	16-29	ML, CL, CL-ML	0.6-2.0	7.4-7.8		
			5	48	76	60	51	41	29-60	ML, CL, CL-ML	0.2-0.6	7.4-7.8		
JEWETT SERIES	WI0006		7						0-11	ML, CL, CL-ML	0.6-2.0	5.1-7.3	>6.0	>60
									11-19	CL	0.6-2.0	5.1-6.0		
									19-37	CL, SC, CL-ML, SM-SC	0.6-2.0	5.1-6.0		
									37-60	SM, SM-SC	0.6-2.0	5.1-6.0		
JEWETT SERIES SANDY SUBSTRATUM	WI0150		7						0-12	ML, CL, CL-ML	0.6-2.0	5.1-7.3	>6.0	>60
									12-16	CL, CL-ML	0.6-2.0	5.1-6.0		
									16-23	CL, SC	0.6-2.0	5.1-6.0		
									23-46	SM, SM-SC	0.6-2.0	5.1-6.0		
									46-60	SP, SP-SM	6.0-20	5.1-6.0		
JOLIET SERIES	IL0153	SHALLOW BEDROCK	3	19	18	14	13	10	0-19	CL, OL	0.6-2.0	6.1-8.4	0-1.0	10-20
									0-19	CL, OL	0.6-2.0	6.1-8.4		
									19		-	-		
JOY SERIES	IL0056		5	36	98	77	64	50	0-19	CL, CL-ML	0.6-2.0	5.6-7.3	2.0-4.0	>60
			5	48	127	101	85	67	19-48	CL	0.6-2.0	5.1-6.5		
									48-74	CL, CL-ML	0.6-2.0	6.1-8.4		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
JOY SERIES SANDY SUBSTRATUM	IL0295		5	36	325	259	219	173	0-20	CL,CL-ML	0.6-2.0	5.6-7.3	2.0-4.0	>60
			5	48	407	327	280	223	20-41	CL	0.6-2.0	5.1-6.5		
									41-60	SM,SW-SM,SM-SC	6.0-20	5.6-7.3		
JUDSON SERIES	IA0018		7						0-28	CL,CL-ML	0.6-2.0	5.6-7.3	>6.0	>60
									28-35	CL	0.6-2.0	5.6-7.3		
									35-60	CL,CL-ML	0.6-2.0	6.1-7.8		
KALMARVILLE SERIES	MN0287		3	36	331	264	224	177	0-10	ML,CL,CL-ML	0.6-2.0	6.6-7.8	0-1.0	>60
			3	48	415	334	285	228	0-10	SM	2.0-6.0	6.6-7.8		
									0-10	ML,CL	0.6-2.0	6.6-7.8		
									10-43	ML,SM,SM-SC,CL-ML	2.0-6.0	6.6-7.8		
									43-60	SP,SM,SW,SP-SM	6.0-20	6.6-7.8		
KAMRAR SERIES	IA0180		7						0-5	CL	0.6-2.0	5.6-7.3	>6.0	>60
									0-5	CL,CH	0.2-0.6	5.6-7.3		
									5-35	CL,CH	0.2-0.6	5.6-7.3		
									35-60	CL	0.6-2.0	7.4-8.4		
KANARANZI SERIES	MN0224		7						0-7	ML,CL,CL-ML	0.6-2.0	5.6-7.3	>6.0	>60
									7-20	CL,ML,CL-ML	0.6-2.0	5.6-7.8		
									20-60	SP,SP-SM,GP,GP-GM	6.0-20	7.4-8.4		
KANDOTA SERIES	MN0502		7						0-6	SM,SM-SC	0.6-6.0	5.1-6.5	>5.0	>50
									6-26	SM,SM-SC	0.6-2.0	5.1-6.5		
									26-33	SC	0.2-2.0	5.6-7.3		
									33-60	SM-SC,SC	0.2-0.6	7.4-8.4		
KARLSTAD SERIES	MN0046		5	36	237	188	160	126	0-9	SM,SM-SC,SC	2.0-6.0	6.1-7.3	2.5-6.0	>50
			5	48	294	236	201	161	0-9	SM,SP-SM	6.0-20	6.1-7.3		
									9-16	SM,SM-SC,SC	2.0-6.0	6.1-7.3		
									16-19	SC,SM,SM-SC,SP-SM	2.0-6.0	6.6-7.8		
									19-60	SP,SP-SM	>6.0	7.4-8.4		
KASOTA SERIES	MN0270		7						0-9	ML,CL	0.6-2.0	5.6-7.3	>6.0	>60
									0-9	CL	0.2-0.6	5.6-7.3		
									0-9	SC,SM-SC	2.0-6.0	5.6-7.3		
									9-28	CL,CH	0.06-0.6	5.6-6.5		
									28-40	SM,SP-SM	6.0-20	6.1-7.3		
									40-60	SP,SP-SM	6.0-20	7.4-8.4		
KASSON SERIES	MN0225		2						0-9	CL,CL-ML	0.6-2.0	5.6-6.5	2.0-3.0	>60
			5	36	53	41	35	27	9-20	CL	0.6-2.0	4.5-6.0		
			5	48	70	55	47	37	20-61	CL,ML	0.2-0.6	5.1-7.3		
									61-70	CL,ML	0.2-0.6	7.4-8.4		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
KATO SERIES	MN0213		5	36	340	271	230	182	0-21	CL,ML	0.6-2.0	6.1-7.8	1.0-2.5	>60
			5	48	417	336	287	230	21-31	ML,CL	0.6-2.0	5.1-7.3		
									31-35	SC,SM-SC,CL,CL-ML	0.6-6.0	5.1-7.3		
									35-60	SP,SW,SP-SM,SW-SM	6.0-20	6.1-7.8		
KATO SERIES PONDED	MN0323		1						0-21	CL,ML,OL	0.6-2.0	6.1-7.8	+1-1.0	>60
			3	36	343	274	233	184	21-31	ML,CL	0.6-2.0	5.1-7.3		
			3	48	421	339	290	232	31-35	SC,SM-SC,CL,CL-ML	2.0-20	5.1-7.3		
									35-60	SP,SW,SP-SM,SW-SM	6.0-20	6.1-7.8		
KATO VARIANT DEPRESSIONAL	MN0459		1						0-13	MH,OH,OL,CL	0.6-2.0	7.4-7.8	+1-3.0	>60
			5	36	221	175	148	115	13-20	MH,OH,OL,CL	0.6-2.0	7.4-7.8		
			5	48	276	221	188	149	20-32	CL,ML,MH,CH	0.6-2.0	6.6-7.8		
									32-36	CL	0.6-2.0	6.6-7.8		
									36-60	GP,SM,SP,GM	>6.0	6.6-7.8		
KEEWATIN SERIES	MN0333		5	36	29	22	19	15	0-6	SM,ML	0.6-2.0	4.5-6.5	0.5-1.5	>60
			5	48	38	30	26	20	0-6	ML,CL,CL-ML	0.6-2.0	4.5-6.5		
									6-16	SM,ML	0.2-2.0	4.5-6.5		
									16-60	CL	0.06-0.2	5.1-6.5		
									60-65	CL,SC	0.06-0.2	6.1-8.4		
KEGONSA SERIES	WI0270		7						0-12	CL-ML,CL	0.6-2.0	5.1-7.3	>6.0	>60
									12-29	CL	0.6-2.0	5.1-6.5		
									29-33	CL,SC	0.6-2.0	6.1-7.8		
									33-60	SP,GP,SP-SM,GP-GM	>20	7.4-8.4		
KENNEBEC SERIES	IA0070		7						0-41	CL	0.6-2.0	5.6-7.3	3.0-5.0	>60
									41-60	CL,CL-ML	0.6-2.0	6.1-7.3		
KENNEBEC SERIES RARELY FLOODED	IA0278		7						0-41	CL	0.6-2.0	5.6-7.3	4.0-6.0	>60
									41-60	CL,CL-ML	0.6-2.0	6.1-7.3		
KENNEBEC VARIANT	MN0421		5	36	98	77	64	50	0-37	CL	0.6-2.0	5.6-7.3	+1-2.0	>60
			5	48	127	101	85	67	37-60	CL,CL-ML	0.6-2.0	5.6-7.3		
KENSETT SERIES	IA0093		3	36	58	47	41	34	0-18	CL,ML	0.6-2.0	6.1-7.3	2.0-4.0	24-40
									18-28	CL	0.6-2.0	6.1-6.5		
									28-36	SM-SC,SC	2.0-6.0	6.1-6.5		
									36		-	-		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	HORIZ DEPTH In.	SOIL CHARACTERISTICS UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BED-ROCK In.
KENSETT	MN0483		5	36	184	145	122	96	0-13	OL,CL,ML	0.6-2.0	6.1-7.3	2.0-4.0	>60
VARIANT			5	48	231	184	157	124	13-24	CL	0.6-2.0	6.1-6.5		
									24-60	GM,ML,SM	2.0-6.0	7.4-8.4		
KENYON	IA0048		7						0-14	CL	0.6-2.0	5.6-7.3	>6.0	>60
SERIES									14-54	CL	0.6-2.0	5.1-7.3		
									54-76	CL	0.6-2.0	6.6-8.4		
KERSTON	MI0022		1						0-22	PT	0.2-6.0	5.6-8.4	+1-1.0	>60
SERIES			3	36	310	247	210	166	22-29	SM,ML	0.6-20	5.6-8.4		
			3	48	382	307	263	210	29-34	PT	0.2-6.0	5.6-8.4		
									34-60	SM,ML,SP-SM	0.6-20	5.6-8.4		
KILKENNY	MN0071		7						0-10	ML,MH	0.2-0.6	5.6-6.5	>6.0	>60
SERIES									0-10	ML,OH,MH,OL	0.6-2.0	5.6-6.5		
									10-48	MH,CH	0.2-0.6	4.5-6.5		
									48-60	CL,ML	0.2-2.0	5.6-7.8		
KINGSLEY	MN0244		7						0-14	SM	0.6-2.0	5.6-6.5	>6.0	>60
SERIES									0-14	ML	0.6-2.0	5.6-6.5		
									14-34	SM,SM-SC,SC	0.2-0.6	5.1-7.3		
									34-60	SM,SM-SC	0.2-0.6	5.6-7.8		
KINGSTON	MN0085		5	36	98	77	64	50	0-16	ML,OL,CL-ML,CL	0.6-2.0	5.6-7.3	2.5-5.0	>60
SERIES			5	48	127	101	85	67	16-25	CL,ML,CL-ML	0.6-2.0	5.6-7.8		
									25-60	CL-ML,CL,ML	0.6-2.0	7.4-8.4		
KITTSON	MN0086		2						0-10	CL,CL-ML	0.6-2.0	6.6-7.8	2.5-6.0	>60
SERIES			5	36	89	70	58	45	0-10	SM,ML,SC,CL	2.0-6.0	6.6-7.8		
			5	48	116	92	78	61	10-17	CL,SC	0.6-2.0	6.6-7.8		
									17-60	CL	0.2-2.0	7.4-8.4		
KITTSON	MN0453		5	36	68	54	46	37	0-10	SM,SM-SC,SC	2.0-6.0	7.4-7.8	1.0-3.0	>60
VARIANT			5	48	87	70	59	47	10-21	SM,SM-SC,SC	2.0-6.0	7.4-7.8		
									21-60	CL	0.2-0.6	7.4-7.8		
KLINGER	IA0064		5	36	78	61	51	40	0-19	CL,ML	0.6-2.0	5.1-7.3	2.0-4.0	>60
SERIES			5	48	101	80	68	53	19-31	CL	0.6-2.0	5.1-6.5		
									31-64	CL	0.6-1.0	5.6-7.8		
KNOKE	IA0256		1						0-8	OH,MH	0.6-2.0	7.4-8.4	+1-1.0	>60
SERIES			5	36	87	68	56	42	0-8	MH,CH	0.2-0.6	7.4-8.4		
			5	48	114	90	76	59	8-18	MH,OH	0.2-0.6	7.4-8.4		
									18-63	MH,CH	0.2-2.0	7.4-8.4		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BED-ROCK In.
KORONIS SERIES	MN0399		7						0-8	CL-ML,CL	2.0-6.0	5.6-7.3	>6.0	>60
									0-8	SM,SC,SM-SC	2.0-6.0	5.6-7.3		
									8-31	SC,CL	0.6-6.0	5.6-7.3		
									31-60	SM-SC,SC	2.0-6.0	7.4-8.4		
KRANZBURG SERIES	SD0161		7						0-9	CL,ML	0.6-2.0	6.1-7.3	>6.0	>60
									0-9	CL,CH	0.6-2.0	6.1-7.3		
									9-25	CL,CH	0.6-2.0	6.6-7.8		
									25-42	CL	0.2-0.6	7.4-9.0		
									42-60	CL	0.2-0.6	7.4-9.0		
KRATKA SERIES	MN0072		5	36	138	111	95	76	0-11	SM	6.0-20.	5.6-7.8	0.5-3.0	>60
			5	48	172	139	119	96	0-11	SM,SM-SC	2.0-6.0	5.6-7.8		
									11-25	SP-SM	6.0-20.	5.6-7.8		
									25-60	SM-SC,SC,CL-ML,CL	0.2-2.0	7.4-8.4		
KRATKA SERIES DEPRESSIONAL	MN0419		1						0-11	SM	6.0-20	7.4-7.8	+1-1.0	>60
			5	36	138	111	95	76	0-11	SM,SM-SC	2.0-6.0	7.4-7.8		
			5	48	172	139	119	96	11-25	SP-SM	6.0-20	7.4-7.8		
									25-60	SM-SC,SC,CL-ML,CL	0.2-2.0	7.9-8.4		
LA FARGE SERIES	WI0099		7						0-8	CL,CL-ML	0.6-2.0	4.5-7.3	>6.0	24-40
									8-25	CL	0.6-2.0	4.5-6.5		
									25-31	CL,SC	0.6-2.0	4.5-6.5		
									31-60		-	-		
LA PRAIRIE SERIES	ND0109		7						0-9	CL-ML,CL	0.6-2.0	6.6-8.4	3.5-6.0	>60
									0-9	CL	0.6-2.0	6.6-8.4		
									9-28	CL-ML,CL	0.6-2.0	6.6-8.4		
									28-60	CL-ML,CL	0.6-2.0	6.6-8.4		
LA PRAIRIE SERIES NONFLOODED	ND0184		7						0-9	CL-ML,CL	0.6-2.0	6.6-8.4	>6.0	>60
									0-9	CL	0.6-2.0	6.6-8.4		
									9-28	CL-ML,CL	0.6-2.0	6.6-8.4		
									28-60	CL-ML,CL	0.6-2.0	6.6-8.4		
LACRESCENT SERIES	MN0379		7						0-17	CL	0.6-2.0	6.6-7.3	>6.0	>40
									0-17	CL	0.6-2.0	6.6-7.3		
									0-17	CL	0.6-2.0	6.6-7.3		
									17-28	SM,SC,ML,CL	0.6-6.0	6.6-7.3		
									28-60	SM,SC,ML,CL	2.0-6.0	7.4-7.8		
LAKEFIELD SERIES	MN0465		5	36	98	77	64	50	0-18	CL-ML,CL	0.6-2.0	7.4-8.4	2.5-5.0	> 60
			5	48	127	101	85	67	18-60	CL-ML,CL	0.6-2.0	7.4-8.4		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
LAMOILLE SERIES	MN0351		7						0-13	CL,CL-ML	0.6-2.0	6.1-7.3	>6.0	>60
									13-27	GC,SC,CL,CH	0.06-0.6	5.1-6.0		
									27-37	GC,SC	0.2-0.6	5.6-7.3		
									37-60	GC,GM	2.0-6.0	7.4-8.4		
LAMONT SERIES	IA0080		7						0-3	SM-SC,SC	2.0-6.0	5.1-7.3	>6.0	>60
									0-3	CL,CL-ML	0.6-2.0	5.1-7.3		
									3-7	SM,SM-SC	2.0-6.0	5.1-7.3		
									7-50	SM-SC,SC	2.0-6.0	5.1-6.0		
									50-60	SM,SP-SM	6.0-20	5.1-6.5		
LAMOURE SERIES	SD0176		3	36	98	77	64	50	0-27	CL,ML	0.6-2.0	7.4-8.4	0-2.0	>60
			3	48	127	101	85	67	0-27	CL,CH,MH,ML	0.6-2.0	7.4-8.4		
									27-34	CL,CH,MH,ML	0.6-2.0	7.4-8.4		
									34-43	CL,ML	0.6-2.0	7.4-8.4		
									43-60	CL,SC	0.6-2.0	7.4-8.4		
LAMOURE SERIES SALINE	SD0419		3	36	98	77	64	50	0-27	CL,ML	0.6-2.0	7.4-8.4	0-2.0	>60
			3	48	127	101	85	67	0-27	CL,CH,ML,MH	0.6-2.0	7.4-8.4		
									27-34	CL,CH,ML,MH	0.6-2.0	7.4-8.4		
									34-43	CL,ML	0.6-2.0	7.4-8.4		
									43-60	CL,SC	0.6-2.0	7.4-8.4		
LANGHEI SERIES	MN0087		7						0-6	CL-ML,CL	0.6-2.0	6.6-8.4	>6.0	>60
									6-60	CL,CL-ML	0.6-2.0	7.4-8.4		
LANGOLA SERIES	MN0271		7						0-14	SM	6.0-20	5.6-7.3	>6.0	>60
									0-14	SM,SP-SM	6.0-20	5.6-7.3		
									14-31	SM,SP-SM	6.0-20	5.6-6.5		
									31-60	SM	0.2-0.6	6.1-7.3		
LASA SERIES	MN0014		7						0-15	SM	2.0-6.0	5.6-6.5	>6.0	>60
									0-15	SM,SP-SM	2.0-6.0	5.6-6.5		
									15-45	SM	2.0-6.0	6.1-7.3		
									45-60	SP	6.0-20	6.1-7.3		
LASA SERIES BEDROCK SUBSTRATUM	MN0108		7						0-22	SM	2.0-6.0	5.6-6.5	>6.0	48-60
									22-48	SM,SP-SM	2.0-6.0	6.1-7.3		
									48-60		-	-		
LAWLER SERIES	IA0051		2						0-21	CL,ML	0.6-2.0	5.6-7.3	2.0-4.0	>60
			5	36	423	339	289	229	21-37	CL,SC	0.6-2.0	5.1-6.5		
			5	48	518	417	358	287	37-60	SW,GP,SP,SW-SM	>20	5.1-7.3		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	HORIZ DEPTH In.	SOIL CHARACTERISTICS: UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
LAWSON SERIES	WI0044		3	36	98	77	64	50	0-30	CL,CL-ML	0.6-2.0	6.1-7.8	1.0-3.0	>60
			3	48	127	101	85	67	30-60	CL	0.6-2.0	6.1-7.8		
LE SUEUR SERIES	MN0088		5	36	98	77	64	50	0-13	CL,ML,CL-ML	0.6-2.0	5.6-7.3	2.0-4.0	>60
			5	48	127	101	85	67	0-13	CL,ML	0.6-2.0	5.6-7.3		
									13-41	CL	0.6-2.0	5.1-6.5		
									41-60	CL-ML,CL	0.6-2.0	7.4-8.4		
LEMOND SERIES	MN0029		5	36	350	280	238	189	0-17	ML,CL,CL-ML	2.0-6.0	7.4-8.4	1.0-3.0	>60
			5	48	429	346	296	237	0-17	SM,SM-SC	2.0-6.0	7.4-8.4		
									17-30	SM,SM-SC	2.0-6.0	7.4-8.4		
									30-60	SP-SM,SP	6.0-20	7.4-8.4		
LEMOND SERIES DEPRESSIONAL	MN0462		1						0-17	ML,SM,CL,SC	2.0-6.0	7.4-7.8	+1-2.5	>60
			5	36	350	280	238	189	17-30	SM,SM-SC	2.0-6.0	7.4-7.8		
			5	48	429	346	296	237	30-60	SP-SM,SP	6.0-20	7.4-8.4		
LEMOND SERIES GRAVELLY SUBSTRATUM	MN0478		5	36	353	282	240	191	0-18	ML,CL,CL-ML	2.0-6.0	7.4-7.8	1.0-3.0	>60
			5	48	432	348	298	239	18-27	SM,SM-SC	2.0-6.0	7.4-7.8		
									27-60	SP-SM,SP	6.0-20	7.4-8.4		
LEMOND SERIES LOAMY SUBSTRATUM	MN0443		5	36	180	145	125	101	0-17	SM,SM-SC	2.0-6.0	7.4-7.8	1.0-3.0	>60
			5	48	200	162	139	112	17-28	SM,SM-SC	2.0-6.0	7.4-7.8		
									28-44	SP,SP-SM	6.0-20	7.4-8.4		
									44-60	CL,CL-ML,SC,SM-SC	0.6-2.0	7.4-8.4		
LENA SERIES	IL0123		1						0-80	PT	0.2-6.0	7.4-8.4	+1-1.0	>60
			5	36	164	130	109	86						
			5	48	207	165	141	112						
LERDAL SERIES	MN0030		2						0-9	CL,ML	0.6-2.0	5.1-6.0	1.0-3.0	>60
			5	36	36	26	21	15	0-9	CL,ML	0.2-2.0	5.1-6.0		
			5	48	56	43	35	27	9-42	MH,CH,CL	0.06-0.2	4.5-6.0		
									42-60	CL	0.2-0.6	6.6-7.8		
LERDAL SERIES SILTY SUBSTRATUM	MN0205		2						0-11	ML,CL	0.2-0.6	5.1-6.5	1.0-3.0	>60
			5	36	36	27	22	16	11-35	CH,CL	0.06-0.2	4.5-6.0		
			5	48	52	40	33	25	35-60	ML,CL,MH,CH	0.06-0.6	6.6-7.8		
LESTER SERIES	MN0061		7						0-9	ML,CL	0.6-2.0	5.6-6.5	>5.0	>60
									0-9	CL	0.6-2.0	5.6-6.5		
									0-9	SM,SM-SC	2.0-6.0	5.6-6.5		
									9-36	CL	0.6-2.0	5.1-6.5		
									36-60	CL,CL-ML	0.6-2.0	6.6-8.4		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEA-BILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BED-ROCK In.
LETRI SERIES	MN0106		4	36	76	59	49	38	0-18	CL	0.6-2.0	6.1-7.8	0.5-2.0	>60
			4	48	99	78	66	52	18-23	CL	0.6-2.0	6.1-7.8		
									23-60	CL,ML	0.6-1.0	6.6-8.4		
LILAH SERIES	IA0054		7						0-6	SM-SC,SC	2.0-6.0	5.1-6.0	>6.0	>60
									6-15	SM,SM-SC,SC	2.0-6.0	4.5-6.0		
									15-39	SW,SW-SM,SP,SP-SM	>20	4.5-6.0		
									39-60	GP,SP,GP-GM,SP-SM	>20	4.5-6.0		
LINDAAS SERIES	ND0005		1						0-15	CL	0.6-2.0	6.6-7.3	+1-2.0	>60
			5	36	71	50	40	28	15-27	CH	0.06-0.2	6.6-7.8		
			5	48	101	79	66	51	27-50	CL	0.2-0.6	7.9-8.4		
									50-60	CL,CL-ML	0.2-2.0	7.9-8.4		
LINDER SERIES	IA0176		5	36	447	358	306	244	0-13	CL,SC	0.6-2.0	5.6-7.8	2.0-4.0	>60
			5	48	544	439	377	303	13-24	SC,SM-SC	2.0-6.0	6.1-7.8		
									24-60	SP,SP-SM	>20	7.4-8.4		
LINDSTROM SERIES	MN0226		7						0-9	ML	0.6-2.0	5.6-7.3	>6.0	>60
									0-9	SM,ML	0.6-2.0	5.6-7.3		
									9-29	ML	0.6-2.0	5.6-7.3		
									29-60	ML,CL	0.6-2.0	5.6-7.3		
									60-70	ML	0.6-2.0	6.6-7.8		
LINO SERIES	MN0251		5	36	366	293	250	199	0-7	SM	6.0-20	5.1-6.0	2.0-4.0	>60
			5	48	448	361	310	249	0-7	SM	2.0-6.0	5.1-6.0		
									0-7	SM,SP-SM	6.0-20	5.1-6.0		
									7-45	SM,SP-SM	6.0-20	5.1-6.0		
									45-60	SM,SP-SM,SP	6.0-20	5.6-6.5		
LINO VARIANT	MN0245		8						0-7	SM	6.0-20	5.1-6.0	4.0-6.0	>60
									7-60	SM,SP-SM	6.0-20	6.1-7.3		
LINVELDT SERIES	MN0405		5	36	135	108	92	74	0-10	SM-SC,SM	2.0-6.0	6.6-7.8	2.5-6.0	>60
			5	48	169	136	117	94	0-10	ML,CL,SM,SC	0.6-2.0	6.6-7.8		
									0-10	SM	6.0-20	6.6-7.8		
									10-19	SM-SC,CL-ML,CL,SC	0.6-6.0	6.6-7.8		
									19-28	SM,SP-SM,SM-SC	6.0-20	7.4-8.4		
									28-60	CL,CL-ML,SC,SM-SC	0.6-2.0	7.4-8.4		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BED-ROCK In.
LISMORE SERIES FLOODED	SD0164		7						0-8	CL	0.6-2.0	6.1-7.3	3.0-6.0	>60
									0-8	ML,CL	0.6-2.0	6.1-7.3		
									8-17	CL	0.6-2.0	6.6-7.8		
									17-24	CL	0.2-0.6	6.6-7.3		
									24-48	CL	0.2-0.6	7.4-8.4		
									48-60	CL	0.2-0.6	7.4-8.4		
LISMORE SERIES NONFLOODED	SD0285		7						0-8	CL	0.6-2.0	6.1-7.3	4.0-6.0	>50
									0-8	ML,CL	0.6-2.0	6.1-7.3		
									8-17	CL	0.6-2.0	6.6-7.8		
									17-24	CL	0.2-0.6	6.6-7.3		
									24-48	CL	0.2-0.6	7.4-8.4		
									48-60	CL	0.2-0.6	7.4-8.4		
LITCHFIELD SERIES	MN0031		5	36	190	150	127	100	0-20	SM	2.0-6.0	6.1-7.3	2.5-5.0	>60
			5	48	238	191	162	129	0-20	SM,SM-SC,SC	2.0-6.0	6.1-7.3		
									20-40	SM	2.0-6.0	5.1-6.5		
									40-60	SM,SP-SM	2.0-6.0	6.1-7.8		
LITTLETON SERIES	IL0059		5	36	98	77	64	50	0-6	CL	0.6-2.0	5.6-7.8	1.0-3.0	>60
			5	48	127	101	85	67	6-32	CL	0.6-2.0	5.6-7.8		
									32-60	CL-ML,CL	0.6-2.0	5.6-7.8		
LOBO SERIES	MN0149		5	36	186	148	125	99	0-38	PT	>6.0	3.6-4.4	0-2.0	>60
			5	48	231	185	158	126	38-60	PT	0.6-6.0	3.6-5.0		
LOHNES SERIES MODERATELY WET	ND0225	SL,COSL LCOS,LS	7						0-16	SM,SM-SC	2.0-20	6.6-7.8	3.0-5.0	>60
			8						0-16	SM,SP-SM	6.0-20	6.6-7.8		
									0-16	SM,SP-SM,SP	6.0-20	6.6-7.8		
									16-60	SM,SP-SM,SP	6.0-20	6.6-8.4		
LOHNES SERIES WELL DRAINED	ND0115	SL,COSL LCOS,LS	7						0-16	SM,SM-SC	2.0-20	6.6-7.8	>6.0	>60
			8						0-16	SM,SP-SM	6.0-20	6.6-7.8		
									0-16	SM,SP-SM,SP	6.0-20	6.6-7.8		
									16-60	SM,SP-SM,SP	6.0-20	6.6-8.4		
LOMAX SERIES	IL0218		7						0-31	CL,CL-ML	2.0-6.0	5.1-6.5	>5.0	>60
									0-31	ML,CL,SM,SC	2.0-6.0	5.1-6.5		
									31-42	SM,SC,CL,ML	2.0-6.0	5.1-6.5		
									42-60	SP-SM,SP,SM	2.0-6.0	5.1-7.3		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEA-BILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BED-ROCK In.
LOWLEIN SERIES	MN0392		7						0-14	SM, SM-SC	2.0-6.0	6.1-7.3	2.5-5.0	>60
									0-14	CL-ML, ML, CL	0.6-2.0	6.1-7.3		
									14-24	SM, SM-SC	2.0-6.0	6.1-7.3		
									24-31	SM, SP-SM	6.0-20	6.1-7.3		
									31-60	CL-ML, CL	0.6-2.0	7.4-8.4		
LOXLEY SERIES	MI0080		1						0-13	PT	0.6-6.0	<4.5	+1-1.0	>60
			5	36	165	130	110	86	0-13	PT	>6.0	<4.5		
			5	48	208	166	141	112	0-13	PT	0.2-6.0	<4.5		
									13-60	PT	0.2-6.0	<4.5		
LUPTON SERIES LOW PRECIPITATION	MI0393		1						0-10	PT	0.2-6.0	5.6-7.8	+1-1.0	>60
			5	36	164	130	109	86	10-65	PT	0.2-6.0	5.6-7.8		
			5	48	207	165	141	112						
LUPTON SERIES PONDED	MI0424		1						0-10	PT	0.2-6.0	5.6-7.8	+2-0.5	>60
			5	36	164	130	109	86	10-65	PT	0.2-6.0	5.6-7.8		
			5	48	207	165	141	112						
LURA SERIES	MN0032		5	36	22	17	14	11	0-10	OH, CH	0.06-0.2	6.1-7.3	+1-1.0	>60
			5	48	42	32	26	19	0-10	CH, OH, CL	0.06-0.2	6.1-7.3		
									10-58	OH, CH	0.06-0.2	6.1-7.3		
									58-72	CL, CH	0.06-0.6	6.6-7.8		
MADDOCK SERIES LOAMY	ND0192		8						0-14	SM	6.0-20	6.6-7.8	>6.0	>60
									14-60	SM, SP-SM	6.0-20	6.6-8.4		
MADDOCK SERIES SANDY	ND0012		8						0-14	SM	6.0-20	6.6-7.8	>6.0	>60
									14-60	SM, SP-SM	6.0-20	6.6-8.4		
MADELIA SERIES	MN0033		5	36	98	77	64	50	0-19	ML	0.6-2.0	6.1-7.3	1.0-2.5	>60
			5	48	127	101	85	67	19-37	CL	0.6-2.0	6.6-7.8		
									37-60	ML, CL	0.6-2.0	7.4-8.4		
									60-70	CL	0.6-2.0	7.4-8.4		
MAHTOMEDI SERIES	MN0246		8						0-8	SM, SM-SC	6.0-20	5.1-6.5	>6.0	>60
									0-8	SP-SM, SM	6.0-20	5.1-6.5		
									8-30	SP-SM, SM	6.0-20	5.1-6.5		
									30-60	SP, SM, SP-SM	6.0-20	5.1-7.8		

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MAHTOMEDI VARIANT	MN0306		7						0-3	SM,SM-SC,SC	2.0-6.0	5.1-6.5	>6.0	40-80
									3-32	SM	6.0-20	5.1-6.0		
									32-42	SP,SP-SM	6.0-20	5.1-6.5		
									42		-	-		
MAHTOWA SERIES	MN0171		5	36	22	17	14	11	0-12	ML	0.6-2.0	5.1-6.5	0-1.0	>60
			5	48	32	25	21	16	12-21	CL,ML,CL-ML	0.06-0.2	6.1-7.3		
									21-60	CL,ML,CL-ML	0.06-0.2	6.6-7.8		
MALACHY SERIES	MN0173		7						0-18	ML	0.6-2.0	7.4-7.8	3.0-5.0	>60
									0-18	SM	2.0-6.0	7.4-7.8		
									18-30	SM,ML,SC,CL	0.6-6.0	7.4-7.8		
									30-60	SM,SP-SM	6.0-20	7.4-7.8		
MARCELLON SERIES	WI0072		2						0-18	CL,CL-ML,SC,SM-SC	0.6-2.0	5.6-7.3	1.0-3.0	>60
			5	36	177	139	117	91	0-18	SM,SM-SC,ML,CL-ML	0.6-2.0	5.6-7.3		
			5	48	223	178	151	120	18-36	CL,SC	0.6-2.0	5.6-7.8		
									36-60	SM,SM-SC,SC	2.0-6.0	7.4-8.4		
MARCUS SERIES	IA0129		5	36	83	63	50	36	0-17	MH,CH	0.2-0.6	6.1-7.8	1.0-3.0	>60
			5	48	114	89	75	58	17-44	CH,MH	0.2-0.6	6.1-8.4		
									44-57	CL	0.6-2.0	7.9-8.4		
									57-62	CL	0.6-2.0	7.9-8.4		
MARCUS VARIANT	MN0479		5	36	47	36	29	23	0-11	ML,CL	0.2-0.6	6.1-7.3	0-2.0	>60
			5	48	64	50	42	33	11-23	CL,CH,MH	0.2-0.6	6.1-7.3		
									23-60	CL,CH,MH	0.2-0.6	7.4-8.4		
MARKEY SERIES	MI0030		1						0-32	PT	0.2-6.0	4.5-7.8	+1-1.0	>60
			5	36	346	277	235	186	32-60	SP,SM,SP-SM	6.0-20	4.5-8.4		
			5	48	425	342	293	234						
MARKEY SERIES LOW PRECIPITATION	MI0387		1						0-32	PT	0.2-6.0	5.6-7.8	+1-1.0	>60
			5	36	346	277	235	186	32-60	SP,SM,SP-SM	6.0-20	5.6-8.4		
			5	48	425	342	293	234						
MARLEAN SERIES	IA0111		7						0-9	CL,CL-ML	0.6-2.0	6.1-7.3	>6.0	>60
									0-9	CL	0.6-2.0	6.1-7.3		
									0-9	SM,SM-SC	2.0-6.0	6.1-7.3		
									9-12	CL	0.6-2.0	6.1-7.3		
									12-60	SM,SC,GM,GC	2.0-6.0	7.4-7.8		
MARNA SERIES	MN0089		5	36	80	61	49	37	0-20	MH,ML	0.06-0.2	6.1-7.3	1.0-2.5	>60
			5	48	106	83	70	54	20-32	CH,MH	0.06-0.2	6.1-7.3		
									32-60	CL	0.2-2.0	6.6-8.4		

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MARQUETTE SERIES	MN0047		7						0-9	SP-SM, SM	6.0-20	5.6-7.3	>6.0	>60
									0-9	SM, SP-SM	6.0-20	5.6-7.3		
									9-14	SM, SC, GM, GC	2.0-6.0	7.4-7.8		
									14-60	SP, SP-SM, GP, GP-GM	>20	7.4-9.0		
MARSHAN SERIES	MN0104		5	36	345	276	234	186	0-14	CL	0.6-2.0	5.6-7.3	1.0-2.5	>60
			5	48	423	341	292	233	0-14	ML, CL	0.6-2.0	5.6-7.3		
									14-23	CL	0.6-2.0	5.6-7.3		
									23-30	CL, CL-ML, SC, SM-SC	0.6-2.0	5.6-7.3		
									30-60	SP, SW, SP-SM	6.0-20	6.1-7.3		
MARSHAN SERIES PONDED	MN0324		1						0-14	CL	0.6-2.0	5.6-7.3	+2-1.0	>60
			5	36	345	276	234	186	0-14	ML, CL	0.6-2.0	5.6-7.3		
			5	48	423	341	292	233	14-23	CL	0.6-2.0	5.6-7.3		
									23-30	CL, CL-ML, SM-SC, SC	0.6-2.0	5.6-7.3		
									30-60	SP, SW, SP-SM	6.0-20	6.1-7.3		
MARTISCO SERIES	NY0106		1						0-13	PT	0.6-6.0	6.1-8.4	+1-0.5	>60
			3	36	28	21	18	14	13-60		0.06-0.2	7.9-8.4		
			3	48	37	29	25	20						
MARYSLAND SERIES	MN0103		5	36	228	181	153	120	0-12	CL	0.6-2.0	7.9-8.4	1.0-2.5	>60
			5	48	284	227	194	154	0-12	SC	0.6-2.0	7.9-8.4		
									12-27	CL, SC	0.6-2.0	7.9-8.4		
									27-60	SP-SM, SM	>6.0	7.9-8.4		
MARYSLAND SERIES PONDED	MN0320		1						0-12	CL	0.6-2.0	7.9-8.4	+1-1.0	>60
			5	36	349	279	237	188	0-12	SC	0.6-2.0	7.9-8.4		
			5	48	427	344	295	236	12-27	CL, SC	0.6-2.0	7.9-8.4		
									27-60	SP-SM, SM	6.0-20	7.9-8.4		
MASSBACH SERIES	IL0181		7						0-11	CL	0.6-2.0	5.6-7.3	3.0-5.0	40-60
									0-11	CL	0.6-2.0	5.6-7.3		
									11-39	CL	0.6-2.0	6.1-7.8		
									39-46	CL, CH	0.06-0.2	6.1-7.8		
									46-60		-	-		
MAVIE SERIES	MN0134		5	36	146	118	101	81	0-7	CL, CL-ML	0.6-2.0	7.4-8.4	0.5-3.0	>60
			5	48	182	147	126	102	0-7	SM	2.0-6.0	7.4-8.4		
									7-14	CL-ML, CL, SM-SC, SC	0.6-2.0	7.9-8.4		
									14-30	SP-SM, SP, GP, GP-GM	6.0-20	7.4-8.4		
									30-60	ML, CL, CL-ML	0.2-2.0	7.4-8.4		

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MAXCREEK SERIES	MN0151		5	36	98	77	64	50	0-21	CL,MH,ML,CH	0.6-2.0	6.1-7.3	1.0-3.0	>60
			5	48	127	101	85	67	21-30	CL	0.6-2.0	6.1-7.3		
									30-41	CL,ML,CL-ML	0.6-2.0	6.6-7.8		
									41-63	CL,ML,CL-ML	0.6-2.0	7.4-7.8		
MAXCREEK SERIES PONDED	MN0365		1						0-21	CL,MH,ML,CH	0.6-2.0	6.1-7.3	+1-2.0	>60
			5	36	98	77	64	50	21-30	CL	0.6-2.0	6.1-7.3		
			5	48	127	101	85	67	30-41	CL,ML,CL-ML	0.6-2.0	6.6-7.8		
									41-63	CL,ML,CL-ML	0.6-2.0	7.4-7.8		
MAXFIELD SERIES	IA0055		4	36	78	61	51	40	0-17	CL,CH	0.6-2.0	6.6-7.3	1.0-2.0	>60
			4	48	102	81	68	54	17-32	CH,CL	0.6-2.0	6.1-7.3		
									32-66	CL	0.6-1.0	6.1-7.8		
MAXFIELD SERIES PONDED	IA0338		1						0-17	CL,CH	0.6-2.0	6.6-7.3	+1-2.0	>60
			5	36	98	77	64	50	17-32	CH,CL	0.6-2.0	6.1-7.3		
			5	48	127	101	85	67	32-66	CL	0.6-2.0	6.1-7.8		
MAYER SERIES NONFLOODED	MN0197		5	36	342	273	232	183	0-18	CL,ML	0.6-2.0	7.4-8.4	1.0-3.0	>60
			5	48	419	337	288	231	18-33	CL,SC,ML,SM	0.6-2.0	7.4-8.4		
									33-60	SP,SW,SP-SM	6.0-20	7.4-8.4		
MAYER SERIES PONDED	MN0314		1						0-18	CL,ML	0.6-2.0	7.4-8.4	+1-1.0	>60
			5	36	342	273	232	183	18-33	CL,SC,ML,SM	0.6-2.0	7.4-8.4		
			5	48	419	337	288	231	33-60	SP,SW,SP-SM	6.0-20	7.4-8.4		
MAZASKA SERIES	MN0272		5	36	76	56	45	33	0-15	CL,CH	0.2-0.6	6.1-7.3	1.0-2.0	>60
			5	48	104	81	68	53	15-42	CH,CL	0.06-0.6	4.5-6.5		
									42-62	CL,SC	0.2-2.0	7.4-7.8		
MCDONALDSVILLE SERIES	ND0145		5	36	343	274	233	184	0-9	CL	0.06-0.2	6.1-7.3	0-3.0	>60
			5	48	421	339	290	232	0-9	CH,CL	0.06-0.2	6.1-7.3		
									9-30	CL,CH	0.06-0.2	6.1-8.4		
									30-60	SM,SW-SM,SP-SM	6.0-20	7.9-8.4		
MCINTOSH SERIES	MN0074		5	36	90	70	59	46	0-13	CL-ML,CL,ML	0.6-2.0	7.4-8.4	3.0-6.0	>60
			5	48	117	93	78	62	13-27	ML,CL,CL-ML	0.6-2.0	7.4-8.4		
									27-60	CL,ML	0.2-2.0	7.4-8.4		
MCINTOSH VARIANT	MN0329		5	36	98	77	64	50	0-13	OL,CL,CL-ML	0.6-2.0	7.4-8.4	2.5-4.0	>60
			5	48	127	101	85	67	13-43	CL-ML,CL	0.6-2.0	7.4-8.4		
									43-60	CL,CL-ML	0.6-2.0	7.4-8.4		

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MCPAUL SERIES	IA0171		7						0-60	CL,CL-ML	0.6-2.0	7.4-8.4	>6.0	>60
MCPAUL SERIES WET	NE8010		3	36	98	77	64	50	0-16	ML,CL,CL-ML	0.6-2.0	7.4-8.4	2.0-6.0	>60
			3	48	127	101	85	67	16-49	ML,CL,CL-ML	0.6-2.0	7.4-8.4		
			7						49-60	ML,CL,CL-ML	0.6-2.0	7.4-8.4		
MEDARY SERIES MODERATELY WET	WI0166		7						0-7	CL,CL-ML	0.6-2.0	5.1-6.5	2.5-6.0	>60
									0-7	CL	0.2-0.6	5.1-6.5		
									7-14	CL,CL-ML	0.2-0.6	4.5-6.0		
									14-30	CL,CH	0.06-0.2	4.5-6.0		
									30-60	CH	0.06-0.2	5.1-7.3		
MEDARY SERIES WELL DRAINED	WI0247		7						0-7	CL,CL-ML	0.6-2.0	5.1-6.5	>6.0	>60
									0-7	CL	0.2-0.6	5.1-6.5		
									7-14	CL,CL-ML	0.2-0.6	4.5-6.0		
									14-30	CL,CH	0.06-0.2	4.5-6.0		
									30-60	CH	0.06-0.2	5.1-7.3		
MEEHAN SERIES	WI0255		5	36	366	293	250	199	0-9	SM	6.0-20	5.1-7.3	1.0-3.0	>60
			5	48	448	361	310	249	0-9	SM,SP-SM	6.0-20	5.1-7.3		
									9-31	SM,SP-SM,SP	6.0-20	5.1-7.3		
									31-60	SP,SP-SM	6.0-20	5.1-7.8		
MEEHAN SERIES LOAMY SUBSTRATUM	WI0306		5	36	201	163	140	113	0-9	SM	6.0-20	6.1-7.3	1.0-3.0	>60
			5	48	230	187	161	130	9-43	SM,SP-SM	6.0-20	5.6-7.3		
									43-60	CL	0.6-2.0	7.4-7.8		
MEEHAN SERIES SANDSTONE SUBSTRATUM	WI8099	SHALLOW BEDROCK	5	29	100	82	71	58	0-7	SM	6.0-20	5.6-6.5	1.0-3.0	20-40
									7-25	SP-SM,SP	6.0-20	5.1-6.0		
									25-29	SP	6.0-20	4.5-5.5		
									29-60		-	-		
MENAHGA SERIES	MN0057		8						0-4	SM,SP-SM	6.0-20	4.5-6.0	>6.0	>60
									0-4	SP,SP-SM	6.0-20	4.5-6.0		
									4-24	SP,SP-SM	6.0-20	4.5-6.0		
									24-60	SP,SP-SM	6.0-20	5.6-7.3		
MERIDIAN SERIES MODERATELY WET	WI0313		7						0-10	ML,CL,CL-ML	0.6-2.0	6.1-7.8	3.0-6.0	>60
									0-10	ML,SM,CL-ML,SM-SC	0.6-2.0	6.1-7.8		
									10-30	CL,SC,SM-SC,CL-ML	0.6-2.0	5.1-6.5		
									30-35	SM,SM-SC,SC	0.6-6.0	5.1-6.5		
									35-60	SM,SP,SP-SM	6.0-20	5.1-6.5		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
MERIDIAN SERIES WELL DRAINED	WI0248		7						0-10	ML,CL,CL-ML	0.6-2.0	6.1-7.8	>6.0	>60
									0-10	ML,SM,CL-ML,SM-SC	0.6-2.0	6.1-7.8		
									10-30	CL,SC,SM-SC,CL-ML	0.6-2.0	5.1-6.5		
									30-35	SM,SM-SC,SC	0.6-6.0	5.1-6.5		
									35-60	SM,SP,SP-SM	6.0-20	5.1-6.5		
MERTON SERIES	MN0198		5	36	98	77	64	50	0-16	CL-ML,CL	0.6-2.0	5.6-7.3	2.0-5.0	>60
			5	48	127	101	85	67	0-16	CL	0.6-2.0	5.6-7.3		
									16-23	CL,CL-ML	0.6-2.0	5.6-7.3		
									23-60	CL,ML,CL-ML	0.6-2.0	5.6-7.8		
MERWIN SERIES	MN0163		1						0-6	PT	>6.0	3.6-5.5	+1-1.0	>60
			5	36	206	161	135	105	6-42	PT	0.06-0.6	3.6-7.3		
			5	48	265	211	180	142	42-60	CL,ML,SM,SC	>6.0	3.6-5.5		
MESABA SERIES	MN0227	SHALLOW BEDROCK	2						0-28	SM,GM	2.0-6.0	4.5-6.5	2.0-3.0	20-40
			5	28	52	43	37	30	28		-	-		
MESABA VARIANT	MN0308		7						0-42	GM,SM	2.0-6.0	4.5-6.5	>6.0	40-60
									42-50	GM,GP-GM,SM,SP-SM	6.0-20	5.6-7.8		
									50		-	-		
MILACA SERIES	MN0273		7						0-10	SM	2.0-6.0	5.1-6.0	>6.0	>60
									0-10	SM	2.0-6.0	5.1-6.0		
									0-10	ML,CL-ML	2.0-6.0	5.1-6.0		
									10-14	SM	2.0-6.0	5.1-6.0		
									14-40	SM	0.2-0.6	5.1-6.5		
									40-60	SM	0.2-0.6	5.6-7.3		
MILACA VARIANT	MN0449		7						0-10	SM,SM-SC,ML,CL-ML	2.0-6.0	5.6-6.5	>6.0	>60
									10-53	CL,SC	0.6-2.0	5.1-7.3		
									53-60	SM,SC,SM-SC	0.2-0.6	6.1-7.3		
MILLERVILLE SERIES	MN0274		1						0-24	PT	2.0-6.0	5.6-7.3	+1-1.5	>60
			5	36	74	59	50	40	24-60	OL	0.2-0.6	5.6-7.8		
			5	48	93	75	64	51						
MILLINGTON SERIES	IL0222		3	36	98	77	64	50	0-15	ML,CL,OL	0.6-2.0	7.4-8.4	0-2.0	>60
			3	48	127	101	85	67	0-15	CL,ML,OL	0.6-2.0	7.4-8.4		
									15-35	CL	0.6-2.0	7.4-8.4		
									35-60	CL,CL-ML	0.6-2.0	7.4-8.4		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	DRAINAGE COEFF. SPACINGS, Ft. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BED-ROCK In.
MILLINGTON SERIES SANDY SUBSTRATUM	IL0349		3	36	411	328	279	221	0-15	CL,ML,OL	0.6-2.0	7.4-8.4	0.5-2.0	>60
			3	48	510	411	352	282	15-41	CL	0.6-2.0	7.4-8.4		
									41-60	SP,SW,SP-SM	>20	7.4-8.4		
MINNEISKA SERIES	MN0288		7						0-10	ML,CL,CL-ML	2.0-6.0	7.4-8.4	3.0-6.0	>60
									0-10	SM	2.0-6.0	7.4-8.4		
									10-60	SM,ML	2.0-6.0	7.4-8.4		
									60-70	SP-SM,SM	6.0-20	7.4-8.4		
MINNEISKA VARIANT	MN0409		7						0-9	SM,SP-SM	6.0-20	7.4-7.8	3.0-6.0	>60
									9-29	SM,SP-SM	2.0-20	7.4-7.8		
									29-60	CL,CL-ML,SC,SM-SC	6.0-20	6.6-7.8		
MINNEOPA SERIES	MN0016		3	36	361	289	247	196	0-15	SM	2.0-6.0	5.6-7.3	3.0-5.0	>60
			3	48	443	357	306	246	0-15	SM,SP-SM	6.0-20	6.1-7.3		
									15-20	SM	2.0-6.0	6.1-7.3		
									20-60	SM,SP-SM	6.0-20	6.1-8.4		
MINNETONKA SERIES	MN0090		5	36	79	60	48	36	0-13	MH,ML	0.2-0.6	5.6-7.3	0-3.0	>60
			5	48	105	82	69	53	13-35	MH,CH,CL,ML	0.06-0.2	5.6-7.3		
									35-60	MH,ML,CL	0.2-2.0	6.6-7.8		
MINNETONKA SERIES SILTY SUBSTRATUM	MN0474		5	36	89	69	57	42	0-16	MH,ML	0.2-0.6	5.6-7.3	1.0-3.0	>60
			5	48	117	92	78	60	16-35	MH,CH	0.06-0.6	5.6-7.3		
									35-60	ML	0.6-2.0	6.6-7.8		
MOLAND SERIES	MN0199		7						0-14	ML,CL	0.6-2.0	5.6-7.3	>6.0	>60
									14-20	ML,CL	0.6-2.0	5.6-6.5		
									20-49	CL,ML,CL-ML	0.6-2.0	5.6-7.3		
									49-60	CL,ML,CL-ML	0.6-2.0	6.6-7.8		
MOODY SERIES	SD0061		7						0-5	CL	0.2-2.0	5.6-7.3	>6.0	>60
									0-5	ML,CL	0.6-2.0	5.6-7.3		
									5-37	CL,CH	0.6-2.0	6.1-7.8		
									37-60	CL,CL-ML,ML	0.6-2.0	6.6-8.4		
MOODY SERIES BEDROCK SUBSTRATUM	SD0357		7						0-5	CL	0.2-2.0	5.6-7.3	>6.0	20-40
									5-37	CL,CH	0.6-2.0	6.1-7.8		
									37-40		-	-		
MOODY SERIES MODERATELY SLOW PERM	SD0343		7						0-5	CL	0.2-0.6	5.6-7.3	>6.0	>60
									0-5	ML,CL	0.6-2.0	5.6-7.3		
									5-37	CL,CH	0.2-0.6	6.1-7.3		
									37-60	CL,CL-ML,ML	0.6-2.0	6.6-8.4		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BED-ROCK In.
MOODY SERIES SANDY SUBSTRATUM	SD0340		7						0-6	CL	0.2-0.6	5.6-7.3	>6.0	>60
									6-20	CL	0.2-0.6	5.6-7.3		
									20-35	ML,CL	0.6-2.0	5.6-7.3		
									35-47	SM	2.0-6.0	6.6-8.4		
									47-60	SP-SM,SM	6.0-20	6.6-8.4		
MOOSELAKE SERIES	MN0167		1						0-6	PT	2.0-6.0	4.5-7.3	+1-1.0	>60
			5	36	190	150	127	100	6-72	PT	2.0-6.0	4.5-7.3		
			5	48	238	191	162	129						
MORA SERIES	MN0249		2						0-12	SM,ML	2.0-6.0	5.1-6.5	2.0-3.0	>60
			5	36	69	55	47	37	0-12	SM,ML	0.6-2.0	5.1-6.5		
			5	48	89	71	60	48	12-24	SM,ML	0.6-6.0	5.1-6.5		
									24-48	SM	0.2-0.6	5.6-6.5		
									48-75	SM	0.2-0.6	6.6-7.8		
MORPH SERIES	MN0340		5	36	98	77	64	50	0-13	ML,CL,CL-ML	0.6-2.0	5.1-6.5	1.0-3.0	>60
			5	48	127	101	85	67	0-13	ML,CL-ML,SM,SM-SC	2.0-6.0	5.1-6.5		
									13-33	ML,CL,SM,SC	0.6-2.0	5.1-7.8		
									33-60	SM,SC,CL,ML	0.6-2.0	6.1-8.4		
MOTTLAND SERIES	IA0182		7						0-11	CL,CL-ML	0.6-2.0	6.6-8.4	>6.0	>60
									11-60	SM,SC,SM-SC	2.0-6.0	7.9-8.4		
MOUNDPRAIRIE SERIES	MN0369		3	36	98	77	64	50	0-10	CL-ML,CL	0.6-2.0	7.4-7.8	1.0-3.0	>60
			3	48	127	101	85	67	0-10	CL	0.6-2.0	7.4-7.8		
									10-40	CL-ML,CL	0.6-2.0	7.4-7.8		
									40-60	CL-ML,CL	0.6-2.0	6.6-7.8		
MOUNDPRAIRIE SERIES PONDED	MN0370		1						0-10	CL-ML,CL	0.6-2.0	7.4-7.8	+1-1.5	>60
			3	36	98	77	64	50	0-10	CL	0.6-2.0	7.4-7.8		
			3	48	127	101	85	67	10-40	CL-ML,CL	0.6-2.0	7.4-7.8		
									40-60	CL-ML,CL	0.6-2.0	6.6-7.8		
MT. CARROLL SERIES	IL0060		7						0-13	CL	0.6-2.0	5.6-7.3	>6.0	>60
									13-46	CL	0.6-2.0	5.1-7.3		
									46-80	CL	0.6-2.0	5.6-8.4		
MT. CARROLL SERIES BENCHES	WI8111		7						0-12	CL	0.6-2.0	6.1-7.3	3.0-5.0	>60
									12-56	CL	0.6-2.0	5.6-7.3		
									56-60	ML,CL-ML,CL	0.2-0.6	5.6-8.4		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
MT. CARROLL SERIES MODERATELY WET	IL0338		7						0-12	CL	0.6-2.0	5.6-7.3	4.0-6.0	>60
									12-53	CL	0.6-2.0	5.1-7.3		
									53-60	CL	0.6-2.0	5.6-8.4		
MUSCATINE SERIES	IA0052		5	36	98	77	64	50	0-16	CL	0.6-2.0	5.1-7.3	2.0-4.0	>50
			5	48	127	101	85	67	0-16	CL,CL-ML	0.6-2.0	5.1-7.3		
									16-42	CL	0.6-2.0	5.1-7.3		
									42-64	CL	0.6-2.0	6.6-7.8		
MUSCATINE SERIES SANDY SUBSTRATUM	IA0246		5	36	292	230	193	150	0-14	CL-ML,CL	0.6-2.0	5.1-7.3	2.0-5.0	>60
			5	48	380	305	260	206	14-47	CL	0.6-2.0	5.1-6.0		
									47-55	SM-SC,SC	2.0-6.0	5.1-7.3		
									55-60	SP-SM,SM,SM-SC	6.0-20	6.1-7.3		
MUSKEGO SERIES	WI0046		1						0-30	PT	0.6-6.0	5.6-7.3	+1-1.0	>60
			3	36	67	54	47	38	30-60	OL	0.06-0.2	6.6-8.4		
			3	48	83	67	58	47						
MUSKEGO SERIES MARSHY	WI0437		1						0-30	PT	0.2-6.0	5.6-7.3	+3-1.0	>60
			5	36	110	87	73	57	30-60	OL,ML	0.6-2.0	6.6-8.4		
			5	48	140	112	95	75	60-70	CL,ML	0.6-2.0	7.4-8.4		
MUSKEGO SERIES OVERWASH	WI0335		1						0-16	MH,CH,CL	0.6-2.0	6.1-7.3	+1-1.0	>60
			5	36	102	83	72	58	16-50	PT	0.2-6.0	5.6-7.3		
			5	48	111	90	78	63	50-70	OH,OL	0.06-0.2	6.6-8.4		
NASHWAUK SERIES	MN0339		7						0-7	SM,ML	0.6-2.0	5.1-6.5	>6.0	>60
									0-7	ML,CL,CL-ML	0.6-2.0	5.1-6.5		
									7-16	ML,SM,CL,SC	0.2-0.6	4.5-6.0		
									16-58	CL,SC	0.06-0.2	5.1-7.3		
									58-72	CL,SC	0.06-0.2	5.6-8.4		
NASSET SERIES	IA0112		7						0-15	CL-ML,CL	0.6-2.0	5.1-7.3	>6.0	40-60
									15-37	CL	0.6-2.0	5.1-6.5		
									37-42	CH	0.06-0.2	6.6-7.3		
									42		-	-		
NEBISH SERIES	MN0138		7						0-9	ML	0.6-2.0	6.1-7.3	>6.0	>60
									0-9	SM	2.0-6.0	6.1-7.3		
									9-33	SC,CL,ML,SM	0.6-2.0	6.1-7.8		
									33-60	SC,CL,ML,SM	0.6-2.0	7.4-8.4		
NEMADJI SERIES	MN0169		5	36	366	293	250	199	0-6	SM,SP-SM	6.0-20	4.5-5.5	1.5-4.0	>60
			5	48	448	361	310	249	0-6	SP-SM,SP	6.0-20	4.5-5.5		
			8						6-60	SP-SM,SP	6.0-20	4.5-6.0		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH in.	SPACINGS, Ft. DRAINAGE COEFF. in./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH in.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY in./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BED-ROCK in.
NERESON SERIES	MN0118		2						0-9	ML,CL,CL-ML	0.6-2.0	6.6-8.4	2.5-6.0	>60
			5	36	170	134	113	89	0-9	SM	2.0-6.0	6.6-8.4		
			5	48	214	171	146	116	9-60	SM,ML,CL,SC	0.6-6.0	7.4-8.4		
NESSEL SERIES	MN0200		2						0-15	ML,CL,CL-ML	0.6-2.0	5.6-7.3	3.0-5.0	>60
									0-15	SM,SM-SC	2.0-6.0	5.6-7.3		
									15-39	CL	0.6-2.0	5.1-7.3		
			5	36	101	79	67	52	39-60	CL,ML,SC,SM	0.6-2.0	7.4-8.4		
			5	48	131	104	88	69						
NEWALBIN SERIES	MN0371		3	36	98	77	64	50	0-3	CL,CL-ML	0.6-2.0	6.1-7.3	1.0-3.0	>60
			3	48	127	101	85	67	3-57	CL,CL-ML	0.6-2.0	6.1-7.3		
									57-84	CL,CL-ML	0.6-2.0	6.1-7.8		
NEWALBIN SERIES MUCK SUBSTRATUM	MN0373		1						0-3	CL,CL-ML	0.6-2.0	6.1-7.3	0-2.5	>60
			3	36	68	54	46	37	3-42	CL,CL-ML	0.6-2.0	6.1-7.3		
			3	48	84	67	57	45	42-60	PT	0.2-0.6	6.1-7.8		
NEWALBIN SERIES PONDED	MN0372		1						0-3	CL,CL-ML	0.6-2.0	6.1-7.3	+1-2.0	>60
			3	36	98	77	64	50	3-57	CL,CL-ML	0.6-2.0	6.1-7.3		
			3	48	127	101	85	67	57-84	CL,CL-ML	0.6-2.0	6.1-7.8		
NEWFOUND SERIES	MN0228		7						0-16	SM,ML,GM	2.0-6.0	4.5-6.0	>6.0	>60
									16-60	SM,ML,GM	0.06-0.2	4.5-6.0		
NEWGLARUS SERIES WELL DRAINED	WI0043		7						0-8	CL	0.6-2.0	6.1-7.3	>6.0	22-40
									0-8	CL	0.2-2.0	6.1-7.3		
									8-23	CL	0.2-2.0	5.6-7.3		
									23-35	CH,MH	0.2-0.6	5.6-7.3		
									35		-	-		
NEWHOUSE SERIES	MN0422		7						0-9	CL-ML,CL	0.6-2.0	5.6-7.3	>6.0	>60
									9-25	CL	0.6-2.0	5.1-7.3		
									25-60	SC,CL,GC	0.6-2.0	5.1-6.0		
NEWRY SERIES	MN0152		5	36	75	58	49	37	0-8	CL,ML	0.6-2.0	5.6-6.5	2.0-5.0	>60
			5	48	98	77	65	51	8-19	CL	0.6-2.0	5.1-6.5		
									19-40	CL,ML	0.6-1.0	5.6-7.3		
									40-66	CL,ML	0.6-1.0	6.6-7.8		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH in.	SPACINGS, Ft. DRAINAGE COEFF. in./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH in.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY in./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK in.
NEWSON SERIES	WI0100		3	36	366	293	250	199	0-6	SM,SP-SM	2.0-6.0	3.6-6.0	+1-1.0	>60
			3	48	448	361	310	249	0-6	SM,SP-SM,SP	6.0-20	3.6-6.0		
									0-6	SM,SM-SC	2.0-6.0	3.6-6.0		
									6-22	SM,SP-SM,SP	6.0-20	3.6-5.5		
									22-60	SM,SP-SM,SP	6.0-20	4.5-6.5		
NEWSON SERIES PONDED	WI0446		1						0-6	SM	2.0-6.0	3.6-6.0	+1-1.0	>60
			5	36	366	293	250	199	0-6	SM,SP-SM,SP	6.0-20	3.6-6.0		
			5	48	448	361	310	249	0-6	SM,SM-SC	2.0-6.0	3.6-6.0		
									6-22	SM,SP-SM,SP	6.0-20	3.6-5.5		
									22-60	SM,SP-SM,SP	6.0-20	4.5-6.5		
NICOLLET SERIES	MN0034		5	36	98	77	64	50	0-17	ML,CL	0.6-2.0	5.6-7.3	2.5-5.0	>60
			5	48	127	101	85	67	17-36	CL	0.6-2.0	5.6-7.8		
									36-60	CL	0.6-2.0	7.4-8.4		
NISHNA SERIES	IA0155		3	36	22	17	14	11	0-36	CH,MH	0.06-0.2	7.4-8.4	1.0-3.0	>60
			3	48	32	25	21	16	36-60	CH	0.06-0.2	7.4-8.4		
NISHNA SERIES PONDED	IA0326		1						0-26	CH,MH	0.06-0.2	7.4-8.4	+1-1.0	>60
			3	36	22	17	14	11	26-60	CH	0.06-0.2	7.4-8.4		
			3	48	32	25	21	16						
NODINE SERIES	MN0375		7						0-7	CL,ML	0.6-2.0	5.6-7.3	>6.0	>60
									7-10	CL,CL-ML	0.6-2.0	5.1-6.5		
									10-60	CL,SC,SM-SC,CL-ML	0.6-2.0	5.1-6.0		
NOKASIPPI SERIES	MN0275		1						0-9	SM	6.0-20	5.1-6.5	+1-2.0	>60
			5	36	142	116	100	81	0-9	SM	2.0-6.0	5.1-6.5		
			5	48	166	135	116	94	9-25	SM,SP-SM	6.0-20	5.1-7.3		
									25-48	SM,SC,ML,CL	0.6-6.0	5.6-7.3		
									48-60	SM,SC,ML,CL	0.2-0.6	5.6-7.3		
NOKAY SERIES	MN0276		5	36	52	41	35	28	0-6	SM	2.0-6.0	4.5-5.5	1.0-3.0	>50
			5	48	66	53	45	36	0-6	ML,CL-ML	0.6-2.0	4.5-5.5		
									6-14	SM,ML	0.6-6.0	4.5-5.5		
									14-31	SM,SM-SC,ML,CL-ML	0.6-2.0	5.1-6.5		
									31-41	SM	0.06-0.2	5.6-7.3		
									41-60	SM	<0.2	5.6-7.3		
NORA SERIES	SD0060		7						0-7	CL,ML	0.6-2.0	6.1-7.3	>6.0	>50
									0-7	CL	0.6-2.0	6.1-7.3		
									7-20	CL,ML	0.6-2.0	6.1-7.3		
									20-60	CL,CL-ML,ML	0.6-2.0	6.6-8.4		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	HORIZ DEPTH In.	SOIL CHARACTERISTICS UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
NORDEN SERIES	WI0105		7						0-7	ML,CL,SM,SC	0.6-2.0	5.1-7.3	>6.0	20-40
									0-7	SM,SM-SC,ML,CL-ML	0.6-2.0	5.1-7.3		
									7-13	CL,SC	0.6-2.0	5.1-7.3		
									13-24	CL,SC	0.6-2.0	5.1-7.3		
									24-38	SM,SC,ML,CL	0.6-2.0	4.5-7.3		
									38		-	-		
NORDEN SERIES SEVERELY ERODED	WI0447		7						0-7	CL	0.6-2.0	5.1-7.3	>6.0	20-40
									0-7	SM,SM-SC,ML,CL-ML	0.6-2.0	5.1-7.3		
									7-11	CL,SC	0.6-2.0	5.1-7.3		
									11-14	CL,SC	0.6-2.0	5.1-7.3		
									14-28	SM,SC,ML,CL	0.6-2.0	4.5-7.3		
									28		-	-		
NORDNESS SERIES	IA0113		7						0-5	CL,CL-ML	0.6-2.0	5.6-7.3	>6.0	8-20
									5-9	CL	0.6-2.0	5.6-7.3		
									9-12	CL,CH	0.06-0.2	6.6-7.3		
									12		-	-		
NORDNESS VARIANT	MN0484		7						0-7	CL,CL-ML	0.6-2.0	5.6-7.3	>6.0	>60
									7-18	CL	0.6-2.0	5.6-7.3		
									18-60	GM,SM,ML	2.0-6.0	7.4-8.4		
NORMANIA SERIES	MN0155		5	36	98	77	64	50	0-17	CL	0.6-2.0	6.1-7.3	2.5-6.0	>60
			5	48	127	101	85	67	17-26	CL	0.6-2.0	6.6-7.8		
									26-60	CL	0.6-2.0	7.4-8.4		
NORTHCOTE SERIES	MN0022		2						0-9	CH	0.06-0.2	6.6-7.3	1.0-3.0	>60
			5	36	22	17	14	11	9-18	CH	0.06-0.2	6.6-7.8		
			5	48	32	25	21	16	18-60	CH	0.06-0.2	7.4-8.4		
NORTHCOTE SERIES PONDED	MN0362		1						0-9	CH	0.06-0.2	6.6-7.3	+1-1.0	>60
			5	36	22	17	14	11	9-18	CH,MH	0.06-0.2	6.6-7.8		
			5	48	32	25	21	16	18-60	CH	0.06-0.2	7.4-8.4		
NORTHWOOD SERIES	MN0486	STONY	1						0-9	PT	2.0-6.0	6.6-7.8	+1-1.0	>60
			5	36	138	110	94	75	0-9	PT	2.0-6.0	6.6-7.8		
			5	48	172	139	119	95	9-18	SM,SM-SC	2.0-20	6.6-7.8		
									18-24	SM,SP-SM	6.0-20	6.6-8.4		
									24-60	ML,CL,CL-ML	0.6-2.0	7.4-8.4		
NOWEN SERIES	MN0201		5	36	98	77	64	50	0-15	SM,ML	0.6-2.0	5.6-7.3	1.0-4.0	>60
			5	48	127	101	85	67	15-49	CL,SM,SC,ML	0.6-2.0	5.6-7.3		
									49-60	SM,SC,SM-SC	0.6-2.0	6.1-7.8		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEA-BILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BED-ROCK In.
NOYES SERIES	MN0119		5	36	24	19	16	12	0-13	CL,SC	0.6-2.0	6.6-7.8	1.0-4.0	>60
			5	48	34	27	23	18	0-13	SM,SC,ML,CL	0.6-2.0	6.6-8.4		
									0-13	CL	0.6-2.0	7.4-8.4		
									13-60	CH	0.06-0.2	6.6-8.4		
NUTLEY SERIES	SD0053		7						0-6	CH,CL	0.06-0.2	7.4-8.4	>6.0	>60
									0-6	CH	0.06-0.2	7.4-8.4		
									6-60	CH	0.06-0.2	7.4-8.4		
NYMORE SERIES	MN0214		8						0-9	SM,SP-SM	6.0-20	5.1-6.5	>6.0	>60
									0-9	SP,SM,SP-SM	6.0-20	5.1-6.5		
									9-60	SP,SP-SM,SM	6.0-20	5.1-6.5		
OCHEYEDAN SERIES	IA0164		7						0-21	CL	0.6-2.0	5.6-7.3	>6.0	>60
									21-34	SC,CL,SM-SC,CL-ML	0.6-2.0	6.1-7.8		
									34-60	CL-ML,CL	0.6-2.0	6.6-8.4		
OESTERLE SERIES	WI0276		5	36	226	179	152	119	0-11	SM,SM-SC,SC	0.6-2.0	4.5-6.5	1.0-3.0	>60
			5	48	282	226	192	153	0-11	CL-ML,SM-SC,CL,SC	0.6-2.0	4.5-6.5		
									11-27	CL-ML,CL,SM-SC,SC	0.6-2.0	4.5-6.5		
									27-31	SM,SP-SM,SM-SC,GM	0.6-6.0	4.5-6.5		
									31-60	SW,SP,GW,GP	>6.0	5.1-6.5		
OGILVIE SERIES	MN0277		5	36	432	347	296	235	0-17	ML,CL,CL-ML	0.6-2.0	5.1-6.0	2.0-4.0	>60
			5	48	527	425	364	293	17-32	ML,CL	0.6-2.0	4.5-6.0		
									32-60	SP,SP-SM,GP,GP-GM	>20	5.1-6.5		
OKOBOJI SERIES	IA0131		1						0-10	CH	0.2-0.6	6.1-7.8	+1-1.0	>60
			5	36	68	48	37	23	0-10	CL	0.6-2.0	6.1-7.8		
			5	48	105	81	68	52	0-10	CH,MH	0.6-2.0	6.1-7.8		
									10-32	CH	0.2-0.6	6.6-7.8		
									32-56	CH	0.2-0.6	7.4-8.4		
									56-60	CL,CH	0.6-2.0	7.4-8.4		
OKOBOJI SERIES PONDED	IA0327		1						0-13	CH	0.2-0.6	6.6-7.8	+3-1.0	>60
			5	36	47	36	29	23	13-29	CH	0.2-0.6	6.6-7.8		
			5	48	64	50	42	33	29-60	CH	0.2-0.6	6.6-7.8		
OLDHAM SERIES	SD0174		1						0-8	CL,CH,MH,ML	0.06-0.6	6.6-7.8	+2-1.0	>60
			5	36	85	66	55	42	8-41	CL,CH,MH,ML	0.06-2.0	7.4-8.4		
			5	48	111	88	74	58	41-60	CL,CL-ML	0.06-2.0	7.4-8.4		
OMEGA SERIES	MN0170		8						0-10	SM,SP-SM,SM-SC	6.0-20	4.5-5.5	>5.0	>60
									0-10	SM,SP-SM	6.0-20	4.5-5.5		
									10-60	SP,SP-SM	6.0-20	5.1-7.3		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	HORIZ DEPTH In.	SOIL CHARACTERISTICS: UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
ONAMIA SERIES	WI0124		7						0-21	ML,CL-ML,CL	0.6-2.0	5.1-7.3	>6.0	>60
									0-21	SM,SC,ML,CL	0.6-2.0	5.1-7.3		
									21-27	SC,SM-SC,CL,CL-ML	0.6-2.0	5.1-7.3		
									27-39	SC,SM-SC,CL,CL-ML	0.6-2.0	5.1-7.3		
									39-44	GM,SM,GP-GM,SP-SM	2.0-6.0	5.1-7.3		
									44-60	GM,SM,GP,SP	>20	6.1-7.3		
ONTONAGON SERIES	MI0075		6						0-3	CH	0.06-0.2	4.5-6.0	>6.0	>60
									0-3	CL	0.2-0.6	4.5-6.0		
									0-3	CL-ML,CL	0.6-2.0	4.5-6.0		
									3-18	CH	<0.06	4.5-7.3		
									18-60	CH	<0.06	7.4-8.4		
ONTONAGON SERIES MODERATELY WET	MI0305		6						0-3	CH	0.06-0.2	4.5-6.0	2.5-6.0	>60
									0-3	CL	0.2-0.6	4.5-6.0		
									0-3	CL-ML,CL	0.6-2.0	4.5-6.0		
									3-18	CH	<0.06	4.5-7.3		
									18-60	CH	<0.06	7.4-8.4		
ORAN SERIES	IA0050		5	36	82	64	54	42	0-19	CL,CL-ML	0.6-2.0	5.1-7.3	2.0-4.0	>60
			5	48	104	83	70	55	19-42	CL	0.6-2.0	4.5-6.5		
									42-60	CL	0.6-1.0	7.4-7.8		
ORION SERIES	WI0042		3	36	98	77	64	50	0-5	CL,CL-ML	0.6-2.0	5.6-7.8	1.0-3.0	>60
			3	48	127	101	85	67	0-5	CL,CL-ML,SC,SM-SC	0.6-2.0	5.6-7.8		
									5-21	CL,CL-ML	0.6-2.0	5.6-7.8		
									21-42	CL,CL-ML	0.6-2.0	5.6-7.8		
									42-60	CL,CL-ML	0.6-2.0	5.6-7.8		
ORONOCO SERIES	MN0183		7						0-11	ML,CL,CL-ML	0.6-2.0	6.1-7.3	>6.0	>60
									0-11	ML,CL-ML,SM,SM-SC	2.0-6.0	6.1-7.3		
									11-74	ML,CL-ML,SM,SM-SC	0.6-2.0	5.6-7.8		
									74-77	ML	0.6-2.0	7.4-7.8		
OSAKIS SERIES	MN0278		5	36	364	292	249	198	0-7	ML,CL,SM,SC	0.6-2.0	6.1-7.3	3.0-6.0	>60
			5	48	446	359	308	247	0-7	SM,SM-SC	2.0-6.0	6.1-7.3		
									7-14	SM,ML,CL-ML,SM-SC	0.6-6.0	6.1-7.3		
									14-60	SP,SP-SM,GP,GP-GM	6.0-20	7.4-8.4		
OSHAWA SERIES	MN0017		1						0-30	MH,CH	0.2-0.6	7.4-7.8	+1-1.0	>60
		SICL,CL	3	36	47	36	29	23	0-30	OL,ML,CL	0.6-2.0	7.4-7.8		
			3	48	64	50	42	33	30-60	CL	0.2-0.6	7.4-7.8		
		SIL,L	3	36	59	46	39	31						
			3	48	77	61	52	41						

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OSHAWA VARIANT	MN0438	STONY	4	36	47	36	29	23	0-13	CH,CL	0.2-0.6	7.4-8.4	0-1.0	>60
			4	48	64	50	42	33	13-42	CL,CH	0.2-0.6	7.4-8.4		
									42-60	CL	0.2-0.6	7.4-8.4		
OSTRANDER SERIES	MN0113		7						0-16	CL-ML,CL	0.6-2.0	5.6-7.3	>6.0	>60
									0-16	CL	0.6-2.0	5.6-7.3		
									16-20	CL,CL-ML	0.6-2.0	5.1-7.3		
									20-50	CL,SC	0.6-2.0	5.1-7.3		
									50-60	CL	0.6-2.0	6.6-7.8		
OTTER SERIES	IL0078		1						0-28	CL	0.6-2.0	6.1-7.8	+.5-2.0	>60
			3	36	98	77	64	50	28-39	CL	0.6-2.0	6.1-7.8		
			3	48	127	101	85	67	39-60	CL-ML,CL,SM-SC,SC	0.6-2.0	6.1-8.4		
OTTERHOLT SERIES	WI0138		7						0-14	ML.CL-ML,CL	0.6-2.0	5.1-7.3	>6.0	>60
									14-40	CL,CL-ML,ML	0.6-2.0	4.5-6.5		
									40-60	ML,CL,SM,SC	0.2-0.6	4.5-6.5		
OVERLY SERIES	ND0069		7						0-10	CL,CL-ML	0.2-0.6	6.6-7.8	4.0-6.0	>60
									0-10	CL	0.2-0.6	6.6-7.8		
									10-38	CL,CL-ML	0.2-0.6	6.6-8.4		
									38-60	CL,CL-ML	0.06-0.6	7.9-8.4		
OVERLY SERIES CLAYEY SURFACE	ND0250		7						0-10	CL	0.2-0.6	6.6-7.8	4.0-6.0	>60
									10-38	CL,CL-ML	0.2-0.6	7.4-8.4		
									38-60	CL,CL-ML	0.06-0.6	7.9-8.4		
OVERLY SERIES SALINE	ND0312		7						0-10	CL,CL-ML	0.2-0.6	6.6-7.8	4.0-6.0	>60
									0-10	CL	0.2-0.6	6.6-7.8		
									10-38	CL,CL-ML	0.2-0.6	6.6-8.4		
									38-60	CL,CL-ML	0.06-0.6	7.9-8.4		
PADDOCK SERIES	MN0289		5	36	44	35	30	24	0-9	SM,SM-SC	0.6-2.0	5.6-7.3	1.0-3.0	>60
			5	48	54	43	37	30	0-9	ML,CL	0.6-2.0	5.6-7.3		
									9-22	SM,SM-SC	0.6-2.0	5.6-6.5		
									22-43	SM,SM-SC,SC	0.2-0.6	5.6-7.3		
									43-60	SM,SM-SC,SC	0.06-0.2	7.4-8.4		
PAGET SERIES	MN0290		2						0-6	ML,CL,CL-ML	0.6-2.0	5.1-6.5	2.0-3.0	>60
			5	36	62	49	42	33	6-17	ML,CL,CL-ML	0.6-2.0	5.1-6.5		
			5	48	80	64	55	43	17-23	SM,ML,CL,SC	0.6-6.0	5.1-6.5		
									23-54	SM	0.2-0.6	6.1-7.3		
									54-60	SM	0.2-0.6	6.1-7.8		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BED-ROCK In.
PALMS SERIES MAAT<50	MI0023		1						0-35	PT	0.2-6.0	5.1-7.8	+1-1.0	>60
			2						35-60	CL-ML,CL	0.2-2.0	6.1-8.4		
			5	36	106	84	71	56						
			5	48	135	108	92	73						
PALMS SERIES MAAT>50	MI0388		1						0-35	PT	0.2-6.0	5.1-7.8	+1-1.0	>60
			2						35-60	CL-ML,CL	0.2-2.0	6.1-8.4		
			5	36	106	84	71	56						
			5	48	135	108	92	73						
PALMS SERIES SANDY SUBSTRATUM	MI0271		1						0-30	PT	0.2-6.0	5.1-7.8	+1-1.0	>60
			2						30-45	CL-ML,CL	0.6-2.0	6.1-7.8		
			5	36	292	231	195	153	45-60	SM,SP-SM,SP,GP	2.0-20	7.4-7.8		
			5	48	372	299	255	203						
PALSGROVE SERIES	IL0062		7						0-8	CL-ML,CL	0.6-2.0	5.6-7.3	>6.0	40-60
									0-8	CL	0.6-2.0	5.1-7.3		
									8-37	CL	0.6-2.0	5.1-7.3		
									37-42	CH	0.06-0.2	5.6-7.3		
									42		-	-		
PARENT SERIES	MN0168		5	36	58	45	38	30	0-7	ML,CL,CL-ML	0.6-2.0	5.6-7.3	0.5-2.5	>60
			5	48	75	60	51	40	0-7	SM	2.0-6.0	5.6-7.3		
									7-28	SM,ML	0.6-2.0	5.6-8.4		
									28-60	SM	0.2-0.6	6.1-8.4		
PARENT SERIES PONDED	MN0387		1						0-7	ML,CL,CL-ML	0.6-2.0	5.6-7.3	+1-2.0	>60
			5	36	58	45	38	30	0-7	SM	2.0-6.0	5.6-7.3		
			5	48	75	60	51	40	7-28	SM,ML	0.6-2.0	5.6-8.4		
									28-60	SM	0.2-0.6	6.1-8.4		
PARNELL SERIES	MN0035		1						0-22	CL,CH	0.2-0.6	6.1-7.8	+2-2.0	>60
									0-22	OH,CH	0.06-0.2	6.1-7.8		
									0-22	OL,ML	0.6-2.0	6.1-7.8		
			5	36	63	51	44	36	22-55	CL,CH	0.06-2.0	6.6-7.8		
			5	48	72	60	50	40	55-60	CL,CH	0.06-0.2	5.6-8.4		
PEEVER SERIES	SD0151		7						0-7	CL	0.2-0.6	6.1-7.3	>6.0	>60
									7-20	CL,CH,MH,ML	0.06-0.6	6.6-7.8		
									20-49	CL,CH,MH,ML	0.06-0.6	7.4-8.4		
									49-60	CL,CH,MH,ML	0.06-0.6	7.4-8.4		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
PELAN SERIES	MN0120		7						0-9	SM	6.0-20	6.1-7.8	2.5-6.0	>60
									0-9	SM, SM-SC	2.0-6.0	6.1-7.8		
									9-14	SM, GM, SC, GC	6.0-20	6.6-7.8		
									14-32	SP-SM, SP, GP, GP-GM	6.0-20	7.4-8.4		
									32-60	SM, ML, CL, SC	0.6-2.0	7.9-8.4		
PENGILLY SERIES	MN0381		1						0-4	ML, CL-ML, SM, SM-SC	2.0-6.0	5.6-7.8	+.5-2.0	>60
			3	36	98	77	64	50	0-4	CL, CL-ML	0.6-2.0	5.6-7.8		
			3	48	127	101	85	67	0-4	ML, SM	2.0-6.0	5.6-7.8		
									4-60	ML, CL-ML, SM, SM-SC	0.6-2.0	6.1-8.4		
PERCY SERIES	MN0048		1						0-6	SC, SM-SC	0.6-2.0	6.6-8.4	0-3.0	>60
			3	36	170	134	113	89	0-6	SM, SC, SM-SC	2.0-6.0	6.6-8.4		
			3	48	214	171	146	116	0-6	CL-ML, CL	0.6-2.0	6.6-8.4		
									6-15	CL, CL-ML	0.6-6.0	7.4-8.4		
									15-60	SM-SC, SC, CL-ML, CL	0.6-6.0	7.4-8.4		
PERELLA SERIES	ND0076		1						0-14	ML, CL, CL-ML	0.2-2.0	6.6-7.8	+1-1.0	>60
			5	36	88	68	57	43	0-14	CL	0.2-2.0	6.6-7.8		
			5	48	115	91	76	60	0-14	CL, CH	0.06-0.2	6.6-7.8		
									14-24	CL, CL-ML	0.2-2.0	6.6-7.8		
									24-60	ML, CL, CL-ML	0.2-2.0	7.4-8.4		
PERELLA SERIES MODERATELY WET	ND0246								0-17	CL	0.2-2.0	6.6-7.8	2.0-4.0	>60
									0-17	CL, CH	0.06-0.2	6.6-7.8		
			5	36	89	69	58	45	17-23	CL, CL-ML, CH	0.06-2.0	6.6-7.8		
			5	48	115	91	77	60	23-60	CL, CL-ML	0.2-2.0	7.4-8.4		
PLAINFIELD SERIES MAAT<50	WI0116		8						0-7	SM, SP-SM	6.0-20	5.1-7.3	>6.0	>60
									0-7	SP-SM, SM, SP	6.0-20	5.1-7.3		
									7-36	SP, SM, SP-SM	6.0-20	4.5-6.5		
									36-60	SP, SM, SP-SM	6.0-20	4.5-6.5		
POINSETT SERIES	SD0180		7						0-8	CL, ML	0.6-2.0	6.1-7.3	>6.0	>60
									0-8	CL, ML	0.6-2.0	6.1-7.3		
									0-8	CL	0.6-2.0	6.1-7.3		
									8-23	CL	0.6-2.0	6.1-7.8		
									23-46	CL	0.6-2.0	7.4-8.4		
									46-60	CL, ML	0.6-2.0	7.4-8.4		
POMROY SERIES	MN0279		7						0-11	SM	6.0-20	5.1-6.0	>6.0	>60
									0-11	SM, SP-SM	6.0-20	5.1-6.0		
									11-24	SM, SP-SM	6.0-20	5.1-6.0		
									24-28	SM, GM	6.0-20	5.1-6.0		
									28-60	SM, SM-SC, GM, GM-GC	0.2-0.6	5.6-7.3		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH in.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH in.	UNIFIED SOIL CLASSIFICATION	PERMEA-BILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BED-ROCK In.
POPPLETON SERIES	MN0131		5	36	366	293	250	199	0-6	SP-SM,SM	6.0-20	5.6-7.3	2.5-5.0	>60
			5	48	448	361	310	249	0-6	SP-SM,SM	6.0-20	5.6-7.3		
									6-60	SM,SP	6.0-20	5.6-7.8		
PORT BYRON SERIES	IL0063		7						0-22	CL	0.6-2.0	5.6-7.3	>6.0	>60
									22-60	CL	0.6-2.0	5.6-8.4		
PORT BYRON SERIES MODERATELY WET	IL0301		7						0-22	CL,ML	0.6-2.0	5.6-7.3	4.0-6.0	>60
									22-60	CL	0.6-2.0	5.6-8.4		
PORT BYRON SERIES SANDY SUBSTRATUM	IL0331		7						0-14	CL	0.6-2.0	5.6-7.3	>6.0	>60
									14-57	CL	0.6-2.0	5.6-8.4		
									57-60	SM,SW-SM,SM-SC	6.0-20	5.6-8.4		
POSKIN SERIES	WI0182		2						0-12	CL,CL-ML	0.6-2.0	4.5-6.5	1.0-3.0	>60
			5	36	218	172	145	113	12-37	CL	0.6-2.0	4.5-6.5		
			5	48	274	219	187	148	37-39	SM,SM-SC,ML,CL-ML	0.6-6.0	4.5-6.5		
									39-60	SP,SP-SM,GP,GP-GM	>6.0	5.1-7.3		
PREBISH SERIES	MN0436								0-16	SM	2.0-6.0	5.6-7.3	0.5-2.0	>50
									0-16	ML,CL-ML,CL	0.6-2.0	5.6-7.3		
			5	36	73	58	50	40	16-46	SM	0.2-2.0	5.6-7.3		
			5	48	89	71	61	49	46-60	SM	0.2-0.6	5.6-8.4		
PREBISH SERIES PONDED	MN0248		1						0-16	SM	2.0-6.0	5.6-7.3	+1-1.0	>60
									0-16	ML,CL-ML	0.6-2.0	5.6-7.3		
									16-46	SM	0.2-2.0	5.6-7.3		
			5	36	73	58	50	40	46-60	SM	0.2-0.6	5.6-8.4		
			5	48	89	71	61	49						
PRIMGHAR SERIES	IA0158		5	36	98	77	64	50	0-17	MH,CH	0.6-2.0	5.6-7.3	3.0-5.0	>60
			5	48	127	101	85	67	17-35	CL,CH	0.6-2.0	6.1-8.4		
									35-44	CL	0.6-2.0	7.9-8.4		
									44-60	CL,CL-ML	0.6-2.0	7.9-8.4		
PROTIVIN SERIES	IA0057		5	36	67	52	42	32	0-15	MH,OH,CL,ML	0.6-2.0	5.1-7.3	2.0-4.0	>60
			5	48	89	70	59	46	15-23	CL	0.2-0.6	5.1-6.0		
									23-60	CL	0.4-1.0	6.1-7.8		

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QUAM SERIES	MN0075		1						0-8	OL	0.2-0.6	6.6-7.8	+2-1.0	>60
			5	36	61	48	41	32	0-8	OL,ML	0.6-2.0	6.6-7.8		
			5	48	78	62	53	42	0-8	CL,ML,OL	0.2-0.6	6.6-7.8		
									8-38	CL,ML	0.2-2.0	6.6-7.8		
									38-60	CL,ML,CL-ML	0.2-0.6	7.4-8.4		
QUETICO SERIES	MN0202	SHALLOW BEDROCK	6						0-5	CL,ML,SM,SC	0.6-2.0	4.5-5.5	> 6.0	4-8
									5		-	-		
RACINE SERIES	MN0203		7						0-12	ML	0.6-2.0	5.1-7.3	> 6.0	> 60
									12-18	CL	0.6-2.0	4.5-6.0		
									18-46	CL,SC	0.6-2.0	4.5-6.0		
									46-65	ML,CL	0.6-2.0	6.6-7.8		
RADFORD SERIES	IL0083		3	36	98	77	64	50	0-28	ML,CL	0.6-2.0	6.1-7.8	1.0-3.0	> 60
			3	48	127	101	85	67	28-60	CL	0.6-2.0	6.6-7.8		
RANSOM SERIES	MN0229		5	36	74	58	49	38	0-16	OL,ML	0.6-2.0	6.6-7.3	2.5-5.0	> 60
			5	48	96	76	65	51	16-33	ML	0.6-2.0	6.6-7.8		
									33-60	ML,CL	0.4-1.0	7.4-8.4		
RASSET SERIES	MN0280		7						0-10	SM	6.0-20	5.6-6.5	> 6.0	> 60
									0-10	SM,SM-SC	2.0-6.0	5.6-6.5		
									10-16	SM,SM-SC	2.0-6.0	5.6-6.5		
									16-43	SM,SM-SC,SC	2.0-6.0	5.6-6.5		
									43-50	SP-SM,SM	6.0-20	5.6-7.8		
RAUVILLE SERIES	SD0177		3	36	165	129	107	82	0-27	CL,ML	0.6-2.0	7.4-8.4	0-2.0	> 60
			3	48	216	172	145	115	0-27	CL,CH,MH	0.2-2.0	7.4-8.4		
									27-45	CL,CH,MH	0.2-2.0	7.4-8.4		
									45-60	SM,SC,CL,ML	2.0-6.0	7.4-8.4		
RAWLES SERIES	IA0253		7						0-26	CL,CL-ML	0.6-2.0	6.6-8.4	> 6.0	> 60
									26-60	CL	0.6-2.0	6.1-7.8		
READLYN SERIES	IA0061		5	36	74	58	48	37	0-17	CL	0.6-2.0	5.1-7.3	2.0-4.0	> 60
			5	48	98	77	65	51	0-17	CL	0.6-2.0	5.6-7.3		
									17-43	CL,SC	0.6-1.0	5.1-6.5		
									43-60	CL,SC	0.6-1.0	6.6-7.8		

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REDBY SERIES	MN0005		5	36	366	293	250	199	0-4	SM,SP-SM	6.0-20	5.6-6.5	2.0-6.0	>60
			5	48	448	361	310	249	4-33	SM,SP-SM	6.0-20	6.1-7.3		
									33-60	SP,SP-SM	6.0-20	6.6-7.8		
REDEYE SERIES	MN0494		7						0-4	SM,SP-SM	6.0-20	5.1-7.3	>6.0	>60
									4-8	SM	6.0-20	5.1-6.5		
									8-36	SM,SP-SM	6.0-20	5.6-6.5		
									36-68	SM,SC,SM-SC	0.06-0.2	5.1-7.3		
									68-72	SM,SC,SM-SC	0.06-0.2	7.4-8.4		
REGAL SERIES	MN0352		5	36	359	287	245	195	0-14	SC	0.6-2.0	6.6-8.4	1.0-3.0	>60
			5	48	440	355	304	244	0-14	CL,CL-ML	0.6-2.0	6.6-8.4		
									14-18	CL,CL-ML,SC,SM-SC	0.6-2.0	7.4-8.4		
									18-60	SP,SM,SP-SM	6.0-20	7.4-8.4		
REINER SERIES	MN0403		7						0-7	SM,ML	2.0-6.0	6.6-7.3	2.5-5.0	>60
									0-7	CL,CL-ML,ML	0.6-2.0	6.6-7.3		
									0-7	SM	6.0-20	6.6-7.3		
									7-17	CL	0.6-2.0	6.6-7.3		
									17-60	CL,ML,SM,SC	0.6-2.0	7.4-8.4		
REINER VARIANT	MN0402		7						0-7	CL	0.2-2.0	6.6-7.8	2.5-6.0	>60
									7-16	CH,CL	<0.06	6.6-7.8		
									16-36	CH	<0.06	7.4-8.4		
									36-60	CL-ML,CL,SC,SM-SC	0.06-2.0	7.4-8.4		
RENOVA SERIES	MN0111		7						0-10	ML,CL,CL-ML	0.6-2.0	5.6-6.5	>6.0	>60
									10-19	CL	0.6-2.0	4.5-6.0		
									19-52	CL,SC,CL-ML,SM-SC	0.6-2.0	4.5-7.3		
									52-60	CL	0.6-2.0	7.4-7.8		
RENSHAW SERIES	SD0142		7						0-7	ML,CL	0.6-2.0	6.1-7.8	>6.0	>60
									0-7	SM,SC,SM-SC	2.0-6.0	6.1-7.8		
									0-7	SC,SM-SC	2.0-6.0	6.1-7.8		
									7-15	SM-SC,SC,ML,CL	0.6-6.0	6.6-8.4		
									15-60	SW,SM,SW-SM,GW-GM	>6.0	6.6-8.4		
RENSHAW SERIES STONY	SD0415		7						0-7	SC,SM-SC	2.0-6.0	6.1-7.8	>5.0	>60
									7-15	SM-SC,SC,ML,CL	0.6-6.0	6.6-7.8		
									15-60	SW,SM,GW,GW-GM	>6.0	6.6-7.8		
REVERE SERIES	MN0433		5	36	98	77	64	50	0-15	CL	0.6-2.0	7.4-8.4	1.0-3.0	>60
			5	48	127	101	85	67	15-35	CL	0.6-2.0	7.4-8.4		
									35-60	CL	0.6-2.0	7.4-8.4		

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RICEVILLE SERIES	IA0085		5	36	47	36	29	23	0-9	CL	0.6-2.0	4.5-7.3	2.0-4.0	>60
			5	48	64	50	42	33	9-20	CL	0.2-0.6	4.5-5.0		
									20-60	CL	0.2-0.6	4.5-7.8		
RICHWOOD SERIES	WI0113		7						0-13	ML	0.6-2.0	5.6-7.3	>6.0	>60
									13-40	CL, CL-ML	0.6-2.0	5.6-7.3		
									40-55	CL, ML, SC, SM	0.6-6.0	5.6-7.3		
									55-60	SM, SP-SM	6.0-20	6.1-7.3		
RIDGEPORT VARIANT	MN0472		7						0-9	ML, SM, CL, SC	2.0-6.0	5.6-7.3	>6.0	20-40
									9-16	SM, ML, CL, SC	2.0-6.0	6.1-7.3		
									16-25	SP, SP-SM, SM, GP	6.0-20	6.1-7.8		
									25-60		-	-		
RIFLE SERIES LOW PRECIPITATION	MI0391		1						0-4	PT	>0.2	5.6-7.3	+1-1.0	>60
			5	36	170	134	113	89	4-60	PT	0.6-6.0	5.6-7.3		
			5	48	214	171	146	116						
RIPON SERIES	WI0067		7						0-11	ML, CL-ML, CL	0.6-2.0	5.6-7.8	>6.0	20-40
									11-32	CL	0.6-2.0	5.1-6.5		
									32-34	SC, CL	0.6-2.0	6.1-8.4		
									34		-	-		
ROCKTON SERIES	MN0121		7						0-15	ML, CL-ML, CL	0.6-2.0	5.1-6.5	>6.0	20-40
									15-26	CL, SC	0.6-2.0	5.1-6.5		
									26-31	CH, CL	0.6-2.0	5.6-7.3		
									31		-	-		
ROCKTON SERIES ERODED	MN0505		7						0-15	ML, CL-ML, CL	0.6-2.0	5.1-6.5	>6.0	20-40
									15-26	CL, SC	0.6-2.0	5.1-6.5		
									26-31	CH, CL	0.6-2.0	5.6-7.3		
									31		-	-		
ROCKTON SERIES HARD BEDROCK SUBSTRATUM	MN0490		7						0-15	SC, CL, SM-SC, CL-ML	0.6-2.0	5.6-6.5	>6.0	20-40
									15-36	SC, CL, CL-ML, SM-SC	0.6-2.0	5.6-7.3		
									36		-	-		
ROCKWELL SERIES	MN0054		5	36	127	102	87	69	0-9	OL, ML	0.6-2.0	7.4-8.4	1.0-3.0	>60
			5	48	160	129	110	88	0-9	ML, SM, SM-SC, CL-ML	2.0-6.0	7.4-8.4		
									9-19	SM, ML, SM-SC, CL-ML	2.0-6.0	7.9-8.4		
									19-27	SM	6.0-20	7.4-7.8		
									27-60	CL, CL-ML, SC, SM-SC	0.2-2.0	7.4-7.8		

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ROCKWELL SERIES PONDED	MN0360		1						0-9	OL,ML	0.6-2.0	7.4-8.4	+1-1.0	>60
			5	36	127	102	87	69	0-9	ML,SM,SM-SC,CL-ML	2.0-6.0	7.4-8.4		
			5	48	160	129	110	88	9-19	SM,ML,SM-SC,CL-ML	2.0-6.0	7.9-8.4		
									19-27	SM	6.0-20	7.4-7.8		
									27-60	CL,CL-ML,SC,SM-SC	0.2-2.0	7.4-7.8		
ROCKWOOD SERIES	MN0292		7						0-8	SM	0.6-2.0	5.1-6.5	>6.0	>60
									8-16	SM,SM-SC,SC	0.6-2.0	5.1-6.5		
									16-37	SM,SM-SC,SC	0.6-2.0	5.6-7.3		
									37-46	SM,SM-SC,SC	0.2-0.6	5.6-7.3		
									46-60	SM,SM-SC,SC	0.06-0.2	6.1-8.4		
ROLFE SERIES	IA0159		1						0-14	OL,CL,ML	0.6-2.0	5.1-7.3	+1-1.0	>60
			5	36	83	64	53	39	14-28	CH	0.06-0.2	6.1-7.3		
			5	48	109	86	72	56	28-60	CL	0.2-2.0	6.1-8.4		
ROLISS SERIES	MN0076		5	36	89	69	58	45	0-11	SC,SM,SM-SC,SP-SM	0.6-2.0	6.6-7.8	1.0-3.0	>60
			5	48	116	91	77	61	0-11	CL	0.2-0.6	6.6-7.8		
									0-11	CL,CL-ML	0.2-2.0	6.6-7.8		
									11-16	CL	0.2-2.0	6.6-7.8		
									16-60	CL,CL-ML	0.2-2.0	7.9-8.4		
ROLISS SERIES DEPRESSIONAL	MN0420		1						0-11	SM,SM-SC,SC,SP-SM	0.6-2.0	6.6-7.8	+.5-3.0	>60
			5	36	88	68	57	43	0-11	CL	0.2-0.6	6.6-7.8		
			5	48	114	90	76	60	0-11	CL,CL-ML	0.2-2.0	6.6-7.8		
									11-16	CL	0.2-0.6	6.6-7.8		
									16-60	CL,CL-ML	0.2-2.0	7.9-8.4		
ROLLINGSTONE SERIES	MN0349		7						0-6	CL,ML,CL-ML	0.6-2.0	5.6-7.3	>6.0	>60
									6-13	CL,ML,CL-ML	0.6-2.0	5.1-6.5		
									13-66	CH,SC,GC	0.06-0.2	4.5-5.5		
ROMNELL SERIES	MN0298		5	36	57	45	38	30	0-27	CL	0.6-2.0	6.6-7.8	0.5-1.0	>60
			5	48	75	59	50	40	27-43	CL	0.2-0.6	6.6-7.8		
									43-60	CL	0.2-0.6	7.4-8.4		
RONDEAU SERIES	MN0148		1						0-44	PT	0.2-6.0	5.1-7.8	+1-1.0	>60
			3	36	94	76	66	53	44-60	OH,MH	<0.2	7.4-7.8		
			3	48	106	86	74	60						
RONNEBY SERIES	MN0247		5	36	81	65	56	45	0-12	SM	2.0-6.0	5.1-6.5	1.5-3.0	>60
			5	48	103	83	71	57	0-12	ML	0.6-2.0	5.1-6.5		
									12-33	SM,ML	0.6-6.0	5.1-6.5		
									33-61	SM	0.2-0.6	6.1-8.4		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BED-ROCK In.
ROOT SERIES	MN0299	STONY	3	36	429	344	293	233	0-34	CL,CL-ML	0.6-2.0	6.6-7.8	0-1.5	>60
			3	48	523	422	362	290	34-50	GP,GM,SM,SP	>20	7.4-7.8		
ROSCOMMON SERIES	MI0159		1						0-4	SM,SP-SM	6.0-20	5.6-7.8	+1-1.0	>60
			5	36	366	293	250	199	0-4	SM,SP,SP-SM	6.0-20	5.6-7.8		
			5	48	448	361	310	249	0-4	PT	0.2-6.0	5.6-7.8		
									4-60	SP,SP-SM,SM	6.0-20	5.6-8.4		
ROSEVILLE SERIES	IA0107		7						0-17	CL,CL-ML	0.6-2.0	5.6-7.3	>6.0	40-60
									17-40	CL,SC,SM-SC,CL-ML	0.6-2.0	5.6-6.0		
									40-44	CH	0.06-0.2	5.6-6.0		
									44		-	-		
ROSEWOOD SERIES	MN0414		5	36	361	289	246	196	0-8	SM,SC,SM-SC	2.0-6.0	7.4-8.4	1.0-3.0	>60
			5	48	442	356	305	245	0-8	SM	6.0-20	7.4-8.4		
									8-18	SM,SC,SM-SC	2.0-6.0	7.4-8.4		
									18-60	SM,SP-SM	6.0-20	7.4-8.4		
ROSEWOOD SERIES WET	MN0427		1						0-8	SM,SC,SM-SC	2.0-6.0	7.9-8.4	0-1.0	> 60
			5	36	361	289	246	196	0-8	SM	6.0-20	7.9-8.4		
			5	48	442	356	305	245	8-18	SM,SC,SM-SC	2.0-6.0	7.9-8.4		
									18-60	SM,SP-SM	6.0-20	7.4-8.4		
ROSHOLT SERIES	WI0226		7						0-6	SM,SM-SC	0.6-6.0	4.5-7.3	> 6.0	>60
									0-6	SM-SC,CL-ML,SM,ML	0.6-6.0	4.5-7.3		
									6-14	SM,ML,SM-SC,CL-ML	0.6-6.0	4.5-7.3		
									14-22	SC,SM,CL,ML	0.6-6.0	4.5-7.3		
									22-29	SM,GM,SP-SM,GP-GM	0.6-6.0	4.5-7.3		
									29-60	GP,SP,SP-SM,GP-GM	>6.0	5.1-6.5		
ROSSFIELD SERIES	IA0184		7						0-15	CL	0.6-2.0	6.1-7.3	>6.0	>60
									0-15	CL	0.6-2.0	6.1-7.3		
									15-32	CL	0.6-2.0	6.1-7.3		
									32-60	SM,SC.SM-SC	2.0-6.0	7.4-8.4		
ROSY SERIES	MN0344		2						0-9	ML,SM,CL-ML,SM-SC	0.6-2.0	5.1-7.3	3.0-5.0	>60
			5	36	98	77	64	50	0-9	ML,CL,CL-ML	0.6-2.0	5.1-7.3		
			5	48	127	101	85	67	9-20	ML,SM,SC,CL	0.6-2.0	5.1-7.3		
									20-60	SM,SC,ML,CL	0.6-2.0	5.6-8.4		
ROTHSAY SERIES	MN0077		7						0-13	ML	0.6-2.0	6.6-7.3	>6.0	>60
									0-13	ML	2.0-6.0	6.6-7.3		
									13-22	ML	0.6-2.0	6.6-7.8		
									22-60	ML	0.6-6.0	7.4-8.4		

DRAINAGE GUIDE DATA FOR MINNESOTA

SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BED-ROCK In.
RUNEBERG SERIES	MN0293		5	36	43	32	27	21	0-10	SM-SC,SM,SC	0.6-2.0	6.1-7.3	0.5-2.0	>60
			5	48	58	45	38	30	0-10	ML,CL	0.6-2.0	6.1-7.3		
									10-26	SM,SC,SM-SC	0.2-0.6	6.1-7.3		
									26-60	SM,SM-SC,SC	0.06-0.6	7.4-8.4		
RUNEBERG SERIES PONDED	MN0500		1						0-10	SM-SC,SM,SC	0.6-2.0	6.1-7.3	+1-1.0	>60
			5	36	43	32	27	21	0-10	ML,CL	0.6-2.0	6.1-7.3		
			5	48	58	45	38	30	10-26	SM,SC,SM-SC	0.2-0.6	6.1-7.3		
									26-60	SM,SM-SC,SC	0.06-0.6	7.4-8.4		
RUSHMORE SERIES	MN0230		4	36	86	67	56	44	0-18	OL,ML,CL	0.6-2.0	6.1-7.8	1.0-3.0	>60
			4	48	112	88	75	59	18-28	CL	0.6-2.0	6.6-8.4		
									28-60	CL	0.4-1.6	7.4-8.4		
RYAN SERIES	ND0077		6						0-2	CH	<0.06	7.4-8.4	0-1.0	>60
									0-2	CH	<0.06	7.4-8.4		
									2-60	CH	<0.06	7.4-9.0		
SAC SERIES	IA0162		7						0-11	ML,CL,MH,CH	0.6-2.0	5.6-7.3	>6.0	>60
									11-28	CL	0.6-2.0	5.6-7.3		
									28-60	CL	0.6-2.0	6.6-8.4		
SAC SERIES MODERATELY SLOW PERM	IA0349		7						0-11	CL,ML,MH,CH	0.6-2.0	5.6-7.3	>6.0	>60
									11-28	CL,ML,MH,CH	0.6-2.0	6.1-7.3		
									28-60	CL	0.2-0.6	6.6-8.4		
SAGO SERIES	MN0331		5	36	98	77	64	50	0-10	PT	0.6-6.0	4.5-6.5	+1-1.0	>60
			5	48	127	101	85	67	10-60	SM,ML,CL,SC	0.6-2.0	5.6-8.4		
SALIDA SERIES	MN0062	GR-SL,GR-COSL	7						0-7	SM,SP-SM	2.0-6.0	6.1-8.4	>6.0	>60
		GR-LS,GR-COS	8						0-7	SP-SM	6.0-20	6.1-8.4		
									0-7	SM	2.0-6.0	6.1-8.4		
									7-11	SP,SW,GP,GP-GM	>20	7.4-8.4		
									11-60	SP,SW,GP,GP-GM	>20	7.4-8.4		
SANDWICK SERIES	MN0348		5	36	105	85	73	59	0-4	SM	6.0-20	5.1-6.5	1.0-2.0	>60
			5	48	131	106	91	74	0-4	SM,SP-SM	6.0-20	5.1-6.5		
									4-22	SM,SP-SM	6.0-20	5.1-6.5		
									22-38	CL,ML	0.2-0.6	5.1-7.3		
									38-60	CL,ML	0.2-0.6	6.1-8.4		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BED-ROCK In.
SANTIAGO SERIES MODERATELY SLOW PERM	WI0137		7						0-3	ML,CL,CL-ML	0.6-2.0	4.5-7.3	>6.0	>60
									3-11	ML,CL-ML	0.6-2.0	4.5-6.5		
									11-21	CL	0.6-2.0	4.5-6.5		
									21-32	CL,SC	0.6-2.0	4.5-6.5		
									32-60	SM,SC,ML,CL	0.2-0.6	5.1-7.3		
SANTIAGO SERIES STONY	WI0346		7						0-3	ML,CL,CL-ML	0.6-2.0	4.5-7.3	>6.0	>60
									3-11	ML,CL-ML	0.6-2.0	4.5-6.5		
									11-21	CL	0.6-2.0	4.5-6.5		
									21-32	CL,SC	0.6-2.0	4.5-6.5		
									32-60	SM,SC,ML,CL	0.2-0.6	5.1-7.3		
SARGEANT SERIES	MN0143		2						0-7	CL,CL-ML	0.6-2.0	5.1-6.5	0.5-1.5	>60
			5	36	34	27	23	18	7-19	CL	0.6-2.0	4.5-6.5		
			5	48	44	35	30	24	19-45	CL	0.06-0.2	4.5-6.5		
									45-64	CL,CL-ML	0.06-0.2	6.1-7.8		
SARTELL SERIES	MN0204		8						0-4	SM,SP-SM	6.0-20	5.1-6.0	>6.0	>60
									0-4	SM,SP-SM	6.0-20	5.1-6.0		
									4-36	SP-SM,SM	6.0-20	5.1-6.0		
									36-60	SP,SP-SM	6.0-20	5.6-7.3		
SATTRE SERIES	IA0106		7						0-13	CL,CL-ML,ML	0.6-2.0	6.1-6.5	>6.0	>50
									13-32	CL,SC,CL-ML,SM-SC	0.6-6.0	5.1-5.5		
									32-75	SW,SM,SP,SP-SM	>20	5.1-5.5		
SAWMILL SERIES	IL0084		3	36	98	77	64	50	0-17	CL	0.6-2.0	6.1-7.8	0-2.0	>60
			3	48	127	101	85	67	0-17	CL	0.6-2.0	6.1-7.8		
									17-32	CL	0.6-2.0	6.1-7.8		
									32-58	CL	0.6-2.0	6.1-7.8		
									58-65	CL	0.6-2.0	7.4-8.4		
SCHAPVILLE SERIES	IL0228		7						0-8	ML,CL,CL-ML	0.6-2.0	5.6-6.5	>6.0	20-40
									0-8	CL	0.6-2.0	5.6-7.3		
									8-22	CL	0.6-2.0	5.6-7.3		
									22-25	CL,CH	0.06-0.2	5.6-7.3		
									25-60		-	-		
SCHLEY SERIES	IA0087		5	36	98	77	64	50	0-17	CL,CL-ML	0.6-2.0	4.5-6.5	1.0-3.0	>60
			5	48	127	101	85	67	17-37	CL,SC,SM-SC,CL-ML	0.6-2.0	4.5-5.5		
									37-63	CL	0.6-2.0	5.1-7.8		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	HORIZ DEPTH In.	SOIL CHARACTERISTICS UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
SCHLEY	IA0330		4	36	314	249	211	165	0-12	CL-ML,CL	0.6-2.0	5.6-7.3	2.0-4.0	>60
SERIES			4	48	401	322	275	220	12-29	CL	0.6-2.0	5.1-6.5		
SANDY SUBSTRATUM									29-49	SM-SC,SM	2.0-6.0	5.1-6.5		
									49-60	SM,SP-SM	6.0-20	5.1-6.5		
SEAFORTH	MN0154		5	36	98	77	64	50	0-15	ML,CL-ML,CL	0.6-2.0	7.4-8.4	3.0-6.0	>60
SERIES			5	48	127	101	85	67	15-24	CL,ML	0.6-2.0	7.4-8.4		
									24-60	CL,ML	0.6-2.0	7.4-8.4		
SEATON	IL0067		7						0-9	CL,CL-ML	0.6-2.0	5.6-7.3	>6.0	>60
SERIES									9-70	CL,CL-ML	0.6-2.0	5.1-7.3		
									70-80	CL,CL-ML	0.6-2.0	5.6-8.4		
SEATON	IL0286		7						0-14	CL,CL-ML	0.6-2.0	6.1-6.5	3.0-6.0	>60
SERIES									14-42	CL	0.6-2.0	5.1-6.0		
MODERATELY WET									42-60	CL	0.6-2.0	5.1-5.5		
SEATON	IL0285		7						0-16	CL,CL-ML	0.6-2.0	5.6-7.3	>6.0	>60
SERIES									16-38	CL	0.6-2.0	5.1-6.5		
SANDY SUBSTRATUM									38-48	CL,CL-ML	0.6-2.0	5.6-8.4		
									48-60	SM,SP-SM,SP	6.0-20	5.6-6.0		
SEELYEVILLE	MN0128		1						0-4	PT	0.2-6.0	4.5-7.3	+2-2.0	>60
SERIES			3	36	164	130	109	86	0-4	PT	0.2-6.0	4.5-7.3		
			3	48	207	165	141	112	4-60	PT	0.2-6.0	4.5-7.3		
SEELYEVILLE	MN0353		1						0-60	PT	0.2-6.0	4.5-7.3	0-2.0	>60
SERIES			2											
SLOPING			5	36	164	130	109	86						
			5	48	207	165	141	112						
SHAKOPEE	MN0466		5	36	329	262	222	175	0-7	CH,CL	0.06-0.2	7.4-7.8	1.0-2.0	>60
SERIES			5	48	408	328	280	224	7-17	CL,CH	0.06-0.2	7.9-8.4		
									17-38	CL,CH	0.06-0.2	7.9-8.4		
									38-60	SM,SP-SM,SM-SC	6.0-20	7.4-7.8		
SHANDEP	IA0226		5	36	304	241	203	159	0-29	CL,CH	0.6-2.0	6.1-7.8	+1-1.0	>60
SERIES			5	48	393	315	269	214	29-45	CL	0.6-2.0	6.1-7.8		
									45-50	SM,SC,SM-SC	2.0-6.0	6.1-7.8		
									50-60	SW,SP,SP-SM	6.0-20	6.1-8.4		
SHIELDS	MN0091		5	36	73	53	42	31	0-10	OL,ML	0.6-2.0	5.6-6.5	1.0-3.0	>60
SERIES			5	48	101	79	66	51	10-41	CH,MH,CL	0.06-0.2	5.1-6.5		
									41-60	CL,ML,MH	0.2-2.0	7.4-7.8		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft., DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
SHILOH SERIES	IL0068		1						0-17	CL,CH	0.2-0.6	6.1-7.3	+1-2.0.	>60
			5	36	25	19	16	12	17-50	CL,CH	0.06-0.2	6.6-7.8		
			5	48	35	27	23	18	50-60	CL	0.06-0.2	7.9-8.4		
SHOOKER SERIES	MN0139		5	36	98	77	64	50	0-9	SM,ML,SM-SC,CL-ML	2.0-6.0	5.6-7.3	1.0-3.0	>60
			5	48	127	101	85	67	0-9	ML,CL-ML,CL	0.6-2.0	5.6-7.3		
									9-27	ML,CL,CL-ML	0.6-2.0	5.6-7.8		
									27-60	ML,CL,SC,SM	0.6-2.0	7.4-8.4		
SHOREWOOD SERIES	MN0092		2						0-10	CL,ML	0.2-0.6	5.6-7.3	3.0-5.0	>60
			5	36	81	63	51	38	0-10	MH	0.2-0.6	5.6-7.3		
			5	48	108	85	71	55	10-33	MH	0.06-0.6	5.1-6.5		
									33-60	CL,ML	0.2-2.0	6.6-7.8		
SHOREWOOD SERIES SILTY SUBSTRATUM	MN0109		5	36	89	68	56	41	0-15	CL,ML	0.2-0.6	5.6-7.3	3.0-5.0	>60
			5	48	116	92	77	60	15-33	MH,CH	0.06-0.2	5.6-7.3		
									33-60	ML	0.6-2.0	6.6-7.8		
SHULLSBURG SERIES	MN0325		2						0-17	ML,CL,CL-ML	0.6-2.0	5.6-7.3	1.0-3.0	20-40
			5	36	27	22	19	16	17-26	CL	0.2-0.6	5.6-7.3		
			5	37	28	23	20	16	26-37	CL,CH	0.06-0.2	6.1-7.8		
									37-60		-	-		
SINAI SERIES	SD0054		7						0-11	CL,CH,MH,ML	0.06-0.2	6.1-7.3	>6.0	>60
									0-11	CL,CH,MH,ML	0.06-0.2	6.1-7.3		
									11-22	CL,CH,MH,ML	0.06-0.2	6.6-7.8		
									22-35	CL,CH,MH,ML	0.06-0.2	7.4-8.4		
									35-60	CL,CH	0.06-0.2	7.4-8.4		
SINGSAAS SERIES	SD0212		7						0-13	ML,CL	0.6-2.0	6.1-7.3	>6.0	>60
									0-13	CL	0.6-2.0	6.1-7.3		
									13-23	CL	0.6-2.0	6.6-8.4		
									23-60	CL	0.2-0.6	7.4-8.4		
SIOUX SERIES LOAMY	SD0052		7						0-5	ML,CL	0.6-2.0	6.6-8.4	>6.0	>60
									0-5	SM	2.0-6.0	6.6-8.4		
									0-5	SM,GM	2.0-6.0	6.6-8.4		
									5-8	SM,GM	2.0-6.0	7.4-8.4		
									8-60	GM,GP,SM,SP	>6.0	7.4-8.4		
SIOUX SERIES SANDY	SD0425		7						0-10	SM,SM-SC	2.0-6.0	6.6-8.4	>6.0	>60
									10-60	GM,GP,SM,SP	>6.0	7.4-8.4		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	HORIZ DEPTH In.	SOIL CHARACTERISTICS: UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
SIOUX	SD0284		7						0-5	ML,CL,SM,SC	0.6-2.0	6.6-8.4	>6.0	>50
SERIES									0-5	SM,SM-SC	2.0-6.0	6.6-8.4		
STONY									0-5	SM,SP-SM,SM-SC	6.0-20	6.6-8.4		
									5-8	SM,SM-SC	2.0-6.0	6.6-8.4		
									8-60	GM,GP,SM,SP	> 6.0	7.4-8.4		
SKYBERG	MN0164		5	36	54	42	36	27	0-12	CL	0.6-2.0	5.6-6.5	1.0-3.0	>60
SERIES			5	48	71	56	48	38	12-22	CL	0.6-2.0	4.5-5.5		
									22-60	CL	0.2-0.6	5.1-7.3		
									60-66	CL	0.2-0.6	7.4-7.8		
SMILEY	MN0413		5	36	98	77	64	50	0-12	SM-SC,SM,ML,CL-ML	2.0-6.0	6.6-7.8	1.0-3.0	>60
SERIES			5	48	127	101	85	67	0-12	ML,CL,CL-ML	0.6-2.0	6.6-7.8		
									12-19	CL	0.6-2.0	6.6-8.4		
									19-60	CL,CL-ML,SC,SM-SC	0.6-2.0	7.4-8.4		
SMILEY	MN0488		1						0-4	PT	0.2-2.0	6.6-7.8	+2-1.0	>60
SERIES			5	36	89	69	58	45	0-4	ML,CL,CL-ML	0.2-2.0	6.6-7.8		
PONDED			5	48	116	91	77	61	4-10	SM-SC,SM,ML,CL-ML	0.2-2.0	6.6-7.8		
									10-18	CL	0.2-2.0	6.6-7.8		
									18-60	CL,CL-ML,SC,SM-SC	0.2-2.0	6.6-8.4		
SODERVILLE	MN0206		5	36	366	293	250	199	0-36	SM,SP-SM	6.0-20	5.1-6.0	2.0-4.0	>60
SERIES			5	48	448	361	310	249	0-36	SM,SP-SM	6.0-20	5.1-6.0		
									36-46	SM,SP-SM	6.0-20	5.1-6.0		
									46-60	SP,SP-SM,SM	6.0-20	5.6-6.5		
SOGN	KS0087		7						0-9	CL,MH,CH,ML	0.6-2.0	6.1-8.4	>6.0	4-20
SERIES									0-9	CL,SC	0.6-2.0	6.1-8.4		
HIGH PPT									9		-	-		
SOUTHRIDGE	MN0350		7						0-8	ML,CL,CL-ML	0.6-2.0	5.6-7.3	>6.0	>60
SERIES									8-33	ML,CL,CL-ML	0.6-2.0	4.5-6.5		
									33-60	CH	0.06-0.2	4.5-6.0		
SPARTA	WI0333		7						0-5	SM	6.0-20	5.6-6.0	>6.0	40-60
SERIES									5-40	SM,SP-SM	6.0-20	5.6-6.0		
BEDROCK SUBSTRATUM									40-44	CL,CH	0.2-2.0	5.1-7.8		
									44		-	-		
SPARTA	WI0407		7						0-16	SM	2.0-6.0	5.1-7.3	>6.0	>60
SERIES									16-38	SP-SM,SM	6.0-20.0	5.1-6.0		
LOAMY SUBSTRATUM									38-54	SP-SM,SM	6.0-20.0	5.1-6.0		
									54-60	CL	0.6-2.0	5.6-6.5		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
SPARTA SERIES MAAT<50	WI0041	LFS,LS S,FS	7						0-15	SM	2.0-6.0	5.1-7.3	>6.0	>60
			8						0-15	SP-SM,SM	6.0-20	5.1-7.3		
									15-34	SP-SM,SM	6.0-20	5.1-7.3		
									34-60	SP-SM,SM,SP	6.0-20	5.1-7.3		
SPENCER SERIES	WI0176		7						0-15	ML,CL,CL-ML	0.6-2.0	5.1-7.3	2.5-6.0	>60
									15-42	CL,ML,CL-ML	0.6-2.0	4.5-6.5		
									42-60	SM,SC,ML,CL	0.2-0.6	4.5-6.5		
SPICER SERIES	MN0093		5	36	98	77	64	50	0-16	ML	0.6-2.0	7.4-8.4	1.0-3.0	>60
			5	48	127	101	85	67	16-40	ML	0.6-2.0	7.4-8.4		
									40-60	ML	0.6-2.0	7.4-8.4		
SPICER SERIES PONDED	MN0318		1						0-16	OL,ML	0.6-2.0	7.4-8.4	+1-1.0	>60
			5	36	98	77	64	50	16-40	ML	0.6-2.0	7.4-8.4		
			5	48	127	101	85	67	40-60	ML	0.6-2.0	7.4-8.4		
SPILLCO SERIES	IA0001		7						0-60	CL	0.6-2.0	6.6-8.4	3.0-5.0	>50
									60-70	CL-ML,CL,SM-SC,SC	2.0-6.0	7.9-8.4		
SPILLVILLE SERIES	IA0076		7						0-54	CL	0.6-2.0	5.6-7.3	3.0-5.0	>60
									54-60	CL,CL-ML,SM-SC,SC	0.6-6.0	5.6-7.3		
SPILLVILLE SERIES NONFLOODED	IA0306		7						0-54	CL	0.6-2.0	5.6-7.3	3.0-5.0	>60
									54-60	CL.CL-ML,SM-SC,SC	0.6-6.0	5.6-7.3		
SPOONER SERIES	MN0135		5	36	101	79	66	51	0-6	SM,ML	2.0-6.0	5.6-7.8	1.0-3.0	>60
			5	48	130	103	87	69	0-6	ML	0.6-2.0	5.6-7.8		
									6-15	SM,ML,SC,CL	0.6-6.0	5.6-7.8		
									15-22	CL,CL-ML	0.6-2.0	6.1-7.8		
									22-60	ML,CL,SM,SC	0.6-2.0	7.4-8.4		
SPOTTSWOOD SERIES	SD0008		7						0-7	CL-ML,CL	0.6-2.0	6.1-7.3	3.0-6.0	>50
									7-25	CL	0.6-2.0	6.6-7.8		
									25-60	SM,GM,SP-SM,GP-GM	6.0-20	7.4-8.4		
STATELINE SERIES	MN0481	SPECIAL DESIGN NEEDED	5	18	16	13	11	9	0-7	CL,ML	0.6-2.0	5.6-7.3	0-2.0	>60
									0-7	CL	0.6-2.0	5.6-7.3		
									7-18	CL,ML	0.2-2.0	4.5-6.0		
									18-60	CH,CL	<0.06	4.5-6.0		

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STEINAUER SERIES	NE0085		7						0-6	CL-ML,CL	0.6-2.0	7.4-8.4	>6.0	>50
									0-6	CL	0.2-0.6	7.4-8.4		
									6-15	CL,CH	0.2-0.6	7.9-8.4		
									15-60	CL	0.2-2.0	7.9-8.4		
STORDEN SERIES	MN0063		7						0-8	ML,CL	0.6-2.0	7.4-8.4	>6.0	>60
									8-60	CL-ML,CL,ML	0.6-2.0	7.4-8.4		
STORDEN SERIES STONY	MN0357		7						0-8	ML,CL	0.6-2.0	7.4-8.4	>6.0	>60
									8-60	CL-ML,CL	0.6-2.0	7.4-8.4		
STRANDQUIST SERIES	MN0122		5	36	128	102	87	69	0-10	SM	2.0-6.0	6.6-8.4	0.5-3.0	>60
			5	48	161	130	111	89	0-10	CL-ML,CL,SM-SC,SC	0.6-2.0	6.6-8.4		
									10-20	SP,GP,GP-GM,SP-SM	6.0-20	7.4-8.4		
									20-60	CL-ML,CL,SC,SM-SC	0.6-2.0	7.4-8.4		
STUNTZ SERIES	MN0141	SIL,L	5	36	51	40	32	25	0-17	ML,SM,CL-ML,SM-SC	2.0-6.0	4.5-6.5	1.5-3.0	>60
			5	48	68	53	45	35	0-17	CL-ML,CL	0.6-2.0	4.5-6.5		
		VFSL,FSL	5	36	60	47	40	32	17-39	CL	0.2-0.6	5.1-7.8		
			5	48	78	62	53	42	39-60	CL,ML	0.2-0.6	6.6-8.4		
SUNBURG SERIES	MN0398		7						0-8	CL-ML,CL	0.6-2.0	6.6-8.4	>6.0	>60
									0-8	SC,SM,SM-SC	2.0-6.0	6.6-8.4		
									8-60	CL,ML,SC,SM	2.0-6.0	7.4-8.4		
SUOMI SERIES	MN0342		7						0-12	CL	0.2-0.6	5.1-7.3	>6.0	>60
									0-12	CL,ML,CL-ML	0.6-2.0	5.1-7.3		
									12-30	CH,CL	0.06-0.2	5.1-7.3		
									30-60	CH,CL	0.06-0.2	7.4-8.4		
SVEA SERIES NONFLOODED, PE>44	ND0231		7						0-10	CL,CL-ML	0.6-2.0	6.6-7.8	4.0-6.0	>60
									0-10	CL	0.6-2.0	6.6-7.8		
									10-21	CL,CL-ML	0.6-2.0	6.6-7.8		
									21-60	CL,CL-ML	0.2-2.0	7.4-8.4		
SVEA SERIES STONY	ND0309		7						0-10	CL,CL-ML	0.6-2.0	6.6-7.8	4.0-6.0	>60
									10-21	CL,CL-ML	0.6-2.0	6.6-7.8		
									21-60	CL,CL-ML	0.2-2.0	7.4-8.4		
SVERDRUP SERIES	MN0078		7						0-12	SM	2.0-6.0	6.1-7.3	>6.0	>60
									0-12	ML,CL,CL-ML	0.6-2.0	6.1-7.3		
									12-24	ML,SM	2.0-6.0	6.1-7.8		
									24-60	SP,SP-SM	6.0-20	7.4-8.4		

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SWANLAKE SERIES	MN0300		7						0-9	CL-ML,CL	0.6-2.0	7.4-7.8	>6.0	>60
									9-43	CL-ML,CL	0.6-2.0	7.4-8.4		
									43-60	ML,CL,CL-ML	0.6-2.0	7.4-8.4		
SWENODA SERIES	SD0143		7						0-15	SM	2.0-6.0	6.1-7.3	2.5-4.0	>60
									0-15	CL,CL-ML	0.6-2.0	6.1-7.3		
									15-29	SM-SC,SM,ML,CL-ML	2.0-6.0	6.6-7.8		
									29-60	CL,CL-ML	0.2-2.0	7.4-8.4		
SWENODA SERIES WELL DRAINED	SD0339		7						0-15	SM	2.0-6.0	6.1-7.3	>6.0	>60
									0-15	CL-ML,CL	0.6-2.0	6.1-7.3		
									15-29	SM-SC,SM,ML,CL-ML	2.0-6.0	6.6-7.8		
									29-60	CL,CL-ML	0.2-2.0	7.4-7.8		
SYRENE SERIES	MN0132		5	36	361	289	247	196	0-9	ML	0.6-2.0	7.4-8.4	1.0-3.0	>60
			5	48	443	357	306	246	0-9	SM,SC,SM-SC	2.0-6.0	7.4-8.4		
									0-9	SM,SC,ML,CL	0.6-2.0	7.4-8.4		
									9-17	SM,ML	2.0-6.0	7.9-8.4		
									17-60	SP-SM,SP	6.0-20	7.4-8.4		
SYRENE SERIES PONDED	MN0363		1						0-9	SM,SC,ML,CL	0.6-2.0	7.4-8.4	+1-1.0	>60
			5	36	361	289	247	196	0-9	ML	0.6-2.0	7.4-8.4		
			5	48	443	357	306	246	0-9	SM,SC,SM-SC	2.0-6.0	7.4-8.4		
									9-17	SM,ML	2.0-6.0	7.9-8.4		
									17-60	SP-SM,SP	6.0-20	7.4-8.4		
TACOOSH SERIES	MI0166		1						0-8	PT	0.2-6.0	5.6-7.8	+1-1.0	>60
			5	36	114	91	77	61	8-40	PT	0.6-6.0	5.6-7.8		
			5	48	141	113	96	77	40-60	SM,ML,CL-ML,CL	0.2-2.0	5.6-8.4		
TALCOT SERIES	MN0315		5	36	345	276	234	186	0-23	CL	0.6-2.0	7.4-8.4	1.0-2.5	>60
			5	48	423	341	292	233	23-30	CL	0.6-2.0	7.4-8.4		
									30-60	SP,SP-SM,SW	6.0-20	7.4-8.4		
TALCOT SERIES FLOODED	MN0504		1						0-22	CL	0.6-2.0	7.4-8.4	0-1.0	>60
			3	36	342	273	232	183	22-33	CL	0.6-2.0	7.4-8.4		
			3	48	419	337	288	231	33-60	SP,SP-SM,SW	6.0-20	7.4-8.4		
TALCOT SERIES PONDED	MN0107		1						0-23	CL	0.6-2.0	7.4-8.4	+1-1.0	>60
			5	36	345	276	234	186	23-30	CL	0.6-2.0	7.4-8.4		
			5	48	423	341	292	233	30-60	SP,SP-SM,SW	6.0-20	7.4-8.4		
TALLULA SERIES	IL0200		7						0-15	CL,CL-ML	0.6-2.0	6.6-7.8	>6.0	>60
									15-26	CL	0.6-2.0	6.6-7.8		
									26-60	CL,CL-ML	0.6-2.0	7.4-8.4		

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TALMOON SERIES	MN0380		1						0-6	ML,CL,CL-ML	0.6-2.0	5.1-7.3	+1-1.5	>60
			5	36	50	39	32	25	0-6	CL,ML,SM,SC	0.6-2.0	5.1-7.3		
			5	48	67	53	44	35	6-16	CL,SC,CL-ML,SM-SC	0.6-2.0	5.1-7.3		
									16-42	CL,ML	0.2-0.6	5.6-7.3		
									42-60	CL,CL-ML,SC,SM-SC	0.2-0.6	7.4-8.4		
TAMA SERIES	IA0049		7						0-14	ML	0.6-2.0	5.1-7.3	>6.0	>60
									14-45	CL	0.6-2.0	5.1-6.0		
									45-60	CL	0.6-2.0	5.6-7.3		
TAMA SERIES MODERATELY WET	IA0302		7						0-15	ML	0.6-2.0	5.1-7.3	4.0-6.0	>60
									15-50	CL	0.6-2.0	5.1-6.0		
									50-60	CL	0.6-2.0	5.6-7.3		
TAMA SERIES SANDY SUBSTRATUM	IA0245		7						0-22	CL-ML,CL	0.6-2.0	5.1-7.3	>6.0	>60
									22-41	CL	0.6-2.0	5.1-6.0		
									41-45	SM-SC,SC	2.0-6.0	5.1-6.5		
									45-60	SP-SM,SM,SM-SC	6.0-20	5.1-7.3		
TARA SERIES	MN0282		7						0-19	OL,ML	0.6-2.0	6.1-7.3	3.0-5.0	>60
									19-27	ML,CL-ML	0.6-2.0	6.6-7.8		
									27-33	CL-ML,ML	0.6-2.0	7.4-8.4		
									33-60	CL,CL-ML	0.6-2.0	7.4-8.4		
TAWAS SERIES	MI0027		1						0-31	PT	0.2-6.0	4.5-7.8	+1-1.0	>50
			5	36	347	278	236	187	31-60	SP,SM,SP-SM	6.0-20	5.6-8.4		
			5	48	426	343	294	235						
TAYLOR SERIES	MN0334		2						0-5	CL	0.6-2.0	5.6-7.3	3.0-6.0	>60
			5	36	22	17	14	11	0-5	CL	0.2-0.6	5.6-7.3		
			5	48	32	25	21	16	5-27	CH	0.06-0.2	5.1-7.8		
									27-60	CH	0.06-0.2	7.4-8.4		
TERRIL SERIES	IA0165		7						0-31	CL	0.6-2.0	6.1-7.3	>6.0	>60
									0-31	CL	0.6-2.0	6.1-7.3		
									31-60	CL	0.6-2.0	6.1-7.8		
TERRIL SERIES SANDY SUBSTRATUM	IA0224		7						0-31	CL	0.6-2.0	6.1-7.3	>6.0	>60
									31-45	CL	0.6-2.0	6.1-7.3		
									45-60	SP-SM,SM	6.0-20	6.1-8.4		

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THIEFRIVER SERIES	MN0412		5	36	135	110	96	78	0-10	ML,SM,SM-SC,CL-ML	2.0-6.0	7.4-8.4	1.0-3.0	>60
			5	48	166	136	117	96	0-10	ML,CL-ML	0.6-2.0	7.4-8.4		
									10-28	SM,SP-SM	6.0-20	7.4-8.4		
									28-33	SP-SM,GP-GM	6.0-20	7.4-8.4		
									33-60	CH,CL	0.06-0.2	7.4-8.4		
THISTLEDEW SERIES	MN0382		2						0-2	SM	6.0-20	5.1-6.5	3.0-4.0	>60
			5	36	102	83	71	58	0-2	SP-SM,SM	6.0-20	5.1-6.5		
			5	48	125	102	88	72	2-23	SM,SP-SM	6.0-20	5.1-6.5		
									23-38	SC,CL	0.2-0.6	5.6-7.8		
									38-60	CH	0.06-0.2	6.1-8.4		
TILFER SERIES	IA0212	SHALLOW BEDROCK	3	36	44	36	31	25	0-19	MH,OL,ML,OH	0.6-2.0	7.4-8.4	0-2.0	20-40
									19-35	SC,CL	0.6-2.0	7.4-8.4		
									35		-	-		
TILFER VARIANT	MN0460	SHALLOW BEDROCK	5	32	37	30	26	21	0-20	CL,CH	0.6-2.0	7.4-8.4	1.0-3.0	20-40
									20-32	CL	0.6-2.0	7.4-8.4		
									32-60		-	-		
TIMULA SERIES	IL0072		7						0-60	ML,CL-ML	0.6-2.0	6.1-8.4	>6.0	>60
TOIMI SERIES	MN0495	STONY AREAS	2						0-3	SM,SM-SC	0.6-2.0	4.5-6.0	1.0-2.5	>60
									0-3	SM,ML,SC,CL	0.6-2.0	4.5-6.0		
			5	36	77	62	53	42	0-3	SM,SM-SC,GM,GM-GC	0.6-2.0	4.5-6.0		
			5	48	97	78	67	54	3-23	SM,SC,ML,CL	0.6-2.0	4.5-6.0		
									23-32	SM,GM	0.6-2.0	5.6-6.5		
									32-60	SM,GM	0.2-0.6	5.6-6.5		
TONKA SERIES MAP>16	ND0229		1						0-19	CL,CL-ML	0.6-2.0	5.6-7.3	+.5-1.0	>60
			5	36	41	30	25	18	19-50	CH,CL	0.06-0.2	5.6-7.8		
			5	48	62	48	40	31	50-60	CL,CL-ML	0.2-0.6	6.6-9.0		
TORNING SERIES	MN0283		7						0-12	SM,ML	2.0-20	7.4-7.8	>6.0	>60
									0-12	ML,CL-ML	2.0-6.0	7.4-7.8		
									12-50	SM,ML	2.0-6.0	7.4-8.4		
TOWNER SERIES LOAMY	ND0228		7						0-6	SM,SM-SC	2.0-6.0	6.6-7.8	3.0-6.0	>60
									6-29	SM,SW-SM,SM-SC	6.0-20	6.6-7.8		
									29-60	CL,CL-ML	0.2-2.0	7.4-8.4		

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TOWNER	ND0022		7						0-6	SM,SM-SC	6.0-20	6.6-7.8	3.0-6.0	>60
SERIES									6-29	SM,SM-SC,SW-SM	6.0-20	6.6-7.8		
SANDY									29-60	CL,CL-ML	0.2-2.0	7.4-8.4		
TRENT	SD0100		7						0-25	CL,CH,ML,MH	0.6-2.0	5.6-7.3	3.5-6.0	>60
SERIES									0-25	CL	0.6-2.0	5.6-7.3		
FLOODED									25-39	CL,CH	0.6-2.0	6.1-7.3		
									39-60	CL	0.6-2.0	6.6-8.4		
TRENT	SD0390		7						0-25	CL,ML	0.6-2.0	6.1-7.3	3.0-6.0	>60
SERIES									25-39	CL,ML	0.6-2.0	6.1-7.8		
MODERATELY WET									39-60	CL,ML	0.6-2.0	6.6-8.4		
TRENT	SD0338		7						0-25	CL,CH,ML,MH	0.6-2.0	5.6-7.3	>6.0	>60
SERIES									0-25	CL	0.6-2.0	5.6-7.3		
NONFLOODED									25-39	CL,CH	0.6-2.0	6.1-7.3		
									39-60	CL	0.6-2.0	6.6-8.4		
TRENT	SD0258		7						0-25	CL,CH,ML,MH	0.6-2.0	6.1-7.3	3.5-6.0	>60
SERIES									0-25	CL,ML	0.6-2.0	6.1-7.3		
TILL SUBSTRATUM									25-39	CL,CH	0.6-2.0	6.1-7.8		
									39-50	CL,ML	0.6-2.0	6.6-8.4		
									50-60	CL	0.2-0.6	7.4-8.4		
TRIPOLI	IA0053		4	36	80	63	53	41	0-18	CL	0.6-2.0	6.1-7.3	1.0-2.0	>60
SERIES			4	48	103	82	69	55	18-38	CL	0.6-2.0	6.6-7.8		
									38-66	CL,SC	0.6-1.0	7.4-8.4		
TROSKY	MN0185		5	36	331	263	223	176	0-20	CL	0.2-2.0	7.4-8.4	1.0-3.0	>60
SERIES			5	48	410	329	281	225	20-38	CL	0.2-0.6	7.4-8.4		
									38-60	SP,SM,GP,GM	6.0-20	7.4-8.4		
TRUMAN	MN0036		7						0-14	ML,CL-ML,CL	0.6-2.0	5.6-7.3	>6.0	>60
SERIES									14-36	ML,CL,CL-ML	0.6-2.0	5.6-7.8		
									36-60	CL,CL-ML,ML	0.6-2.0	7.4-8.4		
TWIG	MN0165	SPECIAL DESIGN	1						0-12	PT	0.6-6.0	3.6-5.0	+1-1.0	>60
SERIES		NEEDED	5	20	16	13	11	9	12-20	OL,CL,CL-ML	0.06-0.6	3.6-5.0		
									20-26	ML	<0.06	3.6-5.0		
									26-72	SM	0.2-0.6	3.6-5.0		
UDOLPHO	MN0232		5	36	340	272	231	182	0-9	CL,ML	0.6-2.0	5.6-6.5	1.0-3.0	>50
SERIES			5	48	418	336	287	230	9-18	CL,ML	0.6-2.0	5.1-6.5		
									18-34	CL,ML	0.6-2.0	5.1-6.5		
									34-60	SP,SP-SM,GP,GP-GM	6.0-20	5.6-7.8		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BED-ROCK In.
UDOLPHO SERIES LOAMY SUBSTRATUM	MN0428		5	36	186	150	129	105	0-9	CL,ML	0.6-2.0	5.6-6.5	1.0-3.0	>60
			5	48	196	158	136	110	9-18	CL,ML	0.6-2.0	5.1-6.5		
									18-34	CL,ML	0.6-2.0	5.1-6.5		
									34-51	SP,SP-SM,GP,GP-GM	6.0-20	5.6-7.8		
									51-60	CL	0.2-2.0	6.6-7.8		
UDOLPHO SERIES LOAMY SUBSTRATUM, PONDED	MN0429		1						0-9	CL,ML	0.6-2.0	5.6-6.5	+1-2.0	>60
			5	36	158	127	109	88	9-18	CL,ML	0.6-2.0	5.1-6.5		
			5	48	166	134	115	92	18-34	CL,ML	0.6-2.0	5.1-6.5		
									34-45	SP,SP-SM,GP,GP-GM	6.0-20	5.6-7.8		
									45-65	CL	0.2-2.0	6.6-7.8		
ULEN SERIES	MN0037		2						0-15	SM	6.0-20	7.9-8.4	2.5-6.0	>60
			5	36	363	291	248	197	0-15	SM,SM-SC,SC	2.0-6.0	7.9-8.4		
			5	48	445	359	307	247	0-15	ML,CL,CL-ML	2.0-20	7.9-8.4		
									15-32	SM	6.0-20	7.9-8.4		
									32-60	SP-SM,SM	6.0-20	7.9-8.4		
ULEN SERIES LOAMY SUBSTRATUM	MN0355		5	36	102	82	71	57	0-6	SM,ML	2.0-6.0	7.9-8.4	2.5-6.0	>60
			5	48	121	98	84	68	6-40	SM	2.0-6.0	7.9-8.4		
									40-60	CL,CL-ML	0.2-0.6	7.9-8.4		
URNESS SERIES	MN0079		1						0-9	OL,CL,CL-ML	0.2-2.0	7.4-8.4	+2-1.0	>60
			5	36	97	75	63	49	9-32	ML,CL,CL-ML,OL	0.2-2.0	7.4-8.4		
			5	48	125	99	84	66	32-60	CL,ML	0.6-2.0	7.4-8.4		
URNESS VARIANT	MN0452		1						0-42	OL,CL,CL-ML	0.6-2.0	7.9-8.4	+1-2.0	>60
			5	36	170	133	112	86	42-74	PT	2.0-6.0	6.6-7.8		
			5	48	219	175	148	117						
VALLERS SERIES	MN0055		5	36	71	55	45	34	0-12	OL,CL,ML	0.2-0.6	7.4-8.4	1.0-2.5	>60
			5	48	94	74	62	49	0-12	OL,ML	0.6-2.0	7.4-8.4		
									12-21	CL	0.2-0.6	7.4-8.4		
									21-60	CL,CL-ML	0.6-1.0	7.4-8.4		
VALLERS SERIES BOULDERY	MN0389	STONY	5	36	71	55	45	34	0-12	OL,CL,ML	0.2-0.6	7.4-8.4	1.0-2.5	>60
			5	48	94	74	62	49	0-12	OL,ML	0.6-2.0	7.4-8.4		
									12-21	CL	0.2-0.6	7.9-8.4		
									21-60	CL,CL-ML	0.6-1.0	7.4-8.4		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	DRAINAGE COEFF. SPACINGS, Ft. In./24 Hrs. 1/4	3/8	1/2	3/4	HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
VALLERS SERIES SALINE	MN0147		5	36	71	55	45	34	0-12	OL,CL	0.2-0.6	7.4-8.4	0-1.0	>60
			5	48	94	74	62	49	0-12	OL,ML	0.6-2.0	7.4-8.4		
									12-21	CL	0.2-0.6	7.4-8.4		
									21-60	CL,CL-ML	0.6-1.0	7.4-8.4		
VASA SERIES	MN0231		5	36	83	67	57	46	0-9	ML	0.6-2.0	5.6-7.3	2.0-4.0	>60
			5	48	99	80	68	55	9-42	CL	0.6-2.0	5.1-7.3		
									42-60	CL-ML,CL,ML	0.6-2.0	6.6-7.3		
									60-65	CL,CL-ML,SC,SM-SC	0.2-0.6	6.6-7.3		
VENLO SERIES	ND0162		5	36	366	293	250	199	0-13	SM,SM-SC	6.0-20	6.6-7.3	0-2.0	>60
			5	48	448	361	310	249	0-13	SM	6.0-20	6.6-7.3		
									13-60	SM,SP-SM	6.0-20	7.4-8.4		
VES SERIES	MN0156		7						0-11	CL,ML	0.6-2.0	6.1-7.8	>6.0	>60
									11-21	CL	0.6-2.0	6.1-7.8		
									21-60	CL,ML	0.6-2.0	7.4-8.4		
VES SERIES STONY	MN0356		7						0-11	CL,ML	0.6-2.0	6.1-7.8	>6.0	>60
									11-21	CL	0.6-2.0	6.6-7.8		
									21-60	CL,ML	0.6-2.0	7.4-8.4		
VIENNA SERIES	SD0231		7						0-9	ML,CL	0.6-2.0	6.1-7.3	>6.0	>60
									0-9	ML,CL	0.6-2.0	6.1-7.3		
									9-17	ML,CL	0.6-2.0	6.1-7.3		
									17-29	CL	0.2-0.6	6.6-8.4		
									29-60	CL	0.2-0.6	7.4-8.4		
VIKING SERIES	MN0056		6						0-7	CL	0.6-2.0	6.6-7.8	1.0-3.0	>60
									0-7	CH,CL	0.2-0.6	6.6-7.8		
									7-18	CH,CL	<0.06	7.4-8.4		
									18-60	CH	<0.06	7.4-8.4		
VLASATY SERIES	MN0207		2						0-7	CL,ML	0.6-2.0	6.1-6.5	1.5-3.0	>60
			5	36	50	39	32	25	7-16	CL	0.6-2.0	5.1-6.0		
			5	48	67	53	44	35	16-42	CL	0.2-0.6	5.1-6.5		
									42-60	CL,CL-ML	0.2-0.6	7.4-8.4		
WACOUSTA SERIES	IA0004		1						0-14	CH,CL	0.6-2.0	6.1-7.8	+1-1.0	>60
			5	36	98	77	64	50	0-14	CL,ML	0.6-2.0	6.1-7.8		
			5	48	127	101	85	67	0-14	OH,MH	0.6-2.0	6.6-7.8		
									14-28	CH,CL	0.6-2.0	6.6-7.8		
									28-60	CL,ML	0.6-2.0	7.4-8.4		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
WADENA SERIES	MN0038		7						0-13	ML	0.6-2.0	6.1-7.3	>6.0	>60
									13-30	SM,ML,CL,SC	0.6-2.0	5.6-7.3		
									30-50	SP,SP-SM,GP,GP-GM	>20	6.6-8.4		
WADENA VARIANT	MN0440		7						0-11	CL,ML,CL-ML	0.6-6.0	6.6-7.3	>6.0	20-40
									11-18	CL,ML,CL-ML	0.6-2.0	6.6-7.3		
									18-32	CL,ML,SC,SM	0.6-6.0	7.4-7.8		
									32		-	-		
WADENILL SERIES	MN0423		7						0-10	CL-ML,CL	0.6-2.0	5.6-7.3	>6.0	>60
									0-10	SM-SC,SM,ML,CL-ML	2.0-6.0	5.6-7.3		
									10-31	CL,ML,SM,SC	2.0-6.0	5.6-7.3		
									31-60	CL,ML,SM,SC	2.0-6.0	7.4-8.4		
WAHPETON SERIES	ND0023		7						0-23	CH	0.2-2.0	6.1-7.8	>6.0	>60
									23-60	CH,CL	0.2-2.0	7.4-7.8		
WALDORF SERIES	MN0094		5	36	76	56	45	33	0-20	ML,MH	0.2-2.0	6.1-7.3	0-3.0	>60
			5	48	106	83	69	54	20-45	MH	0.2-0.4	6.6-7.8		
									45-60	MH,CL,ML,CH	0.2-2.0	7.4-8.4		
WALFORD SERIES	IA0089		5	36	69	50	38	27	0-6	CL	0.6-2.0	5.6-7.3	0-2.0	>60
			5	48	106	82	68	52	6-22	CL-ML,CL	0.6-2.0	5.1-7.3		
									22-60	CL,CH	0.2-0.6	5.1-6.0		
									60-65	CL	0.6-2.0	5.6-7.8		
WARBA SERIES	MN0140		7						0-15	ML,SM	0.6-2.0	5.1-6.5	>6.0	>60
									0-15	ML,CL,CL-ML	0.6-2.0	5.1-6.5		
									15-37	CL	0.2-0.6	5.6-7.3		
									37-60	CL	0.2-2.0	6.6-8.4		
WARMAN SERIES	MN0166		1						0-8	OL,ML	0.6-2.0	4.5-6.0	+2-1.0	>60
			5	36	450	361	309	246	0-8	SM	2.0-6.0	4.5-6.0		
			5	48	548	443	380	306	0-8	SM	2.0-6.0	4.5-6.0		
									8-20	ML,SM	0.6-2.0	5.1-7.3		
									20-60	GW,GP,SP,SW	>20	6.1-7.3		
WASKISH SERIES	MN0208		1						0-63	PT	>6.0	4.5	0-2.0	>60
			5	36	239	190	161	127						
			5	48	297	238	203	162						

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	SOIL CHARACTERISTICS: PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
WAUKON SERIES	MN0080		7		-				0-9	OL,ML,CL,CL-ML	0.2-2.0	6.1-7.3	>6.0	>60
									0-9	SM,SM-SC	2.0-6.0	6.1-7.3		
									9-24	CL,SC	0.6-2.0	6.1-7.8		
									24-60	ML,CL,SM,SC	0.6-2.0	7.4-8.4		
WAWINA SERIES	MN0330		7						0-3	SM,ML	2.0-6.0	5.1-6.5	>6.0	> 60
									0-3	SM	2.0-6.0	5.1-6.5		
									3-60	SM,ML	2.0-6.0	5.1-7.3		
WEBSTER SERIES	IA0072		5	36	98	77	64	50	0-16	CL,CH	0.6-2.0	6.6-7.3	1.0-2.0	>60
			5	48	127	101	85	67	16-32	CL	0.6-2.0	6.6-7.8		
									32-60	CL	0.6-2.0	7.4-8.4		
WEBSTER VARIANT	MN0319	SHALLOW BEDROCK	5	19	18	14	13	10	0-9	CL	0.6-2.0	5.1-6.5	0.5-1.5	10-20
									9-19	CL	0.6-2.0	5.1-7.3		
									19		-	-		
WHALAN SERIES	MN0112		7						0-12	ML	0.6-2.0	5.6-7.3	>6.0	20-40
									12-22	CL	0.6-2.0	5.1-6.5		
									22-24	CL,CH	0.06-0.6	5.6-7.8		
									24		-	-		
WHEATVILLE SERIES	MN0039		2						0-11	OL,ML,CL,CL-ML	2.0-6.0	7.4-8.4	2.5-6.0	>60
			5	36	73	59	51	41	11-30	ML,CL,CL-ML	2.0-6.0	7.4-8.4		
			5	48	90	73	63	51	30-60	CH,CL	0.06-0.2	7.4-7.8		
WHITEWOOD SERIES	SD0045		3	36	85	66	55	41	0-7	ML,CL	0.2-2.0	6.1-7.3	0-2.0	>60
			3	48	111	88	74	58	7-25	CL,CH	0.2-0.6	6.1-7.8		
									25-43	CL,CH	0.2-2.0	7.4-8.4		
									43-60	CL,CH	0.2-2.0	7.4-8.4		
WHITEWOOD SERIES NONFLOODED	SD0392		5	36	54	42	36	27	0-25	CL,CH	0.2-2.0	6.1-7.8	1.0-3.0	>60
			5	48	71	56	48	38	25-43	CL,CH	0.2-0.6	6.6-7.8		
									43-60	CL,CH	0.2-0.6	7.4-8.4		
WILDWOOD SERIES	MN0181		1						0-12	PT	2.0-6.0	5.1-6.5	+1-1.0	>60
			5	36	22	17	14	11	12-24	CH	0.06-0.2	5.6-7.3		
			5	48	32	25	21	16	24-60	CH	0.06-0.2	7.4-8.4		
WILMONTON SERIES	MN0209		5	36	68	52	44	33	0-17	CL	0.6-2.0	6.1-7.3	2.5-5.0	>60
			5	48	89	70	59	46	17-25	CL	0.2-0.6	6.1-7.8		
									25-60	CL	0.4-1.0	7.4-8.4		

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SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	SOIL CHARACTERISTICS: HORIZ DEPTH In.	UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
WILMONTON VARIANT	MN0441	SPECIAL DESIGN NEEDED	2						0-19	CL,SC,CL-ML,SM-SC	0.6-2.0	6.6-7.3	2.0-3.0	>60
			5	19	18	15	13	10	19-41	CH,MH	<0.06	6.6-8.4		
									41-60	CH,MH	<0.06	7.4-8.4		
WINGER SERIES	MN0285		5	36	90	71	59	46	0-7	ML,CL,CL-ML	0.6-2.0	7.4-8.4	1.0-3.0	>60
			5	48	117	93	79	62	7-31	ML,CL,CL-ML	0.6-2.0	7.4-8.4		
									31-60	ML,CL,CL-ML	0.2-2.0	7.4-8.4		
WINNEBAGO SERIES	IL0241		7						0-15	ML,CL	0.6-2.0	5.1-6.5	>6.0	>60
									0-15	SC,CL,GC	0.6-2.0	5.1-6.0		
									15-66	SC,CL,GC	0.6-2.0	5.1-6.0		
									66-74	SC,GM-GC,SM-SC,CL	0.6-2.0	5.6-7.8		
WINNESHIEK VARIANT	MN0485		7						0-12	CL	0.6-2.0	5.6-7.3	>6.0	>60
									12-21	CL	0.6-2.0	5.1-6.5		
									21-31	CH	0.6-2.0	6.1-7.3		
									31-60	SM,ML	2.0-6.0	7.4-8.4		
WINTERFIELD SERIES	MI0263		3	36	366	293	250	199	0-7	SM	2.0-6.0	5.6-7.8	0.5-1.5	>60
			3	48	448	361	310	249	0-7	SM,SP-SM	6.0-20	5.6-7.8		
									0-7	SM,SM-SC	2.0-6.0	5.6-7.8		
									7-31	SM,SP-SM	6.0-20	5.6-7.8		
									31-60	SM,SP-SM,SP	6.0-20	5.6-8.4		
WYANDOTTE SERIES	MN0404		5	36	130	106	92	75	0-8	CL-ML,CL	0.6-2.0	7.4-7.8	1.0-3.0	>60
			5	48	160	130	113	92	8-15	CL-ML,CL	0.6-2.0	7.9-8.4		
									15-34	SM,SP,GP,GM	6.0-20	7.4-8.4		
									34-60	CH,CL	0.06-0.2	7.4-7.8		
WYKEHAM SERIES	MN0503		5	36	57	44	37	29	0-7	SM,SM-SC	0.6-6.0	5.1-6.5	2.5-5.0	>60
			5	48	74	59	50	39	7-19	SM,SM-SC	0.6-2.0	5.1-6.5		
									19-28	SC	0.2-2.0	5.6-7.3		
									28-60	SM-SC,SC	0.2-0.6	7.4-8.4		
WYKOFF SERIES	WI0338		7						0-9	ML,CL,CL-ML	0.6-2.0	5.6-7.3	>5.0	>60
									9-15	CL	0.6-2.0	5.1-6.5		
									15-23	CL,SC	0.6-2.0	5.1-6.5		
									23-30	SC,SM-SC,CL,CL-ML	0.6-2.0	5.1-6.5		
									30-60	SM,ML,SP-SM,GM	0.6-2.0	5.6-6.5		
WYNDMERE SERIES	ND0025		2						0-7	SM,ML	2.0-6.0	7.9-8.4	2.0-5.0	>60
			5	36	190	150	127	100	0-7	ML	2.0-6.0	7.9-8.4		
			5	48	238	191	162	129	7-26	SM,ML	2.0-6.0	7.9-8.4		
									26-60	SM,ML	2.0-6.0	7.9-8.4		

DRAINAGE GUIDE DATA FOR MINNESOTA

SOIL NAME UNIT KIND MODIFIER	ID NO.	DRAIN DESIGN RECOMMENDATIONS: COMMENTS	DSN GRP	DRAIN DEPTH In.	SPACINGS, Ft. DRAINAGE COEFF. In./24 Hrs. 1/4	3/8	1/2	3/4	HORIZ DEPTH In.	SOIL CHARACTERISTICS: UNIFIED SOIL CLASSIFICATION	PERMEABILITY In./Hr.	pH RANGE	DEPTH TO WATER TABLE Ft.	DEPTH TO BEDROCK In.
WYNDMERE SERIES SALINE	ND0226		5	36	190	150	127	100	0-7	SM,ML	2.0-6.0	7.9-8.4	2.0-4.0	>60
			5	48	238	191	162	129	7-26	SM,ML	2.0-6.0	7.9-8.4		
									26-60	SM,ML	2.0-6.0	7.9-8.4		
ZELL SERIES	SD0196		7						0-6	CL,ML	0.6-2.0	6.6-8.4	> 6.0	>60
									0-6	ML,CL-ML	0.6-2.0	6.6-8.4		
									6-26	CL,ML,CL-ML	0.6-2.0	7.4-8.4		
									26-60	ML,CL-ML	0.6-2.0	7.4-8.4		
ZIMMERMAN SERIES	MN0252		8						0-10	SM	6.0-20	5.1-6.5	>6.0	>60
									0-10	SM,SP-SM	6.0-20	5.1-6.5		
									10-60	SM,SP-SM	6.0-20	6.1-7.3		
ZOOK SERIES	IA0073		3	36	35	28	24	19	0-20	CH,CL	0.2-0.6	5.6-7.3	1.0-3.0	>60
			3	48	45	36	31	25	0-20	CH	0.06-0.2	5.6-7.3		
									0-20	CL,CL-ML	0.6-2.0	5.6-7.3		
									20-60	CH	0.06-0.2	5.6-7.8		
ZUMBRO SERIES	MN0210	SL,FSL	7						0-8	SM	2.0-6.0	5.6-7.8	>6.0	>60
		LS,LFS	8						0-8	SM	6.0-20	5.6-7.8		
									8-40	SM	6.0-20	5.6-7.8		
									40-50	SP,SM,SP-SM	6.0-20	6.1-7.8		
									50-65	SP,SM,SP-SM	6.0-20	6.1-7.8		
ZWINGLE SERIES	IA0103		6						0-13	CL-ML,CL	0.2-0.6	4.5-7.3	1.0-2.0	>60
									13-46	CH	<0.06	4.5-6.5		
									46-60	CL,SC,CL-ML,SM-SC	2.0-6.0	6.1-6.5		
ZWINGLE VARIANT	MN0434		6						0-6	CL,CH,MH	0.2-0.6	5.1-7.3	1.0-2.0	>60
									6-47	CH	<0.06	4.5-6.0		
									47-60	CL,CH	0.06-0.2	5.6-7.8		

DRAINAGE SCOPE AND EFFECT

In carrying out the wetland provisions of the Food Security Act there are many cases where we need to make an estimate of the scope and effect of present or planned drainage systems. When determining scope and effect of drainage, both surface and subsurface drainage must be considered in relation to FSA criteria. Assuming that surface drainage is adequate, the question is how far away from a drain is the saturated soil criteria removed?

In order to simplify this evaluation for the most common situations, tables of open ditch and tile drainage lateral effect have been developed. Every hydric soil identified for Minnesota was included in these tables. Before these tables are used, the rationale and assumptions used in their development must be understood.

RATIONALE

1. An area is considered converted (drained) if the saturated soil criteria is not met. This criteria is:
* a water table at less than 1.0 foot in depth if the soil permeability in the top 20 inches is greater than 6.0 in/hr, or
* a water table at less than 1.5 feet in depth if the soil permeability in the top 20 inches is less than 6.0 in/hr.
The water table must exist for a significant period (more than a week) during the growing season.

2. A drain system that lowers the water table below those depths in time less than "significant" under normal circumstances will drain the soil for swampbuster purposes.

3. Mineral soils for which we have data have drainable water volumes of less than 1 inch in the top 1.5 feet of soil. Most have drainable water volumes of less than 1/2 inch for the top 1.5 feet.

4. If we assume that 1 inch of water needs to be removed in approximately 7 days, then 1/7 inch of water must be removed each day (this is a 1/7th inch drainage coefficient). For swampbuster purposes we have used a 1/8 inch drainage coefficient which will remove 1 inch of water in 8 days. This level of drainage is not the same as drainage for optimum crop production. Drainage for crop production is normally based upon a 3/8 inch or greater drainage coefficient.

5. The following formula was used to estimate the lateral effect of drainage:

$$L_e = 0.5 \sqrt{\frac{[8(K_b)(d_e)(\Delta h) + 4(K_a)(\Delta h^2)]}{q}}$$

where: L_e = Maximum lateral effect of the drain (in/hr).

K_a = weighted average soil permeability from the drawdown level to the drain in inches/hr.

K_b = weighted average soil permeability below the drain to an impermeable barrier in inches/hr. When using soil survey data, use the permeability of the lowest layer for depths beyond 5 feet unless better information is available.

d_e = depth from drain to an impermeable layer in feet for open ditches. For tile this is an effective depth that is computed. See the Minnesota Drainage Guide, pg 3-4.

Δh = drainage head, the difference between the drain depth and the desired drawdown level (1 foot or 1.5 feet below the soil surface depending upon soil permeability) in feet.

q = drainage coefficient (in/hour). Note that the units are in inches per hour. The 24 hour drainage coefficient must be converted.

ASSUMPTIONS

The formula described above has been used to estimate the lateral effect of drainage on hydric soils in Minnesota. The results of those computations are included in the attached table. In order to develop this table several assumptions were made. These assumptions are listed below.

a. Surface drainage is assumed to be adequate.

b. The average permeability for each soil layer was used. Actual permeabilities may be higher or lower, which will increase or decrease the effective width of drainage respectively.

c. If an impermeable layer was not identified in the soils data, one was assumed at a depth of 10 feet.

d. It was assumed that the drainage ditch or tile has adequate capacity to remove 1/8 inch of water from the area drained in 24 hours. If a tile size and grade are

known, the maximum area drained by that tile can be checked with Figure 4-7 or 4-8 in the Minnesota Drainage Guide. For a 1/8 inch drainage coefficient, the maximum area drained is is twice the number of acres drained for a 1/4 inch drainage coefficient.

If these assumptions are reasonable for a given situation, the following tables can then be used for determining the effective width of drainage. When using these tables, the drain depth refers to the depth of a tile or ditch. In cases where the normal water level in an open ditch is above the bottom of the ditch, use the depth to the water surface as the drain depth.

By entering these tables with the drain depth and soil type, the lateral effect can be read directly. For most soils, the lateral effect is based upon a 1.5 foot drawdown. However a drawdown of 1.0 foot was used for soils with a permeability of 6 inches per hour or greater in the upper 20 inches. Those soils are marked with an asterisk. The lateral effect distances listed in the tables are an estimated distance each side of the drain where the saturated soil criteria will not be met.

Table 3-2

LATERAL EFFECT OF OPEN DITCHES

CAUTION: See write-up for limitations and assumptions.

SOIL NAME	ID NO.	DRAIN DEPTH 2.0'	3.0'	4.0'	5.0'
ADOLPH	MN0188	28	46	57	66
ADOLPH	MN0489	28	46	57	66
ADRAIN	MI0028	136	233	290	330
ALGANSEE*	MI0123	206	283	335	374
AMES	IA0195	38	66	85	97
ARVESON	MN0050	126	215	268	305
ARVESON	MN0359	126	215	268	305
AUBURNDALE	WI0089	45	75	94	107
AUGSBURG	MN0125	30	43	55	65
AUGSBURG	MN0361	30	43	55	65
BARBERT	MN0006	23	40	50	57
BARODA	MN0007	42	72	90	102
BARRONETT	WI0218	42	70	87	100
BARRONETT	WI0301	159	275	348	395
BEARVILLE	MN0383	15	25	31	36
BEAUFORD	MN0045	14	24	30	34
BELLEVILLE*	MI0054	78	99	120	137
BERGLAND	MI0127	7	12	14	16
BESEMAN	MN0189	37	55	70	81
BISCAY	MN0110	135	231	288	328
BISCAY	MN0316	135	231	288	328
BLACKHOOF	MN0158	36	62	78	91
BLOMFORD*	MN0239	83	113	136	154
BLUE EARTH	MN0064	43	72	90	102
BLUE EARTH	MN0439	25	42	53	60
BLUE EARTH	MN0461	45	76	95	109
BLUE EARTH	MN0507	130	224	283	321
BLUFFTON	MN0184	27	45	56	65
BOASH	MN0396	44	75	93	106
BOOTS	WI0045	72	121	152	173
BORUP	MN0051	130	219	273	311
BORUP	MN0081	130	219	273	311
BORUP	MN0358	130	219	273	311
BOWSTRING	MN0336	77	126	155	177
BREMER	IA0135	25	43	53	61
BRICKTON	MN0258	23	38	48	55
BROPHY	MN0259	80	134	167	190

LATERAL EFFECT OF OPEN DITCHES

CAUTION: See write-up for limitations and assumptions.

SOIL NAME	ID NO.	DRAIN DEPTH 2.0'	3.0'	4.0'	5.0'
BROWNSDALE	MN0432	27	44	55	63
BROWNTON	MN0008	39	66	83	94
BULLWINKLE	MN0469	52	83	102	117
BURR	MN0332	25	42	53	60
CALCO	IA0075	45	76	95	109
CANISTEO	MN0059	45	76	95	109
CANISTEO	MN0095	45	76	95	109
CANISTEO	MN0328	45	76	95	109
CANISTEO	MN0417	131	225	283	322
CARLOS	MN0468	70	118	147	168
CARON	MN0023	70	107	121	142
CARON	MN0044	70	107	121	142
CATHRO	MI0031	43	72	90	103
CATHRO	MI0392	43	72	90	103
CHASKA	MN0065	75	128	160	182
CHILGREN	MN0261	45	76	95	109
CLEARWATER	MN0395	14	24	30	34
CLOTHO	MN0501	25	42	53	60
CLYDE	IA0046	47	79	97	111
COLAND	IA0079	68	116	146	166
COLO	IA0071	45	76	95	109
COLO	IA0291	45	76	95	109
COLO	IA0296	45	76	95	109
COLVIN	ND0001	40	68	85	97
COLVIN	ND0002	40	68	85	97
COLVIN	ND0295	25	42	53	60
COMFREY	MN0066	45	76	95	109
COMFREY	MN0305	45	76	95	109
CORDOVA	MN0024	43	74	92	105
CORIFF	MN0393	62	93	118	136
CORMANT*	MN0385	206	283	335	372
CORUNNA	MI0369	50	82	102	118
DARFUR	MN0009	80	133	167	190
DASSEL	MN0386	139	235	293	334
DAWSON	MI0134	133	227	286	325
DEERWOOD	MN0018	144	241	301	343
DELFT	MN0295	25	35	45	53
DOVRAY	MN0052	19	33	42	48
DUNDAS	MN0211	42	72	91	103
DUSLER	MN0160	16	26	33	38
EFFIE	MN0335	14	24	30	34
ENLOE	ND0013	14	24	30	34
EPOUFETTE	MI0120	172	292	364	415
EPOUFETTE*	MI0206	246	283	335	372

LATERAL EFFECT OF OPEN DITCHES

CAUTION: See write-up for limitations and assumptions.

SOIL NAME	ID NO.	DRAIN DEPTH 2.0'	3.0'	4.0'	5.0'
ESPELIE	MN0406	27	46	59	70
ESSEXVILLE*	MI0421	59	77	94	109
EVART*	MI0226	206	283	335	374
FARGO	ND0020	14	24	30	34
~~FARGO~~	~~ND0111~~	~~14~~	~~24~~	~~30~~	~~34~~
FARGO	ND0201	14	24	30	34
FARGO	ND0233	39	67	83	95
FARGO	ND0235	39	67	83	95
FAXON	MN0082	16	22	29	34
FAXON	MN0294	18	24	31	36
FIELDON	MN0011	133	229	286	325
FLOM	MN0069	25	42	53	60
FLOM	MN0388	25	42	53	60
FORADA	MN0070	139	236	294	335
FORADA	MN0499	139	236	294	335
FORDUM	WI0397	139	235	293	334
FOSSUM	MN0102	144	241	301	343
FOSSUM	MN0424	144	241	301	343
FULDA	MN0187	25	42	52	60
GARWIN	IA0037	45	76	95	109
GLENCOE	MN0026	45	75	94	107
GLENCOE	MN0444	45	75	94	107
GRANBY*	MI0029	206	283	335	374
GREENWOOD	MI0394	72	121	152	173
GRYGLA*	MN0020	88	115	139	157
GRYGLA*	MN0416	88	115	139	157
GRYGLA*	MN0487	88	115	139	157
HAMAR*	SD0141	189	260	308	344
HAMEL	MN0084	43	73	91	104
HAMRE	MN0418	42	70	87	100
HANGAARD*	MN0130	206	283	335	374
HANSKA	MN0028	141	237	295	337
HANSKA	MN0463	141	237	295	337
HANSKA	MN0477	141	237	296	337
HARPS	IA0157	45	76	95	109
HARPSTER	IL0147	45	76	95	109
HARPSTER	IL0348	45	76	95	109
HAUG	MN0021	45	76	95	109
HAVANA	MN0221	41	69	88	101
HAVERHILL	MN0255	5	7	9	10
HEGNE	MN0053	13	22	27	31
HIDEWOOD	MN0013	42	70	87	100
HILLET	MN0267	138	234	291	332
HILLET	MN0467	138	234	291	332

LATERAL EFFECT OF OPEN DITCHES

CAUTION: See write-up for limitations and assumptions.

SOIL NAME	ID NO.	DRAIN DEPTH 2.0'	3.0'	4.0'	5.0'
HOUGHTON	MI0024	70	118	147	168
HOUGHTON	MI0291	70	118	147	168
HUMESTON	IA0136	9	15	19	23
INDUS	MN0268	14	24	30	34
ISAN*	MN0269	206	283	335	374
ISAN*	MN0528	206	283	335	374
ISANTI*	MN0196	206	283	335	374
JEFFERS	MN0296	28	45	57	65
JOLIET	IL0153	8	14	18	21
KALMARVILLE	MN0287	132	226	285	325
KATO	MN0213	135	231	288	327
KATO	MN0323	137	233	290	330
KERSTON	MI0022	121	207	258	294
KNOKE	IA0256	25	42	53	60
KRATKA*	MN0072	79	108	130	147
KRATKA*	MN0419	79	108	130	147
LAKEPARK	MN0475	25	42	53	60
LAMOURE	SD0176	42	70	87	100
LAWSON	WI0044	45	76	95	109
LEAFRIVER	MN0530	144	241	301	343
LEAFRIVER	MN0531	144	241	301	343
LEMOND	MN0029	139	235	294	334
LEMOND	MN0443	73	115	133	154
LEMOND	MN0462	139	235	294	334
LEMOND	MN0478	141	237	295	337
LENA	IL0123	80	134	167	190
LETRI	MN0106	26	44	54	62
LINDAAS	ND0005	37	64	81	93
LOBO*	MN0149	130	170	202	227
LOXLEY	MI0080	70	118	147	168
LUDDEN	ND0032	14	24	30	34
LUPTON	MI0393	70	118	147	168
LURA	MN0032	20	34	44	50
LURA	MN0464	20	34	44	50
MADELIA	MN0033	45	76	95	109
MAHTOWA	MN0171	25	42	53	60
MARCUS	IA0129	42	71	90	102
MARKEY	MI0030	138	234	291	332
MARKEY	MI0387	138	234	291	332
MARNA	MN0089	40	68	84	96
MARSHAN	MN0104	138	234	291	332
MARSHAN	MN0324	138	234	291	332
MARSHAN	MN0521	74	127	144	152
MARTISCO	NY0106	14	24	30	34

LATERAL EFFECT OF OPEN DITCHES

CAUTION: See write-up for limitations and assumptions.

SOIL NAME	ID NO.	DRAIN DEPTH 2.0'	3.0'	4.0'	5.0'
MARYSLAND	MN0103	140	236	294	335
MARYSLAND	MN0320	140	236	294	335
MAVIE	MN0134	59	91	116	134
MAXCREEK	MN0151	45	76	95	109
MAXCREEK	MN0365	45	76	95	109
MAXFIELD	IA0055	45	76	95	109
MAXFIELD	IA0338	45	76	95	109
MAYER	MN0197	136	232	289	329
MAYER	MN0314	136	232	289	329
MAZASKA	MN0272	38	65	82	93
MCDONALDSVILLE	D0145	137	233	290	331
MERWIN	MN0163	72	121	152	173
MILLERVILLE	MN0274	19	32	41	47
MILLINGTON	IL0222	45	76	95	109
MILLINGTON	IL0349	161	277	349	397
MINNETONKA	MN0090	39	67	84	95
MINNETONKA	MN0474	43	74	92	104
MOOSELAKE	MN0167	80	134	167	190
MORPH	MN0340	45	76	95	109
MOUNDPRAIRIE	MN0369	45	76	95	109
MOUNDPRAIRIE	MN0370	45	76	95	109
MUSKEGO	WI0046	26	39	49	58
MUSKEGO	WI0437	48	80	100	114
NEWALBIN	MN0371	45	76	95	109
NEWALBIN	MN0372	45	76	95	109
NEWALBIN	MN0373	31	49	60	70
NEWSON	WI0446	144	241	301	343
NISHNA	IA0155	14	24	30	34
NISHNA	IA0326	14	24	30	34
NOKASIPPI*	MN0275	68	87	105	120
NOKAY	MN0276	19	29	36	42
NORTHCOTE	MN0022	14	24	30	34
NORTHCOTE	MN0362	14	24	30	34
NORTHWOOD	MN0486	51	87	109	125
NOWEN	MN0201	45	76	95	109
NOYES	MN0119	14	24	30	34
OKOBOJI	IA0131	31	53	67	76
OKOBOJI	IA0327	25	42	53	60
OLDHAM	SD0174	23	38	48	55
OSHAWA	MN0017	25	42	53	60
OTTER	ILOO78	45	76	95	109
OTTER	IL0360	45	76	95	109
PALMS	MI0023	47	76	95	109
PALMS	MI0271	118	203	259	294

LATERAL EFFECT OF OPEN DITCHES

CAUTION: See write-up for limitations and assumptions.

SOIL NAME	ID NO.	DRAIN DEPTH 2.0'	3.0'	4.0'	5.0'
PALMS	MI0448	47	76	95	109
PARENT	MN0168	17	27	35	40
PARENT	MN0212	17	27	35	40
PARENT	MN0387	17	27	35	40
PARNELL	MN0035	15	25	31	35
PENGILLY	MN0381	45	76	95	109
PERCY	MN0048	45	76	95	109
PERCY	MN0510	45	76	95	109
PERALLA	ND0076	25	42	53	60
PREBISH	MN0248	30	49	60	69
PREBISH	MN0436	30	49	60	69
QUAM	MN0075	25	42	53	60
RAUVILLE	SD0177	73	124	157	179
RAUVILLE	SD0437	73	124	157	179
REGAL	MN0352	144	241	301	343
REVERE	MN0433	45	76	95	109
RIFLE	MI0391	72	121	152	173
ROCKWELL	MN0054	53	85	108	124
ROCKWELL	MN0360	53	85	108	124
ROLFE	IA0159	41	68	85	97
ROLISS	MN0076	42	70	87	100
ROLISS	MN0420	42	70	87	100
ROMNELL	MN0298	25	42	53	60
RONDEAU	MN0148	36	54	62	73
ROOT	MN0299	167	287	357	406
ROSCOMMON*	MI0159	206	283	335	374
ROSCOMMON*	MI0422	206	283	335	374
ROSEWOOD	MN0414	144	241	301	343
ROSEWOOD	MN0427	144	241	301	343
RUNEBERG	MN0293	23	39	48	55
RUNEBERG	MN0500	23	39	48	55
RUSHMORE	MN0230	27	45	56	64
SAGO	MN0331	45	76	95	109
SARGEANT	MN0143	15	25	31	35
SAWMILL	IL0084	45	76	95	109
SAX	MN0411	45	76	95	109
SEELYEVILLE	MN0128	70	118	147	168
SEELYEVILLE	MN0353	70	118	147	168
SHAKOPEE	MN0466	131	226	283	322
SHANDEP	IA0226	124	214	274	313
SHILOH	IL0068	25	42	53	60
SHILOH	IL0393	25	42	53	60
SHOOKER	MN0139	45	76	95	109
SMILEY	MN0413	45	76	95	109

LATERAL EFFECT OF OPEN DITCHES

CAUTION: See write-up for limitations and assumptions.

SOIL NAME	ID NO.	DRAIN DEPTH 2.0'	3.0'	4.0'	5.0'
SMILEY	MN0488	42	70	87	100
SPICER	MN0093	45	76	95	109
SPICER	MN0318	45	76	95	109
SPOONER	MN0135	45	76	95	109
STAPLES*	MN0509	89	104	127	146
STATELINE	MN0481	7	12	14	16
STRANDQUIST	MN0122	47	80	100	114
SYRENE	MN0132	144	241	301	343
SYRENE	MN0363	144	241	301	343
TACOOSH	MI0166	49	79	98	113
TALCOT	MN0107	138	234	291	332
TALCOT	MN0315	138	234	291	332
TALMOON	MN0380	25	42	53	60
TAWAS	MI0027	138	234	292	333
TAWAS	MI0138	138	234	292	333
THIEFRIVER	MN0412	52	72	93	109
TILFER	IA0212	18	24	31	36
TONKA	ND0229	23	39	50	57
TRIPOLI	IA0053	45	76	95	109
TROSKY	MN0185	131	227	284	322
TWIG	MN0165	25	42	52	59
UDOLPHO	MN0073	136	233	290	330
UDOLPHO	MN0232	135	231	288	328
UDOLPHO	MN0428	71	119	132	147
UDOLPHO	MN0429	62	103	114	132
URNESS	MN0079	42	70	87	100
VALLERS	MN0055	25	42	53	60
VALLERS	MN0389	25	42	53	60
VENLO*	ND0162	206	283	335	374
VIKING	MN0056	7	12	14	16
WABANICA	MN0533	45	76	95	109
WACOUSTA	IA0004	45	76	95	109
WALDORF	MN0094	39	66	84	95
WALFORD	IA0089	39	67	85	99
WARMAN	MN0166	136	232	289	329
WASKISH*	MN0208	206	283	335	374
WAUPACA	WI0398	25	42	53	60
WEBSTER	IA0072	45	76	95	109
WHITEWOOD	SD0392	25	42	53	60
WILDWOOD	MN0181	14	24	30	34
WINGER	MN0285	42	71	88	101
WINGER	MN0508	42	71	88	101
WOODSLAKE	MN0534	7	12	14	16
WYANDOTTE	MN0404	54	74	96	113

LATERAL EFFECT OF OPEN DITCHES

CAUTION: See write-up for limitations and assumptions.

SOIL NAME	ID NO.	DRAIN DEPTH 2.0'	3.0'	4.0'	5.0'
ZIPPEL	MN0523	80	134	167	190
ZOOK	IA0073	21	35	45	51
ZWINGLE	IA0103	69	119	153	173

Table 3-3

LATERAL EFFECT FOR DRAIN TILE

SOIL NAME	ID	24" DEPTH	36" DEPTH	48" DEPTH	60" DEPTH
ADOLPH	MN0188	23	42	54	64
ADOLPH	MN0489	23	42	54	64
ADRAIN	MI0028	129	228	287	328
ALGANSEE*	MI0123	200	278	332	373
AMES	IA0195	32	61	80	95
ARVESON	MN0050	119	210	264	303
ARVESON	MN0359	119	210	264	303
AUBURNDALE	WI0089	38	70	90	105
AUGSBURG	MN0125	26	42	54	64
AUGSBURG	MN0361	26	42	54	64
BARBERT	MN0006	18	35	46	54
BARODA	MN0007	35	66	86	99
BARRONETT	WI0218	36	65	84	98
BARRONETT	WI0301	152	270	344	393
BEARVILLE	MN0383	11	21	28	34
BEAUFORD	MN0045	10	20	27	32
BELLEVILLE*	MI0054	75	98	119	137
BERGLAND	MI0127	4	8	12	15
BESEMAN	MN0189	31	52	68	80
BISCAY	MN0110	128	226	284	326
BISCAY	MN0316	128	226	284	326
BLACKHOOF	MN0158	30	56	74	89
BLOMFORD*	MN0239	79	111	134	153
BLUE EARTH	MN0064	37	67	87	100
BLUE EARTH	MN0439	20	38	49	58
BLUE EARTH	MN0461	39	71	92	106
BLUE EARTH	MN0507	123	218	279	319
BLUFFTON	MN0184	22	41	53	63
BOASH	MN0396	38	69	89	104
BOOTS	WI0045	66	116	148	171
BORUP	MN0051	123	213	269	309
BORUP	MN0081	123	213	269	309
BORUP	MN0358	123	213	269	309
BOWSTRING	MN0336	70	121	151	175
BREMER	IA0135	20	38	50	58
BRICKTON	MN0258	18	34	45	52
BROPHY	MN0259	73	129	163	189
BROWNSDALE	MN0432	22	40	52	62
BROWNTON	MN0008	32	61	79	92
BULLWINKLE	MN0469	46	79	99	116
BURR	MN0332	20	38	49	58
CALCO	IA0075	39	71	92	106
CANISTEO	MN0059	39	71	92	106
CANISTEO	MN0095	39	71	92	106

LATERAL EFFECT FOR DRAIN TILE

SOIL NAME	ID	24" DEPTH	36" DEPTH	48" DEPTH	60" DEPTH
CANISTEO	MN0328	39	71	92	106
CANISTEO	MN0417	124	220	280	320
CARLOS	MN0468	64	113	143	166
CARON	MN0023	64	104	121	142
CARON	MN0044	64	104	121	142
CATHRO	MI0031	37	67	86	101
CATHRO	MI0392	37	67	86	101
~~CHASKA~~	~~MN0065~~	~~68~~	~~123~~	~~156~~	~~180~~
CHILGREN	MN0261	39	71	92	106
CLEARWATER	MN0395	10	20	27	32
CLOTHO	MN0501	20	38	49	58
CLYDE	IA0046	41	74	93	109
COLAND	IA0079	61	111	142	163
COLO	IA0071	39	71	92	106
COLO	IA0291	39	71	92	106
COLO	IA0296	39	71	92	106
COLVIN	ND0001	35	63	81	94
COLVIN	ND0002	35	63	81	94
COLVIN	ND0295	20	38	49	58
COMFREY	MN0066	39	71	92	106
COMFREY	MN0305	39	71	92	106
CORDOVA	MN0024	37	68	88	102
CORIFF	MN0393	56	90	116	135
CORMANT*	MN0385	200	278	332	373
CORUNNA	MI0369	44	77	99	116
DARFUR	MN0009	73	128	163	188
DASSEL	MN0386	132	230	290	332
DAWSON	MI0134	126	222	282	323
DEERWOOD	MN0018	137	236	298	342
DELFT	MN0295	21	35	45	53
DOVRAY	MN0052	14	28	38	46
DUNDAS	MN0211	36	67	87	101
DUSLER	MN0160	12	23	30	36
EFFIE	MN0335	10	20	27	32
ENLOE	ND0013	10	20	27	32
EPOUFETTE	MI0120	165	287	361	414
EPOUFETTE*	MI0206	239	337	401	449
ESPELIE	MN0406	26	45	59	69
ESSEXVILLE*	MI0421	57	77	95	109
EVART*	MI0226	200	278	332	373
FARGO	ND0020	10	20	27	32
FARGO	ND0111	10	20	27	32
FARGO	ND0201	10	20	27	32
FARGO	ND0233	33	62	80	92
FARGO	ND0235	33	62	80	92
FAXON	MN0082	13	22	29	34
FAXON	MN0294	14	24	31	36
FIELDON	MN0011	126	223	282	323

LATERAL EFFECT FOR DRAIN TILE

SOIL NAME	ID	24" DEPTH	36" DEPTH	48" DEPTH	60" DEPTH
FLOM	MN0069	20	38	49	58
FLOM	MN0388	20	38	49	58
FORADA	MN0070	132	230	290	333
FORADA	MN0499	132	230	290	333
FORDUM	WI0397	132	230	290	332
FOSSUM	MN0102	137	236	298	342
FOSSUM	MN0424	137	236	298	342
FULDA	MN0187	20	37	49	57
GARWIN	IA0037	39	71	92	106
GLENCOE	MN0026	38	70	90	105
GLENCOE	MN0444	38	70	90	105
GRANBY*	MI0029	200	278	332	373
GREENWOOD	MI0394	66	116	148	171
GRYGLA*	MN0020	84	113	137	157
GRYGLA*	MN0416	84	113	137	157
GRYGLA*	MN0487	84	113	137	157
HAMAR*	SD0141	183	255	305	342
HAMEL	MN0084	36	68	88	102
HAMRE	MN0418	36	65	84	98
HANGAARD*	MN0130	200	278	332	373
HANSKA	MN0028	134	232	292	335
HANSKA	MN0463	134	232	292	335
HANSKA	MN0477	134	232	293	336
HARPS	IA0157	39	71	92	106
HARPSTER	IL0147	39	71	92	106
HARPSTER	IL0348	39	71	92	106
HAUG	MN0021	39	71	92	106
HAVANA	MN0221	34	64	84	98
HAVERHILL	MN0255	3	7	9	10
HEGNE	MN0053	9	18	24	29
HIDEWOOD	MN0013	36	65	84	98
HILLET	MN0267	131	229	288	330
HILLET	MN0467	131	229	288	330
HOUGHTON	MI0024	64	113	143	166
HOUGHTON	MI0291	64	113	143	166
HUMESTON	IA0136	7	13	18	22
INDUS	MN0268	10	20	27	32
ISAN*	MN0269	200	278	332	373
ISAN*	MN0528	200	278	332	373
ISANTI*	MN0196	200	278	332	373
JEFFERS	MN0296	23	41	54	63
JOLIET	IL0153	8	14	18	21
KALMARVILLE	MN0287	125	221	282	323
KATO	MN0213	128	226	284	326
KATO	MN0323	129	227	287	328
KERSTON	MI0022	114	202	255	292
KNOKE	IA0256	20	38	49	58
KRATKA*	MN0072	75	106	128	147

LATERAL EFFECT FOR DRAIN TILE

SOIL NAME	ID	24" DEPTH	36" DEPTH	48" DEPTH	60" DEPTH
KRATKA*	MN0419	75	106	128	147
LAKEPARK	MN0475	20	38	49	58
LAMOURE	SD0176	36	65	84	98
LAWSON	WI0044	39	71	92	106
LEAFRIVER	MN0530	137	236	298	342
LEAFRIVER	MN0531	137	236	298	342
LEMOND	MN0029	132	230	290	333
LEMOND	MN0443	67	111	131	153
LEMOND	MN0462	132	230	290	333
LEMOND	MN0478	134	232	292	335
LENA	IL0123	73	129	163	189
LETRI	MN0106	21	39	51	60
LINDAAS	ND0005	31	59	77	90
LOBO*	MN0149	124	167	199	226
LOXLEY	MI0080	64	113	143	166
LUDDEN	ND0032	10	20	27	32
LUPTON	MI0393	64	113	143	166
LURA	MN0032	15	30	40	48
LURA	MN0464	15	30	40	48
MADELIA	MN0033	39	71	92	106
MAHTOWA	MN0171	20	38	49	58
MARCUS	IA0129	36	66	86	100
MARKEY	MI0030	130	229	288	330
MARKEY	MI0387	130	229	288	330
MARNA	MN0089	34	62	81	94
MARSHAN	MN0104	131	229	288	330
MARSHAN	MN0324	131	229	288	330
MARSHAN	MN0521	68	122	141	151
MARTISCO	NY0106	10	20	27	32
MARYSLAND	MN0103	133	230	290	333
MARYSLAND	MN0320	133	230	290	333
MAVIE	MN0134	54	89	114	133
MAXCREEK	MN0151	39	71	92	106
MAXCREEK	MN0365	39	71	92	106
MAXFIELD	IA0055	39	71	92	106
MAXFIELD	IA0338	39	71	92	106
MAYER	MN0197	129	227	285	327
MAYER	MN0314	129	227	285	327
MAZASKA	MN0272	32	60	78	91
MCDONALDSVILLE	D0145	130	228	287	329
MERWIN	MN0163	66	116	148	171
MILLERVILLE	MN0274	16	30	39	46
MILLINGTON	IL0222	39	71	92	106
MILLINGTON	IL0349	153	272	346	395
MINNETONKA	MN0090	33	62	80	93
MINNETONKA	MN0474	37	68	88	102
MOOSELAKE	MN0167	73	129	163	189
MORPH	MN0340	39	71	92	106

LATERAL EFFECT FOR DRAIN TILE

SOIL NAME	ID	24" DEPTH	36" DEPTH	48" DEPTH	60" DEPTH
MOUNDPRAIRIE	MN0369	39	71	92	106
MOUNDPRAIRIE	MN0370	39	71	92	106
MUSKEGO	WI0046	22	37	48	57
MUSKEGO	WI0437	42	75	96	112
NEWALBIN	MN0371	39	71	92	106
NEWALBIN	MN0372	39	71	92	106
NEWALBIN	MN0373	25	45	58	68
NEWSON	WI0446	137	236	298	342
NISHNA	IA0155	10	20	27	32
NISHNA	IA0326	10	20	27	32
NOKASIPPI*	MN0275	65	86	105	121
NOKAY	MN0276	15	27	35	41
NORTHCOTE	MN0022	10	20	27	32
NORTHCOTE	MN0362	10	20	27	32
NORTHWOOD	MN0486	46	83	106	124
NOWEN	MN0201	39	71	92	106
NOYES	MN0119	10	20	27	32
OKOBOJI	IA0131	26	48	63	74
OKOBOJI	IA0327	20	38	49	58
OLDHAM	SD0174	18	34	45	52
OSHAWA	MN0017	20	38	49	58
OTTER	ILOO78	39	71	92	106
OTTER	IL0360	39	71	92	106
PALMS	MI0023	41	71	92	107
PALMS	MI0271	111	198	255	292
PALMS	MI0448	41	71	92	107
PARENT	MN0168	14	25	33	39
PARENT	MN0212	14	25	33	39
PARENT	MN0387	14	25	33	39
PARNELL	MN0035	11	21	28	33
PENGILLY	MN0381	39	71	92	106
PERCY	MN0048	39	71	92	106
PERCY	MN0510	39	71	92	106
PERALLA	ND0076	20	38	49	58
PREBISH	MN0248	25	45	57	67
PREBISH	MN0436	25	45	57	67
QUAM	MN0075	20	38	49	58
RAUVILLE	SD0177	66	119	154	177
RAUVILLE	SD0437	66	119	154	177
REGAL	MN0352	137	236	298	342
REVERE	MN0433	39	71	92	106
RIFLE	MI0391	66	116	148	171
ROCKWELL	MN0054	48	82	105	123
ROCKWELL	MN0360	48	82	105	123
ROLFE	IA0159	34	63	82	95
ROLISS	MN0076	36	65	84	98
ROLISS	MN0420	36	65	84	98
ROMNELL	MN0298	20	38	49	58

LATERAL EFFECT FOR DRAIN TILE

SOIL NAME	ID	24" DEPTH	36" DEPTH	48" DEPTH	60" DEPTH
RONDEAU	MN0148	30	51	61	72
ROOT	MN0299	160	281	353	404
ROSCOMMON*	MI0159	200	278	332	373
ROSCOMMON*	MI0422	200	278	332	373
ROSEWOOD	MN0414	137	236	298	342
ROSEWOOD	MN0427	137	236	298	342
RUNEBERG	MN0293	18	34	45	53
RUNEBERG	MN0500	18	34	45	53
RUSHMORE	MN0230	22	41	53	62
SAGO	MN0331	39	71	92	106
SARGEANT	MN0143	11	21	28	33
SAWMILL	IL0084	39	71	92	106
SAX	MN0411	39	71	92	106
SEELYEVILLE	MN0128	64	113	143	166
SEELYEVILLE	MN0353	64	113	143	166
SHAKOPEE	MN0466	124	221	280	320
SHANDEP	IA0226	117	208	271	310
SHILOH	IL0068	20	38	49	58
SHILOH	IL0393	20	38	49	58
SHOOKER	MN0139	39	71	92	106
SMILEY	MN0413	39	71	92	106
SMILEY	MN0488	36	65	84	98
SPICER	MN0093	39	71	92	106
SPICER	MN0318	39	71	92	106
SPOONER	MN0135	39	71	92	106
STAPLES*	MN0509	84	104	127	146
STATELINE	MN0481	4	8	12	15
STRANDQUIST	MN0122	42	75	97	113
SYRENE	MN0132	137	236	298	342
SYRENE	MN0363	137	236	298	342
TACOOSH	MI0166	43	75	95	111
TALCOT	MN0107	131	229	288	330
TALCOT	MN0315	131	229	288	330
TALMOON	MN0380	20	38	49	58
TAWAS	MI0027	131	229	289	331
TAWAS	MI0138	131	229	289	331
THIEFRIVER	MN0412	47	72	93	110
TILFER	IA0212	14	24	31	36
TONKA	ND0229	18	34	46	54
TRIPOLI	IA0053	39	71	92	106
TROSKY	MN0185	124	221	280	320
TWIG	MN0165	19	37	49	57
UDOLPHO	MN0073	129	227	286	328
UDOLPHO	MN0232	128	226	285	326
UDOLPHO	MN0428	64	114	129	146
UDOLPHO	MN0429	56	98	112	131
URNESS	MN0079	36	65	84	98
VALLERS	MN0055	20	38	49	58

CHAPTER 4

SUBSURFACE DRAINAGE

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SUBSURFACE DRAINAGE

Subsurface drainage is used to control high water table conditions in those areas where the benefits of lowering such water tables justify installation costs. Subsurface drainage is an important component of many successful resource management systems, and is often a necessary component of conservation tillage systems and irrigation systems. Benefits from subsurface drainage may be received from one or more of the following:

1. Improve the soil environment for vegetative growth by managing the water table and groundwater flow.

2. Improve soil conditions and thereby reduce energy required for crop production.

3. Intercept and prevent water movement into a wet area.

4. Promote warming of wet soils in the spring for earlier planting and to facilitate harvest operations in wet falls, and to assure greater success of reduced tillage systems.

5. Relieve artesian pressure.

6. Remove surface runoff.

7. Provide groundwater control on irrigated lands and facilitate leaching of saline and alkali soils.

8. Serve as an outlet for other subsurface drains.

9. Provide groundwater regulation and control for subirrigated areas or waste disposal areas.

10. Collect groundwater for beneficial uses.

11. Remove excess water from around buildings, roads, airports, play fields and other physical improvements.

12. Provide water management to control health hazards caused by flies, mosquitoes, liver fluke, etc.

All lands to be drained should be made suitable for the intended use after installation of required drainage and other conservation practices. The soil must have sufficient depth and permeability to permit the installation of an effective and economically feasible system. In order for subsurface drainage systems to be successful, soils must be permeable enough to allow the required movement of water through the soil and toward the drains.

Subsurface drainage systems must have a suitable outlet available, either by gravity flow or by pumping. The outlet must be adequate for

the quantity and quality of the outflow to be disposed of, with consideration given for possible damages above or below the point of discharge that might involve legal action under state laws. The landowner is responsible for securing all necessary permits, complying with all state and local laws and regulations, and meeting all other requirements related to the installation of a surface drainage system including securing an adequate outlet for the system.

The amount of survey work necessary to locate and design a subsurface drainage system varies widely with the topography and the size and complexity of the drainage system. Field examination may be sufficient in flat areas having uniform topography. More complex situations may require the use of detailed contour maps and more field measurements. Those experienced in subsurface drainage design often omit taking profiles along lateral lines when land slopes are uniform; however, accurate level data and plotting of profiles along mainlines are always needed to assure proper installation of the system.

SUBSURFACE DRAINAGE SYSTEM PLANNING AND DESIGN

A properly planned and designed system coordinates the subsurface drainage system with other conservation and management practices to provide the best overall plan for the area. The design must consider the topography, soils, crops, and outlet conditions.

Topography (how the land lays) greatly influences the drainage system and associated practices to be used. Overflow from adjacent uplands should be intercepted or diverted by surface practices. Small surface irregularities and depressions could be drained by land smoothing and shallow surface ditches in addition to subsurface drainage. The location and layout pattern of the drain lines is largely dependent upon the topography. The position of the wetness problem in the topography will dictate whether or not a gravity outlet will be available or whether a pumping plant will be needed. In some instances, a complete topographic map of the area may be required to determine available slope for various parts of the system, while in flat topography the design can often be made in the field.

Soil type influences the type of practices that can be used - surface or subsurface. Soils vary in their ability (permeability) to move water to a drain and this influences the drain spacing and depth. Recommendations for drain depth and spacing are given in Table 3-1.

FIELD LAYOUTS FOR SUBSURFACE DRAINAGE

Field topography is a major factor influencing subsurface drainage layout patterns. Soil type and crops to be grown have greater effect on the depth and spacing of the drain lines. Figure 4-1 shows the basic types of subsurface drainage system layouts or patterns.

The random system layout is used in fields where the topography is undulating, creating isolated wet spots. The number and arrangement of lateral drains within each wet area varies according to the shape and size of the area. Wet spots of narrow width (less than recommended spacing width) can often be drained with a single line running through the middle of the spot. Wet areas of greater width, however, require additional lines to provide adequate drainage. Random layouts are also used in special situations, such as where excess subsurface water from higher elevations moves toward a lower area, creating a drainage problem in the lower area. This is known as side-hill seepage, and in such cases, the drain line is placed on the uphill side of the seep and approximately on the impervious layer along which the water is seeping.

The gridiron or parallel system is used on relatively flat fields having uniform slopes and soil, and with widespread drainage problems occurring throughout the field. In a gridiron system layout, the lateral drains feed into the mainline from only one side of the main. The mainline is usually located to run across the major slope of the field, with the laterals running in the general direction of the field slope. To reduce the number of junctions and to minimize the cost, the lateral lines in a gridiron system are made as long as possible and the mainline as short as possible.

In the herringbone system or layout, parallel laterals may enter the main from either side and from any angle. This system has particular advantages where a swale or natural waterway runs through the field that is being drained. In such situations, the main can be located to follow the waterway with the laterals angling in from either side of the main. Despite having double drainage in the vicinity of the main, and added cost to the numerous junctions, the herringbone system is often advantageous due to more uniform and shallower depth of cuts along both the laterals and the mainline. When side-hill seepage is known to occur in such situations, a double main arrangement may be installed with one main located on each side of the waterway. Double main layouts may also be recommended if the waterway is deep. A deep waterway makes it difficult to bury a single main (located in the waterway) without breaking grade of each lateral before it reaches the main.

Outlets for Subsurface Drainage Systems

First consideration in planning a subsurface drainage system is the location and adequacy of the outlet. Most subsurface drains discharge by gravity flow into natural streams, constructed open ditches, or into larger existing underground mains. Drainage of those field areas which are too low to permit use of gravity flow outlets may be accomplished by the installation of pumping outlets (see section on pump drainage).

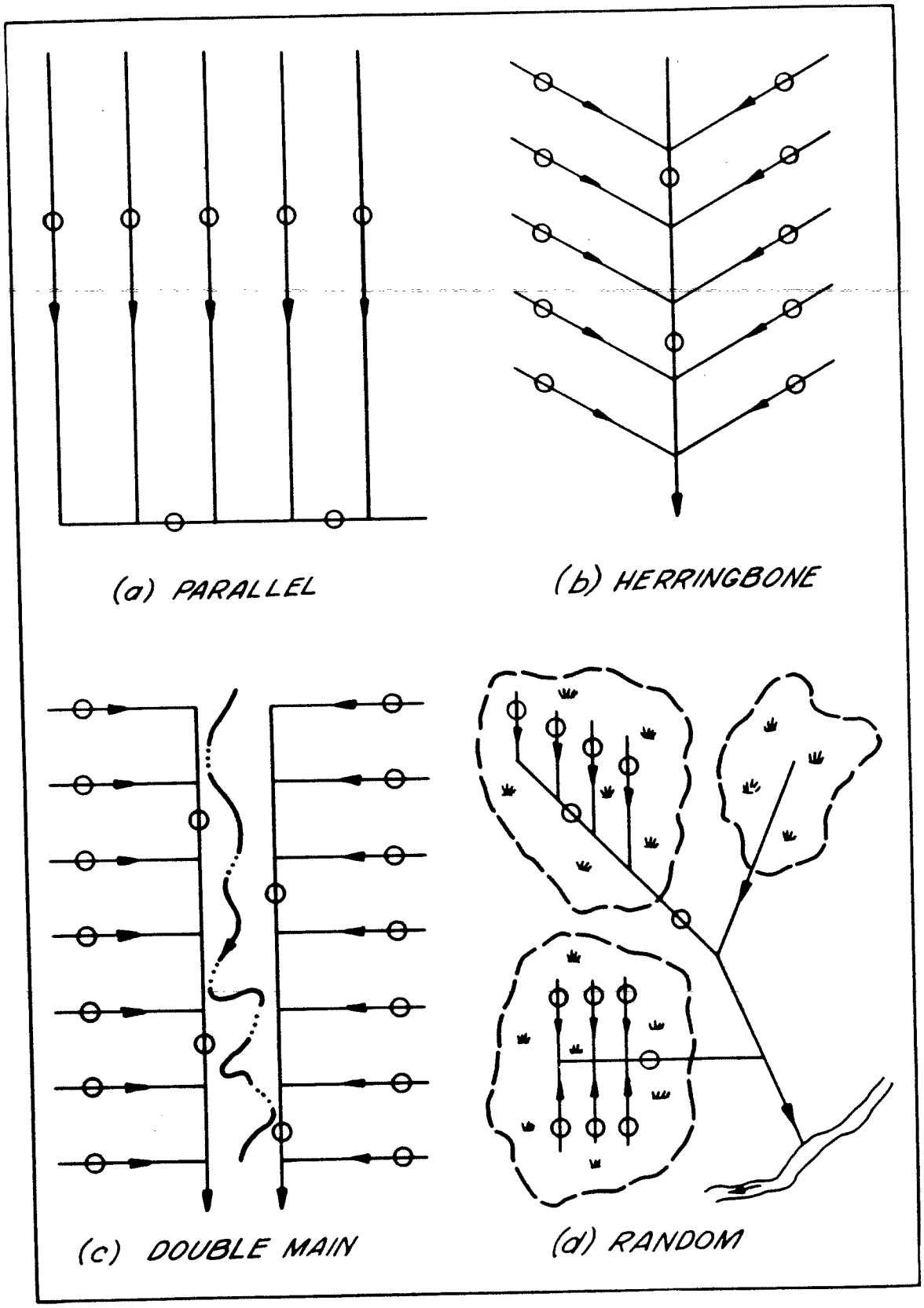


Figure 4-1, Types of drainage collection systems

When natural streams or artificial open ditches are used as outlets for subsurface drainage systems, they must be deep enough and have sufficient capacity to ensure a free outlet and adequate cover for all drain lines. When a subsurface drain outlets into an open ditch, the end portion of the drain must be protected from erosion, damage from periods of submergence, and from entry of rodents, etc., into the drain. A drain line outlet can be protected against erosion by using a length of continuous rigid pipe for that part of the line adjacent to and extending into the open ditch (see Figure 4-2). Such rigid pipe should have a minimum length of 12 feet, with at least two-thirds of its length embedded into the ditch bank. The remaining portion of the pipe should be long enough to place the discharge from the pipe at the toe of the ditch slope and at a minimum of one foot above the low water level in the ditch. This clearance can be reduced where (1) the outlet ditch is on such a grade that silting will not occur, (2) where the tile will flow freely within 24 hours after a storm, or (3) where definite plans have been scheduled for outlet improvement within the next year. The rigid pipe should be made from fireproof material (not plastic) to prevent damage to the pipe from commonly occurring grass fires.

If ice or floating debris may damage the outlet pipe, the outlet must be recessed to the extent that the cantilevered part of the pipe will be protected from the current in the ditch. See Figure 4-2.

Animal guards should be installed on the ends of all outlet pipes. Flap gates, hinged rod gates, screens, and bar gratings are commonly used. Some of the different styles of of guards are shown in Figure 4-3. Flap gates or hinged rod gates, rather than screens and gratings, should be used on drains that receive water from surface inlets, since debris from such inlets may enter and collect on the screen.

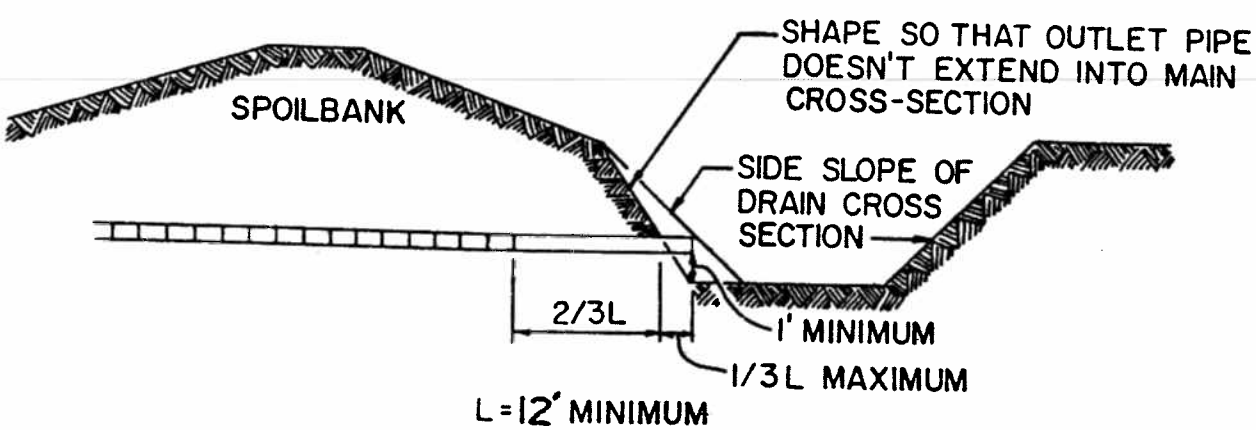


Figure 4-2. Recessed pipe outlet to open drain.

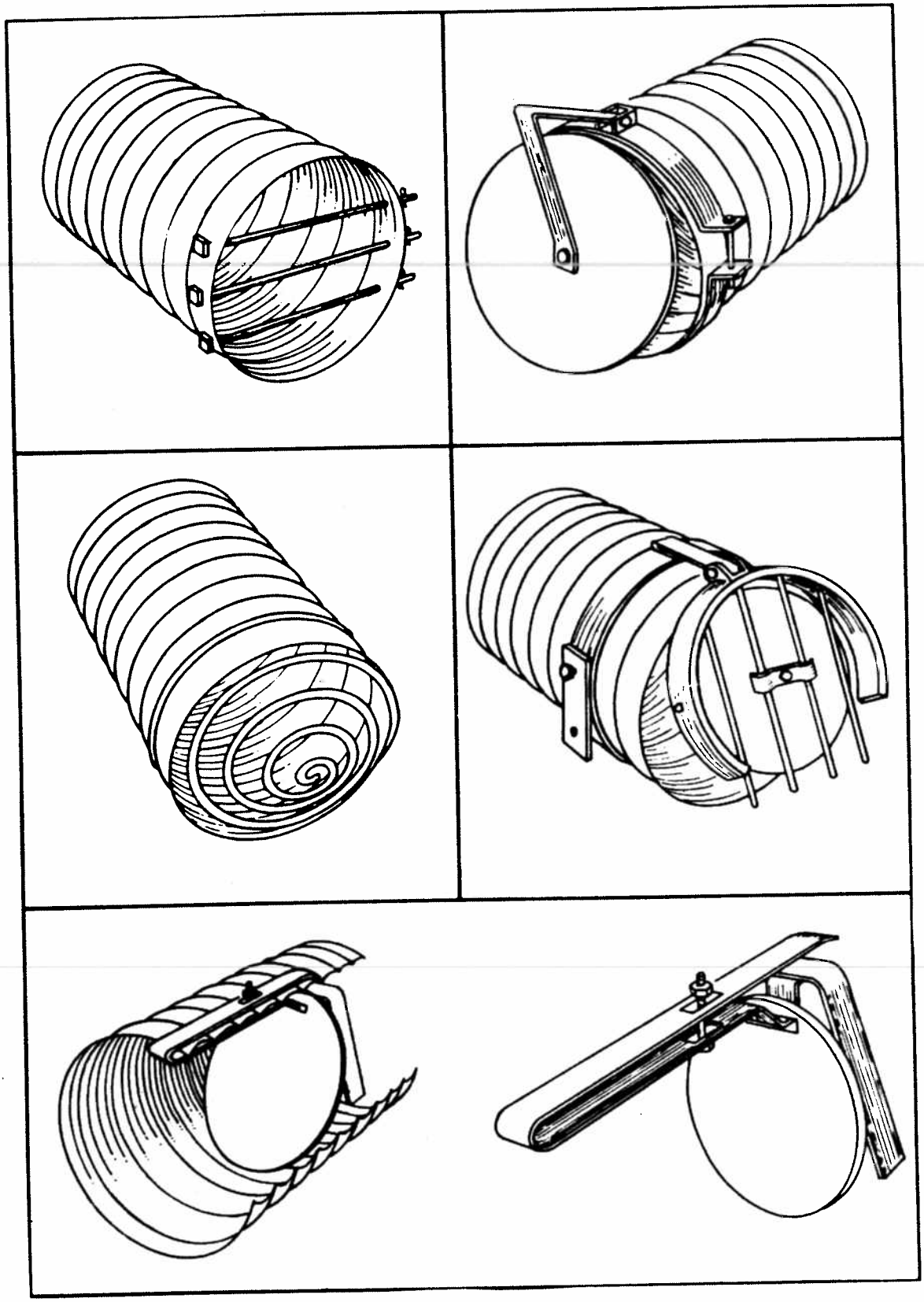


Figure 4-3. Typical rodent guards.

Where surface water enters the ditch at the location of the drain outlet, some type of structure or other precaution is needed to facilitate the lowering of the surface water into the ditch without damage from erosion. The type of structure required is related to the drainage area size, discharge, site topography and soils. Sometimes it may be possible to divert the surface water away from the site of the drain outlet, allowing it to flow into the ditch over a sodded chute. In such cases, the chute should be located at least 60 feet away from the outlet. Where the ditch bottom stays wet, sodded chutes should not be used unless the toe of the chute is protected against erosion by a toe wall structure or other stabilization. In those instances where the surface water must enter at the outlet location, and where there is no spoil bank, the straight-drop spillway is generally found to be most successful. A pipe-drop inlet structure, on the other hand, will usually provide the best solution if there is a spoil bank behind which the surface water can be temporarily stored. See Chapter 6 for design information.

If an existing tile main is to be used as an outlet for a new subsurface drainage system, care must be taken to be sure that the main is working properly with its own free outlet, has adequate capacity to accommodate additional drainage water, and that it is located at sufficient depth to provide recommended minimum cover for all drain lines in the new system. The landowner of the new system must also secure required permits to use the existing main as an outlet. Sink holes and wells are not considered adequate outlets.

Drainage Coefficients for Subsurface Drainage Systems

To provide required protection for the crop, subsurface drainage systems should have sufficient capacity to remove excess water from a major part of the root zone of the soil profile within 24 to 48 hours following a heavy rain. The rate that water must be removed from the drainage area is known as the drainage coefficient. Drainage coefficients, expressed in inches per 24 hours, are selected principally on such factors as the rainfall characteristics (frequency, intensity, and duration) and the kind of crop being grown.

Drainage coefficients historically used in Minnesota are shown in Table 4-1. In practice, selection of the drainage coefficient should be based largely on a knowledge of past cropping and farm operational problems in the area combined with the judgement of the designer. Below are some items to consider in increasing or decreasing the drainage coefficient.

	Increase Drainage Coefficient if:	Decrease Drainage Coefficient if:
1.	Soils are lighter	Soils are heavier
2.	Crops are high value	Crops are lower value
3.	Crops have lower tolerance to wetness	Crops have higher tolerance to wetness
4.	Topography is flat	Topography is sloping
5.	Crop residue left is high (conservation tillage)	Crop residue left is low (Conservation tillage)

Increase Drainage Coefficient if:	Decrease Drainage Coefficient if:
6. Little surface drainage	Extensive surface drainage
7. Crop ET is low	Crop ET is high
8. Frequent and low intensity rainfalls	Infrequent and high intensity rainfalls
9. Planting and harvesting times critical	Planting and harvesting times moderately critical

The drainage coefficient assumes that surface drainage is adequate and applies to the entire area being drained. If surface runoff from an upland area spreads over the area to be drained and is likely to increase the drainage problem, the acres used in determining drain (tile) size shall be proportionately increased. Tile size need not be increased if runoff from upland is diverted from the tiled area and disposed of by surface measures.

Table 4-1

DRAINAGE COEFFICIENTS FOR SUBSURFACE DRAINAGE ONLY

SOIL	FIELD CROPS INCHES	TRUCK CROPS INCHES
Mineral	3/8	1/2
Organic	1/2	3/4

In heavy soils (low permeability soils) where early removal or accelerated removal of the soil water will permit the soil to warm up earlier and allow for earlier planting, a drainage coefficient as low as 1/4" may be warranted. Generally, heavy soils contain less drainable water than lighter soils do. Consequently, removing 1/4" of water on heavy soils may be as beneficial as removing 3/8" of water on light soils. In these cases the selection of the drainage coefficient depends strongly on the designers judgement and the owners evaluation of cost and possible benefits.

Where high value truck crops tend to be damaged from scalding when surface water is ponded, surface inlets should be installed in the depressional areas where surface water tends to collect. If surface water is admitted into a subsurface drainage system through such surface inlets, the drainage coefficient values must be increased as shown in Table 4-2. The selected drainage coefficient will apply to the entire watershed contributing runoff to the surface inlet, except where only a small amount of runoff will be impounded at the location of the inlet with the remainder flowing away in a confined channel. For the latter case, the drain (tile) shall be large enough to remove the impounded water in 24 hours, plus provide capacity for the required internal drainage.

Table 4-2

DRAINAGE COEFFICIENTS WHERE SURFACE WATER ENTERS SUBSURFACE DRAINS

SOIL	FIELD CROPS		TRUCK CROPS	
	BLIND INLETS INCHES	OPEN INLETS INCHES	BLIND INLETS INCHES	OPEN INLETS INCHES
Mineral	3/8	1/2	1/2	1
Organic	1/2	3/4	3/4	2

Drainage coefficients for municipal drains, or other large drainage systems protecting high valued property, etc., are usually higher than those shown for agricultural drainage. In such instances, additional information must be considered such as land use, area drained and the degree of protection required. Usually, these systems are designed using peak flows from storms of certain frequencies from hydrologic analysis.

Example: Find the appropriate drainage coefficient for a field in southern Minnesota. The soil is Glencoe and ordinary row crops will be grown.

Solution: Using Table 4-1, we find that for a mineral soil, such as Glencoe, a 3/8 inch coefficient is recommended. However, Glencoe is a pothole type soil, where ponding is a problem. Unless the surface water can be removed with a ditch, surface inlets are needed. Using Table 4-2, we find that a 1/2 inch coefficient is recommended when open inlets are used. Note that this coefficient will apply to the entire watershed contributing runoff to the surface inlets.

Interceptor Drains

Springs or side-hill seeps normally develop in areas where tight soil layers, located at shallow depths in the soil, prevent seepage water from moving downward. In such instances, the seepage water moves laterally, following the top of the impermeable soil layer. To intercept this flow, the drain line should be located on or near the top surface of the layer and placed on grade toward a suitable outlet. The exact location of such seepage planes is usually determined by making soil borings, using hand or power augers. On some sites, expecially where the soil has several thin layers of different materials, the performance of the interceptor drain can be improved by using a filter envelope similar to Figure 4-6b. Extend the envelope up to intercept all the coarse layers, or to within 6 inches of the surface.

The flow rate for an enterceptor drain can be estimated using Table 4-3. The design flow rate should be based on the permeable soil layers intercepted, and the designer's judgement of relative permeabilities and layer thicknesses.

Table 4-3

FLOW RATES FOR INTERCEPTOR DRAINS

SOIL TEXTURE	INFLOW RATE PER 1,000 FT OF LINE IN C.F.S. 1/ 2/
Coarse sand and gravel	0.15 to 1.00
Sandy loam	0.07 to 0.25
Silt loam	0.04 to 0.10
Clay and clay loam	0.02 to 0.20

1/Discharge of flowing springs or direct entry of surface flow through a surface inlet or filter must be added. Such flow should be measured or estimated.

2/Required inflow rates for interceptor lines on sloping land should be increased by 10 percent for slopes 2 to 5 percent, by 20 percent for 5 to 12 percent, and 30 percent for slopes over 12 percent.

Example: An interceptor drain will be installed to remove a wet area caused by seepage. The land slope is about 6%, and the soil is a medium sandy loam underlain by clay loam. Find the inflow rate for the drain.

Solution: Using Table 4-3, sandy loam has an inflow rate of 0.07 to 0.25 c.f.s. per 1,000 feet. For this site, use 0.20 c.f.s./1,000 ft. Footnote 2 requires that the rate be increased by 20% for land slopes between 5 and 12 percent. The design flow rate for this site is:

Q = 120% X 0.20 = 0.24 c.f.s. per 1,000 feet of line.

Depth and Spacing of Subsurface Drains

The depth and spacing requirements for a subsurface drainage system are based on soil characteristics, type and value of crops, outlet conditions, and the presence (or absence) of impervious soil layers in the upper part of the soil profile. Through areas requiring continuous internal drainage, a minimum average depth of 3 feet is recommended for Minnesota. All subsurface drains in mineral soil should have at least two feet of cover for protection against overloading from heavy machinery. Organic soils should have at least two and one half feet measured between the top of drain and the ground surface. Less cover may be used if the tile is replaced by metal or other high strength durable pipe where drains cross under highway ditches, in small depressional areas, or in areas not subject to heavy equipment travel. Additional protection against breakage may be required in the vicinity of the outlet, where drain lines cross under roads or ditches and in other special situations as shown in Figure 4-4.

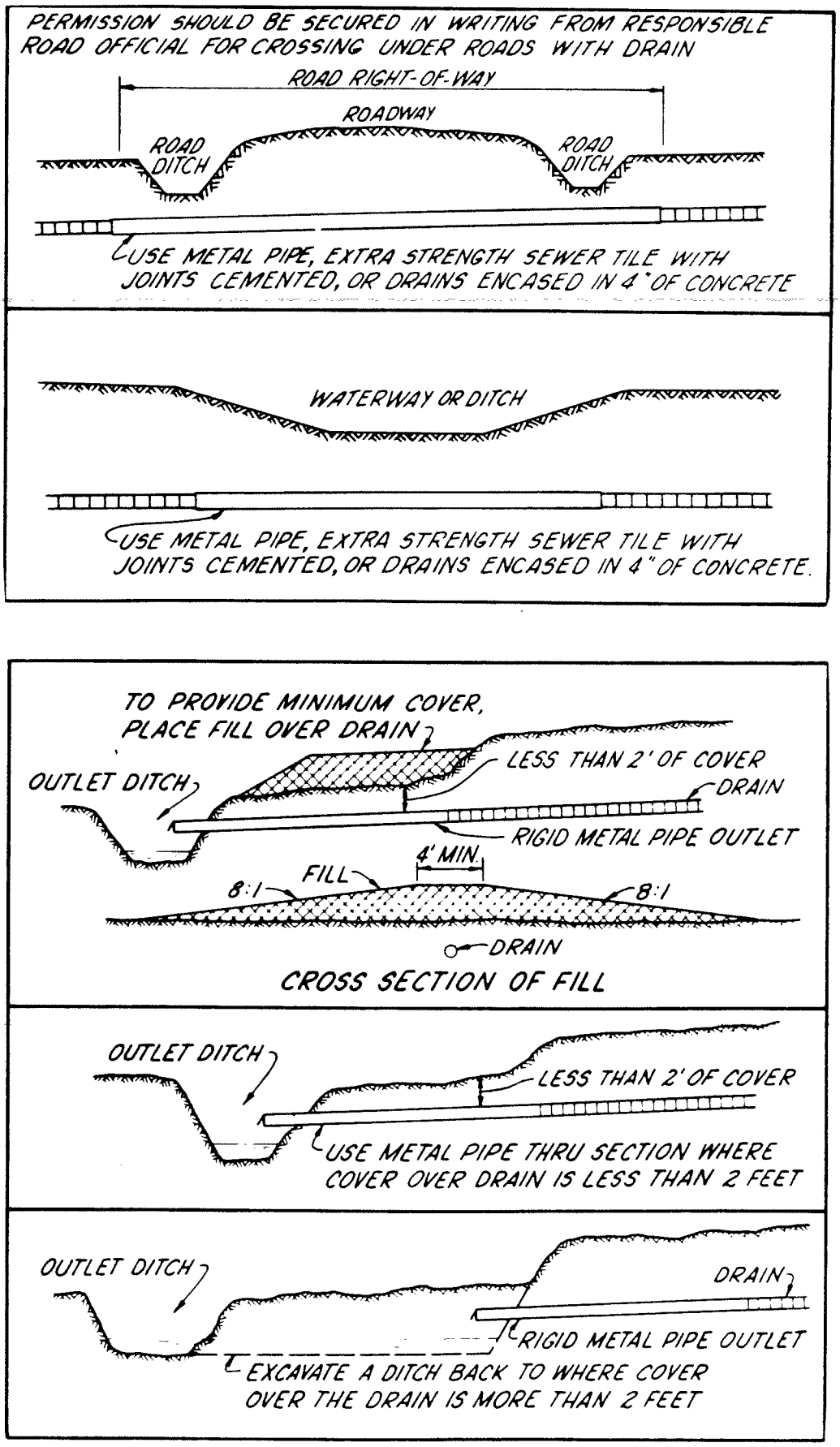


Figure 4-4. Drain crossings and outlet.

Table 3-1 gives recommended depths and spacings for subsurface drains according to drainage coefficient for Minnesota soils. Recommended spacings range from less than 20 feet to over 300 feet. Normally, however, drains are not placed closer than 40 to 50 feet in agricultural drainage work because of excessive costs associated with close spacings. For very high value crops and special use areas (such as playgrounds), closer spacings are justified.

Subsurface Drain Grades

The design grade must be sufficient to provide the capacity required to drain the area. To provide proper drainage, grades along drain lines should, if possible, be sufficient to develop a velocity of at least 1.4 feet per second. Flatter grades result in low velocities and sediment accumulation in the drain. Reverse grades should never be permitted in drain lines. Where sedimentation is a hazard, extra precautions should be made to prevent entry of soil sediment into the drain through the use of filters or the installation of sediment traps. Where sedimentation is not a hazard, minimum grades for drains shall be as shown in Table 4-4.

Table 4-4

MINIMUM GRADES FOR DRAIN LINES*

DRAIN SIZE, INCHES	GRADE, PERCENT
3 to 6	0.10 .10/100'
8 to 10	0.07 .7/100'
12 and larger	0.05 .5/100'

*Where sedimentation is not a hazard.

Because drains placed on steep grades often result in erosive velocities, special measures of protection may be required. Maximum permissible velocities in drains are given in Table 4-5. Protection measures most commonly considered are: 1) Obtaining tighter fitting joints by selecting tile with straight, smooth sections and squared ends. 2) Wrapping open joints of the tile with fabric envelope material, tar-impregnated paper, or plastic sheeting. 3) Placing the drain in a gravel envelope prior to backfilling the trench. 4) Sealing joints of the tile or using a water-tight continuous pipe in those lines where excessive velocities are expected to occur.

Table 4-5

MAXIMUM PERMISSIBLE VELOCITY IN DRAINS IN FEET PER SECOND

SOIL TEXTURE	DRAINS WITHOUT PRO-TECTION 1/	DRAINS 1/ 2/ WITH TAMPED CLAY JOINTS OR GRADED GRAVEL FILTER 3/	SEWER PIPE WITH UN-SEALED JOINTS	CONTINUOUS PIPE OR SEWER PIPE WITH SEALED JOINTS (UNPERFORATED)
Sand & sandy loam	3.5	5.0	5.0	No Limit
Silt & silt loam, peat	5.0	6.0	6.0	No Limit
Silty clay loam, loam	6.0	7.0	7.0	No Limit
Clay & clay loam	7.0	9.0	9.0	No Limit
Coarse sand or gravel 4/	9.0	10.0	11.0	No Limit

1/ The use of tile longer than 12 inches is recommended to reduce the number of joints where excessive velocities are expected.

2/ Includes corrugated plastic drainage tubing installed with filter.

3/ Graded gravel filter shall be a minimum of 3 inches thick around drain pipe and reasonably graded to surrounding soil. The D_{85} of envelope shall be larger than perforations.

4/ Coarse sand or gravel has a median sand size (D_{50}) of 2.0mm (about 1/16 inch) or greater.

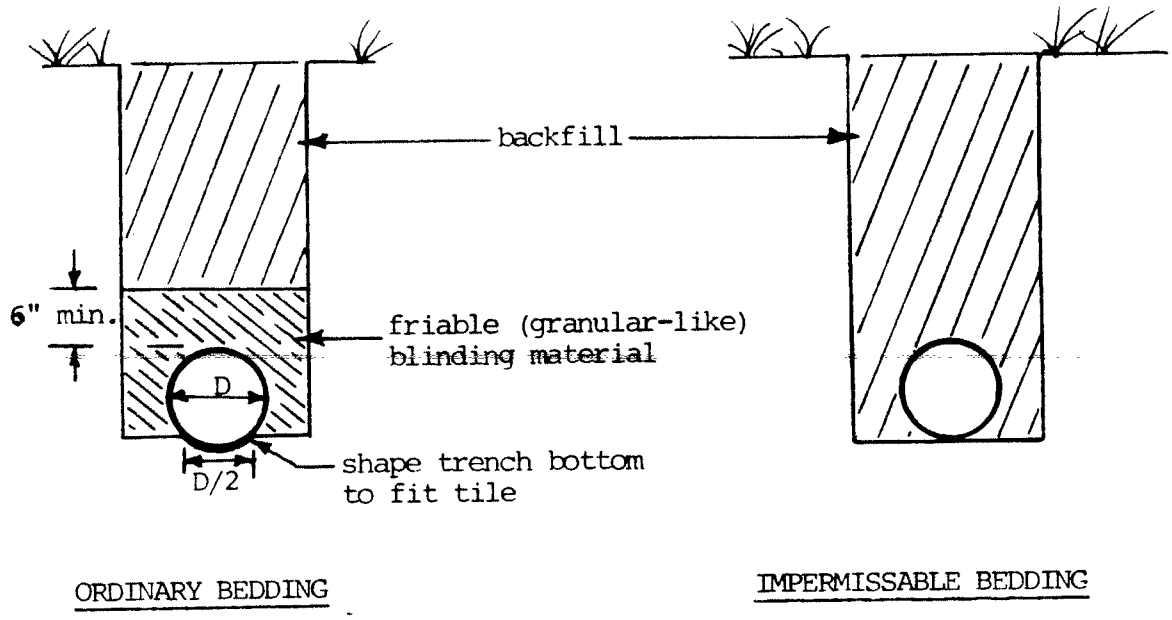
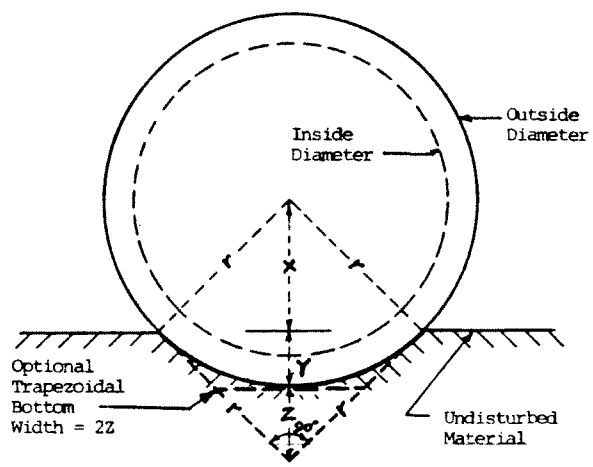


Figure 4-5a. Rigid Conduit Without Sand and Gravel Filter Envelope



DIMENSIONS FOR A 90-DEGREE "V" GROOVE

Inside Diameter (ID) in.	Outside* Diameter (OD) in.	r (OD/2) in.	X (0.707r) in.	Y (0.293r) in.	Z (0.414r) in.
3	3.6	1.8	1.3	0.5	0.7
4	4.8	2.4	1.7	0.7	1.0
5	6.0	3.0	2.1	0.9	1.2
6	7.2	3.6	2.5	1.1	1.5
8	9.6	4.8	3.4	1.4	2.0
10	12.0	6.0	4.2	1.8	2.5
12	14.4	7.2	5.1	2.1	3.0
15	18.0	9.0	6.4	2.6	3.7

*Values are based on typical outside diameters which are assumed to be 20% greater than the inside diameters.

Figure 4-5b. Flexible Tubing Without Sand and Gravel Filter or Support Envelope

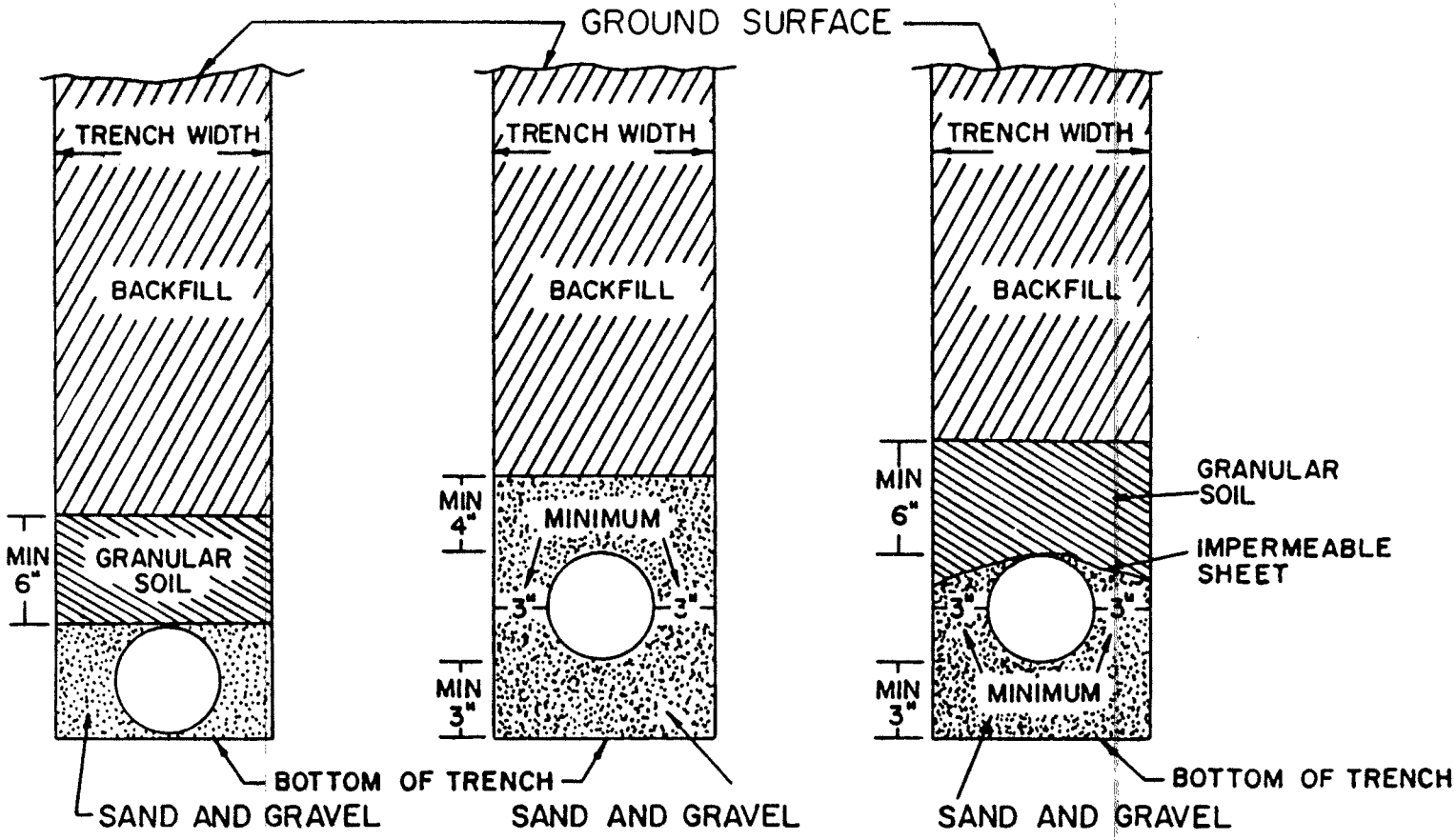


Figure 4-6a. Tubing Encased in Sand and Gravel Envelope for Support.

Figure 4-6b. Tubing Encased in Sand and Gravel Envelope Designed as a Filter.

Figure 4-6c. Tubing Encased in Sand and Gravel Envelope Designed as a Filter with an Impermeable Sheet such as Plastic.

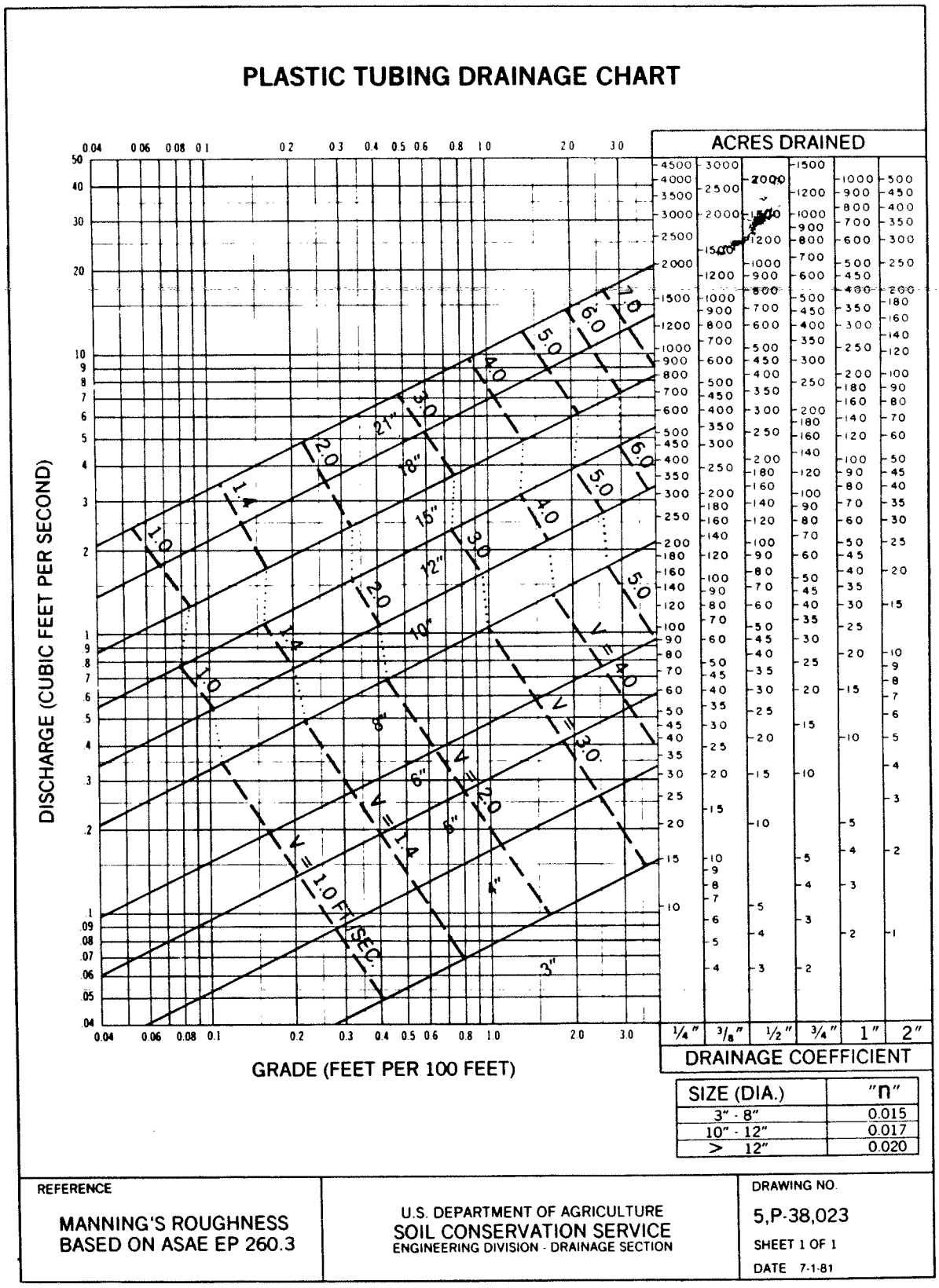
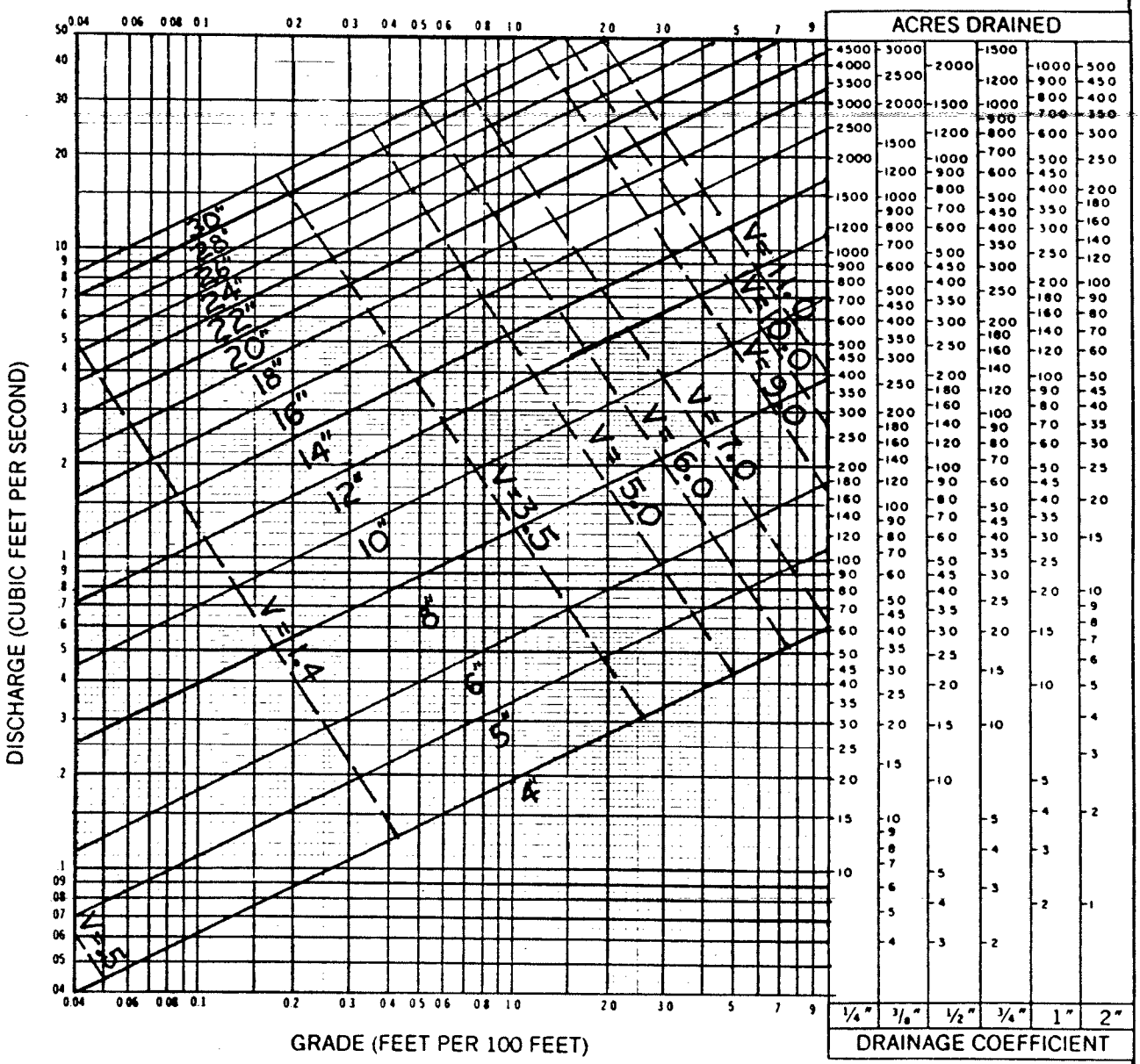


Figure 4-7 CHART FOR DETERMINING REQUIRED SIZE OF CORRUGATED PLASTIC DRAINAGE TUBING.



This chart based on Manning's equation with n=0.013.

The space between the lines indicates the range of capacity for the tile diameter shown.

V = velocity in feet per second.

Figure 4-8. Drainage Chart for Clay and Concrete Tile.

Subsurface Drain Sizes

Subsurface drain lines should be of sufficient diameter at any given point along the line to accommodate the maximum flow expected at that point. This flow depends upon the drainage coefficient and the area being drained upstream of the point in question. Knowing the drainage area, the drainage coefficient and the grade of the line at any given point, the flow and the size of the drain required at that point can be determined from Figures 4-7 or 4-8. Drain flow velocities shown are for full flow conditions.

In agricultural drainage work in Minnesota, a minimum diameter of four inches is generally recommended for lateral lines in all mineral soils except sands. For sandy and organic soils, minimum diameters of five-inch and six-inch, respectively, are recommended. Drains of three-inch diameter can be used on very short lines to drain building or construction areas. For economic reasons, many manufacturers of concrete tile do not make tile less than six inches in diameter. On some lateral lines, a choice must be made between the use of slightly overcapacity six-inch concrete tile, four-inch clay tile, or four-inch corrugated plastic tubing. Where large diameter tile are required, as in mains and submains, concrete or clay tile are usually used. Choices between the tile materials are usually made on the basis of their availability and local cost.

Example: A 6-inch diameter concrete tile line will be installed in a field with silt loam soils. What is the minimum grade that the line should have? If a surface inlet is involved (sediment hazard), what is the minimum grade for the line? What is the maximum allowable velocity without protection? What is the largest area this line could drain if it is installed at a 1.0% grade and the drainage coefficient is ½"?

Solution: Using Table 4-4, the minimum grade for a 6-inch tile drain is 0.10 percent when there is no sediment hazard. When there is a sediment hazard, such as with a surface inlet, the minimum velocity should be at least 1.4 feet per second. Using Figure 4-8, the minimum grade should be 0.25 percent for this requirement. If significant sediment is expected, sediment traps should be installed. The maximum allowable velocity without protection for a silt loam soil is 5.0 feet per second, using Table 4-5. The largest area that can be drained is found using Figure 4-8. For a 1% grade and ½" coefficient, the maximum area is about 27 acres.

Example: Corrugated plastic tubing drains are being installed in a Canisteo soil. What is the maximum length that a 5-inch lateral could handle? Assume a 0.2% grade and 3/8" coefficient.

Solution: Using Table 3-1, the recommended spacing for 3/8" coefficient and 48" depth is 106 feet. Using Figure 4-7, a 5-inch tubing at 0.2% grade can drain about 8.5 acres for a 3/8" coefficient. The maximum length of the lateral can be calculated:

$$\text{Maximum Length} = \frac{8.5 \text{ acres} \times 43{,}560 \text{ ft}^2/\text{acre}}{106 \text{ feet}}$$

$$= 3{,}493 \text{ feet}$$

Filters and Envelopes

Filters - A filter is used to restrict fine particles of silt and sand from entering the drain. A sand and gravel envelope designed as a filter may be used (see Figures 4-6b and 4-6c). Where this type of filter material is not available, prefabricated filters of artificial material can be used. Recommended use of filters is shown in Table 4-6. Most of the fiberglass, spun-bonded or knitted synthetic fabrics, and plastic filter cloth act as protective filters, but with time the cloth may partially clog, resulting in a decrease of flow into the drain. During installation, the material shall span all open joints and perforations without excessive stretch. Care shall be taken not to damage the material during installation. Any damaged areas shall be replaced before backfilling.

Envelopes - Envelope material installed around subsurface drains ensures proper bedding support and improves the flow of the ground water into the drain. When it is not feasible to form a bedding groove for plastic drain tubing, an envelope material can be used as an alternative bedding.

The envelope material provides excellent drain support for all normal agricultural drain depths. The designed minimum envelope thickness may vary from 3 to 6 inches depending on the type of equipment used to install the material and the hydraulic conductivity and availability of the gravel material.

Figure 4-6a shows the envelope used where drain support is required for either tile or tubing. For all shapes when the trench is wider than the specified envelope width, the trench must be filled on both sides with bedding material or gravel envelope so there are no void spaces in the area between the drain and the walls of the trench.

Envelope material should consist of sand-gravel material, all of which should pass a 3/4-inch sieve, but not more than 10% should pass the #60 sieve. The envelope material shall be placed to form an even, firm bedding under the drain, and the remainder of the material shall be carefully placed so as not to disturb the grade or alignment of the drain. Due care shall be exercised to ensure that no mud, excavated material, or foreign matter is mixed with the envelope material during the installation. No special compaction of gravel envelope is necessary except as required for ensuring a firm and even bedding for the drain.

Directional Changes in Drain Lines

Changes in the horizontal direction of drains can be made by various means depending on the conditions. A gradual curve in the trench can be made within the limits of the trenching machine, provided proper grades are maintained. In no case should the radius of curvature be less than 5 feet, or so sharp that joint spacings between the separate tile exceed ¼ inch. The use of manufactured bends or fittings is recommended where sharp changes in direction are necessary. Fittings for small lines can be fabricated in the field. Junction boxes or manholes are recommended where more than two mains or laterals join and make abrupt changes in either direction or elevation.

Table 4-6. The need for drain filters or envelopes

A CLASSIFICATION TO DETERMINE THE NEED FOR DRAIN FILTERS OR ENVELOPES, AND MINIMUM VELOCITIES IN DRAINS

Unified Soil Classification	Soil Description	Filter Recommendation	Envelope Recommendation	Recommendations for Minimum Drain Velocity
SP (fine)	Poorly graded sands, gravelly sands.	Filter needed	Not needed where sand and gravel filter is used but may be needed with flexible drain tubing and other type filters.	None
SM (fine)	Silty sands, poorly graded sand-silt mixture.			
ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity.			
MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.			
GP	Poorly graded gravels, gravel-sand mixtures, little or no fines.	Subject to local on-site determination.	Not needed where sand and gravel filter is used but may be needed with flexible drain tubing and other type filters.	With filter - none. Without filter - 1.40 feet/second.
SC	Clayey sands, poorly graded sand-clay mixtures.			
GM	Silty gravels, poorly graded gravel-sand silt mixtures.			
SM (coarse)	Silty sands, poorly graded sand-silt mixtures.			
GC	Clayey gravels, poorly graded gravel-sand-clay mixtures	None	Optional.	None - for soils with little or no fines.
CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.			
SP,GP(coarse)	Same as SP & GP above.			
GW	Well graded gravels, gravel-sand mixtures, little or no fines.		May be needed with flexible drain tubing.	1.40 feet second for soils with appreciable fines.
SW	Well graded sands, gravelly sands, little or no fines.			
CH	Inorganic, fat clays			
OL	Organic silts and organic silt-clays of low plasticity			
OH	Organic clays of medium to high plasticity.			
Pt	Peat			

REFERENCE: This chart was developed by William F. Long and Ralph Brownscombe.

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION DRAINAGE SECTION

STANDARD DWG. NO.
ES 722
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DATE 8-3-

Junction Boxes

Junction boxes should be located along the edges of the field, along permanent fence lines or in noncultivated areas, if possible. The bottom of the box should be at least 12 inches below the invert of the outletting drain and the top cover of the box should extend above ground level to facilitate inspection and cleanout. When a junction box must be located in a cultivated area, it may be constructed so that the top of the cover is at least 18 inches below field surface. It can then be covered with soil and its location clearly referenced. Junction boxes should be constructed of concrete or of other durable material as shown in Figure 4-9.

Relief Wells and Breathers

Relief wells are designed to relieve pressure in a line that otherwise might cause a line to blow out. Breathers are designed to allow air to enter the pipe at abrupt changes in grade or alignment, beginning of lines, etc. so a vacuum lock will not occur. A relief well or breather can be constructed by installing a "T" junction in the drain line and cementing continuous pipe or tile vertically to it. The top of the riser pipe should extend approximately 12 inches above ground and be capped with wire mesh or suitable grating, as shown in Figure 4-10. A four-inch riser pipe is usually adequate to serve as a relief well or a breather in most farm-size drainage systems. Relief wells and breathers are usually located on the main line and may be necessary at the upper and lower ends of steep slopes, at points where the main line might become temporarily overloaded, or where full flow in the line changes to partial flow due to an increase in grade. When possible, relief wells should be located along fence lines, but wherever they are located, they should be adequately marked to prevent damage.

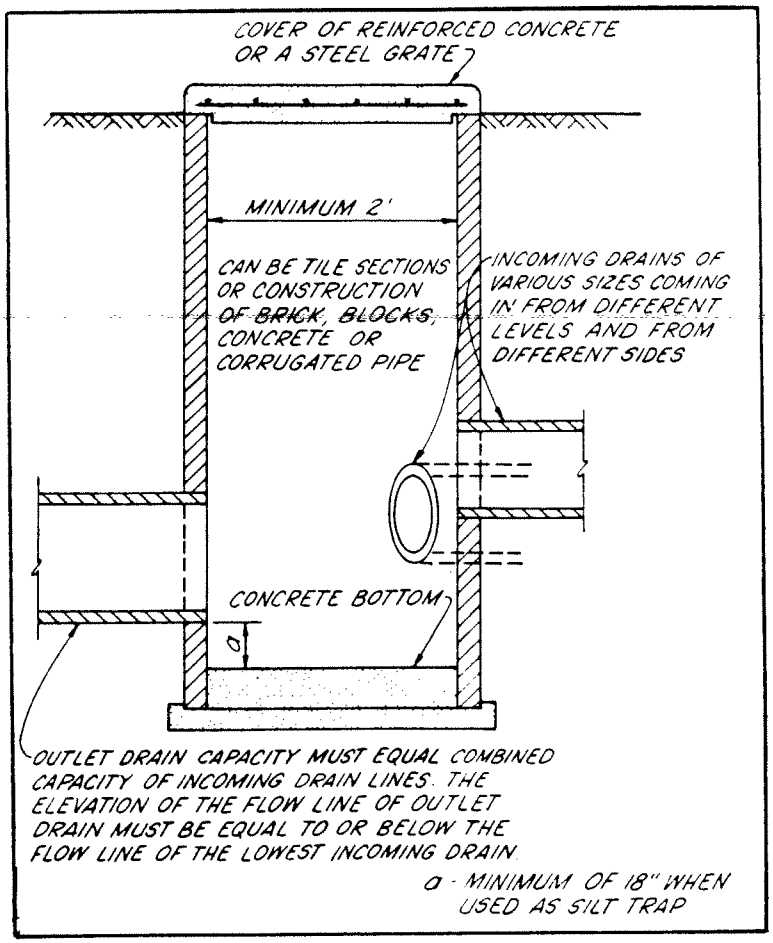


Figure 4-9. Junction Box for Drain Lines.

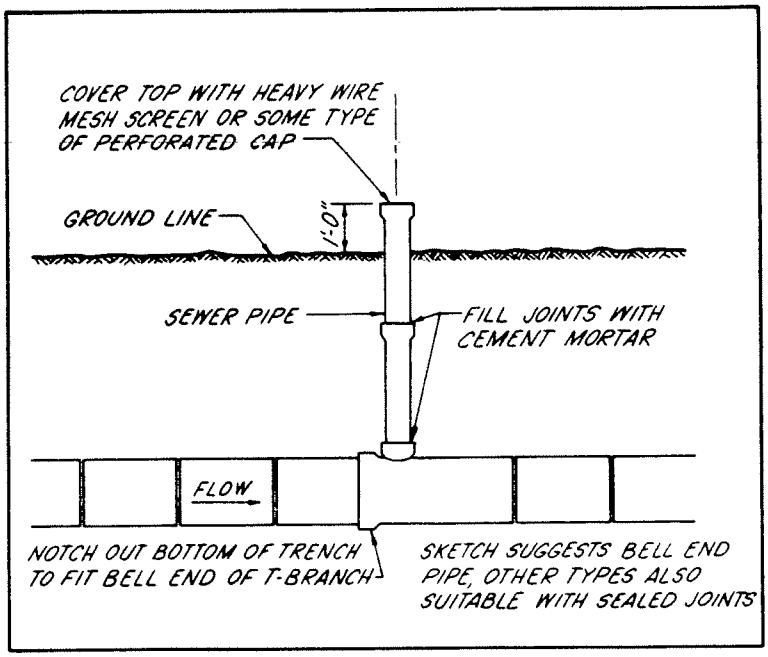


Figure 4-10. Relief Well or Breather Vent.

Surface Inlets

Surface inlets, used to admit surface drainage water into subsurface drainage systems, should be used with caution and properly constructed. Where the amount of surface water to be admitted into the subsurface system is small, the normal drain line should be replaced with sections of continuous rigid pipe or tubing, or the joints of the drain tile should be sealed on each side of the inlet riser. Grates and perforated or slotted pipes, as shown in Figures 4-11 to 4-12, are used to prevent trash or weeds from entering or clogging the drain. When an appreciable amount of water and/or sediment is to be admitted through a surface inlet, a silt trap should be provided similar to that shown in Figure 4-13.

Blind inlets, sometimes called French drains, are occasionally installed in lateral lines (not mains) running through depressional areas where surface water tends to collect. They are most practical where the water quantity is small and where a shallow surface ditch for diverting the surface water is not feasible. Blind inlets are constructed by replacing the natural backfill in a section of the trench with more permeable fill material, such as gravel, graded aggregate, or cinders. If the blind inlet is located in a cultivated area, the gravel material is usually extended to within 12 inches of the ground surface, at which level natural topsoil is applied.

In time, blind inlets tend to become clogged with silt. The rate of clogging will depend on the amount of silt carried into the filter by the surface water. When an inlet fails to work properly, the filter material should be removed and cleaned, or a new inlet installed adjacent to the old one. Blind inlets are sometimes made by digging a 12-foot wide trench at grade level, and at right angles to the direction of the drain line. Construction details of a blind inlet are shown in Figure 4-14. Drainage coefficients used in the design of systems having surface inlets were shown in Table 4-2.

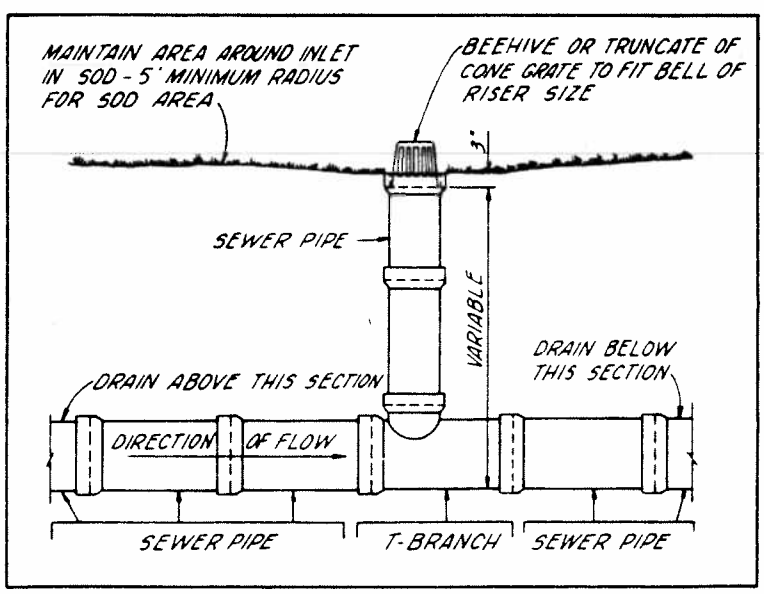
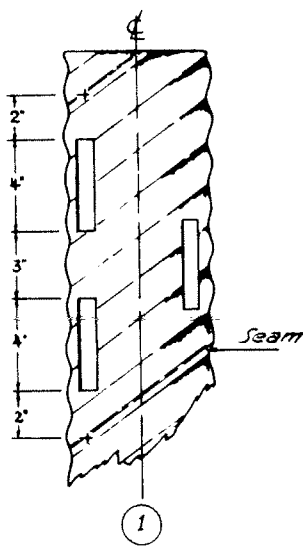
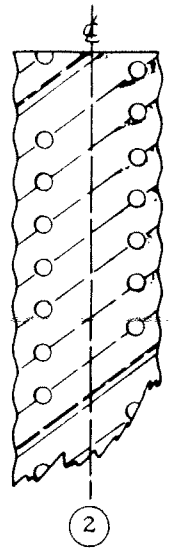
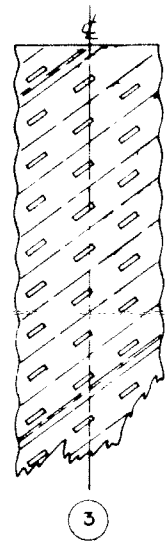


Figure 4-11. Open surface inlet for small drainage areas.







SLOTTED INTAKE

1. Cut 1"x 4" slots in 4 rows around the pipe (90° spacing). Do not space closer than 2" to the seams or end of pipe.
2. Capacity - 20 acre inches per day.

ROUND HOLE INTAKE

1. Fabricate 24 holes per lin. foot, 3/4" diameter.
2. Alternate fabrication - approximately 12 holes per foot of 1" diameter.
3. Capacity - 8 acre inches per day.

CHISEL PERFORATED

1. Fabricate 12 rows of 3/16" x 1" slots, (30° spacing).
2. Capacity - 10 acre inches per day.

GENERAL NOTES

1. Alternates - three are shown. All holes shall be carried to ground line or below.
2. Fabrication - all intakes are fabricated from 16 ga. - 6" dia. H.C.M.P. Any job needing more capacity will require a special design.
3. Wrapping - openings which extend below ground shall be wrapped with a fiber glass material.
4. Restricted flow - flow may be restricted, when necessary, by two methods:
   a. Size the sealed conduit. Minimum size is 4".
   b. Use an orifice plate, placed in the tee as shown.
5. Trash Guard - shall be provided at the top of each intake. One type can be made by drilling holes and inserting two horizontal bars at a 2" spacing.

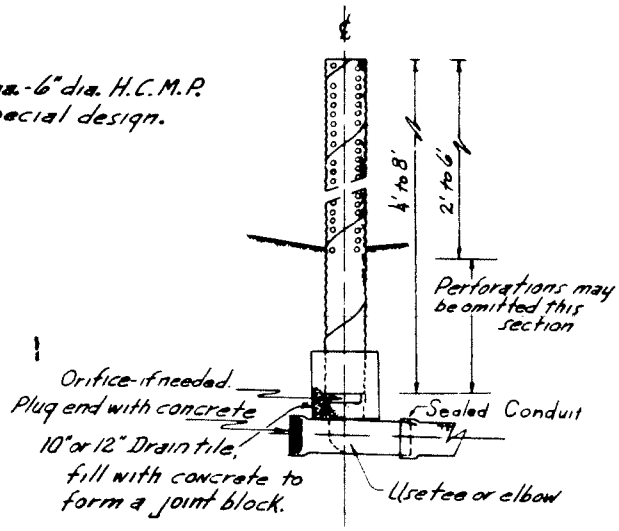


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Figure 4-12. Slotted or Perforated Pipe Intakes.

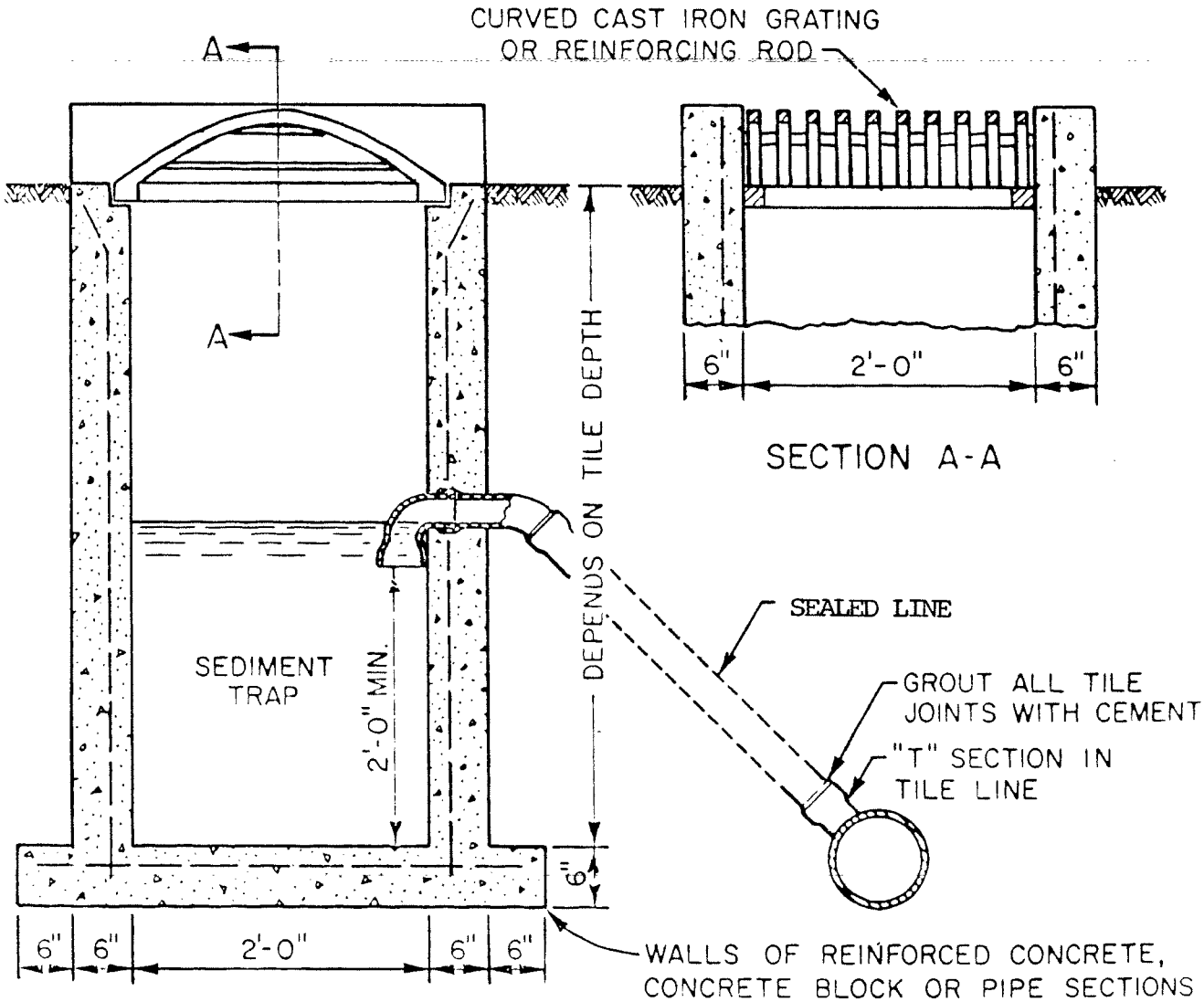

Figure 4-13. Open Surface Inlet with Sediment Trap.

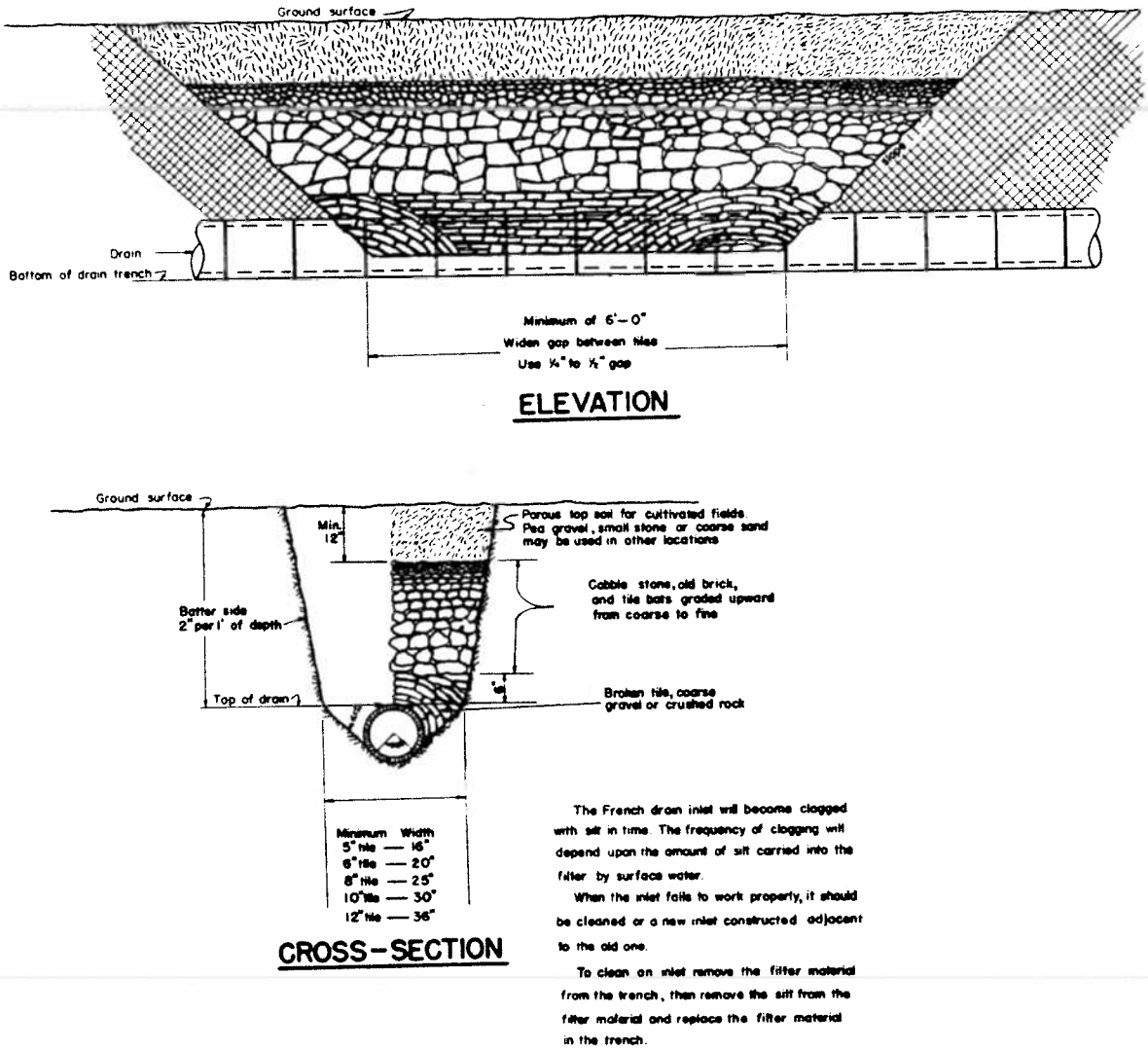

Figure 4-14. Blind Surface Inlet.

Placement of the Drain

Corrugated plastic drainage tubing has relatively little inherent load-bearing strength. Its ability to support soil loads is derived from the lateral pressures induced as the sides of the tubing deflect outward against the soil. Flexible tubing must be installed in the trench in a way which insures good soil support from all sides. There must be no voids remaining which would permit the soil pressure from backfill to cause deflection of the tubing to the point of buckling. This may be accomplished by shaping a groove in the trench bottom as shown in Figure 4-5 and using loose, friable soil or sand-gravel material to completely fill around the sides and over the top of the tubing after it is placed in the groove. The groove may be semicircular, trapezoidal, or a 90 degree V. A 90-degree V-groove of sufficient depth is satisfactory for 3-to 6-inch tubing. The void under the tubing is advantageous for load bearing but may cause undermining by erosion on steep grades. Under steep grade conditions the bottom of the trench shall be shaped to closely fit the tubing. Flow velocities must not exceed the limits for "Drain Without Protection" given in Table 4-5. Figure 4-5 shows dimensions for a 90-degree V-groove. When the same 90-degree V-groove is used for sizes from 3-6-inch tubing, the depth that the tubing sets in the groove varies with the tubing size; therefore, this depth should be considered when setting the grade line. For 8-inch diameter tubing or larger, a curved bottom which more nearly fits the tubing is recommended rather than the 90-degree V-groove. A satisfactory installation also can be made by bedding the tubing in a sand-gravel envelope material. The bedding should have no rocks or hard clods and should be placed at a thickness of at least 3 inches around the tubing. Most installations are made with machinery, without requiring a man in the trench to position the tubing or place the bedding. Some modification of machinery designed for installation of rigid conduits usually is necessary to install flexible conduits efficiently.

The conduit should be placed or bedded in the trench by one of the methods given in Table 4-7.

TABLE NO. 4-7

Type of Conduit	Special Conditions[1/]	Method
Flexible	Filter not required	2 or 3
Flexible	Filter required	
	(a) Prefabricated filter	2
	(b) Sand and gravel filter	4
Rigid	Filter not required	1 or 2
Rigid	Filter required	
	(a) Prefabricated filter	1 or 2
	(b) Sand and gravel filter	4

Type of Conduit	Special Conditions[1/]	Method
Flexible or rigid	Envelope required for support or to increase the flow of groundwater into the drain.	3 or 4

1/See Table 4-6 for suggested filter requirements, or envelopes.

Method 1: For a rigid conduit when filter or envelope material is not required, the conduit can be placed in a conventional trench and blinded and backfilled in the conventional manner using soil from the sides of the trench and excavated material as shown in Figure 4-5a. Blinding is the process of placing friable soil on top of the conduit to a depth of not less than six inches. Such soil, obtained from along the sides and top of the open trench, provides a more permeable material around the conduit and also lessens the risk of damage to the conduit during the remainder of the backfill operation.

Method 2: For flexible conduit, when filter or envelope material is not required nor used, a special shaped groove should be used. The groove provides support for the tubing and a means of maintaining alignment during installation. The groove may be semicircular, trapezoidal shaped, or a 90° "V" as shown in Figure 4-5b. Values for larger diameter tile may be obtained by using the r and/or d relationships shown in parenthesis in each column heading to calculate the various dimension.

As indicated earlier, with the 90° "V" or trapezoidal shape, the void under the tubing may cause undermining on steep grades. Under these conditions, the bottom of the trench shall be semicircular shaped to fit the tubing.

Method 3: For flexible conduit, a sand and gravel envelope can be placed for support in lieu of Method 2. To encase the conduit in a sand and gravel envelope, the conduit shall be laid on the bottom of a conventional trench (no special shaping or grooving) and the trench should be filled with envelope material to a level flush with the top of the conduit. The trench must be completely filled so that there are no void spaces in the area between the sides of the pipe and the walls of the trench. Backfill, for a minimum of six (6) inches above the sand and gravel envelope depth should be friable (granular-like) soil free of large clods or stones. Backfilling can be in the conventional manner. With this method, it is desirable to excavate a narrow trench to conserve on envelope material. The minimum envelope depth should be equal to the outside diameter of the conduit. See Figure 4-6a.

Method 4: Where the conduit is encased in a sand and gravel filter, a minimum of 3 inches depth of filter material shall be placed on the bottom of a conventional trench. The conduit shall be placed on this and the trench completely filled with filter material to a minimum depth of 4 inches above conduit. See Figure 4-6b. An acceptable optional method of placing the filter material is to fill the trench as indicated in Figure 4-6c and to cover this with a plastic sheet (not less than 6 mil.) at least 8 inches wider than the conduit diameter, to separate the filter material from the backfill material. A minimum of 6 inches of

friable (granular-like) blinding soil, free of large clods or stones, should be placed over the plastic prior to conventional backfilling.

Selection of Quality Tile Materials

All drainage materials installed should meet current requirements of the American Society for Testing Materials. See Table 4-9. Copies of these specifications may be obtained from the American Society for Testing Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103. Local SCS and ASCS offices have lists of manufacturers of drainage materials who have submitted their products for testing and have met ASTM specifications. When purchasing drain tile or tubing, the manufacturer should certify that the product meets a specific ASTM specification.

Table 4-8a, Bearing Strength of Drain Tile

Description	Tile Diameter, Inches	Average 3-Edge Bearing Crushing Strength, Pounds per Lineal Foot
Standard-Quality Concrete Drain Tile (ASTM C412)	4,5,6,8,10,12	800
Extra-Quality or Special-Quality Concrete Drain Tile (ASTM C412)	4,5,6,8,10,12,14,15,16	1,100
	18	1,200
	20	1,330
Heavy-Duty Extra-Quality Concrete Drain Tile (ASTM C412)	4,5,6,8	1,300
	10	1,400
	12	1,500
	14	1,750
	15	1,870
	16	2,000
Standard-Quality Clay Drain Tile (ASTM C4)	4,5,6,8,10,12	800
	14	840
	16	870
Extra-Quality Clay Drain Tile (ASTM C4)	4,5,6,8,10,12,14	1,100
	15	1,150
	16	1,200
	18	1,300
Heavy-Duty Clay Drain Tile (ASTM C4)	4,5,6	1,400
	8	1,500
	10	1,550
	12	1,700
	14	1,850
	15	1,980
	16	2,100

Table 4-8b. Maximum allowable trench depths.

MAXIMUM ALLOWABLE TRENCH DEPTHS, RIGID CONDUITS

3-EDGE BEARING CRUSHING STRENGTH	TILE DIAMETER	TRENCH WIDTH (INCHES)							
		18	21	24	27	30	36	42	48
800	4,5,6	9	7	7	7	7	7	7	7
800	8	9	7	6	6	6	6	6	6
800	10	10	7	6	5	5	5	5	5
800	12		7	6	5	5	5	5	5
840	14			6	5	5	5	5	5
870	15			6	5	5	5	5	5
1000	6	19	9	8	8	8	8	8	8
1000	8	19	9	7	7	7	7	7	7
1100	4,5,6	25+	11	9	9	9	9	9	9
1100	8	25+	11	8	7	7	7	7	7
1100	10	25+	11	8	7	6	6	6	6
1100	12		11	8	7	6	6	6	6
1100	15			8	7	5	5	5	5
1150	15			9	7	6	5	5	5
1200	12		14	9	7	6	6	6	6
1200	16			10	8	7	5	5	5
1200	18				8	7	5	5	5
1250	4,5,6	25+	16	11	11	11	11	11	11
1300	4,5,6	25+	18	11	11	11	11	11	11
1300	8	25+	18	11	8	8	8	8	8
1300	18				9	7	5	5	5
1350	8	25+	22	11	9	9	9	9	9
1400	4,5,6	25+	25+	12	10	10	10	10	10
1400	10	25+	25+	12	9	8	8	8	8
1400	15			13	9	8	6	6	6
1450	4,5,6	25+	25+	13	11	11	11	11	11
1500	8	25+	25+	14	10	9	9	9	9
1500	12			14	10	8	7	7	7
1550	10	25+	25+	15	11	9	8	8	8
1600	4,5,6	25+	25+	16	12	12	12	12	12
1600	8	25+	25+	16	11	10	10	10	10
1600	10	25+	25+	17	11	9	9	9	9
1600	14			17	12	8	7	7	7
1650	15			19	12	10	7	7	7
1700	8	25+	25+	25	12	11	11	11	11
1700	12			25	12	10	8	8	8
1700	16			25	13	11	8	7	7
1700	18				13	11	8	7	7
1750	15			25	14	11	8	7	7
1800	8	25+	25+	25+	14	11	8	8	8
1800	12			25+	15	11	8	7	7
1800	18				15	11	8	7	7
1850	14				15	11	8	8	8
2000	4,5,6	25+	25+	25+	19	14	14	14	14
2000	8	25+	25+	25+	19	12	12	12	12
2000	10		25+	25+	19	13	10	10	10
2000	18				20	14	9	7	7

Based on: K_u & K_u' = 0.13, Load Factor 1.5, Safety Factor 1.5, weight of soil - 120 lb./cu.ft.

REFERENCE: Technical Release No. 5. This chart was developed by Guy B. Fasken.

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DRAINAGE SECTION

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TABLE 4-8c
MAXIMUM TRENCH DEPTHS FOR TUBING BURIED IN LOOSE, FINE-TEXTURED SOILS

Nominal diameter of tubing (inches)	Quality of tubing [1]	Maximum trench depths (feet) for various trench widths (inches) at top of tubing			
		12	16	24	32 or greater
4	Standard[2]	12.8[4]	6.9	5.6	5.2
	Heavy-duty[3]	...[5]	9.8	6.9	6.2
6	Standard[2]	10.2	6.9	5.6	5.2
	Heavy-duty[3]	....[5]	9.5	6.7	6.2
8	Standard[2]	10.2	7.2	5.6	5.2
	Heavy-duty[3]	....[5]	9.8	6.9	6.2
10	...[3]	....[5]	9.2	6.7	6.2
12	...[3]	....	8.9	6.7	6.2
15	...[3]	....	...	6.9	6.2
18	...[3]	....	...	...	...

[1]ASTM designations.
[2]Pipe stiffness is 13 psi (90 KN/m^2) for 20 percent deflection.
[3]Pipe stiffness is 18 psi (124 KN/m^2) for 20 percent deflection.
[4]It is assumed that E' = 50 psi, (345 KN/m^2) that D_1 = 3.4, that K = 0.096 (bedding angle of 90 degrees), that w = 109 pcf, (1,750 kg/m^3) and that $\Delta y = 1.1\Delta x$.
[5]Any depth is permissible for this width or less. For a trench width of 8 inches (0.2 m), any depth is permissible for any size of tubing.
This table is revised from A.D. Fenemor, B.R. Bevier, and G.O. Schwab. (1978), Prediction of Deflection for Corrugated Plastic Tubing, ASAE Paper No. 78-2542, Submitted for publication in the Transactions of the ASAE.
Note: The commercial tubing supplied by the various manufacturers varies in corrugation design and pipe stiffness. These variations as well as differences in soil conditions may change the assumptions of this table and make the maximum depths more or less than those stated here. These depths are based on limited research and should be used with caution.

Table 4-8d. Percent of Wheel Loads Transmitted to Underground Tile

Depth of backfill over top of tile (feet)	Percent of wheel loads for various trench widths at top of tile (feet)						
	1	2	3	4	5	6	7
1	17.0[a]	26.0[a]	28.6[a]	29.7[a]	29.9[a]	30.2[a]	30.3[a]
2	8.3	14.2	18.3	20.7	21.8	22.7	23.0
3	4.3	8.3	11.3	13.5	14.8	15.8	16.7
4	2.5	5.2	7.2	9.0	10.3	11.5	12.3
5	1.7	3.3	5.0	6.3	7.3	8.3	9.0
6	1.0	2.3	3.7	4.7	5.5	6.2	7.0

[a] These percentages include both live load and impact transmitted to 1 lineal foot of tile.
[b] Live loads transmitted are practically negligible below 6 feet.

Four classes of concrete drain tile are recognized. These are standard quality, extra quality, heavy duty and special quality. There are three classes of clay drain tile: standard quality, extra quality and heavy duty, and two classes of corrugated plastic tubing: standard and heavy duty. In choosing the quality of product to use, the following general recommendations are made.

1. Standard quality drainage tile or tubing may be used when there is at least two feet of cover over the material and the trenches are of moderate depth and width. The tubing or tile should be installed according to the recommendations for installation for the specific material being used.

2. Extra quality, special quality or heavy duty drain tile or tubing should be specified for unusual conditions of exposure or where tile are laid in trenches of considerable depth, width or both. See Tables 4-8. Heavy duty corrugated drainage tubing should be used where the trenches are expected to impose heavier than normal loads on the tubing.

Maximum depth of cover for clay and concrete drain tile depends on the soil, the tile quality, type of tile bedding, and the trench width. Depth should not exceed those values given in Table 4-8b and 4-8c. The trench depth is measured to the bottom of the trench. The width is measured at

TABLE 4-9. MATERIALS FOR SUBSURFACE DRAINAGE

Type of Material	Specification[a]
Clay drain tile	ASTM[b] - C-4
Clay drain tile, perforated	ASTM - C-498
Clay pipe, perforated standard and extra strength	ASTM - C-700
Clay pipe, testing	ASTM - C-301
Concrete drain tile	ASTM - C-412
Concrete pipe for irrigation or drainage	ASTM - C-118
Concrete pipe or tile, determining physical properties of	ASTM - C-497
Concrete sewer, storm drain, and culvert pipe	ASTM - C-14
Reinforced concrete culvert, storm drain, sewer pipe	ASTM - C-76
Perforated concrete pipe	ASTM - C-444
Portland cement	ASTM - C-150
Asbestos-cement storm drain pipe	ASTM - C-663
Asbestos-cement nonpressure sewer pipe	ASTM - C-428
Asbestos-cement perforated underdrain pipe	ASTM - C-508
Asbestos-cement pipe, testing	ASTM - C-500
Pipe, bituminized fiber (and fittings)	Federal Specification SS-P-1540
Homogeneous bituminized fiber pipe for general drainge	ASTM - D-2311
Homogeneous bituminized fiber pipe, testing	ASTM - D-2314
Laminated-wall bituminized fiber perforated pipe for agricultural land and general drainage	ASTM - D-2417
Laminated-wall bituminized fiber pipe, physical testing of	ASTM - D-2315
Styrene rubber plastic drain pipe and fittings	ASTM - D-2852
Polyvinyl chloride (PVC) sewer pipe and fittings	ASTM - D-2729
Polyvinyl chloride (PVC) pipe	ASTM - D-3033 or D-3034 Type PSM or PSP
Corrugated polyvinyl chloride tubing	(SCS Standard and Specification 606)
Corrugated polyethylene tubing and fittings	ASTM - F-405
Corrugated polyethylene tubing and fittings, 10-15 in.	ASTM - F-667
Pipe, corrugated (aluminum alloy)	Federal Specification WW-P-402
Pipe, corrugated (iron or steel, zinc coated)	Federal Specification WW-P-405

[a] This information is from Subsurface Drain, Standards and Specifications (606), National Handbook of Conservation Practices, United States Department of Agriculture, Soil Conservation Service.

[b] Specifications can be obtained from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania, 19103.

the top of the tile because the width of the excavation above this point does not significantly affect the loading. Live and impact loads transmitted to underground drains are shown in Table 4-8d. Transmitted loads are negligible below six feet. The type of bedding affects the amount of load which a tile will support without crushing. These types of bedding are shown in Figures 4-5 to 4-6. Table 4-8b is based on "ordinary bedding", shown in Figure 4-5a, which can be obtained using common trenching machines and ordinary care in backfilling. If this bedding condition is not obtained, significantly higher stresses are imposed on the tile. For "impermissable bedding", shown in Figure 4-5a, the maximum allowable trench depth is about 60 percent of the value given in Table 4-8b.

Example: What is the maximum trench depth for an 8-inch diameter standard quality concrete tile? Assume a trench width of 24 inches and ordinary bedding.

Solution: Using Table 4-8a, the 3-Edge Bearing strength for an 8-inch standard quality concrete tile is 800 pounds/foot. Next, using Table 4-8b, for 800 pounds/foot strength and 8-inch diameter, the maximum depth for a 24-inch trench is 6 feet.

Example: A tile main will have to be cut through a knoll in order to get an outlet. The maximum cut will be 11 feet, the trench will be 24 inches wide, and the main will be 10-inch concrete tile. Assume ordinary bedding. What quality tile is needed?

Solution: Using Table 4-8b, for a 24-inch trench, 12 feet depth, and 10-inch diameter, the 3-edge crushing strength is 1,400. (Note that the next shallower depth for 10-inch is 8 feet, so you must use 12 feet.) Going to Table 4-8a, you find that a 10-inch concrete tile with 1,400 pound per foot strength is heavy-duty extra-quality. Heavy-duty extra-quality tile is needed on this job wherever the cut is more than 8 feet.

Concrete drain tile should be properly cured before installing. It is not a good practice to install air-cured concrete drain tile until 28 days after manufacture. Steam-cured concrete will approach ultimate strength at a slightly earlier age. Concrete tile should never be removed from the manufacturing plant until properly cured to meet ASTM specifications. Some clay or shale drain tile may be severely damaged by frost. Do not "string out" or stack clay or shale tile on the ground during periods of freezing and thawing.

Soil acids affect concrete tile to varying degrees depending upon the degree of acidity and the tile quality. Clay tile and plastic tubing are not affected by soil acids. The degree of soil acidity is commonly expressed as a pH number. A pH value of 7 is neutral. When pH number is more than 7.0, the soil is alkaline. Conversely, when the pH number is less than 7.0, the soil is acid. The smaller the number the greater the acidity. Table 4-10 may be used as a guide when recommending concrete tile in acid soils. The pH value is given in Table 3-1 for each Minnesota soil.

Table 4-10

GUIDE FOR USING CONCRETE TILE IN ACID SOILS

STANDARD AND CLASS OF TILE	LOWEST PERMISSIBLE pH VALUES 1/	
	ORGANIC AND SANDY SOILS	MEDIUM AND HEAVY TEXTURED SOILS
ASTM C412:		
Standard Quality	6.5	6.0
Extra Quality	6.0	5.5
Special Quality	5.5	5.0
ASTM C 14, C 118, C 444	5.5	5.0

1/ Figures given represent lowest readings of pH values for soil-water or soil at tile depth.

Plastic tubing is not affected by acids and chemicals normally found in the soil at the drainage depth. As indicated later, plastic tubing becomes stiff and brittle at low temperatures and is soft when exposed to the sun on a hot day. This temperature-related characteristic of plastic is a problem only at the time of handling and is not of serious consideration once it is installed and buried. If plastic tubing is to be installed under unusually cold conditions, the manufacturers recommendations for use under these conditions should be obtained.

Trees

All water-loving trees, such as the willow, soft maple, elm, poplar and cottonwood, should be removed for a distance of 100 feet from a drain line (unless joints are sealed or nonperforated and continuous) that is designed to carry water over prolonged periods during the growing season. Roots from such trees will clog the drain if they are allowed to grow. Other trees should be removed for a distance of 50 feet. If a tree (or trees) cannot be removed from the vicinity of a drain line, the drain line should be rerouted or a continuous nonperforated pipe should be used for the drainage conduit for a distance of 50 to 100 feet on each side of the tree, depending upon the species.

Ochre Formation

Ochre is a red to yellow, filamentous, amorphous mass of ferric hydroxide with an organic matrix that commonly sticks to drain wall openings and drain envelopes. It can clog drains, the surrounding drain envelopes, or drain openings. It seldom closes the drain completely, but it can reduce the efficiency of a drainage system so that performance is unsatisfactory.

Soils must have iron and must be wet for ochre to form. Those in which ochre is most likely to form are:

1. Mucks, peats, and other highly organic soils.

2. Sandy soils high in organic matter content.

3. Soils with buried layers or abrupt changes in texture at the depth of the drain line, particularly those with a high organic matter content in the surface layer or in a buried horizon.

4. Soils that are alternately wet and dry, such as those under irrigation.

Measures That Help Prevent Drain Clogging

There is no effective economical long-term method for controlling ochre clogging. Based upon chemical and microbiological requirements, the options are limited. Emphasis must be on living with the problem. The following are examples of some treatments that may help prevent clogging, but none are completely effective.

1. Promote oxidation and precipitation of iron in the soil before it reaches the drain line. All measures aimed at soil aeration are acceptable. If soil type and soil moisture permit, soils containing high levels of ferrous iron (including but not limited to soils with gray or drab colors) should be predrained either by mole drains or by trench drains. This method can be used only in loamy and sandy soils that have clay contents of 30 percent or less and are not underlain by heavier bog-like materials. Even with the predrain treatment, there is no assurance that iron precipitated in the soil will not become soluble again if the area is reflooded. Other recommendations involve deep ground breaking with suitable plows, use of a two-stage drain system with one drain on a different level than the first drain, and preliminary drainage with open trenches for 2 to 3 years.

2. Large inlet holes. Inlet holes larger than 1 mm are advantageous. Ochre clogs an inlet hole by sticking to the edges and then gradually closing the hole. The larger holes are helpful. However, it must be remembered that ochre can also form in the drain envelope and in the zone abutting the drain envelope.

3. Submerged outlets. A longtime recommendation has been to let drains discharge under water if ochre is a problem. The drain line must be completely under water (anaerobic) at all times, during both drainage and subirrigation. This means very deep drains are needed. If the line becomes aerated for even a short period, ochre can form.

4. Minimizing ochre problems through installation procedures. Drains should not be installed below the water table. If possible, the soil should be dry.

Each drain should open separately into ditches rather than through collector systems. Use single, shorter lines with no laterals. A small area in a field may be potentially ochreous, so trouble should be confined to single drains. Cleaning is also easier for single drains.

FIELD INSTALLATION OF SUBSURFACE DRAINAGE SYSTEMS

Introduction

Application of correct installation techniques is necessary for proper performance of a subsurface drainage system. With good design and selection of quality materials, proper installation greatly reduces future maintenance problems and prolongs the life of the subsurface drainage system. Most subsurface drainage systems in Minnesota are installed with trenches and/or plows. Trench-type machines excavate the trench by means of a bucket-wheel or chain. The drain tile or tubing is then placed in the bottom of the open trench and the trench is backfilled. Plows do not dig an open trench, but rather pull a projectile-shaped mole through the soil at the required drain depth. The plow then places flexible tubing in the slot formed by the mole. Backhoes are used to dig trenches for large diameter tile lines (over 18") and to excavate at junctions and where junction boxes, blind inlets, or other appurtenances are to be installed in the system. Backhoes are sometimes used to dig open trenches in small systems. However, if a backhoe is used for trenching work, considerable hand labor and checking is necessary to control the grade and shape of the trench and to lay the tile.

Construction Plans

All construction work should follow a definite plan which has been prepared or considered prior to construction. The job site should be inspected by the contractor and owner to ensure that all work and/or facilities on which this installation depends is satisfactory. The owners of other lands, easements, highways and railroads should be contacted by the owner for permission to cross, well in advance of construction. Buried cables, pipelines or other utilities should be noted and the public utility concerned should be requested to mark the exact location of such buried obstacles at points where drains are to be constructed. The owner should ensure that the soil will respond to subsurface drainage. When construction is completed, a plan of the work as installed in the field should be left with the landowner by the contractor.

Inspection and Handling of Materials

Inspection of material for drains should be made by the contractor before and during installation. All materials should be satisfactory for the intended use and should meet the requirements as set forth in the Quality of Materials section and any additional requirements of

the owner. Defective or damaged clay, shale, concrete or other rigid drain pipe should be rejected; defective or damaged sections of plastic pipe should be cut out and the tubing joined.

Storage

Drainage materials should be protected from hazards and care should be exercised during handling to avoid damage to the material. The storage area should be a dry area with good drainage and be free of rodents and vegetation. The area should have a protected floor area (peagravel or concrete) with adequate security. Plastic tubing can be destroyed by fire. Therefore, precautions need to be taken to protect it from any potential fire hazard. It is recommended that end caps be used where rodents could be a potential problem. Tubing with filter wrap should be either stored inside or placed in protective bags. Since excessive exposure to ultraviolet rays from sunlight can be harmful to the tubing, protection from sunlight is required when tubing is subjected to long periods of storage. Coils and/or reels of tubing should be protected from damage and deformation by being laid flat when stored for extended periods of time. Stacked coils of tubing should not exceed four high and reels should not be stacked.

Safety

High standards of safety for men and machines must be observed at all times. All contractors must comply with existing State and Federal laws. Men working in trenches should be protected from cave-ins by the shoe shield of the drainage machine or by proper trench shoring. Men should not work alone in trenches. Moving parts of the machine should be protected by proper guards. Casual observers should not be permitted close to machine or excavating operations. Livestock should not be allowed in the field where construction work is in progress or where trenches are left open. Safety barricades and warning signs should be erected by the contractor where the public has access to the construction area.

Grade Control

As indicated earlier, grade and alignment are important factors to consider in subsurface drainage installation. Grade stakes, to govern alignment and grade, should be set approximately every 100 feet. Targets are frequently used as a guide to keep the trench bottom to exact grade. As least three targets should be set along any given strip of continuous grade. Key targets should be set at 500 to 700-foot intervals, or at points of change in grade. Intermediate targets may be set in correct position by carefully sighting between key targets.

After setting, each target should be checked for depth of cut, as indicated by its respective grade stake. Where laser and/or other automatic depth and grade control systems are used, stakes are needed only for alignment or to indicate locations where grade changes. However, it is important to check the accuracy of the laser equipment often to assure its accuracy and adjustment.

The constructed grade may be slightly less than the design grade for short distances (not to exceed 100 feet) as long as the constructed grade provides the required capacity for the area to be drained. A gradual change in grade over a distance of not less than 30 feet is permissible if the maximum variation from the design grade does not exceed 0.3 foot times the design grade in percent (Example: 0.3 x 0.2% = 0.06 foot). A slight "sag" in the constructed grade line is less harmful than a "hump" in the line. Variations from designed grade for the "sag" and "hump" within a distance of 100 feet should not exceed the maximum permissible variation as computed above, except that the maximum permissible variation from designed grades of 0.1 percent or less should be ± 0.05 foot. Correction for overdigging may be accomplished by filling with either well-graded gravel or well-pulverized soil. Soil must be tamped to the approximate density of the original soil condition to provide a firm foundation, and the bottom of the trench must then be graded and shaped to the desired grade.

Trenching Procedures

1. Beginning Point

   Construction of the trench should normally begin at the outlet and proceed upgrade.

2. Alignment. Trenches should be aligned so that the pipe can be laid in straight lines or in smooth curves.

3. Trench Width. The trench width at the top of the drain should be a minimum required to permit installation and provide bedding conditions suitable to support the load on the drain but not less than 3 inches of clearance on both sides of the drain.

4. Trench Bottom. Tile should be bedded with ordinary care in an earth foundation shaped to fit the lower part of the tile. This can be accomplished with most trenching machines. When a backhoe is used to dig the trench, it will generally be necessary to hand grade and shape the trench bottom to fit the tile. For corrugated plastic tubing, a specially shaped groove is required in the trench bottom where a gravel envelope is not specified. The groove provides side and bottom support to the lower part of the tubing and it further provides a means of controlling alignment during installation.

   The groove can be formed or cut in a number of ways. In all cases, some type of a forming tool is attached to the shoe of the trenching machine. One method is to install a forming tool on the bottom of the shoe and use compaction pressure to form the bedding groove. A better method is to install a device on the front of the finishing shoe and plow out the groove during the trenching operation. Special shaping cutters can also be attached to the trenching wheel. The latter two methods are preferred since they minimize soil compaction and permeability reduction.

5. Rock Excavation. When tile or tubing is to be laid in a rock-cut, the trench should be overexcavated to a depth of 6 inches below grade level and this space filled with graded sand and gravel or well-pulverized soil and tamped sufficiently to provide a firm foundation. The bottom of the trench should then be shaped and leveled to grade, and the trench filled with designed bedding or envelope material to the top of the rock-cut.

6. Unstable Trench Walls. Unstable or fluid soil conditions encountered in the trench wall, or base, such as may be found by excavation below a ground water level or in a saturated sand, may cause tile or tubing failure by caving of the trench sidewalls. This situation may also cause tile lines to fail due to tile misalignment. A means must be provided where there are unstable trench sidewalls to protect the tubing or tile from caving of the sidewalls until the drain has been properly laid and blinded. In some cases, the trencher shield behind the shoe may be made longer to protect a greater length of the trench.

   The drain conduit should be laid immediately after the shoe has passed. The trencher shield must provide enough time to surround the drain with blinding or envelope material which will provide some protection against caving. Provisions for safety during trenching operations shall be in compliance with the safety and health regulations for construction.

7. Unstable Trench Bottom. Where an unstable trench bottom condition is encountered, such as in fine sandy soils or in quicksand conditions, extreme care must be taken to keep sediment from entering the drain and to provide a firm foundation for the drain.

   The following considerations should be made when draining these soils:

   a. Install the drain only when soil profile is in the driest possible condition;

   b. Use stabilizing envelope materials under the drain;

   c. Use an envelope material to cover the remainder of the drain;

   d. Use nonperforated tubing, self-sealing sewer or continuous rigid pipe where small pockets less than 100 ft. in length of noncohesive soils are encountered;

   e. If the drain is tile, be sure to secure a snug fit of the joints;

   f. If tubing is used, precautions must be taken to prevent it from floating.

Should unstable soil material be encountered, it may be removed and replaced with a foundation and bedding of processed stone or processed gravel, suitably graded and acting as a filter into which the unstable soil will not penetrate. The depth of this processed material, as used for foundation and bedding, should depend on the severity of the trench bottom soil condition. Such special foundation and bedding material should be installed in maximum of 6 in. layers and compacted. If the foundation contains large particles that create a hazard to the drain, provide a cushion of acceptable bedding material between the foundation and the drain.

Where stabilizer materials do not furnish adequate support, the drain should be placed in a 90 degree rigid V prefabricated foundation cradle with top of the V equal to the outside diameter of the drain. Each section of the cradle must provide rigidity and continuous support throughout the entire length of the cradle. Occasionally, it is necessary to place the cradle on piling by driving pairs of posts along the edge of the cradle into solid material to provide the required support.

For drainage of unstable soils, a fast-moving trencher or drain plow that can maintain a continuous forward motion and disturb the in-place material as little as possible should be used.

8. Installing the Drain Tile or Tubing:

a. The laying of the drain tile or tubing should normally begin at the lower end of the drain and progress upgrade. It is preferable that the pipe be laid inside the shoe casing of the drainage machine during the trenching operation.

b. Drain tiles or tubing should be laid in the groove and on the planned grade on a firm bed, free of loose soil.

c. All soil or debris in a drain tile or tubing should be removed before installation.

d. The drain tile or tubing should be free from clinging wet or frozen material that would hinder the laying of drain on grade.

e. The upper end of all drain lines should be closed tightly with an end plug.

f. Before work is suspended for the day, all drain lines laid in trenches should be blinded and any open ends closed.

g. Automatic drain-laying devices are acceptable, provided requirements of this guide are met.

h. Plastic tubing should be held in position on planned grade immediately after installation by careful placement of either blinding or backfill material.

i. Where lengths of plastic tubing are to be joined, the ends should be cut square and all ragged or burred edges removed. A plastic coupling should be used to secure the ends of the tubing in proper alignment and prevent the joint from separating during installation.

13. Stretch During Installation. Stretch of corrugated plastic tubing that occurs during installation will cause some decrease in strength. Also, perforations may be pulled open wider than desirable. The stretch acquired during installation is influenced by the temperature of the tubing at the time it is being installed, the amount and duration of drag encountered when the tubing feeds through the installation equipment, and the stretch-resistance characteristics of the tubing. Tubing should not be stretched so much that its stiffness is reduced to less than the allowable minimum stiffness. Stretch is expressed as a percent increase of length and should not exceed 5 percent. The use of a power feeder to counteract stretching is recommended for all sizes of plastic tubing.

14. Weakening Due to High Temperature. The internal wall temperature of plastic tubing can reach 150°F or more when strung out in a field on a hot bright day. The ability of corrugated polyethylene tubing to resist deflection is reduced about 40 percent when its temperature rises from 70°F to 100°F and by about 50 percent when the temperature is raised from 70°F to 120°F. Therefore, it is essential that the contractor take precautions when these conditions exist so there is not a direct impact of sharp and heavy objects or excessive pull on the tubing during installation. The tubing will regain its strength when its temperature returns to that of the surrounding soil, which is usually in 5 min. or less after installation.

15. Brittleness Due to Low Temperatures. Tubing stiffness increases and flexibility decreases as its temperature is lowered. If the tubing is rapidly uncoiled in cold weather, it is stressed excessively and may even crack. The tubing may have a tendancy to coil, which presents difficulty in laying it flat and level and necessitates extra care. Check with the manufacturer concerning his recommendation for handling the material under either hot or cold conditions.

16. Floating in Water. Plastic tubing floats in water. If floating is allowed to occur during installation, it is difficult to get backfill material around and over the tubing without getting the material underneath it, causing misalignment. Therefore, floating should be avoided by mechanically holding the tubing in place until blinding is completed.

17. Blinding. Blinding is the process of placing bedding material of loose mellow soil on the sides and over the top of the drain to a depth of 6 inches. Except in those areas where chemical deposits

in and around the drain area are a problem, the soil should be friable top soil or other porous soil. Fine sand should not be placed directly on or around the drain. In tight soils where blinding with soil is not adequate, a suitable envelope should be used. The bedding material must also permit the water to easily reach the drain. The drain should be blinded immedately after being installed. A number of different blinding methods have proven acceptable. Some contractors place such importance on blinding that they hand place selected material around and over the tubing. There are also a number of mechanical blinding devices which can be mounted in the trencher. These devices place selected material from near the top of the trench around and over the drain. Their main advantages are immediate blinding after laying the drain, selection of the most suitable blinding material that is readily available, and reduced labor requirements.

a. Blinding for tile

All tile should be blinded immediately to maintain alignment and to protect the tile from falling rocks, ditch cave ins, and backfill operations.

Acceptable methods of automatic blinding and backfilling in one operation can be used provided the soil is suitable.

b. Blinding for tubing

Blinding will ensure proper alignment of the tubing in the groove the trench. Careful soil placement on both sides of the tubing is necessary to provide good side support which will reduce deflection of the tubing. Tubing should be held in place in the trench until secured by blinding. This is especially important when water is in the trench and when the air temperature is below 45°F. Blinding quantities may be increased under these conditions. Blinding is not necessary where drains are placed in sand and gravel filters or envelopes.

No stones or other hard objects should be allowed in immediate contact with the tubing. Such objects apply point loads and may cause the tubing to fail. Blinding provides protection for the tubing during the backfilling operation when the impact of rocks and hard clods could damage it.

Inspection. All lines should be carefully inspected for grade alignment and other specifications prior to backfilling.

18. Backfilling. At the conclusion of each day's work, the upstream ends of the drain lines should be stoppered and the trench backfilled to prevent sediment or debris from entering the line in the event of rain. Backfilling should be done even sooner if there is any danger of heavy rains or freezing temperatures. The upper end of each drain should be tightly covered with a manufactured plug or other equivalent material.

Various methods can be used to move the remaining excavated material back into the trench and mound it up and over the trench to allow for settlement. This may be done by hand shovels, graders, bulldozer, auger and conveyor methods. The backfill material shall be placed in the trench in such a manner that displacement of the drain will not occur. This is preferably on an angle so the material flows down the front slope. Large stones, clods and heavy direct loads must be avoided in backfill operations.

When installing tubing on a hot day and if the tubing feels warm to the touch (100°F), delay the backfilling until the tubing reaches the soil temperature.

Trenchless Plow Method

The trenchless method, using a drainage plow to install corrugated plastic drain tubing, can be used. Except for practices specifically applicable to the trenching method of construction, all other practices related to corrugated plastic drain tubing apply to the trenchless method.

The "trenchless" method places the drain at a prescribed depth in an open channel beneath a temporarily displaced wedge or column of soil. The drainage plow equipment constructs a smooth-bottomed opening in the soil, maintains the opening until the tubing has been properly installed, and then surrounds it with permeable material. The backfill should be relatively loose and the walls of the trench or slot fissured and loosened rather than compacted. The size of the shoe and drain placing attachment should conform to the outside diameter of the drain. The plow blade is designed to lift and split the overburden soil as it moves forward. The lifting action causes a deformation and disruption of the soil upward and outward at an angle on both sides of the plow blade. The tubing is fed in behind the plow blade before the soil falls back around the tubing. The soil which is heaved up above the general field surface by the trenchless plow shall be loosened up by one or more passes of a rototiller to provide a soil condition suitable for planting.

1. Critical Depth

Whether the slot wall is fissured or compacted depends upon how the trenchless plow moves the soil under the prevailing conditions. A plow working in a relatively shallow depth (28 inches or less) in dry conditions will disturb the soil as shown in Figure 4-15. The soil is broken loose right from the base of the plow, heaving forwards and upwards ahead of the tine and falling back around the pipe as the plow moves on. This type of disturbance creates cracks and fissures without compaction. The same plow working at a much greater depth (5.5 feet) in the same dry soil will tend to move the soil as shown in Figure 4-16. Disturbance near the soil surface is similar as in Figure 4-15, but below a certain depth, the soil is compressed sideways and this results in compaction with a reduction in soil permeability. Between these two extremes of working depth there is a certain depth, termed critical depth,

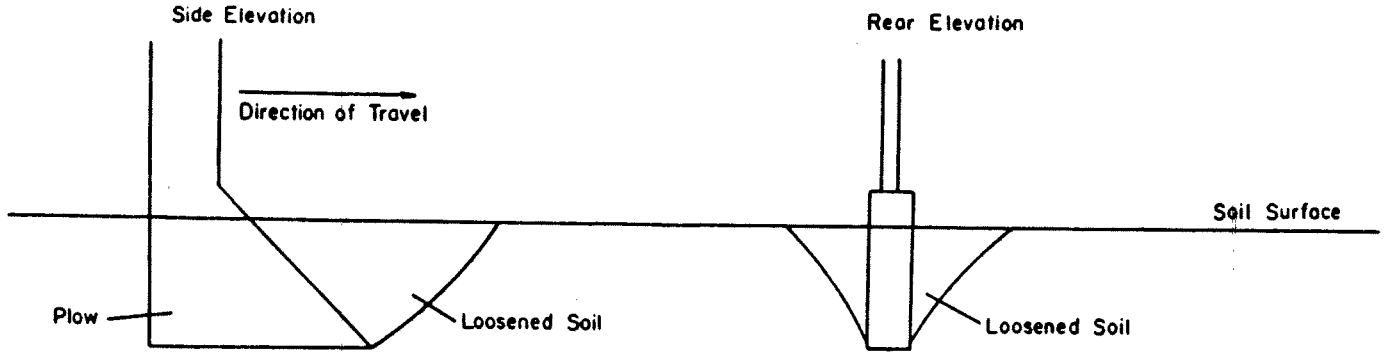


Figure 4-15 Soil disturbance caused by trenchless plow working relatively shallow (28 in.)

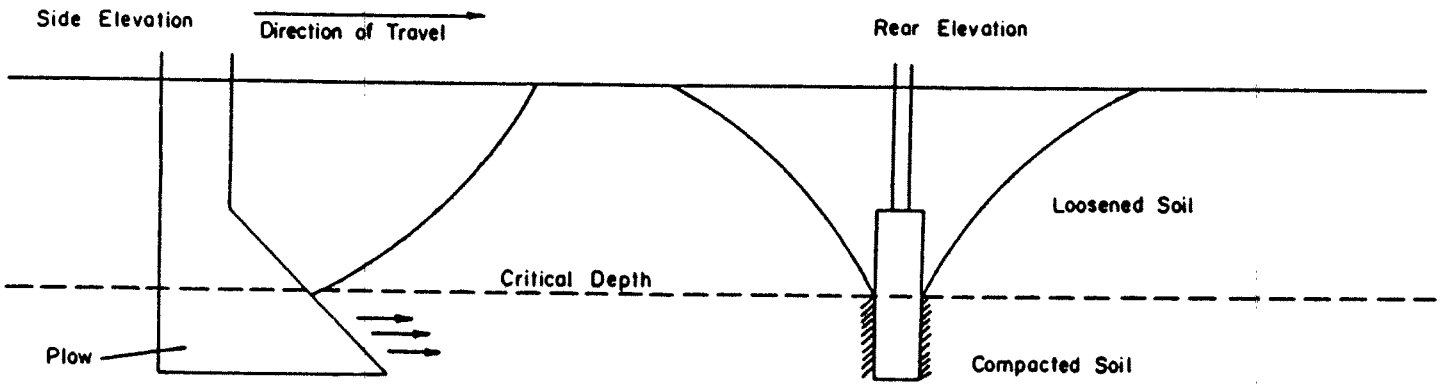


Figure 4-16 Soil disturbance caused by trenchless plow working relatively deep (5½ ft.)

where the transition between one type of soil disturbance and the other occurs. This critical depth represents the maximum working depth of that trenchless plow, if compaction around the pipe is to be avoided. The position of the critical depth depends upon the following factors: (1) forward inclination of tine, (2) tine width, (3) soil moisture content and (4) soil density.

When working under uniform, compact, dry, seedbed-producing conditions, the critical depth will be at a depth of approximately 15 times the tine width. As the surface layers become very dry and strong, or the soil becomes moister at depth, the critical depth will reduce to about 10 times the tine width. The critical depth can sometimes be increased by loosening the surface layers of the soil to a depth between 8 and 16 inches in a strip approximately 1 1/2 times as wide as the working depth of the plow. The shallow tining can be done as the plow runs back empty prior to the next run. Where the critical depth is less than the working depth, the use of a wider tine and surface loosening will reduce the draft force and in many circumstances the draft can be reduced by a substantial amount.

2. Soils

Soil textures and soil moisture conditions vary considerably and so will the soil disruption patterns caused by the drain plow. The disturbed soil zone extends upward and outward from the drain at different angles from the vertical depending on the soil conditions, depth and plow geometry. Soils ranging from sands to clay loam have exhibited good fracturing properties by the plow blade and these soils can be drained quite effectively by the drain plow. In fact, in some cases when the surface layer is loose, it tends to flow down behind the tubing chute and cover the top of the tubing similar to a blinding operation. Wet and high-clay soils are more likely to cause traction, structure and soil compaction problems. However, when high-clay soils are dry, a high degree of fracture and fissuring is possible which could improve water movement to the drains when draining these soils. In heavy clay soils or under wet installation conditions, radial and surface compaction problems have occurred.

3. Rocks

The occurrence of rocks constitutes a serious problem in drain installations. Plows do not appear to be affected as much by rocks as trenchers. Locations where rocks are encountered should be flagged at the time of contact by the operator for later inspection and correction if needed. A plow will tend to either push the smaller rocks aside or, where larger rocks are encountered, the plow will move sideways around the rock. Where the large rocks jut above or near grade, the plow tends to bounce over them disrupting the tubing grade. If the plow is deflected upward a small distance by a rock, where slopes permit, an alert operator will make a small adjustment in grade from that point on and thereby not leave a hump in the line for later correction.

If there is a significant deviation in grade, the point of deviation should be marked. The drain is to be excavated at this point and the grade corrected.

4. Blinding with Trenchless Plows

Trenchless plows should be designed to bring blinding soil over the drain immediately as the drain is placed to keep the drain on grade. Where the surface layer is a loose, dry sand, it will flow down freely behind the tubing boot and cover the top of the tubing. This is desirable where the surface material is highly permeable and stable, but it could cause siltation problems if the surface material is extremely silty or is very fine and uniform or if a filter is not used. With a filter, a covering of medium to coarse sand around the tubing could enhance inflow.

5. Stringing tubing

Because of the high plow speeds, stringing of the tubing in the field prior to installation is a major item. Spools mounted on trailers have been developed to reduce both labor and material costs and to meet the high-speed stringing requirements of the plow.

6. Stretch

Stretch is influenced by the stretch-resistance characteristics of the tubing, the amount and duration of drag encountered when the tubing feeds through the machine, and the temperature of the tubing at the time it is installed. Other factors may include the methods in which the tubing is handled when strung in the field and the way tubing is picked up and fed into the installation chute. Tubing should not be stretched so that its stiffness is reduced to less than the allowable minimum pipe stiffness. The permitted stretch during installation should not exceed 5%. It is recommended that trenchless plows be equipped with a power feeder to reduce stretch during the installation process.

7. Drain Repairs

Drain repairs shall be made in accordance with recommended construction practice for the trenching method.

8. Grade Control

The laser automatic grade control method shall be used for grade control for drains installed with a trenchless plow.

MAINTENANCE

Inspection

Subsurface drainage systems do not require extensive maintenance, but the maintenance that is required is extremely important. If the subsurface drains are working, water will stand in the field for only a short time after a heavy rain. If water stands for a few days, the drain is perhaps partly or completely blocked. If the drainage system has inspection wells, silt wells or manholes, it is important that they and the outlets be watched after a heavy rain to check the amount and rate of flow. A change in either may indicate a blockage somewhere in the line. Therefore, regular inspection of the drainage system is essential. Prompt repair of any drain failure will keep the system in working order and prevent permanent damage to the entire system.

Cleaning Outlet Ditches

Many subsurface drainage systems fail because outlet ditches are blocked. If the outlet ditch is filled with sediment, a survey should be conducted to determine the extent of the cleanout work. Also, an investigation should be made to determine the type of conservation practice that should be used on the contributing watershed area to reduce soil movement.

Clean Surface Inlets

Poorly constructed surface inlets are subject to severe damage and require frequent repair. Inlet covers often become sealed with trash and should be checked frequently. Clean the covers after a heavy rain and replace them carefully. If a cover is left off, trash can enter and perhaps plug the line.

Repair Blowouts

Holes that have developed over subsurface drains should be repaired at once. Otherwise, large amounts of soil may wash into the lines and block the entire system.

Holes form where a drain is broken and where joints or slots are too wide. If the tile is broken, replace it. If the joint is too wide, place tile bats (pieces of broken tile) over the joint to prevent soil from washing into the line. To repair crushed or punctured corrugated plastic tubing, cut the damaged segment from the line and replace it with new tubing using the manufacturer's couplers.

Remove Sediment

Sediment traps can be used for subsurface drains laid in fine sand or silty soils. If cleaned periodically, traps keep soil from filling the lines. Clean the traps every few days after the lines are laid, because initially, sizeable quantities of fine soil will wash in through the joints between tiles or through perforations in plastic tubing. Later, soils will wash in more slowly, and you need to check the traps only once or twice a year.

Inspection wells can be used as access points for flushing drainage lines.

Protect Drain Outlets

Gullies commonly form at unprotected outlets of subsurface drains. Gullies may damage the field, silt up the drainage ditch, and reduce the flow of water from the subsurface drain.

Where both surface runoff water and the subsurface drain empty into the ditch at the same place, a drop structure is needed to prevent gullies.

If surface runoff water enters the ditch at another location, a pipe outlet is the best and least expensive way to prevent gullies. See Figure 4-2. Pipe outlets should be carefully built so that water from the drain does not wash under the pipe. The pipe should extend beyond the ditchbank so that water will pour into the ditch without eroding the bank. Along large channels where ice or floating debris may damage the outlet, the cantilevered section of the pipe should be protected by having the bank of the channel recessed and setting the pipe within the indented area. If this method is not acceptable, the pipe outlet should be set flush with the bank and rock placed below it to prevent scouring of the bank.

Control Rodents

Flap gates, hinged rod gates and fixed pin guards can be used to prevent rodents and other small animals from entering and blocking outlets.

Fixed pin guards are suitable for lines without surface inlets. The pins are inserted horizontally through the end of the pipe, not more than 1 1/2 inches apart. The outlet must be checked frequently to be sure that roots and other debris carried through the drain do not block the opening between pins.

Flap gates or hinged rod gates should be used for lines that have surface inlets. Flap gates and hinged rod gates should be made of noncorrosive material. Flap gates and hinged rod gates should be checked periodically to ensure that the flap gates can swing open and that the gates are not held open by debris or silt.

Control Tree Roots

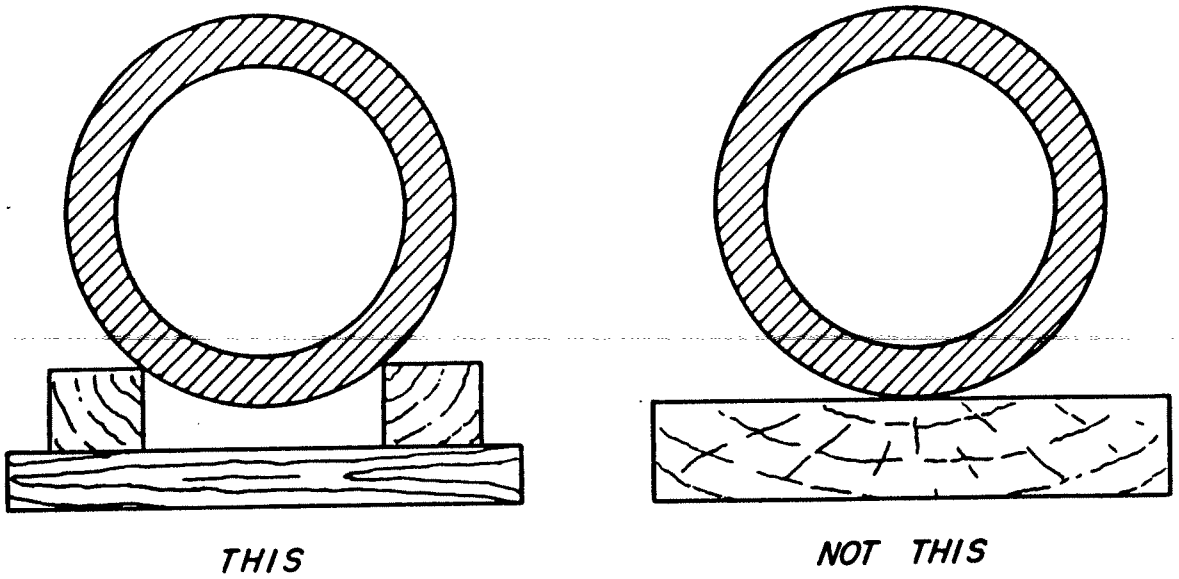
Trees such as willow, elm, soft maple, cottonwood, and other water-loving trees within approximately 100 feet of the drain should be removed and kept cleared. A clearance of 50 feet should be maintained from other species of trees. If it is not possible to remove the trees or reroute the line, a closed line with sealed joints should be constructed. This closed line should extend throughout the root zone area of the tree or trees.

Ochre Accumulations in the Drain

Ochre, which is an iron oxide, may block the drain when iron in solution moves from the soil to the drain and accumulates there. The process by which ochre accumulates may either be chemical, microbial, or both. Ochre usually enters drains through organic soils, but has been known to occur in other soils as well. There is no certain solution (except an open ditch) to the ochre problem. The use of high pressure and low pressure acid solution jetting has been successful in cleaning many drains clogged with ochre. It is used commercially in southern California, the Netherlands, and Germany.

Sulfur dioxide mixed with water forms sulfurous acid. A 2 percent solution in drain lines with less than 5 percent organic matter will usually remove ochre.

Hydrochloric and sulfuric acids can also be used at 5 to 10 percent concentration, but the outflow after treatment must be neutralized to prevent pollution of water in lakes, streams, and ditches.



CRADLING TILE IN UNSTABLE SOILS

DRAIN TILE SIZE & WEIGHT DATA			
Inside Dia. Inches	Outside Dia. Feet	Approx. Wgt. per Foot	Average Wgt. Feet/Carload
4	0.42	7#	5,700
5	0.51	11	3,600
6	0.59	12	3,300
8	0.79	17½	2,000
10	0.97	27½	1,300
12	1.17	37½	930
14	1.34	47	780
15	1.43	53½	650
16	1.54	62½	560
18	1.71	74	470
20	1.88	84	420
22	2.08	108	320
24	2.29	132	260
26	2.48	154	230
28	2.69	174	200
30	2.88	211	170

TILE REQUIRED/ACRE	
Feet Spacing	Feet Required per Acre
20	2,178
25	1,742
30	1,452
33	1,320
40	1,089
50	872
66	660
80	545
100	436
150	291
200	218

DRAIN TILE INFORMATION

Figure 4-17. Concrete Drain Tile Information.

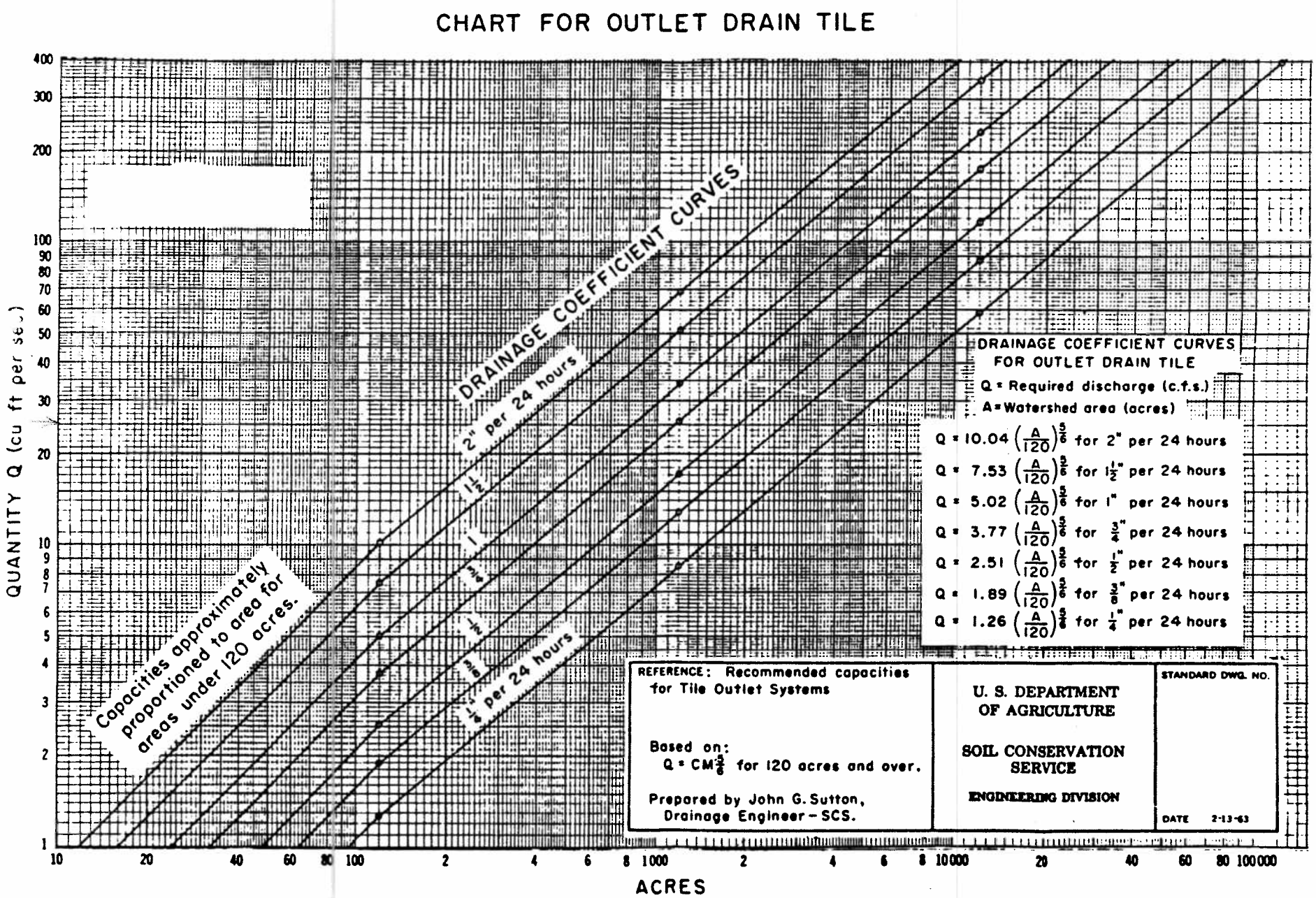


Figure 4-18. Recommended Capacities for Tile Outlet Systems Draining More than 120 Acres.

CHAPTER 5

SURFACE DRAINAGE

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SURFACE DRAINAGE

GENERAL

Surface drainage is the diversion or orderly removal of excess water from the land surface and soil profile by means of improved natural or constructed channels, supplemented when necessary by shaping and grading of land surfaces to such channels.

The drainage system may be used to regulate water tables to provide water (subirrigate) during the growing season and then provide for lowering the water table for harvest and planting operations.

Surface drainage is normally required for efficient crop production on slowly permeable soils with restrictive topography. It is not required when excess water is removed naturally. Typical problem areas are glaciated areas, bottomlands, and old lake beds. Surface drainage may supplement subsurface drains.

The rate of water removal depends on several interrelated factors, such as rainfall characteristics, soil properties, and cropping patterns. For most row crops, the surface water systems should remove the excess water within 24 to 48 hours. More rapid removal is necessary for higher value truck crops.

Before constructing any new surface drainage system or modifying an existing system, an engineering survey should be made.

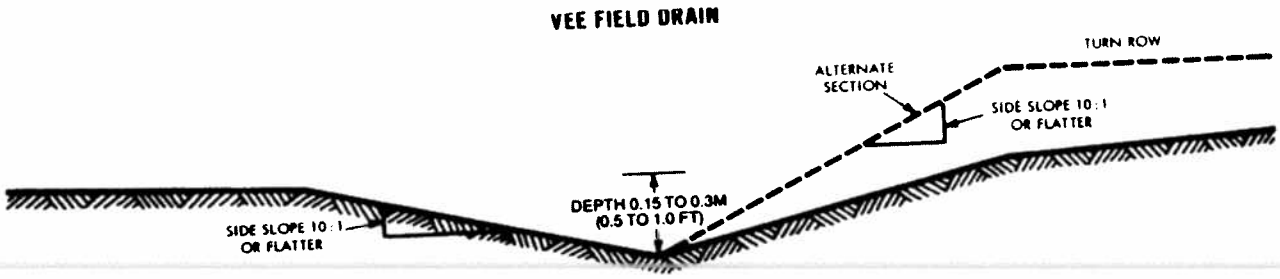
SURFACE DITCHES

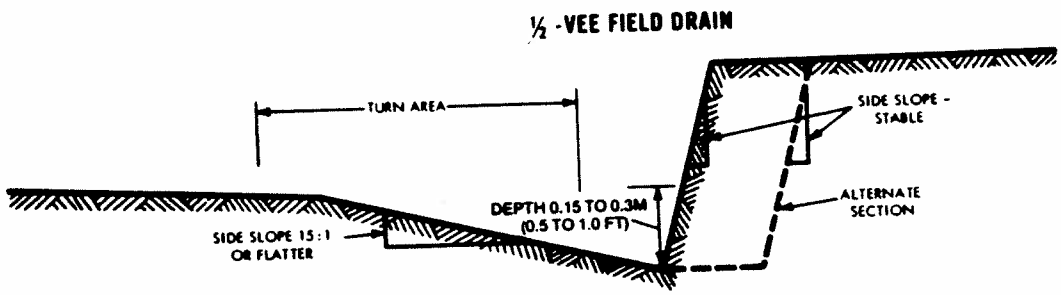
The principal means to convey water in a surface drainage system are by: (1) Field ditch (2) Lateral, and (3) Main. Other practices, such as waterways, diversions, field road ditches, etc., may be incorporated into the drainage system.

Field ditches are shallow graded channels, usually having relatively flat side slopes, that collect water within a field. Figure 5-1 shows typical field ditches.

In general, the primary purpose of a field ditch is to remove excess surface water from the field in a non-erosive manner and before significant crop damage will result from inundation.

Field ditches may require cleaning following tillage operations. When the field ditches are not cultivated, weed growth shall be kept under control by mowing, spraying or burning.





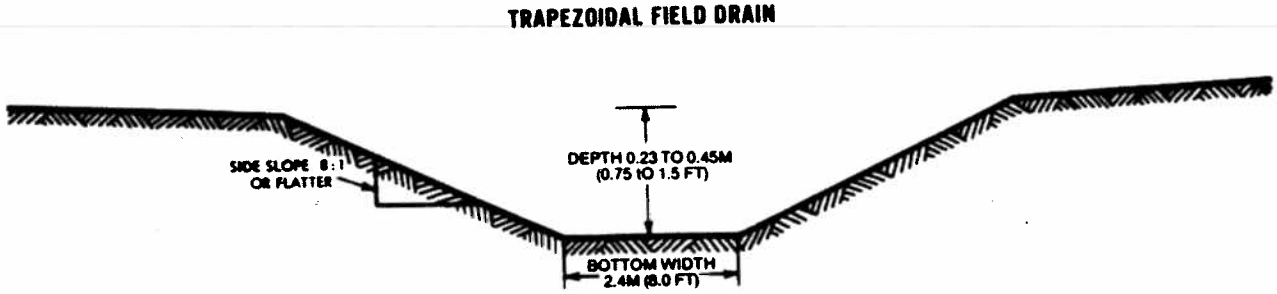


Figure 5-1. Field Ditches.

TABLE 5-1 RECOMMENDED MINIMUM FIELD DITCH DIMENSIONS

Type	Depth (Ft.)	Bottom Width (Ft.)	Side Slope
Vee	0.5 to 1.0	0	10:1 or flatter[1/]
Modified	0.5 to 1.0		15:1 or flatter
Trapezoidal	0.75 to 1.5	6[3/]	8:1 or flatter[2/]

[1/] 10 horizontal to 1 vertical.

[2/] If not crossed with equipment to steepest recommended side slopes are 4:1 in cropland and hayland and 3:1 in pastureland.

[3/] A 4 foot bottom may be used in pastureland.

Field ditches may be designed using tables 5-3, 5-4 and 5-5. NOTE: Tables 5-3 and 5-4 were developed for an "n" of 0.040 (maintained grass) and Table 5-5 for an "n" of 0.025 (bare). For bare channels or other cover, design for appropriate "n". See the tables for correction factors.

The Vee and Trapezoidal cross sections are chosen as a matter of preference, topography, farming operations, etc. The modified cross section is a variation of the vee and the trapezoidal cross sections. It is used where construction on one side of the ditch is restricted due to property lines, roads, or other restrictions. The steeper side slope side should be designed for stable slope conditions and vegetated for erosion protection.

Field lateral is the principal ditch that receives water from field ditches, and, in some areas, from field surfaces, and carry it to the mains. Figure 5-2 shows typical lateral.

Laterals shall be designed to discharge the rates of flow indicated by the drainage curves. Laterals occupy productive land and are costly to construct and maintain. They should be spaced as widely apart as field conditions permit. The following table shows lateral dimensions.

Table 5-2 Recommended Lateral Side Slopes

Type	Depth	Recommended[1/] Side Slope	Recommended Minimum Bottom Width Ft.
Trapezoidal	1.0 to 3.0	4:1	6
Trapezoidal	3.1 and over	3:1	6

[1/] Minimum side slopes are those required for slope stability.

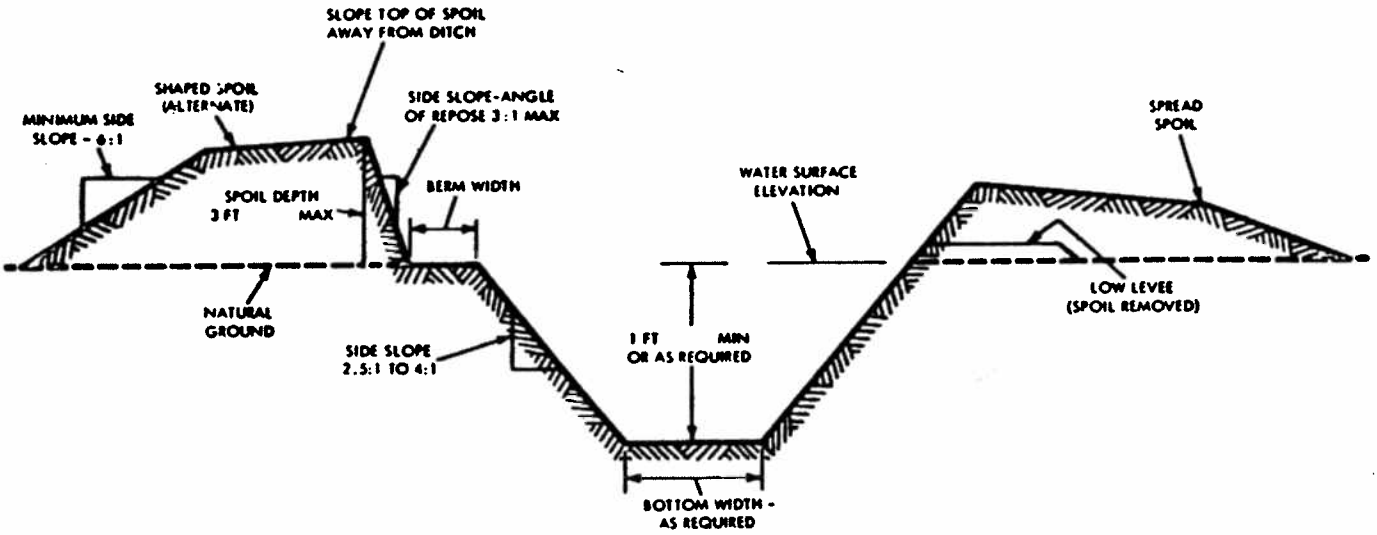


Figure 5-2. Laterals.

Sizing for field laterals may be done from Tables 5-3 to 5-7.

Laterals require periodic maintenance. Suitable chemical weed and bush sprays are effective in controlling cattails, willows, and other undesirable vegetation. Mowing is effective where side slopes are not steeper than 3:1. Controlled grazing by livestock is a good method. Laterals require cleanout where excess deposition has occured.

Main is the outlet ditch that may serve an individual farm or several farms. It receives flow from laterals, subsurface drains, and sometimes other "mains". See the Open Channel section for design, construction, and maintenance.

In some situations, where erosion may be a problem and/or in an urban setting, it may be more desirable to use a vegetated channel. Sections, other than those given in the tables, should be designed using Mannings equation. For a well maintained vegetated channel, an "n" of 0.040 is appropriate.

METHODS

The principal surface drainage methods are: (1) Land smoothing (2) Land grading (3) Random system (4) Parallel system (5) Runoff diversion (6) Interceptor drain. Each method is discussed in more detail in the following sections.

Land smoothing is performed by smoothing the land surface with a land plane or land leveler to eliminate minor depressions and irregularities without changing the general topography. The purpose is to provide a more uniform plane for surface runoff to move into the field ditches.

The smoothing operation on land with more than 0.1% grade usually may be directed in the field without detailed surveys or plans. However, surveys may be required in critical portions of some fields when visual observations do not provide the accuracy required. Field ditches and/or laterals shall be installed in the remaining low areas. Figure 5-3 shows a typical land smoothing operation.

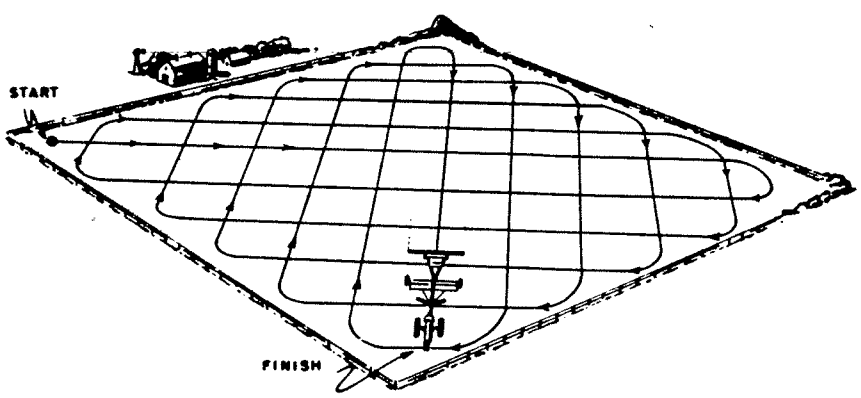


Figure 5-3. Land Smoothing Operation

Land grading is the process of forming the surface of land to predetermined grades so each row or surface slopes to a ditch or outlet. Land grading, by carefully designed cutting and filling operations, provides excellent surface drainage.

Areas to be graded shall be planned for a minimum number of field ditches with the ditches located, where possible, normal (right angles) to laterals and crop rows.

Surface drainage and land smoothing will be adequate if all depressions are eliminated. Minimum grade limits should include a tolerance for construction that will permit the elimination of all depressions either in original construction or the post-construction touchup. Depressions can be eliminated with relative ease on fields designed with 0.2 percent (0.002 ft/ft) minimum grades. Unusual precision in construction is required with 0.1 percent (0.001 ft/ft) and flatter grades.

The recommended grades range from 0.1 to 0.5 percent; the grades may be uniform or increase or decrease.

The cross slopes normally should not exceed 0.5 percent (0.005 ft/ft). Reverse cross slopes are satisfactory, providing field ditches have the minimum required grades and drainage outlets are adequate.

The maximum allowable depth of cut depends upon soils and costs. Soils data shall be used for determining maximum allowable depths of cut.

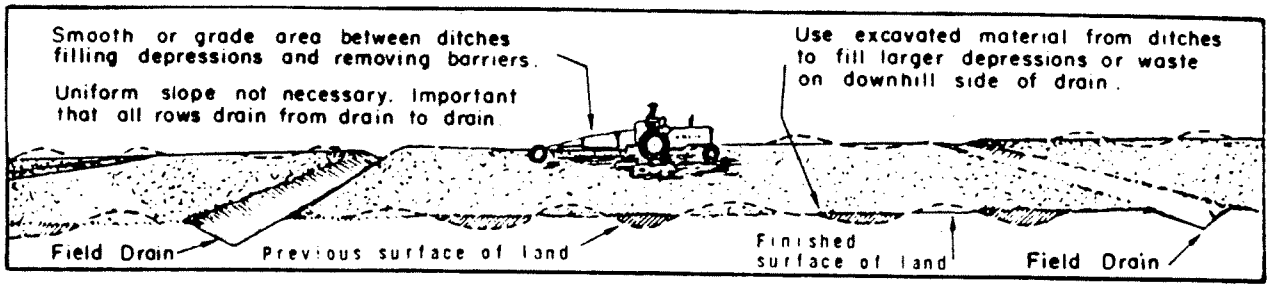
Land grading is hampered by trash and vegetation which should be destroyed or removed prior to construction and kept under control while the work is being done. The field shall be scarified prior to construction if there are hardpans. The field surface shall be firm when surveyed so that rod readings taken at stakes will reflect the true elevations. Fields shall not be graded when wet because this impairs the physical condition of the soil.

Land smoothers shall be passed over the field surface at least three times as a finishing operation. The first two passes shall be on opposite diagonals to the stake lines and the last pass shall be in the primary direction it will be farmed. Figure 5-4 illustrates typical operations.

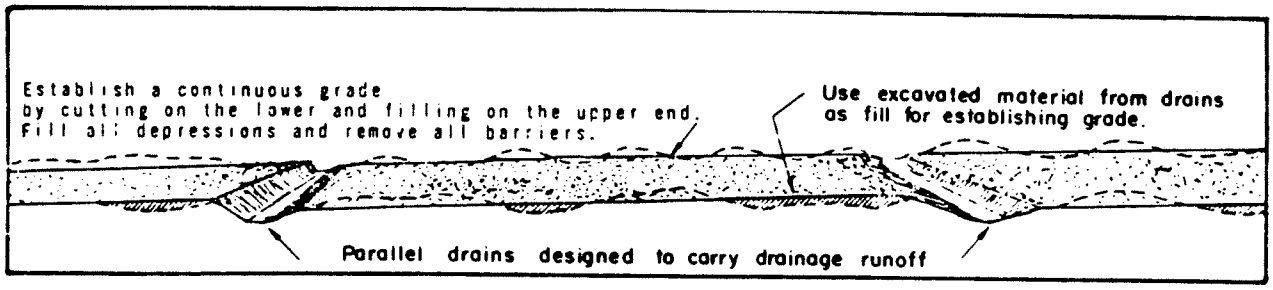
Fields should be deep disced before or after the final land smoothing operation to loosen the cut surfaces and to blend the fill material with the underlying soil. Good mixing of the surface soils after construction is essential.

Tractors and scrapers are used for land grading; land smoothers, commonly known as land levelers or land planes, are used to finish land grading.

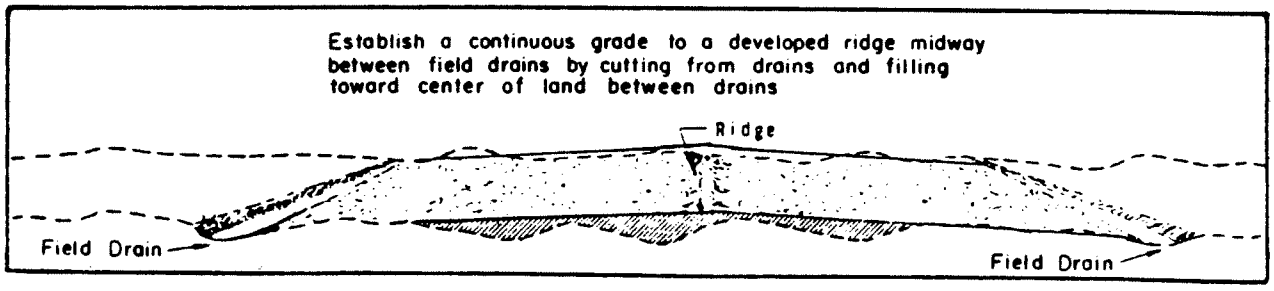
Maintenance is critical during the first year or two after construction. Settlement of the fill areas may make several annual land smoothing



TYPICAL CROSS SECTION OF GROUND SURFACE THAT HAS SOME GENERAL SLOPE IN ONE DIRECTION AND IS COVERED WITH MANY SMALL DEPRESSIONS AND POCKETS



TYPICAL CROSS SECTION OF GROUND SURFACE THAT HAS LITTLE OR NO GENERAL SLOPE AND IS COVERED WITH MANY SMALL DEPRESSIONS AND POCKETS



TYPICAL CROSS SECTION OF GROUND SURFACE THAT HAS LITTLE OR NO GENERAL SLOPE AND IS COVERED WITH MANY SMALL DEPRESSIONS AND POCKETS

Figure 5-4. Methods of grading land surfaces for drainage.

operations necessary. In some cases, particularly where deep fills have been made, it may be necessary to cut and fill again with tractors and scrapers to eliminate depressions and reverse row grades. It is recommended that the land planing operation be substituted for one of the secondary tillage operations. The final land maintenance operations shall be in the direction of the crop rows.

Random system is a system of meandering field ditches and/or laterals that are located to drain depressions in a field. The random system is adapted to to slowly permeable soils having depressional areas too large to be eliminated by land smoothing or grading. These ditches connect the various lowspots in a field and provide an outlet to remove the excess surface water. These systems are relatively low in cost and give a high return on the investment. They require frequent maintenance and are obstacles to farm machinery, particularly if drains are closely spaced. In severely undulating topography, random drainage may be the only economical system. Figure 5-5 shows a typical random layout.

Double Field Ditches, or "W" ditches, are special forms of the random system. They are recommended only on ungraded land for use in wide, shallow depressions where runoff enters from both sides and the excavated soil must be placed between the twin ditches. Recommended minimum distances between the centerlines are 50 feet for ditches 0.5 feet deep, plus 10 feet for each additional 0.1 feet of depth. Lesser distances may be necessary at the outlet ends because of construction requirements. Figure 5-6 shows a "W" ditch layout.

Parallel System is a system of parallel laterals with most of the field ditches normal to the laterals. The parallel system is suitable for flat, poorly drained soils that have numerous shallow depressions where fields can be cultivated up and down the slope. These systems facilitate mechanization by eliminating short rows and point rows. Crossable field ditches with 10 or 12:1 side slopes are constructed between parallel field laterals. This permits farm equipment to travel greater distances without turning. Field surfaces between laterals should be improved by land smoothing or land grading for maximum benefits.

Additional suggestions for use and design of the parallel system include:

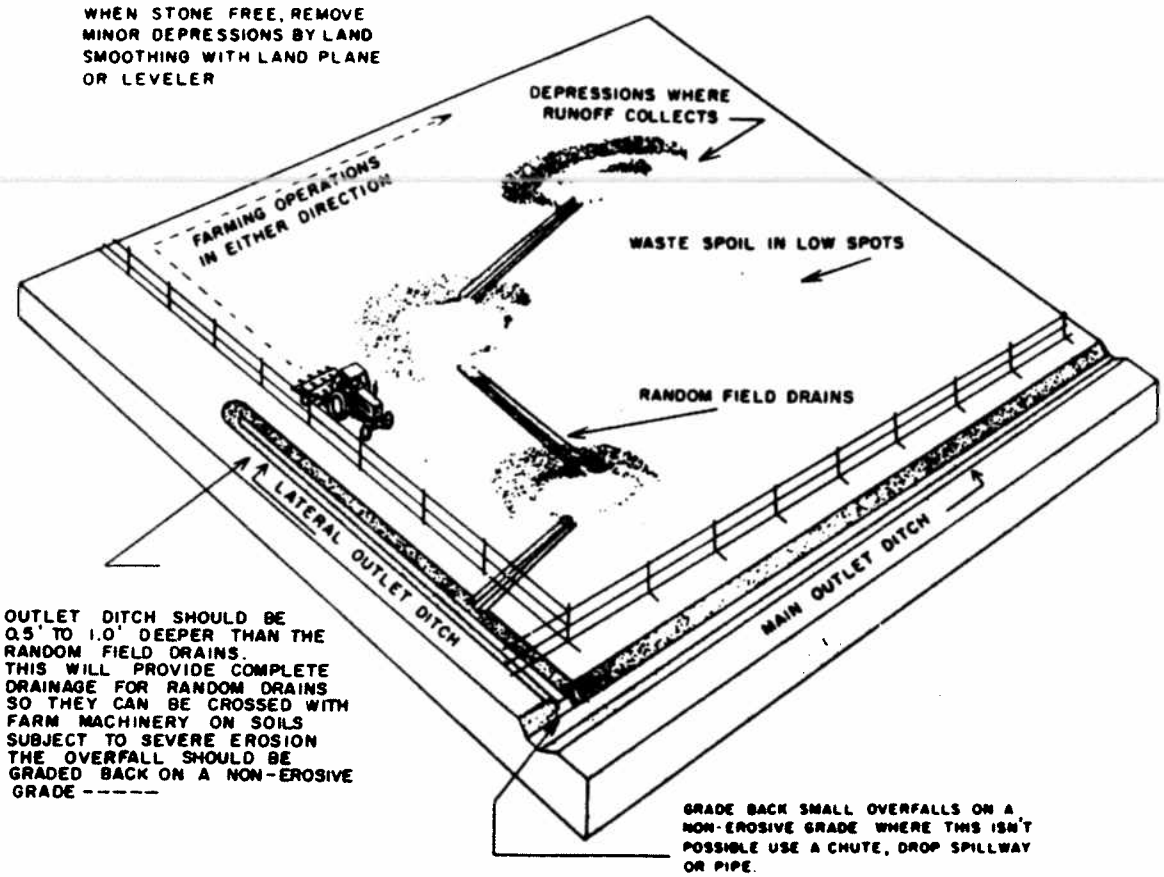
a. Plan the system so that crop rows run in the direction of greatest slope.

b. Lay out collection ditches across the slope but never with less fall than 0.1 feet in 100 feet unless tiled, then 0.05 feet in 100 feet. Grade the surface between the ditches, if necessary, to have all rows drain to the ditch.

c. Be sure each collection ditch has a good outlet.

d. Plow the field in the direction of greatest slope. Dead furrows should be on a continuous slope to avoid ponding of water.

SMOOTH AREA SO LAND WILL DRAIN TO THE LARGE DEPRESSIONS OR RANDOM DRAINS



CROSS SECTION OF RANDOM FIELD DITCH

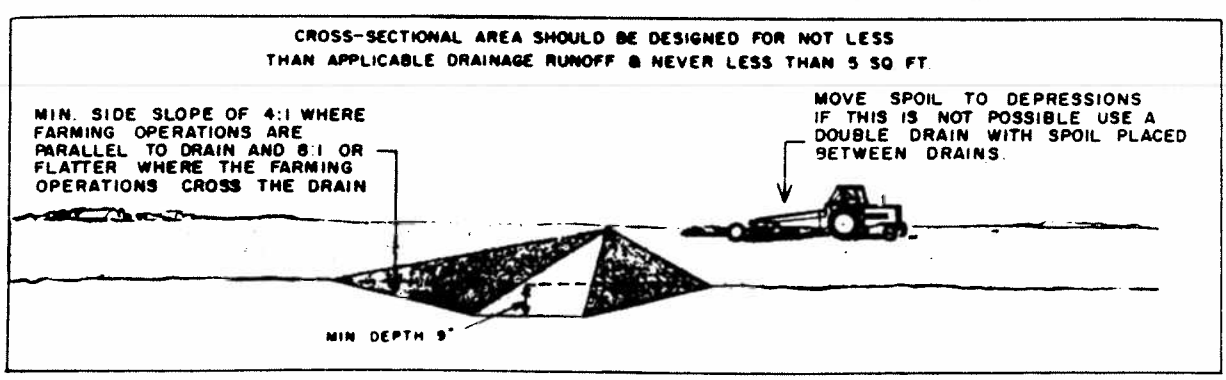
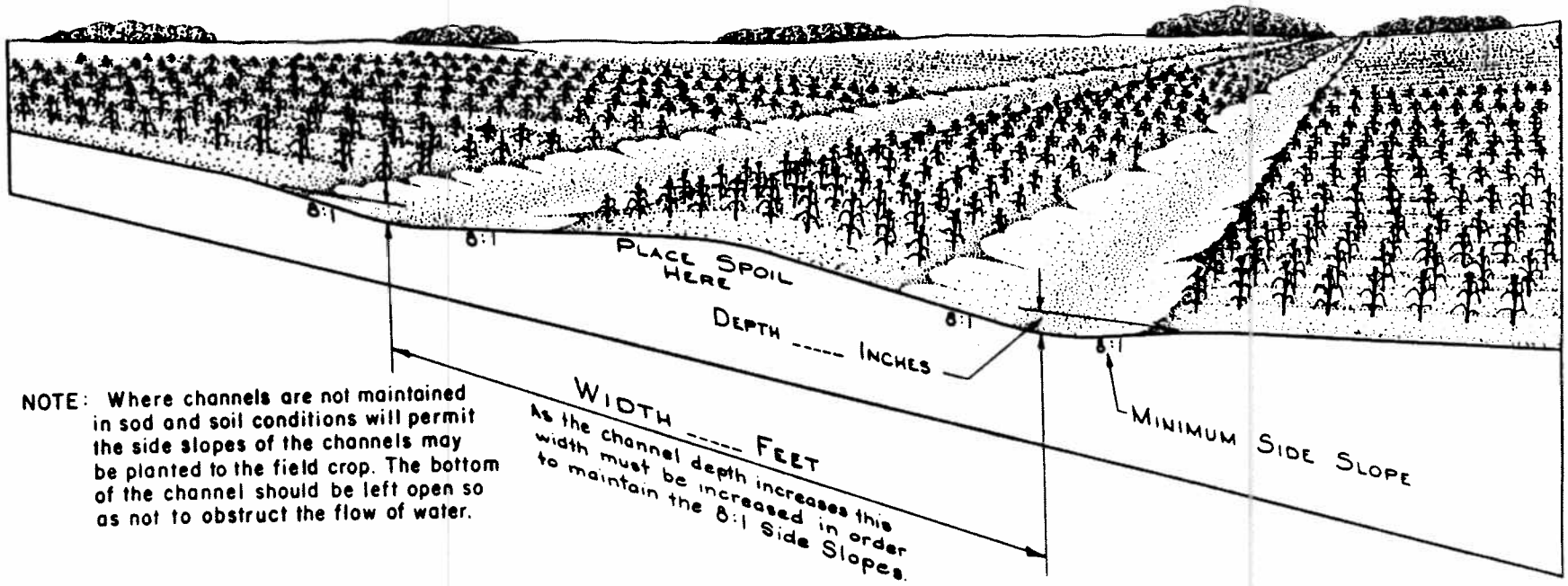


Figure 5-5. Random system of surface drainage.



NOTE: Where channels are not maintained in sod and soil conditions will permit the side slopes of the channels may be planted to the field crop. The bottom of the channel should be left open so as not to obstruct the flow of water.

Figure 5-6 Layout of the "W" Ditch

e. Use land smoothing every 2 to 3 years for maintenance of a continuous grade between collection ditches.

Figure 5-7 illustrates the typical layout of the parallel system.

The cross-slope system is a special form of the parallel system used on fields with more slope (up to 4 percent). This system resembles terracing in that the ditches go around the slope on a grade according to the lay of the land. In this way, they can be used for both drainage and erosion control in sloping wet fields. This method has application where internal drainage below the plow sole is poor and where the bottom of the slope remains wet for longer periods of time after rains. The field ditches convey water to a collector lateral by drop structures or other means at the field ditch outlets. If the grade is too erosive for the lateral, a lined waterway may have to be used. The collector ditches are located to one side of the field to permit continuous cultivation. For slopes up to 1%, crop rows are still normally laid out in the direction of greatest slope. For slopes steeper then 1%, crop rows normally run parallel to the ditches, similar to a terrace system.

Field ditches in the cross-slope system should be as straight as topography permits with limited cuttings through ridges and humps. Spacing for each field should be designed to control erosion losses and permit adequate drainage. Ditch slopes should be between 0.1 and 0.5 feet per 100 feet and the cross sections should be not less than 6 square feet.

The spoil should be spread over the field and placed in depressions on the slopes between ditches. Excess material should be spread no higher than 3 to 6 inches on the downhill side of the ditch. Land smoothing, after depressions have been filled, will help eliminate all surface basins and humps that obstruct the free flow of surface water between ditchs. Figure 5-8 illustrates the cross-slope system.

Runoff Diversion is intercepting the surface runoff and conducting it to a safe outlet. A diversion or terrace system can intercept surface runoff and conduct it to a safe outlet. The topography and land use (cropped or non-cropped) needs to be considered when deciding between terrace or diversion systems. Diversions or terraces intercept upland runoff and prevent it from overflowing bottomlands. Used in this sense, the diversion is normally located at the base of the hill or the area with steeper slopes. The diversion simplifies and reduces the costs of the drainage systems for the bottomlands. The diversion should be designed on grades that will not be erosive nor exceed the maximum allowable velocity suggested for open ditches. It should normally be designed to carry the 10-year frequency event. Figure 5-9 illustrates a typical diversion layout.

Interceptor Ditches are channels located across the flow of groundwater and installed to collect subsurface flow before it surfaces. Surface

SHALLOW DRAINS TO INTERCEPT AND REMOVE SURFACE WATER FROM THE FIELD AND REDUCE THE LENGTH OF ROW DRAINAGE ON FLAT LANDS

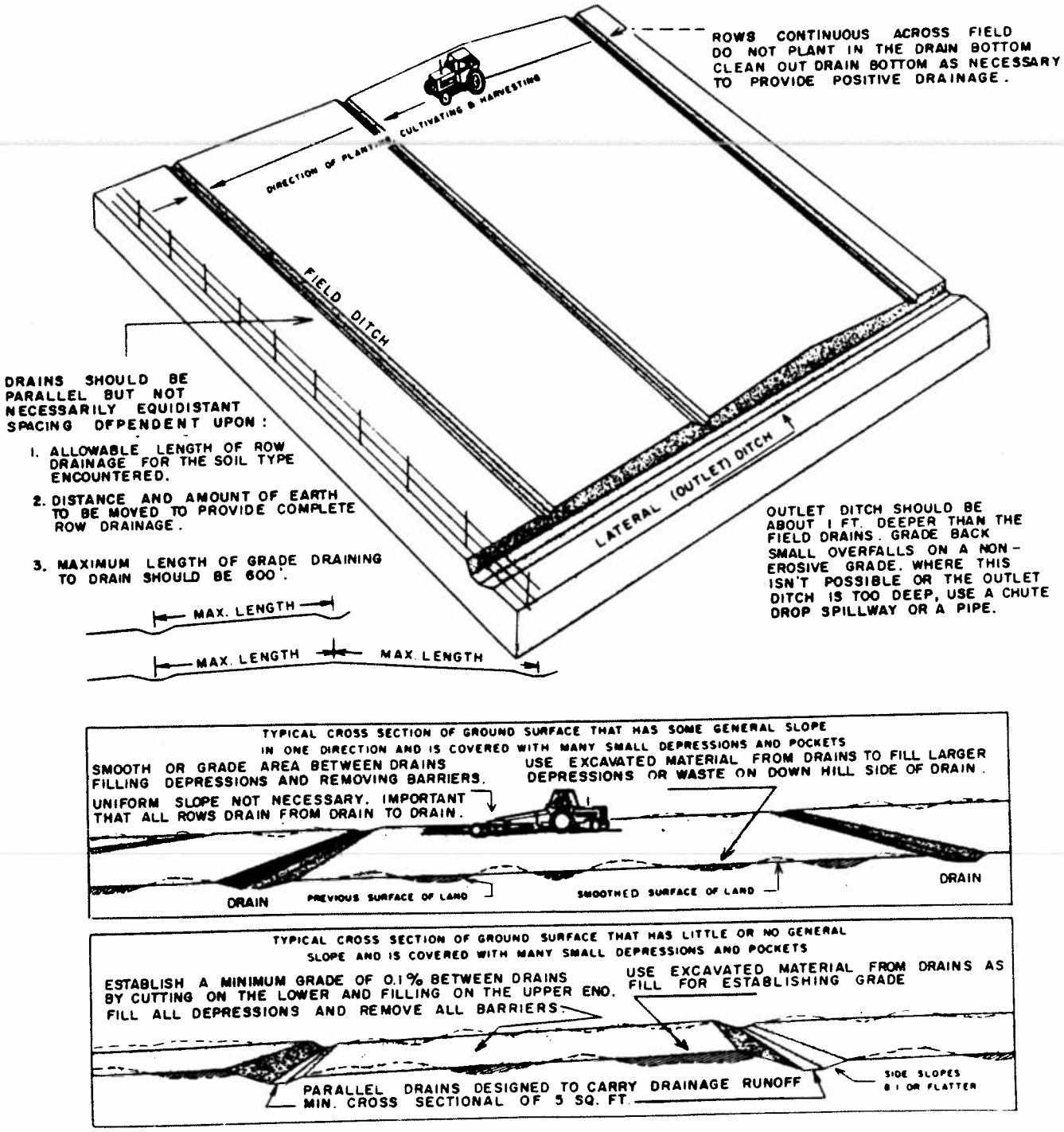


Figure 5-7. Parallel system of surface drainage.

water may also be collected and removed. They are used on long slopes with one percent or steeper grades and shallow, permeable soils overlying relatively impermeable subsoils. Interceptor ditches shall be designed to meet the field conditions disclosed by soil borings and topography. Figure 5-10 illustrates typical layouts for the interceptor ditch.

Example: A trapezoidal field ditch with 8 foot bottom and 4:1 sideslopes will be dug at 0.10% grade. If the ditch is 2.0 feet deep, what is the velocity and capacity of the ditch? Assume an "n" value of 0.040.

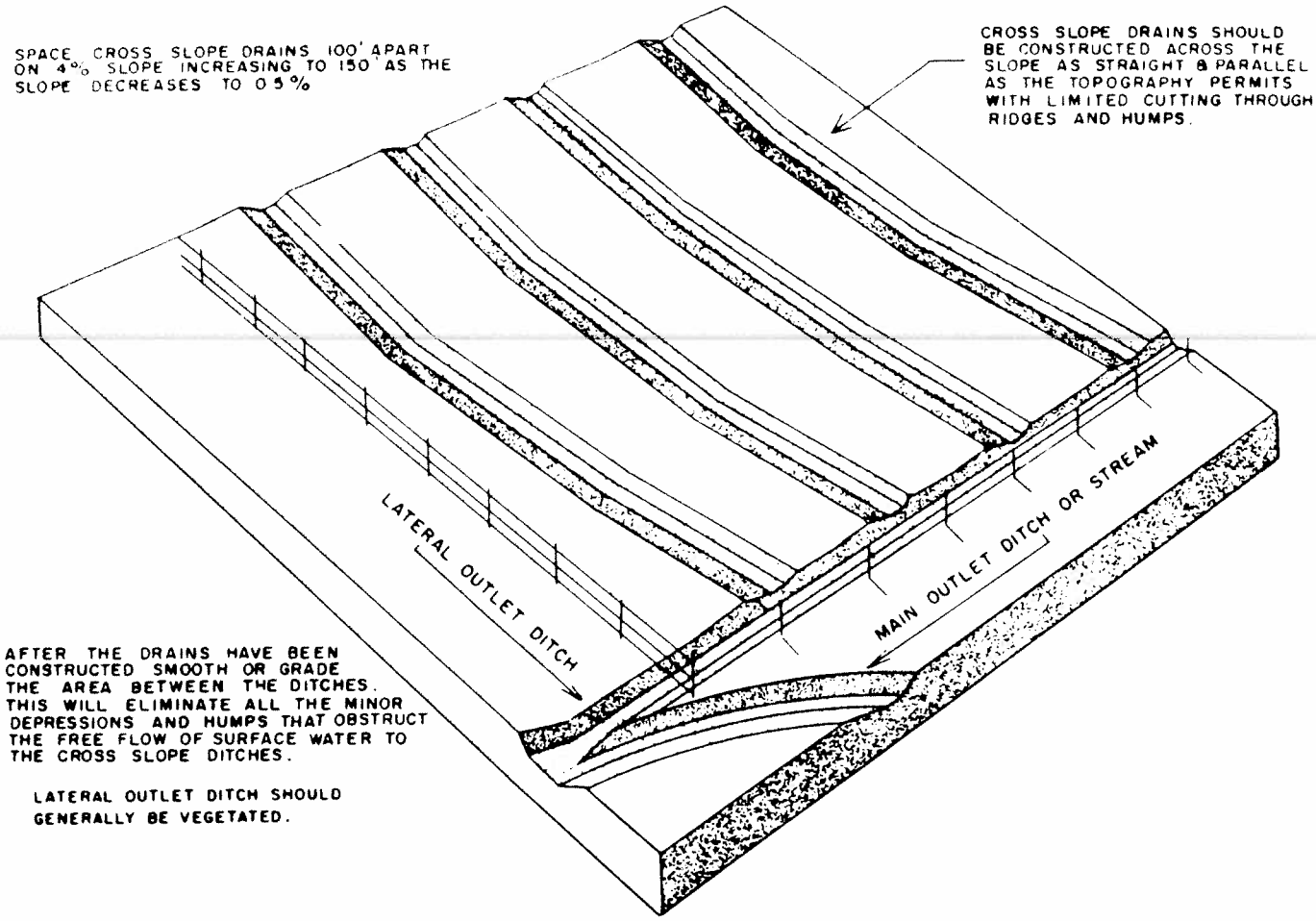
Solution: Using Table 5-4 (4:1 sideslopes and n = .040), we find that velocity is 1.41 feet per second, and Q = 45 c.f.s.

Example: For the above example, find V and Q if n is 0.065.

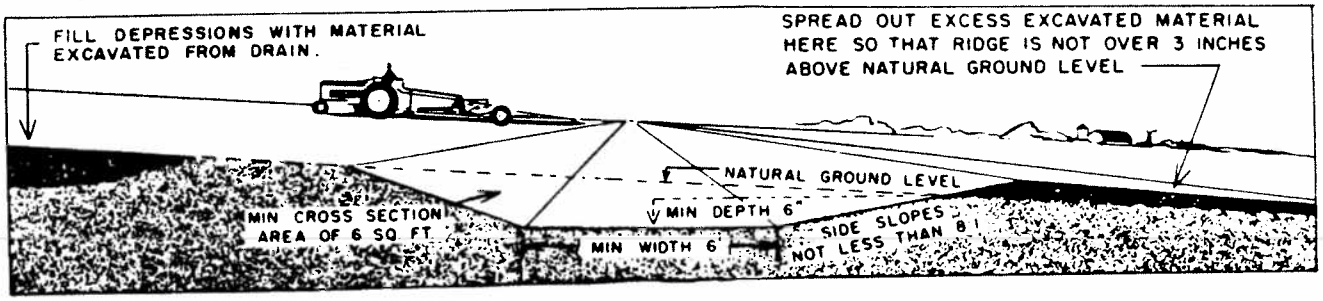
Solution: Use the correction factor found on the right edge of the above Table 5-4. The factor is 0.62. Multiply the factor times the V and Q for n = .040:

V = 0.62 X 1.41 = 0.87 feet per second

Q = 0.62 X 45 = 28 c.f.s.



TYPICAL FLAT BOTTOM SECTION



TYPICAL V-CHANNEL SECTION

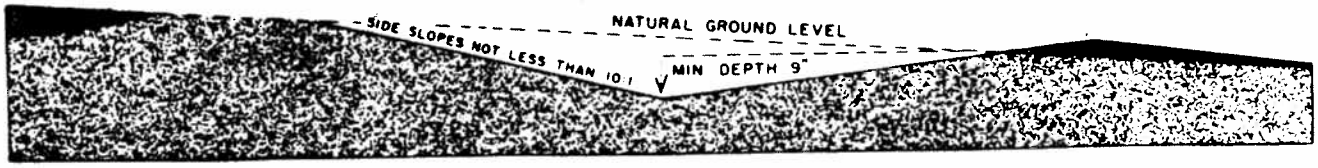
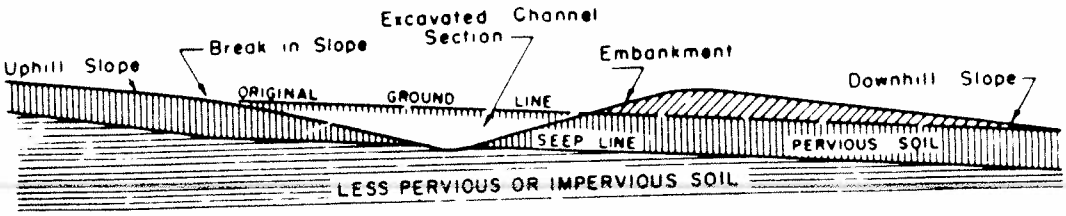
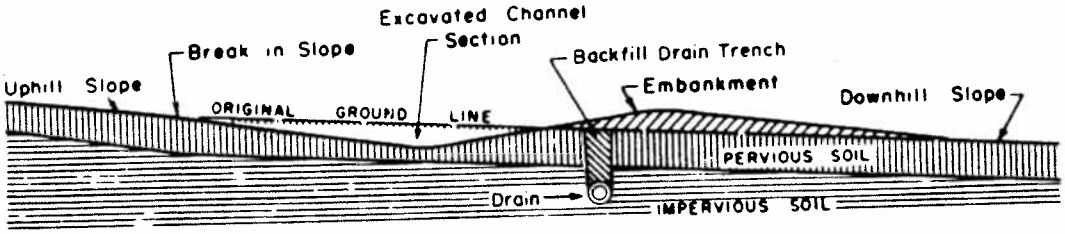


Figure 5-8. Cross slope system of surface drainage.

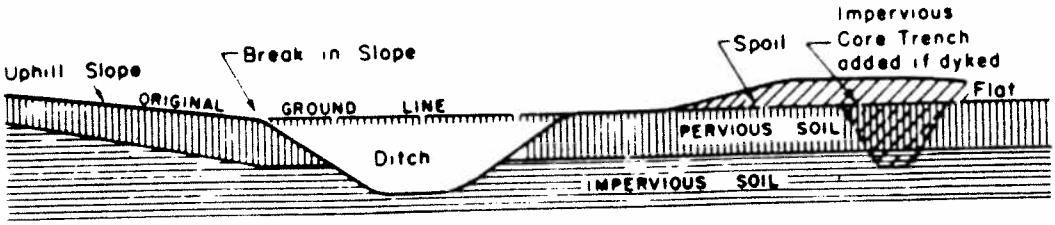
Figure 5-9. Diversion.



CROSS SECTION SHOWING DITCH AS SURFACE WATER DIVERSION AND SUB-SURFACE INTERCEPTOR ON SLOPE

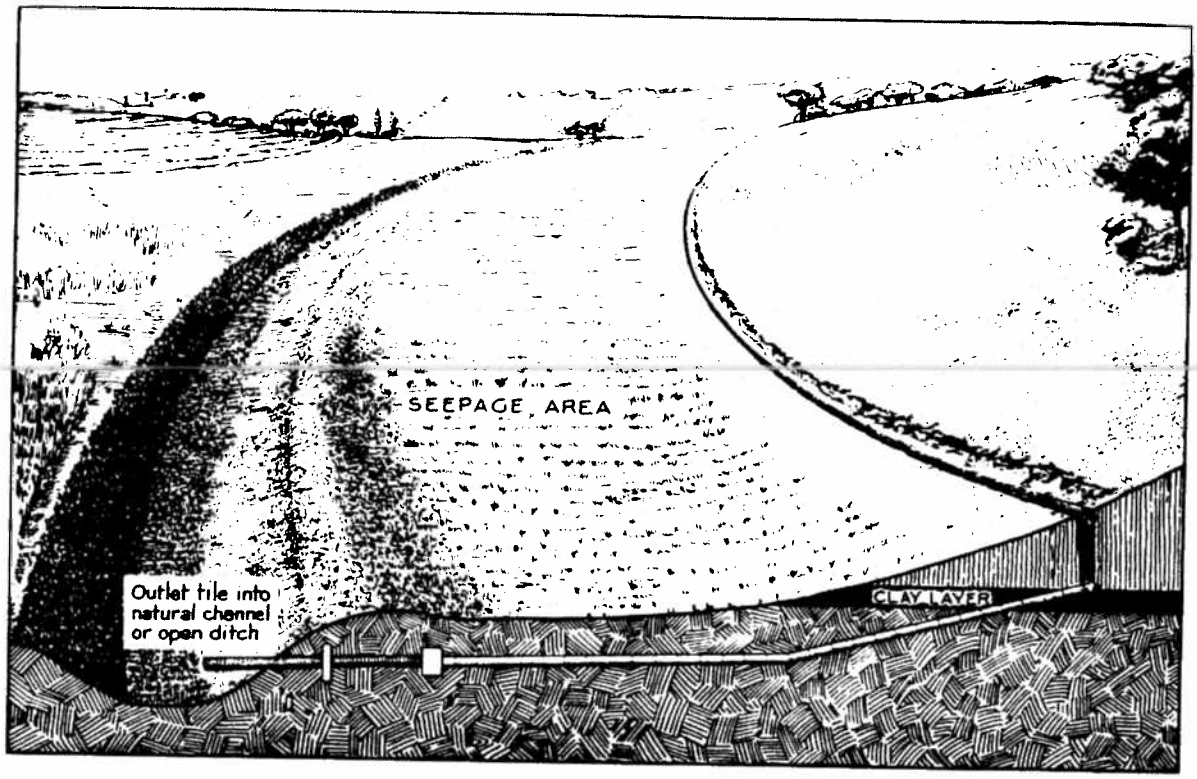


CROSS SECTION SHOWING DITCH AS SURFACE WATER DIVERSION WITH DRAIN AS SUB-SURFACE INTERCEPTOR



CROSS SECTION SHOWING DITCH AS SURFACE WATER DIVERSION AND SUB-SURFACE INTERCEPTOR FOR FLAT LAND

Figure 5-10. Typical Interceptor Installations.



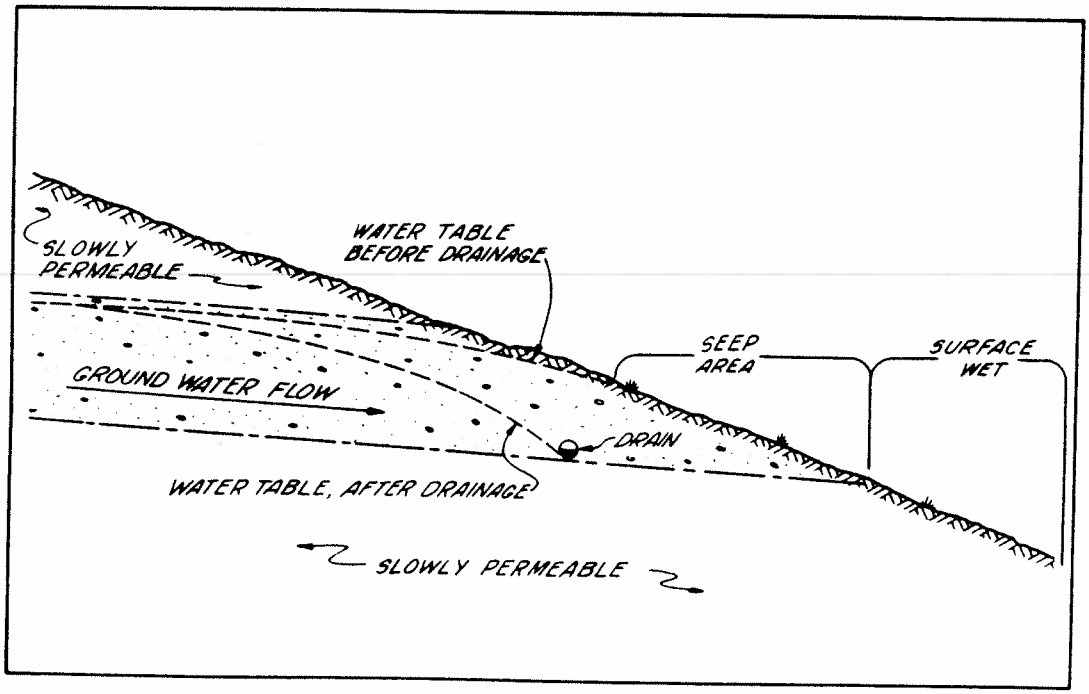


Figure 5-11. Interception of seepage under barrier conditions with a cross section (bottom) of the interceptor drain.

TABLE 5-3

VALUES OF V AND Q FOR DRAINAGE DITCHES 2:1 SIDE SLOPES n = 0.040

DITCH SIZE					PERCENT SLOPE																				CORRECTION FACTORS FOR V AND Q
BOTTOM WIDTH FT.	DEPTH FT.	TOP WIDTH FT.	AREA SQ.FT.	r - FT.	0.02		0.04		0.06		0.08		0.10		0.15		0.20		0.25		0.30		n
					V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	
4	1.0	8.0	6.00	0.71	0.42	2.5	0.60	3.6	0.72	4.3	0.84	5.0	0.93	5.6	1.14	6.8	1.32	7.9	1.47	8.8	1.61	9.7	0.025 - 1.60
	1.5	10.0	10.50	0.98	0.52	5.5	0.73	7.7	0.90	9.4	1.04	11	1.15	12	1.42	15	1.64	17	1.83	19	2.00	21	
	2.0	12.0	16.00	1.24	0.61	9.8	0.86	14	1.05	17	1.21	19	1.36	22	1.65	26	1.92	31	2.14	34	2.35	38	0.030 - 1.33
	2.5	14.0	22.50	1.48	0.68	15	0.97	22	1.18	27	1.36	31	1.52	34	1.86	42	2.16	49	2.40	54	2.64	59	
	3.0	16.0	30.00	1.72	0.76	23	1.07	32	1.31	39	1.51	45	1.69	51	2.06	62	2.38	71	2.66	80	2.92	88	0.035 - 1.14
	3.5	18.0	38.50	1.96	0.82	32	1.16	45	1.43	55	1.64	63	1.84	71	2.26	87	2.60	100	2.90	112	3.19	123	
	4.0	20.0	48.00	2.19	0.89	43	1.26	60	1.53	73	1.77	85	1.98	95	2.42	116	2.80	134	3.12	150	3.43	165	0.040 - 1.00
	4.5	22.0	58.50	2.43	0.95	56	1.34	78	1.64	96	1.89	111	2.13	125	2.60	152	3.00	176	3.35	196	3.68	216	
	5.0	24.0	70.00	2.66	1.01	71	1.42	99	1.75	123	2.02	141	2.25	158	2.76	193	3.18	223	3.56	249	3.90	273	0.045 - 0.89
	6.0	28.0	96.00	3.11	1.12	108	1.58	152	1.94	186	2.24	215	2.50	240	3.06	294	3.54	340	3.95	379	4.33	415	
6	1.0	10.0	8.00	0.76	0.44	3.5	0.62	5.0	0.75	6.0	0.88	7.0	0.98	7.8	1.20	9.6	1.38	11	1.54	12	1.69	14	0.050 - 0.80
	1.5	12.0	13.50	1.06	0.55	7.4	0.77	10	0.95	13	1.10	15	1.22	16	1.50	20	1.72	23	1.93	26	2.11	29	
	2.0	14.0	20.00	1.34	0.64	13	0.90	18	1.11	22	1.28	26	1.43	28	1.74	35	2.02	40	2.25	45	2.47	49	0.055 - 0.73
	2.5	16.0	27.50	1.60	0.72	20	1.02	28	1.24	34	1.44	40	1.61	44	1.97	54	2.27	62	2.54	70	2.78	76	
	3.0	18.0	36.00	1.85	0.80	29	1.12	40	1.38	50	1.58	57	1.77	64	2.17	78	2.50	90	2.80	101	3.06	110	0.060 - 0.67
	3.5	20.0	45.50	2.10	0.86	39	1.22	56	1.50	68	1.73	79	1.93	88	2.36	107	2.73	124	3.04	138	3.34	152	
	4.0	22.0	56.00	2.34	0.93	52	1.31	73	1.60	90	1.85	104	2.08	116	2.54	142	2.93	164	3.27	183	3.59	207	0.065 - 0.62
	4.5	24.0	67.50	2.59	0.99	67	1.40	95	1.72	116	1.98	134	2.22	150	2.71	183	3.03	205	3.50	236	3.83	258	
	5.0	26.0	80.00	2.82	1.05	84	1.48	118	1.82	146	2.10	168	2.34	187	2.97	238	3.32	266	3.70	296	4.05	324	0.070 - 0.57
	6.0	30.0	108.00	3.29	1.17	127	1.64	177	2.01	217	2.32	251	2.60	281	3.18	344	3.67	397	4.10	443	4.50	486	
8	1.0	12.0	10.00	0.80	0.45	4.5	0.64	6.4	0.78	7.8	0.91	9.1	1.01	10	1.24	12	1.43	14	1.60	16	1.75	17	0.075 - 0.53
	1.5	14.0	16.50	1.12	0.57	9.4	0.80	13	0.98	16	1.13	19	1.26	21	1.55	26	1.79	30	2.00	33	2.19	36	
	2.0	16.0	24.00	1.42	0.67	16	0.94	23	1.15	28	1.32	32	1.48	36	1.82	44	2.10	50	2.34	56	2.57	62	0.100 - 0.40
	2.5	18.0	32.50	1.70	0.75	24	1.06	34	1.30	42	1.50	49	1.68	55	2.04	66	2.36	77	2.64	86	2.89	94	
	3.0	20.0	42.00	1.96	0.82	34	1.16	49	1.43	60	1.64	69	1.84	77	2.25	95	2.60	109	2.90	122	3.19	134	0.125 - 0.32
	3.5	22.0	52.50	2.22	0.90	47	1.27	67	1.55	81	1.78	94	2.00	105	2.45	129	2.82	148	3.15	165	3.46	182	
	4.0	24.0	64.00	2.47	0.96	61	1.36	87	1.67	107	1.92	123	2.15	138	2.63	168	3.04	195	3.39	217	3.72	238	0.150 - 0.27
	4.5	26.0	76.50	2.72	1.02	78	1.45	111	1.78	136	2.05	157	2.28	174	2.30	214	3.23	247	3.60	276	3.96	303	
	5.0	28.0	90.00	2.96	1.08	97	1.53	138	1.88	169	2.17	196	2.42	218	2.96	266	3.42	308	3.82	344	4.19	377	0.175 - 0.23
	6.0	32.0	120.00	3.45	1.21	145	1.71	206	2.09	251	2.41	290	2.69	323	3.29	395	3.80	456	4.24	509	4.65	558	
10	1.0	14.0	12.00	0.83	0.46	5.5	0.65	7.8	0.80	9.6	0.93	11	1.03	12	1.27	15	1.47	18	1.63	20	1.79	22	0.200 - 0.20
	1.5	16.0	19.50	1.16	0.58	11	0.82	16	1.00	20	1.16	23	1.30	25	1.58	31	1.84	36	2.04	40	2.24	44	
	2.0	18.0	28.00	1.48	0.69	19	0.97	27	1.18	33	1.36	38	1.52	43	1.86	52	2.16	61	2.40	67	2.64	74	0.250 - 0.16
	2.5	20.0	37.50	1.77	0.77	29	1.09	41	1.33	50	1.53	57	1.72	65	2.10	79	2.42	91	2.71	102	2.97	111	
	3.0	22.0	48.00	2.05	0.85	41	1.19	57	1.47	71	1.69	81	1.89	91	2.32	111	2.68	129	2.99	144	3.29	158	0.300 - 0.13
	3.5	24.0	59.50	2.32	0.92	55	1.30	77	1.60	95	1.84	110	2.06	123	2.52	150	2.91	173	3.25	193	3.57	213	
	4.0	26.0	72.00	2.58	0.99	71	1.39	100	1.71	123	1.97	142	2.21	159	2.70	194	3.02	218	3.49	252	3.82	275	
	4.5	28.0	85.50	2.84	1.05	90	1.49	127	1.83	157	2.11	181	2.35	201	2.89	247	3.33	285	3.72	318	4.07	348	
	5.0	30.0	100.00	3.09	1.12	112	1.58	158	1.93	193	2.23	223	2.49	249	3.05	305	3.52	352	3.93	393	4.32	432	
	6.0	34.0	132.00	3.58	1.23	162	1.74	230	2.13	282	2.46	325	2.75	364	3.36	444	3.88	513	4.34	573	4.76	630	
12	1.0	16.0	14.00	0.85	0.47	6.6	0.67	9.4	0.81	11	0.95	13	1.05	15	1.29	18	1.49	21	1.66	23	1.82	26	
	1.5	18.0	22.50	1.20	0.60	13	0.84	19	1.03	23	1.19	27	1.33	30	1.62	36	1.88	42	2.10	47	2.30	52	
	2.0	20.0	32.00	1.53	0.70	22	0.99	32	1.21	39	1.40	45	1.56	50	1.90	61	2.20	70	2.46	79	2.70	86	
	2.5	22.0	42.50	1.83	0.79	34	1.11	47	1.36	58	1.57	67	1.76	75	2.15	91	2.49	106	2.78	118	3.04	129	
	3.0	24.0	54.00	2.12	0.87	47	1.23	66	1.50	81	1.73	93	1.94	105	2.37	128	2.74	148	3.06	165	3.36	181	
	3.5	26.0	66.50	2.40	0.94	62	1.33	89	1.63	108	1.88	125	2.11	140	2.58	172	2.98	198	3.33	222	3.65	243	
	4.0	28.0	80.00	2.68	1.01	81	1.44	115	1.77	142	2.03	162	2.27	182	2.78	222	3.20	256	3.58	286	3.92	314	
	4.5	30.0	94.50	2.94	1.08	102	1.53	145	1.88	178	2.16	204	2.41	228	2.95	279	3.41	322	3.81	360	4.17	394	
	5.0	32.0	110.00	3.20	1.14	126	1.62	178	1.98	218	2.28	251	2.55	281	3.12	343	3.61	397	4.03	444	4.42	487	
	6.0	36.0	144.00	3.71	1.26	182	1.78	256	2.18	314	2.52	363	2.82	406	3.44	496	3.98	573	4.44	639	4.88	703	
16	1.0	20.0	18.00	0.38	0.48	8.6	0.68	12	0.82	15	0.96	17	1.07	19	1.33	24	1.52	27	1.71	31	1.86	34	
	1.5	22.0	28.50	1.25	0.61	17	0.87	25	1.06	30	1.22	35	1.37	39	1.66	47	1.93	55	2.15	61	2.36	67	
	2.0	24.0	40.00	1.60	0.77	29	1.02	41	1.24	50	1.44	58	1.61	64	1.97	79	2.27	91	2.54	102	2.78	111	
	2.5	26.0	52.50	1.93	0.8[illegible]	43	1.16	61	1.42	75	1.63	86	1.82	96	2.23	117	2.58	136	2.87	151	3.15	165	
	3.0	28.0	66.00	2.24	0.90	59	1.27	84	1.56	103	1.79	118	2.01	133	2.46	162	2.84	188	3.17	210	3.48	230	
	3.5	30.0	80.50	2.54	0.98	79	1.38	111	1.70	137	1.95	157	2.19	176	2.68	216	3.09	249	3.45	278	3.78	304	
	4.0	32.0	96.00	2.83	1.05	101	1.49	143	1.82	175	2.10	202	2.34	225	2.88	277	3.32	319	3.71	356	4.06	390	
	4.5	34.0	112.50	3.11	1.12	126	1.58	178	1.94	218	2.24	252	2.50	281	3.06	344	3.54	398	3.95	444	4.33	488	
	5.0	36.0	130.00	3.39	1.19	155	1.68	218	2.06	268	2.37	308	2.66	346	3.24	421	3.75	488	4.18	543	4.59	537	
	6.0	40.0	168.00	3.92	1.30	218	1.85	311	2.26	380	2.61	438	3.58	602	4.13	694	4.60	773	5.06	850	5.46	918	
20	1.0	24.0	22.00	0.90	0.50	11	0.70	15	0.84	18	0.98	22	1.09	24	1.36	30	1.55	34	1.74	38	1.89	42	
	1.5	26.0	34.50	1.30	0.63	22	0.89	31	1.08	37	1.24	43	1.40	48	1.71	59	1.98	68	2.21	76	2.43	84	
	2.0	28.0	48.00	1.66	0.74	36	1.05	50	1.27	61	1.47	71	1.65	79	2.01	97	2.32	111	2.59	124	2.85	137	
	2.5	30.0	62.50	2.00	0.84	52	1.19	74	1.44	90	1.67	104	1.86	116	2.28	143	2.64	165	2.94	184	3.23	202	
	3.0	32.0	78.00	2.33	0.93	73	1.31	102	1.59	124	1.84	144	2.07	162	2.53	197	2.92	228	3.26	254	3.58	280	
	3.5	34.0	94.50	2.65	1.01	95	1.42	134	1.75	165	2.01	190	2.25	213	2.75	260	3.18	301	3.55	336	3.89	368	
	4.0	36.0	112.00	2.96	1.08	121	1.53	172	1.88	211	2.17	244	2.42	271	2.96	332	3.42	383	3.82	428	4.19	470	
	4.5	38.0	130.50	3.25	1.15	150	1.62	212	2.01	262	2.31	302	2.58	337	3.15	412	3.65	477	4.07	532	4.46	583	
	5.0	40.0	150.00	3.54	1.22	183	1.73	260	2.12	318	2.44	366	2.73	410	3.34	501	3.86	579	4.30	645	4.72	708	
	6.0	44.0	192.00	4.10	1.38	265	1.88	361	2.29	440	2.66	510	2.96	569	3.64	700	4.20	807	4.68	900	5.14	985	

EXAMPLE: n = 0.045
slope = 0.20
bottom width = 12 ft.
depth = 2.5 ft.
Q = 0.89 (106) = 94 c.f.s.
V = 0.89 = 222 f.p.s.

TABLE 5-3

VALUES OF V AND Q FOR DRAINAGE DITCHES 2:1 SIDE SLOPES n = 0.040

DITCH SIZE					PERCENT SLOPE																				CORRECTION FACTORS FOR V AND Q
BOTTOM WIDTH FT.	DEPTH FT.	TOP WIDTH FT.	AREA SQ.FT.	r - FT.	0.35		0.40		0.45		0.50		0.60		0.70		0.80		0.90		1.00		n
					V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	
4	1.0	8.0	6.00	0.71	1.76	11	1.86	11	1.98	12	2.08	12	2.28	14	2.46	15	2.63	16	2.79	17	2.94	18	0.025 - 1.60
	1.5	10.0	10.50	0.98	2.17	23	2.32	24	2.46	26	2.59	27	2.84	30	3.06	32	3.27	34	3.47	36	3.66	38	
	2.0	12.0	16.00	1.24	2.53	41	2.71	43	2.87	46	3.03	49	3.32	53	3.58	57	3.83	61	4.07	65	4.28	69	0.030 - 1.33
	2.5	14.0	22.50	1.48	2.85	64	3.04	68	3.24	73	3.41	77	3.74	84	4.04	91	4.32	97	4.58	103	4.82	108	
	3.0	16.0	30.00	1.72	3.15	95	3.37	101	3.58	108	3.77	113	4.13	124	4.46	134	4.78	144	5.06	152	5.32	160	0.035 - 1.14
	3.5	18.0	38.50	1.96	3.44	132	3.68	142	3.91	151	4.11	158	4.50	173	4.86	187	5.20	200	5.52	212			
	4.0	20.0	48.00	2.19	3.70	178	3.96	190	4.20	202	4.43	213	4.86	234	5.23	251	5.60	269					0.040 - 1.00
	4.5	22.0	53.50	2.43	3.97	232	4.25	243	4.50	263	4.75	278	5.21	305	5.60	328							
	5.0	24.0	70.00	2.66	4.21	295	4.50	315	4.78	335	5.05	354	5.55	388									0.045 - 0.89
	6.0	28.0	96.00	3.11	4.68	450	5.00	480	5.31	510	5.59	537											
6	1.0	10.0	8.00	0.76	1.83	15	1.95	16	2.08	17	2.18	17	2.40	19	2.59	21	2.77	22	2.93	23	3.08	25	0.050 - 0.80
	1.5	12.0	13.50	1.06	2.29	31	2.44	33	2.59	35	2.73	37	3.00	41	3.23	44	3.45	47	3.66	49	3.86	52	
	2.0	14.0	20.00	1.34	2.66	53	2.85	57	3.03	60	3.20	64	3.50	70	3.78	76	4.04	81	4.29	86	4.52	90	0.055 - 0.73
	2.5	16.0	27.50	1.60	3.00	84	3.21	88	3.41	94	3.59	99	3.94	108	4.25	117	4.55	125	4.82	133	5.07	139	
	3.0	18.0	36.00	1.85	3.30	119	3.54	127	3.76	135	3.96	143	4.34	156	4.68	169	5.00	180	5.32	192	5.60	202	0.060 - 0.67
	3.5	20.0	45.50	2.10	3.60	164	3.85	175	4.09	186	4.30	196	4.72	215	5.09	232	5.45	248					
	4.0	22.0	56.00	2.34	3.87	217	4.14	232	4.39	246	4.63	259	5.07	284	5.47	306							0.065 - 0.62
	4.5	24.0	67.50	2.59	4.14	279	4.42	298	4.69	306	4.96	335	5.44	367									
	5.0	26.0	80.00	2.82	4.38	350	4.69	375	4.97	398	5.25	420											0.070 - 0.57
	6.0	30.0	108.00	3.29	4.85	524	5.19	561	5.52	596													
8	1.0	12.0	10.00	0.80	1.89	19	2.02	20	2.15	21	2.26	23	2.48	25	2.68	27	2.86	29	3.04	30	3.20	32	0.075 - 0.53
	1.5	14.0	16.50	1.12	2.37	39	2.53	42	2.68	44	2.83	47	3.10	51	3.35	55	3.58	59	3.80	63	4.00	66	
	2.0	16.0	24.00	1.42	2.77	66	2.96	71	3.15	76	3.32	80	3.63	87	3.93	94	4.20	101	4.46	107	4.69	112	0.100 - 0.40
	2.5	18.0	32.50	1.70	3.12	102	3.34	109	3.55	115	3.74	122	4.10	133	4.42	144	4.74	154	5.02	163	5.28	172	
	3.0	20.0	42.00	1.96	3.44	145	3.68	155	3.91	164	4.11	173	4.50	189	4.86	204	5.20	219	5.52	232			0.125 - 0.32
	3.5	22.0	52.50	2.22	3.73	196	3.99	210	4.24	222	4.46	235	4.90	258	5.28	278							
	4.0	24.0	64.00	2.47	4.00	256	4.29	275	4.55	291	4.80	307	5.27	337									0.150 - 0.27
	4.5	26.0	76.50	2.72	4.28	327	4.58	350	4.84	370	5.12	392	5.64	431									
	5.0	28.0	90.00	2.96	4.52	406	4.84	435	5.13	462	5.41	487											0.175 - 0.23
	6.0	32.0	120.00	3.45	5.00	600	5.37	644															
10	1.0	14.0	12.00	0.83	1.94	23	2.06	25	2.21	27	2.31	28	2.54	30	2.74	33	2.92	35	3.10	37	3.26	39	0.200 - 0.20
	1.5	16.0	19.50	1.16	2.42	47	2.59	50	2.74	53	2.90	57	3.17	62	3.42	67	3.66	71	3.88	76	4.10	80	
	2.0	18.0	28.00	1.48	2.85	80	3.04	85	3.24	91	3.40	95	3.73	104	4.03	113	4.31	121	4.57	128	4.82	135	0.250 - 0.16
	2.5	20.0	37.50	1.77	3.20	120	3.43	129	3.65	137	3.84	144	4.20	158	4.54	170	4.87	183	5.16	194	5.43	204	
	3.0	22.0	48.00	2.05	3.54	170	3.79	182	4.02	193	4.24	204	4.64	222	5.00	240	5.34	256					0.300 - 0.13
	3.5	24.0	59.50	2.32	3.84	228	4.11	245	4.36	260	4.60	274	5.04	300	5.44	324							
	4.0	26.0	72.00	2.58	4.13	297	4.40	317	4.67	337	4.94	355	5.42	390									
	4.5	28.0	85.50	2.84	4.40	376	4.71	403	4.99	427	5.27	451											
	5.0	30.0	100.00	3.09	4.66	466	4.98	498	5.28	528	5.57	557											
	6.0	34.0	132.00	3.58	5.13	678	5.50	727															
12	1.0	16.0	14.00	0.85	1.97	28	2.10	29	2.23	31	2.35	33	2.58	36	2.68	38	2.93	41	3.13	44	3.30	46	
	1.5	18.0	22.50	1.20	2.48	56	2.65	60	2.81	63	2.97	67	3.25	73	3.50	79	3.71	83	3.96	89	4.18	94	
	2.0	20.0	32.00	1.53	2.91	93	3.11	99	3.31	106	3.48	111	3.82	122	4.12	132	4.41	141	4.68	150	4.92	158	
	2.5	22.0	42.50	1.83	3.28	139	3.52	150	3.73	159	3.93	167	4.31	183	4.65	198	4.95	210	5.28	224	5.56	236	
	3.0	24.0	54.00	2.12	3.62	196	3.87	209	4.11	222	4.33	234	4.74	256	5.12	277	5.48	296					
	3.5	26.0	66.50	2.40	3.94	262	4.21	280	4.47	297	4.71	313	5.16	343	5.57	371							
	4.0	28.0	80.00	2.68	4.23	338	4.53	362	4.80	384	5.08	406	5.58	446									
	4.5	30.0	94.50	2.94	4.50	425	4.81	455	5.12	483	5.40	510											
	5.0	32.0	110.00	3.20	4.76	524	5.10	561	5.41	595													
	6.0	36.0	144.00	3.71	5.26	758																	
16	1.0	20.0	18.00	0.88	2.02	36	2.15	39	2.34	42	2.41	44	2.64	47	2.85	51	3.04	55	3.23	58	3.40	61	
	1.5	22.0	28.50	1.25	2.54	72	2.72	77	2.88	82	3.04	87	3.33	95	3.60	103	3.85	110	4.09	117	4.30	122	
	2.0	24.0	40.00	1.60	3.00	120	3.21	128	3.41	137	3.59	144	3.94	158	4.25	170	4.55	182	4.82	193	5.07	203	
	2.5	26.0	52.50	1.93	3.40	178	3.64	191	3.86	202	4.07	214	4.46	234	4.82	253	5.14	270	5.47	287			
	3.0	28.0	66.00	2.24	3.75	248	4.00	264	4.26	281	4.49	296	4.92	325	5.31	351							
	3.5	30.0	80.50	2.54	4.08	329	4.37	352	4.63	373	4.89	394	5.37	432									
	4.0	32.0	96.00	2.83	4.39	421	4.69	450	4.97	477	5.25	504											
	4.5	34.0	112.50	3.11	4.68	527	5.00	563	5.31	598	5.59	629											
	5.0	36.0	130.00	3.39	4.95	643	5.30	689															
	6.0	40.0	168.00	3.92																			
20	1.0	24.0	22.00	0.90	2.06	45	2.19	48	2.35	52	2.45	54	2.69	59	2.90	64	3.09						
	1.5	26.0	34.50	1.30	2.62	90	2.80	97	2.97	102	3.14	108	3.42	118	3.70	128	3.96						
	2.0	28.0	48.00	1.66	3.08	148	3.29	158	3.50	168	3.67	176	4.03	193	4.35	209	4.66						
	2.5	30.0	62.50	2.00	3.49	218	3.73	233	3.96	248	4.16	260	4.56	285	4.92	308	5.26						
	3.0	32.0	78.00	2.33	3.86	301	4.13	322	4.37	341	4.61	360	5.05	394	5.45	425							
	3.5	34.0	94.50	2.65	4.20	397	4.50	425	4.76	450	5.04	476	5.54	524									
	4.0	36.0	112.00	2.96	4.52	506	4.84	542	5.13	575	5.41	606											
	4.5	38.0	130.50	3.25	4.82	630	5.16	674	5.48	717													
	5.0	40.0	150.00	3.54	5.09	763	5.45	817															
	6.0	44.0	192.00	4.10	5.54	1062																	

TABLE 5-4

VALUES OF V AND Q FOR DRAINAGE DITCHES — 4:1 SIDE SLOPES — n = 0.040

DITCH SIZE					PERCENT SLOPE																				CORRECTION FACTORS FOR V AND Q
BOTTOM WIDTH FT.	DEPTH FT.	TOP WIDTH FT.	AREA SQ.FT.	r - FT.	0.02		0.04		0.06		0.08		0.10		0.15		0.20		0.25		0.30		n
					V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	
4	1.0	12.0	8.00	0.65	0.39	3.1	0.56	4.5	0.68	5.4	0.79	6.3	0.89	7.1	1.08	8.6	1.24	9.9	1.39	11	1.57	13	0.025 - 1.60
	1.5	16.0	15.04	0.91	0.50	7.5	0.70	11	0.85	13	0.99	15	1.10	17	1.37	21	1.56	23	1.75	26	1.90	29	
	2.0	20.0	24.00	1.17	0.59	14	0.83	20	1.02	25	1.17	28	1.30	31	1.59	38	1.85	44	2.06	50	2.26	54	0.030 - 1.33
	2.5	24.0	35.00	1.42	0.67	23	0.94	33	1.15	40	1.32	46	1.48	52	1.82	64	2.10	74	2.34	82	2.57	90	
	3.0	28.0	48.00	1.67	0.74	36	1.05	50	1.28	61	1.48	71	1.66	80	2.02	97	2.33	112	2.60	125	2.86	137	0.035 - 1.14
	3.5	32.0	63.00	1.92	0.81	51	1.15	73	1.41	89	1.62	102	1.81	114	2.22	134	2.57	162	2.86	180	3.14	198	
	4.0	36.0	80.00	2.16	0.88	70	1.24	99	1.52	122	1.75	140	1.96	157	2.40	192	2.78	222	3.10	248	3.40	272	0.040 - 1.00
	4.5	40.0	99.00	2.46	0.96	93	1.35	134	1.66	164	1.91	189	2.14	222	2.62	259	3.03	300	3.38	335	3.71	367	
	5.0	44.0	120.00	2.65	1.01	121	1.42	171	1.75	210	2.01	241	2.25	270	2.75	330	3.18	382	3.55	427	3.89	467	0.045 - 0.89
	6.0	52.0	168.00	3.14	1.13	190	1.59	267	1.95	328	2.25	378	2.52	423	3.08	518	3.56	599	3.98	669	4.36	733	
6	1.0	14.0	10.00	0.70	0.41	4.1	0.59	5.9	0.72	7.2	0.83	8.3	0.92	9.2	1.13	11	1.30	13	1.46	15	1.60	16	0.050 - 0.80
	1.5	18.0	18.00	0.98	0.52	9.4	0.73	13	0.90	16	1.04	19	1.15	21	1.42	26	1.64	30	1.83	33	2.00	36	
	2.0	22.0	28.00	1.24	0.61	17	0.86	24	1.05	29	1.21	34	1.36	38	1.65	46	1.92	54	2.14	60	2.35	66	0.055 - 0.73
	2.5	26.0	40.00	1.50	0.69	27	0.98	39	1.19	48	1.37	55	1.54	62	1.88	75	2.18	87	2.42	97	2.66	107	
	3.0	30.0	54.00	1.76	0.77	42	1.08	58	1.33	72	1.53	83	1.72	93	2.10	113	2.42	131	2.70	146	2.96	160	0.060 - 0.67
	3.5	34.0	70.00	2.01	0.84	59	1.19	83	1.45	102	1.68	118	1.87	131	2.29	160	2.65	186	2.95	207	3.24	227	
	4.0	38.0	88.00	2.26	0.91	80	1.28	113	1.57	138	1.81	159	2.03	179	2.48	218	2.86	252	3.19	281	3.50	308	0.065 - 0.62
	4.5	42.0	108.00	2.50	0.97	105	1.37	148	1.68	182	1.93	209	2.17	234	2.65	287	3.06	331	3.41	369	3.75	405	
	5.0	46.0	130.00	2.75	1.03	134	1.46	190	1.79	233	2.06	268	2.30	300	2.82	367	3.26	424	3.64	474	3.99	519	0.070 - 0.57
	6.0	54.0	180.00	3.24	1.15	207	1.62	292	2.00	360	2.30	414	2.57	463	3.14	565	3.64	655	4.06	732	4.46	804	
8	1.0	16.0	12.00	0.74	0.43	5.2	0.61	7.3	0.74	8.9	0.86	10	0.96	12	1.17	14	1.36	16	1.52	18	1.66	20	0.075 - 0.53
	1.5	20.0	21.00	1.03	0.54	11	0.76	16	0.93	20	1.08	23	1.19	25	1.47	31	1.69	36	1.90	40	2.07	44	
	2.0	24.0	32.00	1.31	0.63	20	0.89	28	1.09	35	1.25	40	1.41	45	1.72	55	1.99	64	2.22	71	2.44	78	0.100 - 0.40
	2.5	28.0	45.00	1.57	0.71	32	1.01	45	1.23	55	1.42	64	1.59	72	1.96	88	2.24	101	2.50	113	2.74	123	
	3.0	32.0	60.00	1.83	0.79	47	1.11	67	1.36	82	1.57	94	1.76	106	2.15	129	2.49	150	2.78	167	3.04	183	0.125 - 0.32
	3.5	36.0	77.00	2.09	0.86	66	1.22	94	1.49	115	1.72	133	1.92	148	2.35	181	2.72	210	3.03	234	3.33	257	
	4.0	40.0	96.00	2.34	0.93	89	1.31	126	1.60	154	1.85	178	2.08	200	2.54	244	2.93	282	3.27	314	3.59	344	0.150 - 0.27
	4.5	44.0	117.00	2.59	0.99	116	1.40	164	1.72	201	1.98	232	2.22	248	2.71	318	3.03	355	3.50	410	3.83	449	
	5.0	48.0	140.00	2.84	1.05	147	1.49	209	1.83	256	2.11	296	2.35	330	2.89	405	3.33	467	3.72	521	4.07	570	0.175 - 0.23
	6.0	56.0	192.00	3.34	1.18	227	1.66	319	2.04	392	2.35	452	2.62	504	3.21	617	3.71	713	4.14	794	4.54	872	
10	1.0	18.0	14.00	0.77	0.44	6.2	0.63	8.8	0.76	11	0.89	12	0.99	14	1.22	17	1.40	20	1.56	22	1.71	24	0.200 - 0.20
	1.5	22.0	24.00	1.07	0.55	13	0.78	19	0.95	23	1.10	26	1.22	29	1.50	36	1.74	42	1.94	47	2.12	51	
	2.0	26.0	36.00	1.36	0.65	23	0.91	33	1.12	40	1.29	46	1.44	52	1.76	63	2.04	73	2.27	82	2.50	90	0.250 - 0.16
	2.5	30.0	50.00	1.63	0.73	36	1.03	51	1.26	63	1.46	73	1.63	81	1.99	99	2.30	115	2.56	128	2.81	140	
	3.0	34.0	66.00	1.90	0.81	53	1.14	75	1.40	92	1.61	106	1.80	119	2.20	145	2.55	168	2.84	187	3.12	206	0.300 - 0.13
	3.5	38.0	84.00	2.16	0.88	74	1.24	104	1.52	128	1.75	147	1.96	165	2.40	202	2.78	234	3.10	260	3.40	286	
	4.0	42.0	104.00	2.42	0.95	99	1.34	139	1.64	171	1.89	197	2.12	220	2.60	271	2.99	311	3.36	350	3.67	382	
	4.5	46.0	126.00	2.67	1.01	127	1.43	180	1.76	222	2.02	254	2.26	285	2.77	349	3.19	402	3.57	450	3.91	493	
	5.0	50.0	150.00	2.93	1.08	162	1.52	228	1.87	281	2.15	323	2.40	360	2.94	441	3.40	510	3.80	570	4.16	625	
	6.0	58.0	204.00	3.43	1.20	245	1.69	345	2.07	423	2.39	488	2.67	545	3.27	668	3.78	772	4.22	862	4.63	944	
12	1.0	20.0	16.00	0.79	0.45	7.2	0.64	10	0.78	12	0.90	14	1.00	16	1.22	20	1.42	23	1.58	25	1.73	28	
	1.5	24.0	27.00	1.11	0.57	15	0.80	22	0.98	26	1.13	30	1.26	34	1.54	42	1.78	48	1.99	54	2.17	59	
	2.0	28.0	40.00	1.40	0.66	26	0.93	37	1.14	46	1.31	52	1.47	59	1.80	72	2.08	83	2.32	93	2.55	102	
	2.5	32.0	55.00	1.68	0.75	41	1.05	58	1.29	71	1.48	81	1.66	91	2.03	112	2.34	129	2.62	144	2.87	158	
	3.0	36.0	72.00	1.96	0.82	59	1.16	84	1.43	103	1.64	118	1.84	132	2.25	162	2.60	187	2.90	209	3.19	230	
	3.5	40.0	91.00	2.22	0.90	82	1.27	116	1.55	141	1.78	162	2.00	182	2.45	223	2.82	257	3.15	287	3.46	315	
	4.0	44.0	112.00	2.49	0.97	109	1.36	152	1.67	187	1.93	216	2.16	242	2.64	296	3.05	342	3.40	381	3.74	419	
	4.5	48.0	135.00	2.75	1.03	139	1.46	197	1.79	242	2.06	278	2.30	311	2.80	381	3.26	440	3.64	492	3.99	539	
	5.0	52.0	160.00	3.01	1.10	176	1.55	248	1.90	304	2.19	351	2.44	390	2.99	479	3.46	554	3.86	618	4.24	677	
	6.0	56.0	216.00	3.51	1.22	264	1.72	372	2.10	454	2.42	523	2.71	585	3.32	718	3.84	830	4.28	924	4.70	1015	
16	1.0	24.0	20.00	0.82	0.46	9.2	0.65	13	0.79	16	0.92	18	1.02	20	1.26	25	1.46	29	1.62	32	1.78	36	
	1.5	28.0	33.00	1.16	0.58	19	0.82	27	1.00	33	1.16	38	1.30	43	1.58	52	1.84	61	2.04	67	2.24	74	
	2.0	32.0	48.00	1.48	0.69	33	0.97	47	1.18	57	1.36	65	1.52	73	1.86	89	2.16	104	2.40	115	2.64	127	
	2.5	36.0	65.00	1.77	0.77	50	1.09	71	1.33	86	1.53	99	1.72	112	2.10	136	2.42	157	2.71	176	2.97	193	
	3.0	40.0	84.00	2.06	0.85	71	1.20	101	1.48	124	1.70	143	1.90	160	2.33	196	2.69	226	3.00	252	3.30	277	
	3.5	44.0	105.00	2.35	0.93	98	1.31	138	1.61	169	1.85	194	2.08	218	2.55	268	2.94	309	3.28	344	3.60	378	
	4.0	48.0	128.00	2.61	1.00	128	1.41	181	1.73	222	1.99	255	2.23	286	2.73	350	3.15	404	3.51	450	3.85	494	
	4.5	52.0	153.00	2.87	1.06	162	1.50	230	1.85	283	2.13	326	2.37	363	2.91	445	3.35	513	3.74	572	4.10	628	
	5.0	56.0	180.00	3.15	1.13	203	1.59	286	1.96	353	2.25	405	2.52	453	3.09	556	3.57	643	3.93	717	4.37	787	
	6.0	64.0	240.00	3.67	1.25	300	1.77	425	2.16	519	2.50	600	2.79	670	3.41	819	3.95	948	4.41	1060	4.83	1160	
20	1.0	28.0	24.00	0.85	0.47	11	0.67	16	0.81	19	0.95	23	1.05	25	1.29	31	1.49	36	1.66	40	1.82	44	
	1.5	32.0	39.00	1.20	0.60	23	0.84	33	1.03	40	1.19	46	1.33	52	1.62	63	1.88	73	2.10	82	2.30	90	
	2.0	36.0	56.00	1.53	0.70	39	0.99	55	1.21	68	1.40	78	1.56	87	1.90	106	2.20	123	2.46	138	2.70	151	
	2.5	40.0	75.00	1.85	0.80	60	1.12	84	1.38	104	1.58	119	1.77	133	2.17	163	2.50	188	2.80	210	3.06	230	
	3.0	44.0	96.00	2.15	0.88	84	1.24	119	1.51	145	1.74	167	1.95	187	2.39	230	2.77	266	3.09	297	3.39	326	
	3.5	48.0	119.00	2.43	0.95	113	1.34	160	1.65	197	1.90	226	2.13	254	2.61	311	3.00	357	3.37	401	3.68	438	
	4.0	52.0	144.00	2.72	1.02	147	1.45	209	1.78	256	2.05	295	2.28	329	2.80	403	3.23	465	3.60	519	3.96	570	
	4.5	56.0	171.00	3.00	1.10	188	1.55	265	1.90	325	2.18	373	2.44	418	2.99	512	3.46	592	3.86	660	4.23	723	
	5.0	60.0	200.00	3.27	1.16	232	1.64	328	2.00	400	2.31	462	2.59	518	3.16	632	3.66	732	4.08	816	4.48	896	
	6.0	68.0	264.00	3.80	1.28	338	1.81	478	2.21	584	2.56	676	2.86	755	3.50	923	4.04	1062	4.52	1192	4.95	1308	

EXAMPLE: n = 0.05
slope = 0.30
bottom width = 10 ft.
depth = 2.0
Q = 0.80 (90) = 72 c.f.s.
V = 0.80 (2.50) = 2.0 f.p.s.

TABLE 5-4

VALUES OF V AND Q FOR DRAINAGE DITCHES 4:1 SIDE SLOPES n = 0.040

DITCH SIZE					PERCENT SLOPE																				
BOTTOM WIDTH FT.	DEPTH FT.	TOP WIDTH FT.	AREA SQ.FT.	r - FT.	0.35		0.40		0.45		0.50		0.60		0.70		0.80		0.90		1.00		CORRECTION FACTORS FOR V AND Q
					V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	n
4	1.0	12.0	8.00	0.65	1.65	13	1.76	14	1.88	15	1.97	16	2.16	17	2.32	19	2.50	20	2.64	21	2.79	22	0.025 - 1.60
	1.5	16.0	15.04	0.91	2.07	31	2.20	33	2.36	36	2.46	37	2.70	41	2.92	44	3.11	47	3.30	50	3.48	52	
	2.0	20.0	24.00	1.17	2.44	59	2.60	62	2.76	66	2.92	70	3.20	77	3.45	83	3.68	88	3.91	94	4.12	99	0.030 - 1.33
	2.5	24.0	35.00	1.42	2.77	97	2.96	104	3.15	110	3.32	116	3.63	127	3.93	138	4.20	147	4.46	156	4.69	164	
	3.0	28.0	48.00	1.67	3.09	148	3.30	158	3.51	168	3.69	177	4.05	194	4.37	210	4.68	224	4.95	238	5.21	250	0.035 - 1.14
	3.5	32.0	63.00	1.92	3.39	214	3.63	228	3.85	243	4.06	256	4.44	280	4.80	302	5.12	323	5.45	344			
	4.0	36.0	80.00	2.16	3.66	293	3.92	314	4.16	333	4.39	351	4.80	384	5.18	415	5.54	443					0.040 - 1.00
	4.5	40.0	99.00	2.46	4.00	396	4.28	424	4.54	450	4.79	474	5.25	520									
	5.0	44.0	120.00	2.65	4.20	504	4.50	540	4.76	571	5.04	605	5.54	665									0.045 - 0.89
	6.0	52.0	168.00	3.14	4.70	790	5.03	847	5.34	897	5.62	945											
6	1.0	14.0	10.00	0.70	1.73	17	1.84	18	1.96	20	2.06	21	2.26	23	2.44	24	2.62	26	2.77	28	2.92	29	0.050 - 0.80
	1.5	18.0	18.00	0.98	2.17	39	2.32	42	2.46	44	2.59	47	2.84	51	3.06	55	3.27	59	3.47	63	3.67	66	
	2.0	22.0	28.00	1.24	2.53	71	2.71	76	2.87	80	3.03	85	3.32	93	3.58	100	3.83	107	4.07	114	4.28	120	0.055 - 0.73
	2.5	26.0	40.00	1.50	2.87	115	3.07	123	3.27	131	3.44	138	3.76	151	4.07	163	4.35	174	4.61	185	4.86	195	
	3.0	30.0	54.00	1.76	3.20	173	3.42	185	3.63	196	3.83	207	4.20	227	4.53	244	4.85	262	5.14	278	5.41	292	0.060 - 0.67
	3.5	34.0	70.00	2.01	3.50	245	3.74	262	3.97	278	4.18	293	4.58	321	4.94	346	5.28	370	5.60	392			
	4.0	38.0	88.00	2.26	3.78	332	4.04	355	4.28	377	4.52	397	4.95	436	5.34	470							0.065 - 0.62
	4.5	42.0	108.00	2.50	4.04	437	4.32	467	4.58	495	4.84	523	5.31	574									
	5.0	46.0	130.00	2.75	4.31	560	4.60	598	4.88	635	5.16	670											0.070 - 0.57
	6.0	54.0	180.00	3.24	4.80	865	5.14	926	5.46	983													
8	1.0	16.0	12.00	0.74	1.80	22	1.92	23	2.04	24	2.16	26	2.36	28	2.54	30	2.72	33	2.88	35	3.03	36	0.075 - 0.53
	1.5	20.0	21.00	1.03	2.25	47	2.40	50	2.54	53	2.68	56	2.94	62	3.17	67	3.38	71	3.59	75	3.79	80	
	2.0	24.0	32.00	1.31	2.63	84	2.81	90	2.98	95	3.15	101	3.44	110	3.72	119	3.98	127	4.33	135	4.44	142	0.100 - 0.40
	2.5	28.0	45.00	1.57	2.96	133	3.16	142	3.37	152	3.54	159	3.88	175	4.19	189	4.49	202	4.76	224	5.00	225	
	3.0	32.0	60.00	1.83	3.28	197	3.52	211	3.73	224	3.93	236	4.31	259	4.65	279	4.95	297	5.28	317	5.56	334	0.125 - 0.32
	3.5	36.0	77.00	2.09	3.59	277	3.84	296	4.08	314	4.29	330	4.70	362	5.07	391	5.43	418					
	4.0	40.0	96.00	2.34	3.87	372	4.14	397	4.39	422	4.63	444	5.07	487	5.47	525							0.150 - 0.27
	4.5	44.0	117.00	2.59	4.14	484	4.42	517	4.69	549	4.96	581	5.44	637									
	5.0	48.0	140.00	2.84	4.40	617	4.71	660	4.99	700	5.27	738											0.175 - 0.23
	6.0	56.0	192.00	3.34	4.90	941	5.24	1006	5.58	1072													
10	1.0	18.0	14.00	0.77	1.85	26	1.97	28	2.16	29	2.20	31	2.42	34	2.62	37	2.80	39	2.94	41	3.11	44	0.200 - 0.20
	1.5	22.0	24.00	1.07	2.30	55	2.46	59	2.60	62	2.75	66	3.00	72	3.25	78	3.47	83	3.68	88	3.88	93	
	2.0	26.0	36.00	1.36	2.69	97	2.88	104	3.06	110	3.23	116	3.53	127	3.82	137	4.08	147	4.33	156	4.56	164	0.250 - 0.16
	2.5	30.0	50.00	1.63	3.04	152	3.25	162	3.46	173	3.63	181	3.99	200	4.30	225	4.60	230	4.88	244	5.13	256	
	3.0	34.0	66.00	1.90	3.36	222	3.60	238	3.82	252	4.03	266	4.41	291	4.76	314	5.10	337	5.42	358			0.300 - 0.13
	3.5	38.0	84.00	2.16	3.66	308	3.92	329	4.16	350	4.38	368	4.80	403	5.18	435	5.34	448					
	4.0	42.0	104.00	2.42	3.96	412	4.23	440	4.49	467	4.76	495	5.20	541	5.60	583							
	4.5	46.0	126.00	2.67	4.22	532	4.52	570	4.79	604	5.06	639	5.56	701									
	5.0	50.0	150.00	2.93	4.50	675	4.81	722	5.10	765	5.38	808											
	6.0	58.0	204.00	3.43	4.99	1018	5.34	1090															
12	1.0	20.0	16.00	0.79	1.87	30	2.00	32	2.12	34	2.24	36	2.46	39	2.66	43	2.83	45	3.00	48	3.16	51	
	1.5	24.0	27.00	1.11	2.35	63	2.50	68	2.66	72	2.80	76	3.08	83	3.32	90	3.54	96	3.76	102	3.97	107	
	2.0	28.0	40.00	1.40	2.75	110	2.94	118	3.12	125	3.29	132	3.60	144	3.89	155	4.16	167	4.41	176	4.65	186	
	2.5	32.0	55.00	1.68	3.10	171	3.32	183	3.52	194	3.70	204	4.06	224	4.38	241	4.70	258	4.98	274	5.24	288	
	3.0	36.0	72.00	1.96	3.44	248	3.68	265	3.91	282	4.11	296	4.50	324	4.86	350	5.20	374	5.52	397			
	3.5	40.0	91.00	2.22	3.73	340	3.99	363	4.24	385	4.46	406	4.90	445	5.28	481							
	4.0	44.0	112.00	2.49	4.03	451	4.32	484	4.58	514	4.83	541	5.30	594									
	4.5	48.0	135.00	2.75	4.31	582	4.61	623	4.88	659	5.16	697											
	5.0	52.0	160.00	3.01	4.57	732	4.90	784	5.20	832	5.47	875											
	6.0	56.0	216.00	3.51	5.07	1096	5.42	1171															
16	1.0	24.0	20.00	0.82	1.93	39	2.06	41	2.20	44	2.30	46	2.52	50	2.72	54	2.90	58	3.08	62	3.24	65	
	1.5	28.0	33.00	1.16	2.42	80	2.59	85	2.74	90	2.90	96	3.17	105	3.42	113	3.66	121	3.88	128	4.10	135	
	2.0	32.0	48.00	1.48	2.85	137	3.04	146	3.24	156	3.40	163	3.73	179	4.03	193	4.31	207	4.57	219	4.82	232	
	2.5	36.0	65.00	1.77	3.20	208	3.43	223	3.65	237	3.84	250	4.20	273	4.54	294	4.87	317	5.16	336	5.43	353	
	3.0	40.0	84.00	2.06	3.55	298	3.80	319	4.03	338	4.25	357	4.66	392	5.02	422	5.36	450					
	3.5	44.0	105.00	2.35	3.88	408	4.15	436	4.40	462	4.64	487	5.09	534	5.50	578							
	4.0	48.0	128.00	2.61	4.16	533	4.45	570	4.71	603	4.99	639	5.48	702									
	4.5	52.0	153.00	2.87	4.43	678	4.75	727	5.04	772	5.31	813											
	5.0	56.0	180.00	3.15	4.72	850	5.04	907	5.35	963													
	6.0	64.0	240.00	3.67	5.21	1250	5.59	1340															
20	1.0	28.0	24.00	0.85	1.97	47	2.10	50	2.23	54	2.35	56	2.58	62	2.68	64							
	1.5	32.0	39.00	1.20	2.48	97	2.65	103	2.81	110	2.97	116	3.25	127	3.50	137							
	2.0	36.0	56.00	1.53	2.91	163	3.11	174	3.31	185	3.48	195	3.82	214	4.12	231							
	2.5	40.0	75.00	1.85	3.30	248	3.54	266	3.76	282	3.96	297	4.34	325	4.68	351							
	3.0	44.0	96.00	2.15	3.65	350	3.91	375	4.15	398	4.37	420	4.79	460	5.16	496							
	3.5	48.0	119.00	2.43	3.97	472	4.24	504	4.50	536	4.78	570	5.22	622	5.62	670							
	4.0	52.0	144.00	2.72	4.28	617	4.58	675	4.84	698	5.12	738	5.64	812									
	4.5	56.0	171.00	3.00	4.56	780	4.88	835	5.18	886	5.26	900											
	5.0	60.0	200.00	3.27	4.83	966	5.17	1034	5.49	1098													
	6.0	68.0	264.00	3.80	5.34	1410																	

TABLE 5-5

VALUES OF V AND Q FOR DRAINAGE DITCHES 8:1 SIDE SLOPES n = 0.040

DITCH SIZE					PERCENT SLOPE																						CORRECTION FACTORS FOR V AND Q
BOTTOM WIDTH FT.	DEPTH FT.	TOP WIDTH FT.	AREA SQ.FT.	r - FT.	0.02		0.04		0.06		0.08		0.10		0.15		0.20		0.25		0.30		n
					V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	
4	0.5	12.0	4.00	0.33	0.26	1.0	0.35	1.4	0.42	1.7	0.50	2.0	0.55	2.2	0.68	2.8	0.78	3.1	0.87	3.5	0.96	3.8	0.025 - 1.60
	1.0	20.0	12.00	0.60	0.37	4.4	0.53	6.4	0.65	7.8	0.75	9.0	0.84	10	1.02	12	1.18	14	1.32	16	1.45	17	0.030 - 1.33
	1.5	28.0	24.00	0.85	0.47	11	0.67	16	0.81	19	0.95	23	1.05	25	1.29	31	1.49	36	1.66	40	1.82	44	0.035 - 1.14
	2.0	36.0	40.00	1.10	0.57	23	0.79	32	0.94	39	1.12	45	1.25	50	1.53	61	1.77	71	1.98	79	2.16	86	0.040 - 1.00
	2.5	44.0	60.00	1.36	0.65	39	0.91	55	1.12	67	1.29	77	1.44	86	1.76	106	2.04	122	2.27	136	2.50	150	0.045 - 0.89
	3.0	52.0	84.00	1.60	0.72	60	1.02	86	1.24	104	1.44	121	1.61	135	1.97	165	2.27	191	2.54	214	2.78	234	0.050 - 0.80
6	0.5	14.0	5.00	0.36	0.27	1.3	0.38	1.9	0.46	2.3	0.53	2.6	0.60	3.0	0.72	3.6	0.84	4.2	0.93	4.6	1.02	5.1	0.055 - 0.73
	1.0	22.0	14.00	0.63	0.38	5.3	0.55	7.7	0.67	9.4	0.78	11	0.87	12	1.06	15	1.21	17	1.36	19	1.52	21	0.060 - 0.67
	1.5	30.0	27.00	0.90	0.50	13	0.69	19	0.84	23	0.98	26	1.09	29	1.36	37	1.55	42	1.74	47	1.89	51	0.065 - 0.62
	2.0	38.0	44.00	1.15	0.58	26	0.81	36	0.99	44	1.15	51	1.29	57	1.57	69	1.83	81	2.03	89	2.23	98	0.070 - 0.57
	2.5	46.0	65.00	1.40	0.66	43	0.93	60	1.14	74	1.31	85	1.47	96	1.80	117	2.08	135	2.32	151	2.55	166	0.075 - 0.53
	3.0	54.0	90.00	1.66	0.74	67	1.05	95	1.27	114	1.47	132	1.65	149	2.01	181	2.32	209	2.59	233	2.85	257	
8	0.5	16.0	6.00	0.37	0.28	1.7	0.38	2.3	0.46	2.8	0.54	3.2	0.60	3.6	0.73	4.4	0.85	5.1	0.95	5.7	1.04	6.2	0.100 - 0.40
	1.0	24.0	16.00	0.66	0.39	6.2	0.56	9.0	0.69	11	0.80	13	0.90	14	1.09	17	1.25	20	1.40	22	1.58	25	0.125 - 0.32
	1.5	32.0	30.00	0.93	0.51	15	0.71	21	0.87	26	1.01	30	1.12	34	1.39	42	1.59	48	1.78	53	1.94	58	0.150 - 0.27
	2.0	40.0	48.00	1.19	0.60	29	0.83	40	1.02	49	1.18	57	1.32	63	1.61	77	1.87	90	2.09	100	2.29	110	0.175 - 0.23
	2.5	48.0	70.00	1.45	0.68	48	0.96	67	1.17	82	1.34	94	1.50	105	1.84	129	2.13	149	2.37	166	2.60	182	0.200 - 0.20
	3.0	56.0	96.00	1.70	0.75	72	1.06	102	1.30	125	1.50	144	1.68	161	2.04	196	2.36	227	2.64	254	2.89	278	0.250 - 0.16
10	0.5	18.0	7.00	0.39	0.29	2.0	0.40	2.8	0.48	3.4	0.56	3.9	0.63	4.4	0.76	5.3	0.88	6.2	0.99	6.9	1.08	7.6	0.300 - 0.13
	1.0	26.0	18.00	0.69	0.41	7.4	0.58	10	0.71	13	0.82	15	0.91	16	1.12	20	1.29	23	1.45	26	1.59	29	
	1.5	34.0	33.00	0.97	0.52	17	0.72	24	0.89	29	1.03	34	1.14	38	1.41	46	1.63	54	1.82	60	1.99	66	
	2.0	42.0	52.00	1.23	0.61	32	0.85	44	1.04	54	1.20	62	1.35	70	1.64	85	1.91	99	2.13	111	2.34	122	
	2.5	50.0	75.00	1.49	0.69	52	0.98	74	1.19	89	1.37	103	1.53	115	1.87	140	2.17	163	2.41	181	2.65	199	
	3.0	58.0	102.00	1.75	0.77	79	1.07	109	1.32	135	1.52	155	1.71	174	2.09	213	2.41	246	2.69	274	2.95	301	
12	0.5	20.0	8.00	0.40	0.29	2.3	0.40	3.2	0.49	3.9	0.57	4.6	0.64	5.1	0.78	6.2	0.90	7.2	1.00	8.0	1.10	8.8	
	1.0	28.0	20.00	0.71	0.42	8.4	0.60	12	0.72	14	0.84	17	0.93	19	1.14	23	1.32	26	1.47	29	1.61	32	
	1.5	36.0	36.00	1.00	0.53	19	0.74	27	0.91	33	1.05	38	1.17	42	1.44	52	1.66	60	1.86	67	2.03	73	
	2.0	44.0	56.00	1.27	0.62	35	0.87	49	1.07	60	1.23	69	1.38	77	1.68	94	1.95	109	2.17	122	2.38	133	
	2.5	52.0	80.00	1.53	0.70	56	0.99	79	1.21	97	1.40	112	1.56	125	1.90	152	2.20	176	2.46	197	2.70	216	
	3.0	60.0	108.00	1.79	0.78	84	1.10	119	1.35	146	1.54	167	1.73	187	2.12	229	2.45	265	2.74	296	3.00	324	
16	0.5	24.0	10.00	0.41	0.30	3.0	0.41	4.1	0.50	5.0	0.58	5.8	0.65	6.5	0.79	7.9	0.92	9.2	1.02	10	1.12	11	
	1.0	32.0	24.00	0.75	0.44	11	0.62	15	0.75	18	0.87	21	0.97	23	1.19	29	1.37	33	1.53	37	1.68	40	
	1.5	40.0	42.00	1.04	0.56	23	0.76	32	0.93	39	1.08	45	1.20	50	1.48	62	1.70	71	1.91	80	2.09	88	
	2.0	48.0	64.00	1.33	0.64	41	0.90	58	1.10	70	1.27	81	1.42	91	1.73	111	2.00	128	2.24	143	2.46	157	
	2.5	56.0	90.00	1.60	0.72	65	1.02	92	1.24	112	1.44	130	1.61	145	1.97	177	2.27	204	2.54	228	2.78	250	
	3.0	64.0	120.00	1.87	0.80	96	1.13	135	1.38	166	1.59	191	1.78	214	2.18	262	2.52	302	2.81	337	3.09	371	
20	0.5	28.0	12.00	0.43	0.31	3.7	0.42	5.0	0.52	6.2	0.60	7.2	0.67	8.0	0.81	9.7	0.94	11	1.05	13	1.15	14	
	1.0	36.0	28.00	0.78	0.45	13	0.64	18	0.77	22	0.90	25	1.00	28	1.22	34	1.41	40	1.57	44	1.72	48	
	1.5	44.0	48.00	1.09	0.56	27	0.79	38	0.97	47	1.11	53	1.24	60	1.52	73	1.76	84	1.96	94	2.15	103	
	2.0	52.0	72.00	1.38	0.66	47	0.92	66	1.13	81	1.30	94	1.46	105	1.78	128	2.06	148	2.30	166	2.53	182	
	2.5	60.0	100.00	1.66	0.74	74	1.05	105	1.27	127	1.47	147	1.65	165	2.01	201	2.32	232	2.59	259	2.85	285	
	3.0	68.0	132.00	1.93	0.81	107	1.16	153	1.42	188	1.63	215	1.82	240	2.23	294	2.58	341	2.87	379	3.15	416	

EXAMPLE: n = 0.025
slope = 0.10
bottom width = 8 ft.
depth = 3.0 ft.
Q = 1.60 (161) = 258 c.f.s.
V = 1.60 (1.68) = 2.7 f.p.s.

TABLE 5-5

VALUES OF V AND Q FOR DRAINAGE DITCHES 8:1 SIDE SLOPES n = 0.040

DITCH SIZE					PERCENT SLOPE																		CORRECTION FACTORS FOR V AND Q n
BOTTOM WIDTH FT.	DEPTH FT.	TOP WIDTH FT.	AREA SQ.FT.	r - FT.	0.35		0.40		0.45		0.50		0.60		0.70		0.80		0.90		1.00		
					V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	
4	0.5	12.0	4.00	0.33	1.03	4.1	1.10	4.4	1.17	4.7	1.24	5.0	1.34	5.4	1.46	5.8	1.56	6.2	1.66	6.6	1.75	7.0	0.025 - 1.60
	1.0	20.0	12.00	0.60	1.56	19	1.67	20	1.77	21	1.87	22	2.05	25	2.21	26	2.36	28	2.50	30	2.64	32	0.030 - 1.33
	1.5	28.0	24.00	0.85	1.97	47	2.10	50	2.23	54	2.35	56	2.58	62	2.68	64	2.93	70	3.13	75	3.30	79	0.035 - 1.14
	2.0	36.0	40.00	1.10	2.34	94	2.49	100	2.65	106	2.79	112	3.07	123	3.31	132	3.52	141	3.74	150	3.95	158	0.040 - 1.00
	2.5	44.0	60.00	1.36	2.69	162	2.88	173	3.06	183	3.23	194	3.53	212	3.82	229	4.08	245	4.33	260	4.56	274	0.045 - 0.89
	3.0	52.0	84.00	1.60	3.00	252	3.21	270	3.41	287	3.59	302	3.94	331	4.25	357	4.55	382	4.82	405	5.07	426	0.050 - 0.80
6	0.5	14.0	5.00	0.36	1.10	5.5	1.18	5.9	1.25	6.2	1.32	6.6	1.44	7.2	1.56	7.8	1.67	8.3	1.77	8.8	1.86	9.3	0.055 - 0.73
	1.0	22.0	14.00	0.63	1.61	23	1.72	24	1.83	26	1.93	27	2.12	30	2.28	32	2.45	34	2.58	36	2.72	38	0.060 - 0.67
	1.5	30.0	27.00	0.90	2.06	56	2.19	59	2.35	64	2.45	66	2.69	73	2.90	78	3.09	83	3.28	89	3.46	93	0.065 - 0.62
	2.0	38.0	44.00	1.15	2.41	106	2.58	114	2.73	120	2.88	127	3.15	139	3.40	150	3.64	160	3.86	170	4.08	180	0.070 - 0.57
	2.5	46.0	65.00	1.40	2.75	179	2.94	191	3.12	203	3.29	214	3.60	234	3.89	253	4.16	270	4.41	287	4.65	302	0.075 - 0.53
	3.0	54.0	90.00	1.66	3.08	277	3.29	296	3.50	315	3.67	330	4.03	363	4.35	392	4.66	420	4.93	444	5.19	467	0.100 - 0.40
8	0.5	16.0	6.00	0.37	1.12	6.7	1.20	7.2	1.28	7.7	1.35	8.1	1.47	8.8	1.59	9.5	1.70	10	1.80	11	1.90	11	0.125 - 0.32
	1.0	24.0	16.00	0.66	1.66	27	1.77	28	1.89	30	1.98	32	2.18	35	2.34	37	2.52	40	2.66	43	2.80	45	0.150 - 0.27
	1.5	32.0	30.00	0.93	2.11	63	2.25	68	2.40	72	2.51	75	2.76	83	2.97	89	3.17	95	3.36	101	3.56	107	0.175 - 0.23
	2.0	40.0	48.00	1.19	2.47	119	2.64	127	2.80	134	2.95	142	3.23	155	3.48	167	3.68	177	3.93	188	4.15	199	0.200 - 0.20
	2.5	48.0	70.00	1.45	2.81	197	3.00	210	3.20	224	3.37	236	3.68	258	3.98	279	4.25	298	4.52	316	4.75	332	0.250 - 0.16
	3.0	56.0	96.00	1.70	3.12	300	3.34	321	3.55	341	3.74	359	4.10	394	4.42	425	4.74	455	5.02	482	5.28	507	0.300 - 0.13
10	0.5	18.0	7.00	0.39	1.16	8.1	1.25	8.8	1.32	9.3	1.41	9.9	1.52	11	1.65	12	1.77	12	1.88	13	1.98	14	
	1.0	26.0	18.00	0.69	1.72	31	1.83	33	1.95	35	2.04	37	2.24	40	2.42	44	2.60	47	2.74	49	2.89	52	
	1.5	34.0	33.00	0.97	2.16	71	2.31	76	2.45	81	2.57	85	2.82	93	3.04	100	3.25	107	3.45	114	3.65	120	
	2.0	42.0	52.00	1.23	2.52	131	2.70	140	2.86	149	3.00	156	3.30	172	3.56	185	3.81	198	4.05	211	4.26	222	
	2.5	50.0	75.00	1.49	2.86	214	3.06	230	3.26	244	3.42	256	3.75	281	4.05	304	4.33	324	4.59	344	4.84	363	
	3.0	58.0	102.00	1.75	3.19	326	3.41	348	3.61	368	3.81	389	4.18	427	4.51	460	4.83	493	5.11	522	5.38	549	
12	0.5	20.0	8.00	0.40	1.19	9.5	1.28	10	1.35	11	1.43	11	1.55	12	1.68	13	1.80	14	1.91	15	2.00	16	
	1.0	28.0	20.00	0.71	1.76	35	1.86	37	1.98	40	2.08	42	2.28	46	2.46	49	2.63	53	2.79	56	2.94	59	
	1.5	36.0	36.00	1.00	2.20	79	2.35	85	2.49	90	2.63	95	2.88	104	3.11	112	3.32	120	3.52	127	3.72	134	
	2.0	44.0	56.00	1.27	2.57	144	2.75	154	2.92	163	3.08	172	3.37	189	3.64	204	3.90	218	4.14	232	4.35	244	
	2.5	52.0	80.00	1.53	2.91	233	3.11	249	3.31	265	3.48	278	3.82	306	4.12	330	4.41	353	4.68	375	4.92	394	
	3.0	60.0	108.00	1.79	3.24	350	3.46	374	3.68	396	3.88	419	4.25	459	4.58	494	4.90	529	5.20	562	5.48	592	
16	0.5	24.0	10.00	0.41	1.21	12	1.30	13	1.37	14	1.45	15	1.58	16	1.71	17	1.83	18	1.94	19	2.04	20	
	1.0	32.0	24.00	0.75	1.82	44	1.94	47	2.06	49	2.17	52	2.38	57	2.57	62	2.75	66	2.91	70	3.06	73	
	1.5	40.0	42.00	1.04	2.27	95	2.41	101	2.56	108	2.70	113	2.97	125	3.20	134	3.41	143	3.62	152	3.82	160	
	2.0	48.0	64.00	1.33	2.65	170	2.84	182	3.00	192	3.18	204	3.48	223	3.76	240	4.02	258	4.28	274	4.50	288	
	2.5	56.0	90.00	1.60	3.00	270	3.21	289	3.41	308	3.59	323	3.94	354	4.25	382	4.55	410	4.82	435	5.07	457	
	3.0	64.0	120.00	1.87	3.33	400	3.57	429	3.78	454	4.00	480	4.37	525	4.72	567	5.04	605	5.36	644			
20	0.5	28.0	12.00	0.43	1.24	15	1.34	16	1.41	17	1.50	18	1.63	20	1.76	21	1.88	23	2.00	24	2.10	25	
	1.0	36.0	28.00	0.78	1.86	52	1.99	56	2.11	59	2.22	62	2.44	68	2.64	74	2.82	79	2.98	83	3.14	88	
	1.5	44.0	48.00	1.09	2.32	111	2.48	119	2.63	126	2.78	133	3.04	146	3.28	157	3.50	168	3.73	179	3.93	189	
	2.0	52.0	72.00	1.38	2.72	196	2.91	210	3.09	222	3.26	235	3.57	257	3.86	278	4.12	297	4.37	315	4.61	332	
	2.5	60.0	100.00	1.66	3.08	308	3.29	329	3.50	350	3.67	367	4.03	403	4.35	435	4.66	466	4.93	493	5.19	519	
	3.0	68.0	132.00	1.93	3.40	449	3.64	481	3.86	510	4.07	538	4.46	589	4.82	637	5.14	678	5.47	722			

TABLE 5-6 VEE SHAPED FIELD DRAINAGE DITCHES

10:1 Side Slopes n= 0.025

				SLOPE (in percent)									
				.02		.04		.06		.08		.10	
D	TW	A	r	V	Q	V	Q	V	Q	V	Q	V	Q
.4	8.0	1.6	.19	.28	.4	.40	.6	.49	.7	.57	.9	.64	1.0
.6	12.0	3.6	.29	.37	1.3	.53	1.9	.65	2.3	.75	2.7	.84	3.0
.8	16.0	6.4	.39	.45	2.9	.64	4.1	.78	5.0	.91	5.8	1.01	6.5
1.0	20.0	10.0	.49	.52	5.2	.74	7.4	.91	9.1	1.05	10.5	1.18	11.8
1.2	24.0	14.4	.59	.59	8.5	.84	12.1	1.03	14.8	1.19	17.1	1.33	19.2
1.4	28.0	19.6	.69	.66	12.9	.93	18.3	1.14	22.4	1.32	25.9	1.47	28.9
1.6	32.0	25.6	.79	.72	18.4	1.02	26.1	1.25	32.0	1.44	36.9	1.61	41.3
1.8	36.0	32.4	.89	.78	25.3	1.10	35.8	1.35	43.8	1.56	50.6	1.74	56.6
2.0	40.0	40.0	.99	.83	33.5	1.18	47.4	1.45	58.0	1.67	67.0	1.87	74.9
2.2	44.0	48.4	1.09	.89	43.2	1.26	61.1	1.54	74.8	1.78	86.4	1.99	96.6
2.4	48.0	57.6	1.19	.94	54.5	1.33	77.1	1.63	94.4	1.89	109.0	2.11	121.9
2.6	52.0	67.6	1.29	.99	67.5	1.41	95.4	1.72	116.9	1.99	135.0	2.23	150.9
2.8	56.0	78.4	1.39	1.04	82.2	1.48	116.3	1.81	142.4	2.09	164.5	2.34	183.9
3.0	60.0	90.0	1.49	1.09	98.8	1.55	139.8	1.90	171.2	2.19	197.7	2.45	221.0

	SLOPE (in percent)													
	.15		.20		.25		.30		.35		.40		.45	
D	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q
.4	.78	1.2	.90	1.4	1.01	1.6	1.11	1.7	1.19	1.9	1.28	2.0	1.35	2.1
.6	1.02	3.7	1.18	4.2	1.32	4.7	1.45	5.2	1.57	5.6	1.68	6.0	1.78	6.4
.8	1.24	7.9	1.43	9.2	1.60	10.2	1.76	11.2	1.90	12.1	2.03	13.0	2.15	13.8
1.0	1.44	14.4	1.67	16.7	1.86	18.6	2.04	20.4	2.20	22.0	2.36	23.6	2.50	25.0
1.2	1.63	23.5	1.88	27.1	2.10	30.3	2.30	33.2	2.49	35.9	2.66	38.4	2.82	40.7
1.4	1.81	35.4	2.09	40.9	2.33	45.8	2.55	50.1	2.76	54.1	2.95	57.9	3.13	61.4
1.6	1.97	50.6	2.28	58.4	2.55	65.3	2.79	71.6	3.02	77.3	3.23	82.7	3.42	87.7
1.8	2.14	69.3	2.47	80.0	2.76	89.5	3.02	98.0	3.26	105.9	3.49	113.2	3.70	120.1
2.0	2.29	91.8	2.65	106.0	2.96	118.5	3.24	129.8	3.50	140.2	3.74	149.9	3.97	159.0
2.2	2.44	118.4	2.82	136.7	3.15	152.8	3.45	167.4	3.73	180.8	3.99	193.3	4.23	205.1
2.4	2.59	149.3	2.99	172.4	3.34	192.7	3.66	211.1	3.96	228.1	4.23	243.8	4.49	258.6
2.6	2.73	184.8	3.15	213.4	3.53	238.6	3.86	261.4	4.17	282.4	4.46	301.8	4.73	320.2
2.8	2.87	225.2	3.31	260.1	3.70	290.8	4.06	318.5	4.38	344.1	4.69	367.8	4.97	390.1
3.0	3.00	270.7	3.47	312.6	3.88	349.5	4.25	382.9	4.59	413.6	4.91	442.1	5.21	468.9

	SLOPE (in percent)											
	.5		.6		.7		.8		.9		1.0	
D	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q
.4	1.43	2.2	1.57	2.5	1.69	2.7	1.81	2.9	1.92	3.0	2.02	3.2
.6	1.87	6.7	2.05	7.4	2.22	8.0	2.37	8.5	2.52	9.0	2.65	9.5
.8	2.27	14.5	2.49	15.9	2.69	17.2	2.87	18.4	3.05	19.5	3.21	20.5
1.0	2.64	26.4	2.89	28.9	3.12	31.2	3.34	33.4	3.54	35.4	3.73	37.3
1.2	2.98	42.9	3.26	47.0	3.52	50.8	3.77	54.3	4.00	57.6	4.21	60.7
1.4	3.30	64.7	3.62	70.9	3.91	76.6	4.18	81.9	4.43	86.9	4.67	91.6
1.6	3.61	92.4	3.95	101.3	4.27	109.4	4.56	116.9	4.84	124.0	5.10	130.7
1.8	3.90	126.6	4.28	138.6	4.62	149.7	4.94	160.1	5.24	169.8	5.52	179.0
2.0	4.19	167.6	4.59	183.6	4.95	198.3	5.30	212.0	5.62	224.9	5.92	237.1
2.2	4.46	216.1	4.89	236.8	5.28	255.8	5.65	273.4	5.99	290.0	6.31	305.7
2.4	4.73	272.6	5.18	298.6	5.60	322.6	5.98	344.8	6.35	365.8	6.69	385.5
2.6	4.99	337.5	5.46	369.7	5.90	399.3	6.31	426.9	6.69	452.8	7.06	477.3
2.8	5.24	411.2	5.74	450.5	6.20	486.6	6.63	520.2	7.03	551.7	7.41	581.6
3.0	5.49	494.3	6.01	541.5	6.49	584.9	6.94	625.3	7.36	663.2	7.76	699.1

TABLE 5-7 VEE SHAPED FIELD DRAINAGE DITCHES

10:1 Side Slopes n= 0.040

				SLOPE (in percent)									
				.02		.04		.06		.08		.10	
D	TW	A	r	V	Q	V	Q	V	Q	V	Q	V	Q
.4	8.0	1.6	.19	.17	.2	.25	.4	.31	.4	.35	.5	.40	.6
.6	12.0	3.6	.29	.23	.8	.33	1.1	.40	1.4	.46	1.6	.52	1.8
.8	16.0	6.4	.39	.28	1.8	.40	2.5	.49	3.1	.56	3.6	.63	4.0
1.0	20.0	10.0	.49	.33	3.3	.46	4.6	.57	5.7	.66	6.6	.73	7.3
1.2	24.0	14.4	.59	.37	5.3	.52	7.5	.64	9.2	.74	10.7	.83	12.0
1.4	28.0	19.6	.69	.41	8.0	.58	11.4	.71	14.0	.82	16.1	.92	18.1
1.6	32.0	25.6	.79	.45	11.5	.63	16.3	.78	20.0	.90	23.1	1.00	25.8
1.8	36.0	32.4	.89	.48	15.8	.69	22.3	.84	27.4	.97	31.6	1.09	35.3
2.0	40.0	40.0	.99	.52	20.9	.74	29.6	.90	36.3	1.04	41.9	1.17	46.8
2.2	44.0	48.4	1.09	.55	27.0	.78	38.2	.96	46.8	1.11	54.0	1.24	60.4
2.4	48.0	57.6	1.19	.59	34.0	.83	48.1	1.02	59.0	1.18	68.1	1.32	76.2
2.6	52.0	67.6	1.29	.62	42.1	.88	59.6	1.08	73.0	1.24	84.3	1.39	94.3
2.8	56.0	78.4	1.39	.65	51.4	.92	72.7	1.13	89.0	1.31	102.8	1.46	114.9
3.0	60.0	90.0	1.49	.68	61.7	.97	87.3	1.18	107.0	1.37	123.5	1.53	138.1

	SLOPE (in percent)															
	.15		.20		.25		.30		.35		.40		.45	
D	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q
.4	.49	.7	.56	.9	.63	1.0	.69	1.1	.74	1.1	.80	1.2	.84	1.3
.6	.64	2.3	.74	2.6	.83	2.9	.90	3.2	.98	3.5	1.05	3.7	1.11	4.0
.8	.77	4.9	.89	5.7	1.00	6.4	1.10	7.0	1.18	7.6	1.27	8.1	1.34	8.6
1.0	.90	9.0	1.04	10.4	1.16	11.6	1.27	12.7	1.38	13.8	1.47	14.7	1.56	15.6
1.2	1.02	14.6	1.17	16.9	1.31	18.9	1.44	20.7	1.55	22.4	1.66	24.0	1.76	25.4
1.4	1.13	22.1	1.30	25.6	1.46	28.6	1.59	31.3	1.72	33.8	1.84	36.2	1.95	38.4
1.6	1.23	31.6	1.42	36.5	1.59	40.8	1.74	44.7	1.88	48.3	2.01	51.6	2.14	54.8
1.8	1.33	43.3	1.54	50.0	1.72	55.9	1.89	61.2	2.04	66.2	2.18	70.7	2.31	75.0
2.0	1.43	57.3	1.65	66.2	1.85	74.1	2.02	81.1	2.19	87.6	2.34	93.7	2.48	99.4
2.2	1.52	74.0	1.76	85.4	1.97	95.5	2.16	104.6	2.33	113.0	2.49	120.8	2.64	128.1
2.4	1.62	93.3	1.87	107.7	2.09	120.4	2.29	131.9	2.47	142.5	2.64	152.4	2.80	161.6
2.6	1.70	115.5	1.97	133.4	2.20	149.1	2.41	163.4	2.61	176.5	2.79	188.6	2.96	200.1
2.8	1.79	140.7	2.07	162.5	2.31	181.7	2.53	199.1	2.74	215.0	2.93	229.9	3.11	243.8
3.0	1.88	169.2	2.17	195.4	2.42	218.4	2.65	239.3	2.87	258.5	3.07	276.3	3.25	293.1

	SLOPE (in percent)											
	.5		.6		.7		.8		.9		1.0	
D	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q
.4	.89	1.4	.98	1.5	1.06	1.6	1.13	1.8	1.20	1.9	1.26	2.0
.6	1.17	4.2	1.28	4.6	1.38	5.0	1.48	5.3	1.57	5.6	1.66	5.9
.8	1.42	9.1	1.55	9.9	1.68	10.7	1.79	11.5	1.90	12.2	2.01	12.8
1.0	1.65	16.5	1.80	18.0	1.95	19.5	2.08	20.8	2.21	22.1	2.33	23.3
1.2	1.86	26.8	2.04	29.3	2.20	31.7	2.35	33.9	2.50	36.0	2.63	37.9
1.4	2.06	40.4	2.26	44.3	2.44	47.8	2.61	51.2	2.77	54.3	2.92	57.2
1.6	2.25	57.7	2.47	63.3	2.67	68.3	2.85	73.1	3.02	77.5	3.19	81.7
1.8	2.44	79.1	2.67	86.6	2.88	93.6	3.08	100.0	3.27	106.1	3.45	111.9
2.0	2.61	104.7	2.86	114.7	3.09	123.9	3.31	132.5	3.51	140.5	3.70	148.2
2.2	2.79	135.1	3.05	148.0	3.30	159.8	3.53	170.9	3.74	181.2	3.94	191.0
2.4	2.95	170.4	3.24	186.6	3.50	201.6	3.74	215.5	3.96	228.6	4.18	240.9
2.6	3.12	210.9	3.41	231.0	3.69	249.6	3.94	266.8	4.18	283.0	4.41	298.3
2.8	3.27	257.0	3.59	281.5	3.87	304.1	4.14	325.1	4.39	344.8	4.63	363.5
3.0	3.43	308.9	3.76	338.4	4.06	365.5	4.34	390.8	4.60	414.5	4.85	436.9

CHAPTER 6

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CHANNELS FOR DRAINAGE SYSTEM

(MAINS AND LATERALS)

GENERAL

Mains and laterals considered in this chapter are open channels which serve as outlets for other conservation practices which are installed for the disposal of excess surface and subsurface water.

The side slopes are generally too steep to be crossed by farm equipment.

PLANNING

Mains and laterals should be located and designed to serve as integral parts of a surface or subsurface drainage system that meets the conservation and land use needs.

The entire drainage area contributing water to the open channel must be determined. The degree of drainage required needs to be determined to establish the channel capacity.

The extent of the area drained by tile, tubing, or other subsurface drainage methods outletting into the open channel shall be determined. These areas will require special consideration for the required channel depth. This subsurface drainage can be expected to reduce normal surface runoff considerably.

The area benefitting from either new construction or rehabilitation of an existing open ditch must be determined as well as the usage of these areas. This is needed to establish the extent of required channel work.

Damages resulting from the work must also be considered. This can be in the form of damages to existing wetlands, wet woodlands, fisheries, wildlife habitat, water quality, and aesthetics of the area. The potential for induced different flood stages downstream from the project area must also be considered.

An adequate outlet must be available for the improved open channel by either gravity flow or by pumping.

DESIGN

CAPACITY

The required capacity of the open channel may be determined from drainage curves consistent with area practices or from other methods for flood routings of the drainage area.

Drainage curves for Minnesota shown in Figure 6-3 were adapted from work by John G. Sutton which is based upon stream gage records and studies made of the flow of excess rainfall from flatland (drainage type) watersheds. The curves also include an adjustment for protection needed by different types of agriculture and kinds of crops for specific climatic areas. This adjustment is based upon many years of experience. As the general character of the watershed significantly changes, the drainage curves could change, so periodic review is necessary.

Other data that may be used are information from the stream gaging program carried out by the Geological Survey in cooperation with the State of Minnesota and with other agencies or other hydrologic procedures developed to predict runoff for a particular type of storm being considered.

The first consideration for determining capacity is damages resulting from impaired drainage or over-bank flow. Obviously, damages through a highly developed area will be much greater than an area used primarily for agricultural purposes. Likewise, damages occurring to truck or row crops will be significantly greater than to pasture.

Watershed characteristics will determine whether general drainage curves may be used or whether more detailed hydrologic studies will be necessary. The drainage curves apply to areas where the natural land slopes are less than 1 percent but can include a minor portion of the area having steeper land. Typically rolling to rugged watersheds do not fit the intent of the drainage curves. Watersheds in which prolonged out-of-bank flows do or may occur will require a more detailed hydrologic study. More detailed hydrologic studies may also be needed when considering economic considerations and other critical damages such as flood plain scour, road and bridge damage, danger to livestock, and danger to human life. However, attempting to confine sharp peak flows within a channel may result in erosive channel velocities and may induce damaging downstream storm stages. There will be no attempt to specify reasonable design requirements for such conditions as this is beyond the scope of this text. Guidelines for conducting more detailed hydrologic studies such as runoff prediction, water surface profiles, etc., can be found in published engineering handbooks and from guides developed by the Soil Conservation Service, USDA, such as the Hydrology Guide for Minnesota, Technical Release 61 (Computer Program for Water Surface Profiles), Technical Release 20 (Computer Program for Project Formulation - Hydrology), and Technical Release 25 (Design of Open Channels).

For drainage type watersheds, the drainage runoff curves from Figure 6-3 (Drawing No. 3-N-45058) apply. These curves are applicable to areas with average watershed slopes of less than 25 feet per mile. For lands with steeper slopes and ordinary valley drainage, a more detailed hydrologic analysis should be made; however, the next higher runoff curve may be used if experience and engineering judgement can support it. Other physical characteristics, such as depressional areas, sand areas, etc., should also receive consideration when determining the curve. The above recommendation should be modified for the production of high value crops.

Differences in topography, land use, and soils may occur within the watershed. Each sub-watershed should be evaluated for its discharge contribution to the main channel.

The timing of the flow from these sub-watersheds should be reconciled in the design capacity of the main channel. Where general drainage curves are used, the "20-40 rule" may be used to adjust for this contribution.

"20-40 RULE"

Procedure 1. Where the tributary area of one of the channels is from 40 to 50 percent of the total tributary area, the required capacity of the channel below the junction is determined by adding the required design capacities of the channels above the junction.

Procedure 2. Where the watershed area of a lateral is less than 20 percent of the total watershed area immediately below the junction, the design capacity of the channel is determined from the drainage curve for the total watershed area below the junction.

Procedure 3. Where the watershed area of a lateral is in the range of 20 to 40 percent of the total watershed area, the discharge below the junction should be proportioned between the larger discharge obtained under the first procedure at the 40 percent level and the smaller discharge obtained under the second procedure at the 20 percent level.

EXAMPLE FOR PROCEDURE 3

Assume that a lateral channel draining 640 acres joins another ditch draining 1,360 acres making a total drainage area below the junction of 2,000 acres. The lateral represents 32 percent of the total watershed. The watersheds are located in South Central Minnesota (Drainage Curve No. 2).

For the design, (Procedure 3).

Step 1.	Runoff from 640 acres	27 c.f.s.
	Runoff from 1,360 acres	46 c.f.s.
	Total discharge from the two water-sheds (Procedure 1).	73 c.f.s.
Step 2.	Runoff from total watershed 2,000 acres (Procedure 2)	65 c.f.s.
Step 3.	Subtract step 2 from step 1	8 c.f.s.

Step 4. Percent of small watershed (640 acres) of total watershed

$$(2{,}000 \text{ acres}) \text{ is } \frac{640}{2{,}000} \times 100 = 32 \text{ percent.}$$

Step 5. Difference between 32 and 20 = 12

Step 6. $\frac{12}{40-20} = 0.60$ (0.6 of the way between 20 and 40).

Step 7. 8 c.f.s (from step 3) x 0.6 = 4.8 c.f.s. (Use 5.0 c.f.s.)

Step 8. Add 65 c.f.s., from step 2, and 5 c.f.s. from step 7, for total discharge of 70 c.f.s.

This is the final interpolated discharge from this watershed below the junction.

If the 20-40 rule increases the ditch section above that section indicated by Procedure 2 for the drainage area, the enlarged section is carried downstream without changing size until additional drainage area requires a larger channel section based on total watershed area (Procedure 2).

After the capacity requirements are determined, the sizing of the channel is determined by a trial and error method using the below equations. Table 5-3 in the surface drainage section is an aid to solve for the more common sizes for open channels.

VELOCITY

The velocity in the channel must be high enough to prevent siltation but low enough to avoid erosion. Many agencies and consultants now require extensive hydraulic stability analysis using tractive force and/or allowable velocity procedures to establish acceptable velocities for design. An example of this is the Soil Conservation Service Technical Release No. 25 procedure.

When these more definitive analyses are not required, the following procedure may be used to design channels. Table 6-1 provides a guide for maximum allowable velocities. Velocities less than 1.5 feet per second should normally be avoided since siltation will take place and it is conducive to growth of mosses and weeds which ultimately reduce channel cross-section. Where channel velocities are greater than 6 feet per second, channel linings or grade-reducing structures will be required to control erosion and velocity.

The most-used equation for velocity in an open channel design is the Manning equation:

$$V = \frac{1.49}{n} r^{2/3} s^{1/2}$$

Where V = average velocity of flow in feet per second.

TABLE 6-1

MAXIMUM ALLOWABLE VELOCITIES FOR GIVEN SOIL TEXTURES

Soil on Channel Bottom and Sides			
Descriptive Term or Name	Soil Classification		Velocity, fps
	USDA	Unified	
Fine sand, Sandy loam	s, fs, vfs, lvfs, vfsl, lfs, si	ML(PI≤10), ML-CL, SM-SC, SM, SP, SW, SP-SM	2.50
Silt loam, loam	sil, scl, l, GR-s	ML(PI>10), CL(PI<15), SC(PI=10-15), MH(PI<20) Coarse Clean Sand (D_{50}>#10 sieve) Fine clean gravels (D_{50}≥3/8")	3.00
Clay loam, sandy clay, silty clay loam	cl, sicl, sc	CL(PI>15), SC(PI>15), MH(PI>20)	4.00
Stiff clay (very colloidal); Non-colloidal loam graded to cobbles. Colloidal alluvial silts	cl, sicl, c, sc, GR-l	CL(PI>15, CH, SC(PI>15), GC(PI<10), GM(PI>10)	5.00
Colloidal sediments graded to cobbles	GR-c	GC(PI>10)	5.50
Coarse gravels, cobbles Shales and hard pans	Coarse GR, Cobbles, Flaggy, Unweathered shales and hardpans	Clean gravels (D_{50} > 3/4"), Cobbles, unweathered shales and hardpans	6.00

After V is determined, capacity is calculated from the continuity equation:

$$Q = AV$$

where Q = capacity in cubic feet per second

Definitions for n, r, A, p and s are discussed below.

The ROUGHNESS COEFFICIENT (n) is a factor that takes into account all retarding influences on channel flow such as vegetation, meanders, obstructions, varying cross-sections, etc. but does not account for retardance caused by structures, culverts and similar grade control features. The degree of expected maintenance before the next cleanout is extremely important. A channel based upon newly-constructed roughness values in the design can easily become inadequate with poor maintenance. For most minor channel designs (and surface drainage), a value of n = 0.04 is commonly used to determine capacity and many design tables are based on this value. It is recommended that an n = 0.025 for bare earth be used to check the channel velocity so that the new channel will not erode. With good alignment and grassed vegetation, the "n" value varies with the hydraulic radius. Table 6-2 reflects these values.

Table 6-2 Value of Roughness Coefficient For Extablished Vegetated Channels

Hydraulic radius	"n"
Less than 2.5	.040-.045
2.5 to 4.0	.035-.040
4.1 to 5.0	.030-.035
More than 5.0	.025-.030

The HYDRAULIC RADIUS (r) is calculated from the following equation:

$$r = A/p$$

A = Cross sectional area of flow in square feet

p = Wetted perimeter of the channel in feet

The WETTED PERIMETER (p) for the trapezoidal sections is calculated from the following equation:

$$p = b + 2d\sqrt{Z^2+1}$$

The CROSS-SECTIONAL AREA (A) is the area of flow. For the most common trapeqoidal section, area is calculated from the following equation:

$$A = bd + Zd^2$$

A = area of flow in square feet

b = bottom width in feet

d = channel flow depth in feet (see below)

Z = side slope ratio in ft. horizontal per ft. vertical

The CHANNEL FLOW DEPTH (d) relates to the depth of flow in the channel for the above equations. The actual depth of channel below ground level when compared with the depth of flow must satisfy outlet requirements for surface and subsurface drains and will determine whether tile drainage will normally have a free outlet. The clearance between a subsurface drain invert and the normal low water level should be at least 1 foot for channels that fill with sediment at a normal rate, except where lower values are justified because of unusual site conditions. Other considerations for depth selection are:

1. The elevation of significant adjacent low field areas.

2. The elevations of the bottoms of existing bridge abutments or inverts of culverts.

3. Potential for degrading of tributary streams.

4. Water table control in adjacent lands.

5. Expected rates of sediment build-up of the ditch bottom.

6. Legally defined grades and elevations.

The SIDE SLOPE (Z) is the ratio of feet horizontal per one foot vertical. Side slopes should be stable, meet maintenance requirements, and be designed according to site conditions. When seepage is present in channel banks from high water table conditions, low strength soils are encountered, or where channel soils are erosive and could cause erosion of bank toes, additional investigation and side slope stability analysis are often needed. Where these conditions do not exist, side slopes should be no steeper than:

1. Mineral soils - 2:1

2. Peat and muck - 1:1

The BOTTOM WIDTH (b) will be determined after satisfying requirements for velocity, capacity, depth, and the side slopes. If excessive velocities are encountered, special measures will have to be considered for channel erosion stability.

The SLOPE (s) in Manning's equation is the slope of the water surface

(hydraulic grade line). Normally, the slope of this water surface is the same as the grade or fall of the channel bottom in uniform channels. The location of the hydraulic grade line is normally set by control points along the profile of the channel. These control points represent the elevations of subsurface drain outlets, culvert and bridge bottoms, side drainage or tributary stream outlets, or other legally defined control elevations. The hydraulic grade line also accounts for "head" losses through bridges and culverts and tailwater conditions imposed by outlet streams.

CHANNEL ALIGNMENT

Where possible, all open channels should be located near or parallel to field boundaries or property lines so as not to interfere with cropping patterns. Straight lines and gentle curves are recommended in laying out open channels. However, it may be more desirable in some instances to follow existing natural drainage courses to minimize excavation. Table 6-3 shows recommended minimum radii of curvature without bank protection. Bank protection should be provided if changes in alignment sharper than those listed are necessary.

Table 6-3 Minimum Radii of Curvature Without Bank Protection

Width of Ditch Top (Feet)	Fall per Mile	Minimum Radius Curvature (Feet)
Small ditches less than 15 ft.	Under 3 ft.	300
	3 ft. to 6 ft.	400
Medium size ditches 15 to 35 ft.	Under 3 ft.	500
	3 ft. to 6 ft.	600
Large ditches greater than 35 ft.	Under 3 ft.	600
	3 ft. to 6 ft.	800

Excavated spoil may either be field spread or left in spoil banks along the channel. A vegetated travelway should be left next to the channel (10 to 15 ft.) to provide for maintenance and erosion control, and to prevent excessive loading on the bank from heavy farm machinery operations. Spoil banks should have stable side slopes.

Figure 6-1 shows typical cross-sections for channel work.

Provisions should be made to control surface water runoff on the unconstructed side. This will prevent excessive erosion into the channel thereby reducing maintenance on the open ditch. Ideally, surface water should enter the channel only through lateral ditches graded to the bottom of the channel or through stabilizing structures. Structures for this purpose may be chutes, drop spillways, or pipe conduits.

Collection ditches and channel alignment may be used to reduce the numbers of structures.

PUBLIC AND PRIVATE UTILITIES

In the survey for design, check with all available sources as to the possibility of hidden utilities. Landowners and contractors should call underground utility companies who have facilities in the area of work. The utility company representative should locate the line for alignment and depth. During construction, again contact the utility company for on-site assistance. Disrupting utilities, either private or public, can be costly and dangerous.

LIVESTOCK CROSSINGS AND FENCING

Provision should be made for fencing the livestock out of the open channel. If necessary, livestock crossings can be provided in the channel design. See Figure 6-2 for a typical crossing.

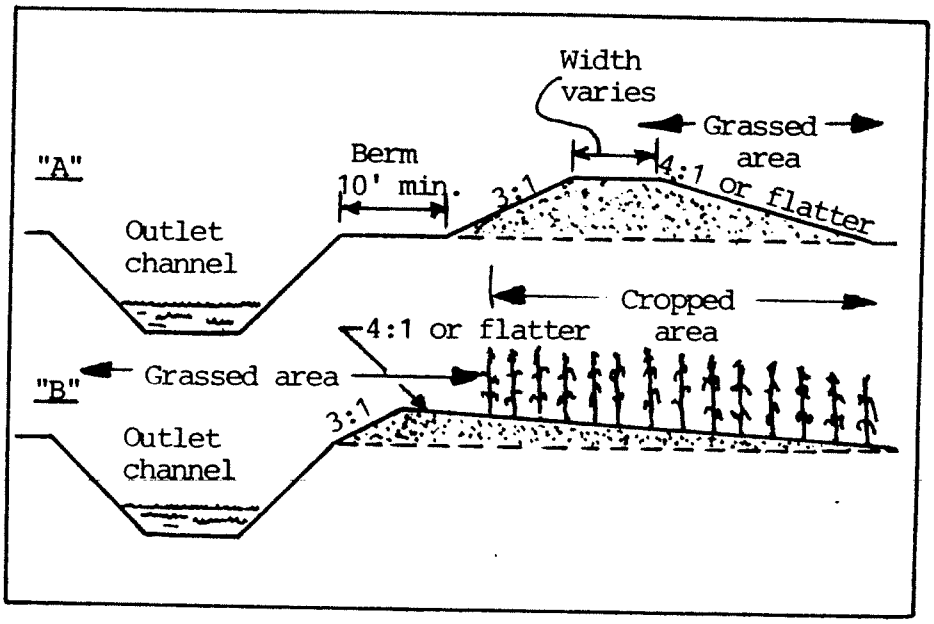
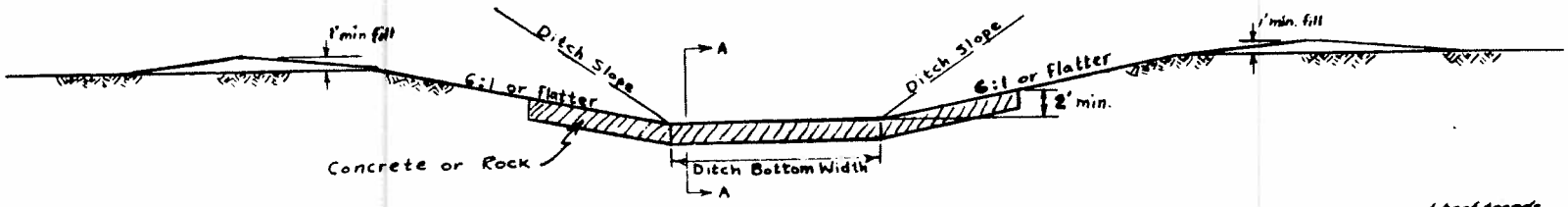
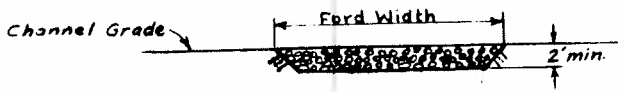


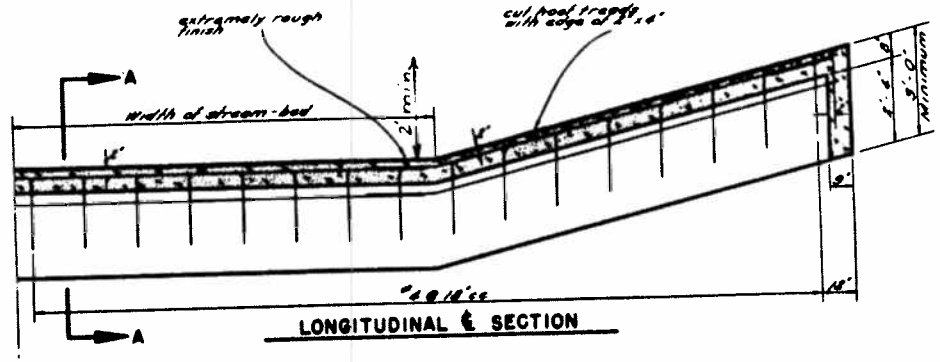
Figure 6-1. Typical Channel and Spoil Banks. In drawing "A", excavated soil has been placed in a spoil bank and a berm has been created. In "B", the spoil has been spread to a flat sideslope without a berm.



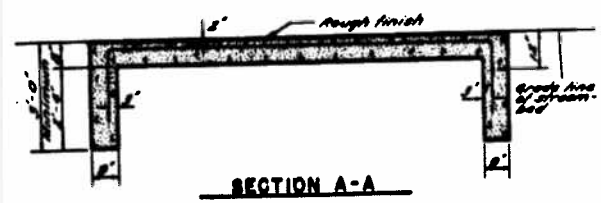


COMPACTED ROCK OR BROKEN CONCRETE

One man rock or broken concrete with smaller graded material to fill voids. Rock fill shall be compacted in 1'-0" layers with a smooth roller or track type tractor.

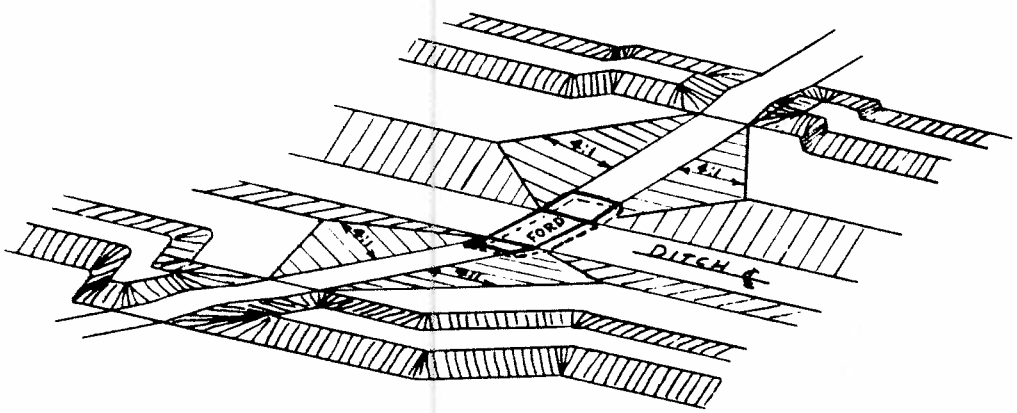


LONGITUDINAL ℄ SECTION



SECTION A-A

REINFORCED CONCRETE



STREAM FORDS

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed	Date 11-1-63	Approved by	
Drawn		Title	
Traced		Title	
Checked		Sheet No. of	Drawing No.

Figure 6-2. Stream Ford Details

ORDER THIS BLANK DATA SHEET BY DRAWING NUMBER

ENVIRONMENTAL CONSIDERATIONS

In most cases, a channel can be built and maintained that will carry out its intended use and still provide favorable environmental values.

When existing channel banks are stable and whenever possible, construction should be performed from one side, leaving the opposite bank intact. Construction may be carried out from one side to preserve a dense tree canopy. The canopy left will provide shading to the stream for at least a portion of the day. Other favorable effects are:

1. Provide a windbreak for erosion and snow control.

2. Reduce water temperatures from an otherwise unshaded situation. This will enhance the fishery potential.

3. Reduce sunlight on the stream and thereby reduce the formation of mosses, algae, etc.

4. Provide a wildlife edge between the cropped area and the water.

5. Provide a pleasing esthetic picture of land use that might otherwise be totally committed to agricultural usage.

Mowing in the channel and on the maintenance travel-way is rarely necessary but when done should be delayed until the ground-nesting species have left. This is normally safe after the middle of July in Minnesota.

Areas lying within the constructed side that are not restricted to channel flow, travel, or farming may be planted to shrubs, trees, etc., that can provide food for wildlife.

CHANNEL VEGETATION

Seeding is needed on all ditches. Side slopes and berms should be seeded. If there is no spoil bank, the seeding should extend a minimum of one rod from the top of ditch bank. In pasture areas, all disturbed areas should be seeded.

EROSION AND SEDIMENT CONTROL MEASURES FOR CONSTRUCTION

Erosion and sediment control during construction can be handled in numerous ways, such as phasing construction where only a small portion of exposed channel is open at a time, mulching immediately after construction, or providing means of controlling sediment that is eroded from the site. Sediment traps can be basins constructed by an embankment or a temporary dike system. Sediment traps can also be excavated into the bottom of a channel at regular intervals to trap sediment in the channel flow. The effectiveness of the in-channel excavated trap is essentially dependent on the width of the trap (W), the length of the

trap (L) and the amount of water flowing past it (Q). The width is limited normally to the bottom width of the channel and the flow is design flow. A recommended design value for LW/Q is 100 or greater ($LW/Q \geq 100$).

In-channel excavated sediment traps are also an excellent method of reducing maintenance if they are left in after construction is complete and periodically cleaned out to their original capacity.

CULVERTS AND BRIDGES

Culverts and bridges across channels should be designed for loads carefully determined from the weight of farm machinery, trucks, and other vehicles expected to use them. Openings must be large enough to avoid reduction of channel flow capacity. Where bridges and culverts are not feasible, fords with suitable ramps for livestock and machinery may be used.

Bridges and culverts in a drainage system should be checked for a number of conditions to insure proper performance. The following are some recommended checks and some suggested design minimums.

1. Head loss check should be made on the drainage flow to insure that the upstream water surface is not so high as to prevent good drainage, cause damage to property or present a hazard, and it meets all state and local ordinances.

2. Velocity should be made using an appropriate design storm. The maximum velocity under bridges is dependent on the type of soil under the bridge, but it should not exceed 4 to 6 fps. The maximum velocity through culverts should not exceed 10 fps depending on the duration of flow. Where long duration flows are expected, such as in the Red River Valley, the lower recommended velocities should be used. Where velocities can not be kept in this range, riprap may be needed for erosion protection.

3. Minimum capacity design is required by the State of Minnesota. The Department of Transportation requires culverts and bridges to pass the flow from the storm frequency shown in Table 6-4 or the flow determined by a risk analysis method developed by the Federal Highway Administration. For the frequency design method, minimum design discharges can be obtained using SCS hydrology methods or the methods in Techniques for Estimating Magnitude and Frequency of Floods in Minnesota by U.S. Geological Survey. In no case should the capacity of the bridge or culvert be less than the design capacity of the channel.

4. Cross Section. Highway specifications will apply for primary and secondary roads in the design of the inlet and outlet sections of the culvert. Side slopes of the earth fill shall be stable and comply with those set by the road authority but not steeper than 2:1.

5. Clearance check should be made on all bridges to allow for passage of ice and debris.

TABLE 6-4

MDOT MINIMUM CAPACITY
FOR CULVERTS AND BRIDGES

Type of Road	Culverts	Bridges 2/	
	Design Flow 1/	Full Flow	Island Type 3/
1st Class State Highways	50 Yr.	50 yr.	Do Not Use
All other public roads	25 Yr.	50 Yr.	25 Yr.
Private road to residence	10 Yr.	50 Yr.	10 Yr.
Field Crossing	4/	25 Yr.	5 Yr.

1/ One foot of freeboard between design flow water surface upstream and road surface.

2/ Recommended design flows should pass the bridge at a maximum water surface elevation lower than the lowest member on the bridge deck. See Item 5 in the text for additional requirements.

3/ Total design flow under and around the bridge should equal full flow capacity. The minimum under the bridge capacity is shown in the table.

4/ Island type design may be used. Culvert capacity should be compatible with channel design capacity.

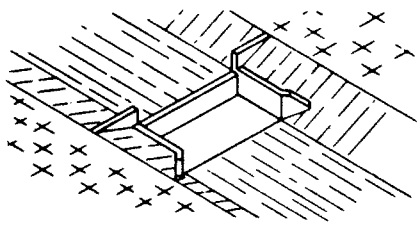
SURFACE WATER INLETS (SIDE INLETS) TO DITCHES

Provisions should always be made for lowering surface water from adjoining fields or laterals into the ditch. This is necessary at the head end of the ditch as well as along the banks. One of the following methods should be used:

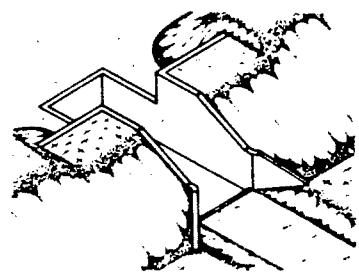
1. If the elevation difference between the lateral and main ditch grades is small and site conditions permit it, the need for a structure can be avoided by adjusting the lateral inlet grades.

   Excavate the side inlet back from the junction on a level grade from the bottom of the main for a distance to 50 to 300 feet, depending on the size of the inlet, and thence on a non-erodible grade to the point of intersection with normal grade of the lateral.

2. Drop spillways and chutes are adapted to locations where the volume of water to be handled is large. They can also be used as a tile outlet structure. The drop spillway fits conditions where there is no spoil bank and is particularly adapted for protecting the head end of a ditch. Where topography permits, the island-type spillway procedure should be used. The island-type spillway can also be used along the side of a ditch having spoil banks.

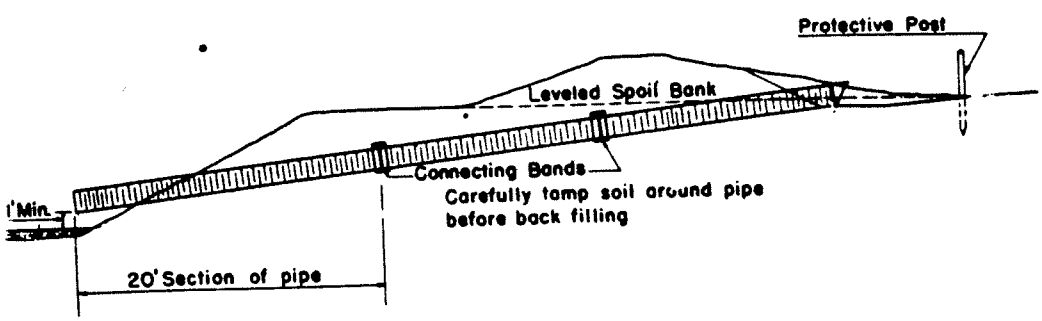


Straight Drop Spillway



Box Inlet Drop Spillway

3. The pipe spillway can be used advantageously to convey water back of levees and continuous spoil banks into a drainage ditch. The hood inlet is most efficient where discharge capacity is a problem. The flared inlet is less efficient but facilitates the passing of field debris such as corn stalks and grasses. The pipe drop inlet is efficient and can be used as a tile outlet.



Hood Inlet Pipe Spillway

CONSTRUCTION

Staking should be provided at regular intervals. The stakes should be set to indicate where "cut" begins for the design channel. The amount of "cut" should also be shown on the stake. By following the information shown on the stakes, the contractor should be able to install the open ditch according to the plans and avoid over- or under-excavation.

It is often desirable to seed the bank slope with the desired vegetation immediately upon completion of the channel construction activities to avoid crusting of the soil and/or excessive erosion of exposed side slopes.

All structures, such as pipes and concrete structures, should have controlled compaction of the backfill to avoid settling and wash-outs.

MAINTENANCE

Maintenance of a drainage system is the key to longer life and lower operating costs and must be considered in all proposals beginning with design.

A brief operation and maintenance plan should be prepared outlining the operation and maintenance needs and responsibility. This is a valuable tool for the sponsors to use to administer its maintenance work.

Maintaining the proper vegetation, such as grass, within the channel periphery will prevent excessive channel erosion. Armoring with stone or riprap, where vegetative treatment will not suffice, should be done on raw and eroding banks.

Livestock traffic in and out of the channel should be only at controlled access points for both channel erosion and water quality considerations.

Brush, trees and weeds should be controlled by either hand operation or by chemical sprays. The use of chemical sprays requires caution and must comply with current regulations regarding its use.

Sediment may deposit in certain reaches of the channel and on the inside of curves. It should be removed periodically before it causes damages to channel alignment or reduces capacity below intended design levels. As previously discussed, sediment traps can provide an effective way to confine the extent of this maintenance and prolong channel life.

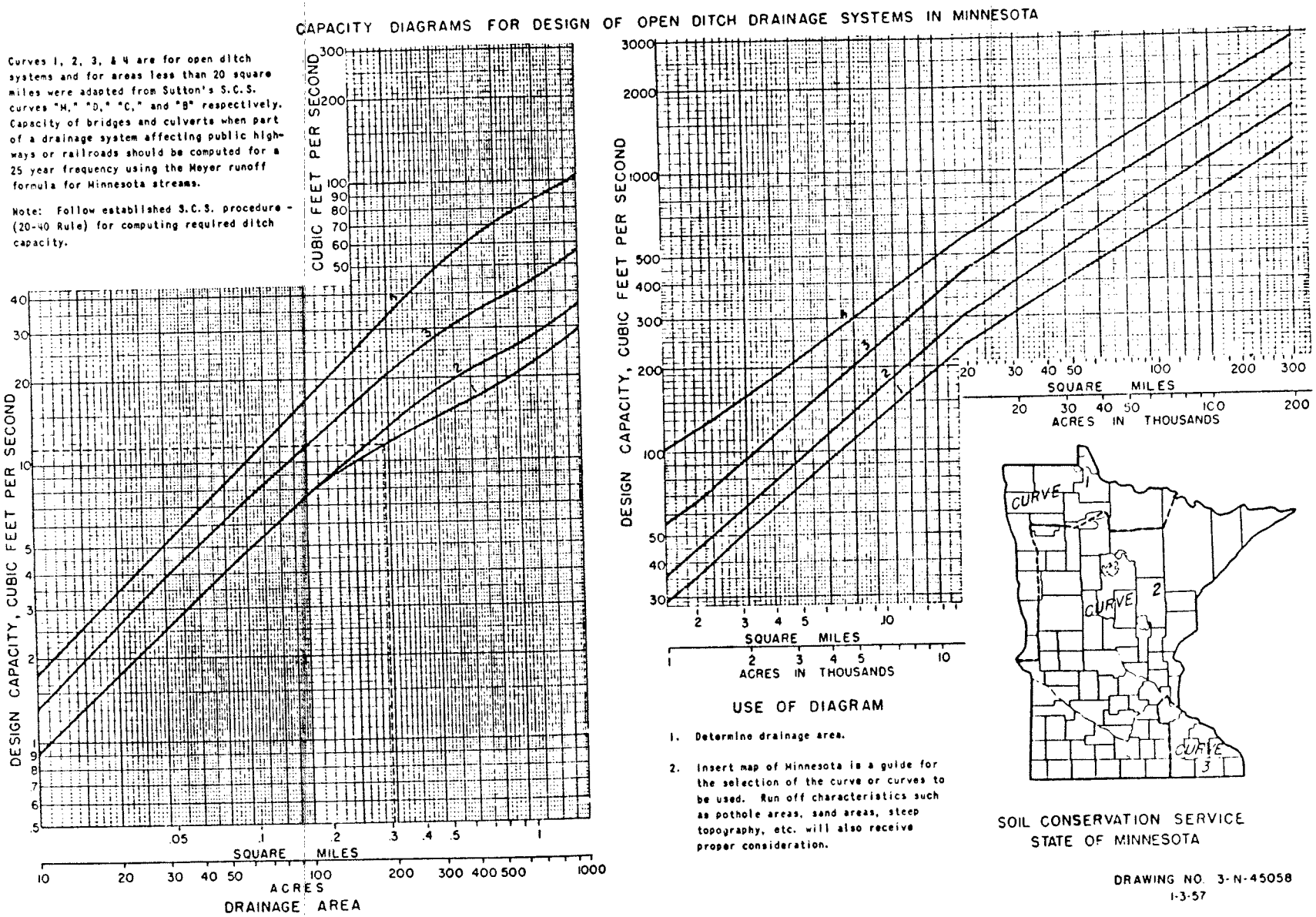


Figure 6.3 Drainage Design Curves for Minnesota

SIDE INLET PIPE STRUCTURES TO OPEN DITCHES

TABLE 6-5

Runoff
Minn. No. 3 & 4
Dr. Curve
3-N-45058

Acres	CFS 3	CFS 4
10	1.3	1.7
15	2.0	2.5
20	2.6	3.4
25	3.3	4.2
30	3.9	5.0
35	4.5	5.9
40	5.0	6.7
50	6.2	8.4
60	7.4	10
70	8.4	12
80	9.4	13
90	10.0	15
100	11	17
110	12	18
120	13	20
130	14	22
140	15	23
150	16	25
160	17	26
170	18	28
180	19	30
190	20	32
200	21	33
220	22	36
240	24	40

TABLE 6-6

Bottom Width In Feet	Emergency Spillway Capacity In CFS (z=3:1 n=0.04, L=20', Case No. 1)								
	0.4Hp	0.6Hp	0.8Hp	1.0Hp	1.2Hp	1.4Hp	1.6Hp	1.8Hp	2.0Hp
10	1	9	19	31	45	61	80	102	126
20	3	18	35	55	79	106	136	169	206
30	4	26	50	79	113	150	191	236	286
40	5	34	66	104	147	194	247	304	366
50	7	42	82	128	180	239	302	371	446
60	8	51	98	153	214	283	358	439	526
80	10	67	129	201	282	371	469	574	686
100	13	83	158	244	339	443	555	675	801
150	19	124	237	366	509	665	833	1012	1200
200	26	165	316	488	678	886	1110	1350	1602

Table 6-6 is to be used only in the design of side inlet pipe structures to open ditches and Waste Storage Ponds.

TABLE 6-7a

Capacity of Culverts with a free outlet, inlet submerged, and a minimum slope of 1.0% (Inlet Control)

Pipe Dia.	12"	15"	18"	21"	24"	30"	36"
CFS. Plain Inlet	4.2	6.1	8.0	10.0	11.6	20	31
CFS. Flared Inlet	4.5	6.5	9.0	10.5	12.5	22	35

Minimum depth of water at inlet invert used in above table is 2.0 feet or the pipe diameter whichever is greater.

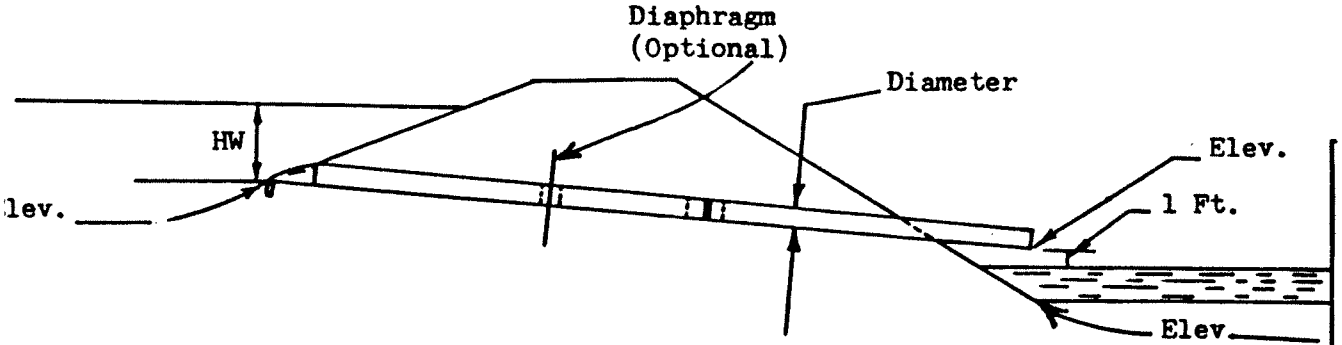
Table 6-5 is to be used for the pipe discharge <u>only</u> when a typical drainage type watershed exists above the structure and when:

1. 50% or more of watershed is "A" slope.
2. Temporary storage in watershed will reduce the peak rate of run-off. Emergency spillway crest should be at least 1.5 feet above average ground unless watershed is extremely flat.
3. Watershed area is less than 250 acres.

TABLE 6-7b

SURFACE WATER INLET CAPACITY CHART, CFS

INLET CONTROL, CMP WITH FLARED END SECTION						
	Pipe Diameter, Inches					
HW, ft.	12	15	18	21	24	30
1.0	2.2	2.6	3.1			
1.5	3.7	5.0	6.1	7.3	8.0	
2.0	4.5	6.5	9.0	10.5	12.5	16
2.5	5.5	8.0	11	14	17	22
3.0			12.5	16	20	28



SECTION ON CENTERLINE
Depicting HW and Diameter

Thickness, tolerances, and nominal gage for corrugated metal pipe.

Nominal gage 2/	16	14	12	10	8
Aluminum, Fed. Spec. WW-P-402					
Specified thickness (in)	.060	.075	.105	.135	.164
Tolerance under 1/ (in)	.007	.007	.008	.009	.009
Iron or Steel, Fed. Spec. WW-P-405					
Specified thickness (in)	.064	.079	.109	.138	.168
Tolerance under 1/ (in)	.007	.007	.012	.012	.012

1/ No limit on over thickness.
2/ For informational purposes only.

TABLE 6-8

HYDRAULICS FOR CMP PIPE STRUCTURES INTO DITCHES

CAPACITY OF PIPE DROP INLETS AND HOODED INLETS

Flowing Full, n = 0.025 $Q = A\sqrt{\frac{2gh}{2+Kpl}}$

Conduit Pipe Diameter		12"	15"	18"	21"	24"	30"	36"
Kp		0.116	0.086	0.067	0.055	0.046	0.034	0.027
Length	Head on Pipe	CFS						
30′	1.0	2.7	4.6	7.1	10.1	13.7	22.6	33.7
	2.0	3.8	6.5	10.0	14.3	19.4	32.0	47.7
	3.0	4.7	8.0	12.3	17.5	23.7	39.1	58.3
	4.0	5.4	9.2	14.2	20.2	27.3	45.2	67.4
	5.0	6.0	10.3	15.9	22.6	30.6	50.6	75.5
40′	1.0	2.4	4.2	6.6	9.4	12.8	21.4	32.3
	2.0	3.4	6.0	9.3	13.3	18.2	30.2	45.7
	3.0	4.2	7.3	11.4	16.2	22.2	37.0	55.9
	4.0	4.9	8.4	13.1	18.8	25.7	42.8	64.6
	5.0	5.5	9.5	14.7	21.0	28.8	48.0	72.3
50′	1.0	2.3	3.9	6.1	8.8	12.2	20.4	30.9
	2.0	3.2	5.5	8.7	12.5	17.2	28.8	43.7
	3.0	3.9	6.8	10.6	15.3	21.1	35.3	53.5
	4.0	4.5	7.8	12.3	17.6	24.4	40.8	61.8
	5.0	5.1	8.8	13.7	19.8	27.4	45.7	69.2
60′	1.0	2.1	3.7	5.8	8.4	11.5	19.6	29.8
	2.0	3.0	5.2	8.2	11.8	16.4	27.7	42.1
	3.0	3.6	6.4	9.9	14.5	20.0	33.9	51.6
	4.0	4.2	7.4	11.6	16.7	23.1	39.2	59.5
	5.0	4.7	8.2	12.9	18.7	25.8	43.8	66.6
70′	1.0	2.0	3.5	5.5	8.0	11.0	18.8	28.7
	2.0	2.8	4.9	7.8	11.2	15.6	26.6	40.5
	3.0	3.4	6.0	9.5	13.8	19.0	32.5	49.6
	4.0	4.0	7.0	11.0	15.9	22.0	37.6	57.3
	5.0	4.4	7.8	12.3	17.8	24.6	42.1	64.1

CAPACITY OF CIRCULAR RISERS IN CFS

$Q = 3.1(\pi D - 0.5)h^{3/2}$

Head-Feet	Diameter 18"	24"	30"	30"	36"	42"	48"
0.5	4.6	6.3	8.1		9.8	11.5	13.2
1.0	13.1	17.9	22.8		27.7	32.5	37.4
1.5	24.0	32.9	41.9		50.8	59.8	68.7
2.0	36.9	50.7	64.5		78.3	92.0	105.8

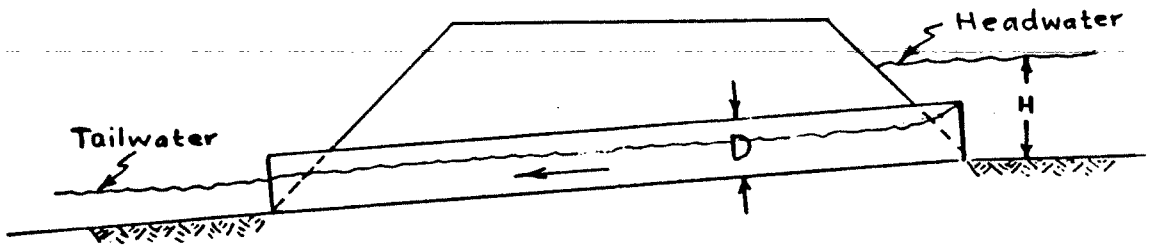
Head on pipe is measured in feet. It is the difference in elevation between the crest of emergency spillway and the tailwater level in the main channel or the centerline of pipe at inlet, whichever is the least.

Head on riser equals the difference in elevation between crest of emergency spillway and crest of riser outlet. Head is usually noted as h (stage).

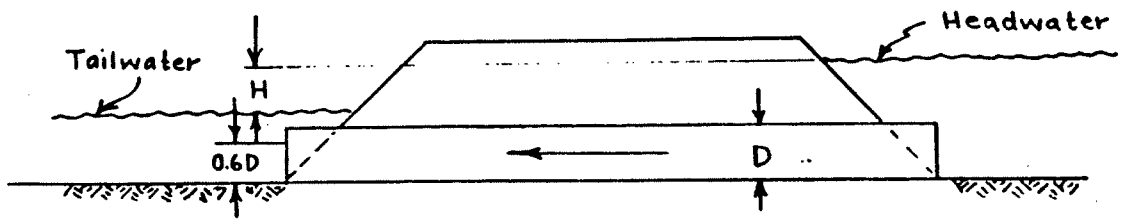
For pipe drop inlets, the minimum size riser is given in the column directly below the size conduit to be used.

CULVERTS

Culvert flow can frequently be classified in one of two categories, inlet control or outlet control. The condition that gives the larger size culvert (or smaller discharge) governs. Check both.



Inlet Control:
1. Free water surface in culvert barrel.
2. Culvert on steep slope.
3. Inlet may or may not be submerged.
4. Free outlet.



Outlet Control: (full flow)
1. Culvert on flat slope.
2. Inlet at least 3/4 full.
3. H (head) = difference between headwater level and tailwater level or 0.6D level if outlet not submerged.

The above is a very simplified discussion of culvert hydraulics. Conditions that can not be classified as inlet or outlet control will generally be some type of channel flow. This is not covered in the following tables. Culvert flow in drainage applications will usually be outlet control for storm flow and outlet control or channel flow for drainage flow.

More complete information on culverts will be found in Section 5, Hydraulics, NATIONAL ENGINEERING HANDBOOK.

TABLE 6-9

CAPACITY OF CORRUGATED METAL PIPE CULVERTS
Without Headwalls and With Outlet Submerged (outlet control-full flow)
(Circular)

DIA. IN INCHES		CUBIC FEET PER SECOND																
		Head on Pipe in Feet																
		0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.5	3.0	3.5	4.0
12	Length = 20 Feet	1.0	1.4	1.7	2.0	2.2	2.4	2.8	3.1	3.4	3.7	4.0	4.2	4.4	5.0	5.4	5.8	6.2
15		1.7	2.4	2.9	3.4	3.8	4.1	4.8	5.3	5.8	6.3	6.8	7.1	7.5	8.4	9.2	9.9	11
18		2.6	3.6	4.4	5.2	5.7	6.2	7.2	8.0	8.8	9.5	10	11	11	13	14	15	16
21		3.6	5.1	6.2	7.2	8.0	8.8	10	11	12	13	14	15	16	18	19	21	22
24		4.9	6.8	8.4	9.6	11	12	14	15	17	18	19	20	21	24	26	28	30
27		6.2	8.8	11	12	14	15	18	20	21	23	25	26	28	31	34	36	39
30		7.8	11	14	16	17	19	22	25	27	29	32	33	35	39	42	46	49
36		12	16	20	23	26	28	33	37	40	43	46	49	52	57	63	68	72
42		16	23	28	32	36	39	45	51	55	60	64	68	71	79	86	93	100
48		22	30	37	43	48	52	60	68	74	80	85	90	94	106	117	125	134
54		28	39	48	55	61	67	78	87	94	102	109	116	121	136	149	160	171
60		34	48	59	68	76	83	96	107	118	126	134	142	150	167	182	197	210
		velocities				4		5	6			7		8	9	10		

DIA. IN INCHES		CUBIC FEET PER SECOND																
		Head on Pipe in Feet																
		0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.5	3.0	3.5	4.0
12	Length = 40 Feet	0.8	1.1	1.4	1.6	1.8	2.0	2.3	2.5	2.8	3.0	3.2	3.4	3.6	4.0	4.4	4.8	5.1
15		1.4	1.9	2.4	2.7	3.1	3.4	3.9	4.3	4.8	5.2	5.5	5.9	6.2	6.9	7.6	8.2	8.8
18		2.1	3.0	3.7	4.3	4.8	5.2	6.0	6.8	7.4	8.0	8.6	9.0	9.6	11	12	13	14
21		3.0	4.3	5.3	6.1	6.8	7.4	8.6	9.6	11	12	12	13	14	15	17	18	19
24		4.2	5.9	7.2	8.4	9.4	10	12	13	15	16	17	18	19	21	23	25	27
27		5.5	7.8	9.6	11	12	14	16	17	19	21	22	23	25	28	30	33	35
30		7.0	9.8	12	14	16	17	20	22	24	26	28	30	31	35	38	42	44
36		10	15	18	21	24	26	30	33	36	39	42	45	47	53	58	62	66
42		15	21	26	30	33	36	42	47	51	55	59	62	66	74	80	88	93
48		20	28	35	40	45	49	56	63	69	74	80	84	89	99	109	118	127
54		26	36	45	51	57	63	72	81	89	96	103	109	115	128	140	152	163
60		32	45	55	64	72	78	90	100	110	120	128	136	143	160	175	190	202
		velocities					4	5		6			7	8		9	10	

DIA. IN INCHES		CUBIC FEET PER SECOND																
		Head on Pipe in Feet																
		0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.5	3.0	3.5	4.0
12	Length = 60 Feet	0.7	1.0	1.2	1.4	1.6	1.7	2.0	2.2	2.4	2.6	2.8	2.9	3.1	3.5	3.8	4.1	4.4
15		1.2	1.7	2.1	2.4	2.7	3.0	3.4	3.8	4.2	4.5	4.8	5.1	5.4	6.0	6.6	7.1	7.6
18		1.9	2.7	3.3	3.8	4.2	4.6	5.3	5.9	6.5	7.0	7.5	8.0	8.4	9.3	10	11	12
21		2.7	3.9	4.8	5.5	6.1	6.6	7.7	8.7	9.5	10	11	12	12	14	15	16	17
24		3.8	5.4	6.6	7.6	8.4	9.2	11	12	13	14	15	16	17	19	21	22	24
27		5.0	7.1	8.7	10	11	12	14	16	17	19	20	21	22	25	27	29	31
30		6.4	9.0	11	13	14	16	18	20	22	24	25	27	28	32	35	37	40
36		9.7	14	17	19	22	24	27	31	33	36	38	41	43	48	52	56	60
42		14	19	24	28	31	34	39	44	48	51	55	58	61	68	74	80	86
48		19	27	32	38	42	46	53	59	64	69	74	78	82	92	100	108	116
54		24	34	42	48	54	59	68	77	83	90	96	102	108	120	131	142	152
60		31	43	53	61	68	74	86	97	105	113	120	128	135	150	166	178	190
		velocities					4	5		6			7	8	9			

$$H = \left(\frac{2.52\,(1+K_e)}{D^4} + \frac{466.2\,n^2 L}{D^{16/3}}\right)\left(\frac{Q}{10}\right)^2 \qquad K_e = 0.9 \qquad n = 0.024$$

From Bur. of Public Roads Hydr. Circ. #5

USDA-SCS-MINNESOTA
11-4-63

TABLE 6-10

CAPACITY OF CORRUGATED METAL PIPE CULVERTS
Without Headwalls and With Outlet Submerged (outlet control-full flow)
- ARCH -

DIAMETER IN INCHES		CUBIC FEET PER SECOND																
		Head on Pipe in Feet																
		0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.5	3.0	3.5	4.0
18"x11"	Length = 20 Feet	1.4	2.1	2.5	2.9	3.2	3.5	4.1	4.6	5.0	5.4	5.8	6.1	6.5	7.2	7.9	8.5	9.1
22"x13"		2.2	3.1	3.8	4.4	4.9	5.3	6.2	6.9	7.6	8.2	8.7	9.2	9.7	11	12	13	14
25"x16"		3.2	4.1	5.6	6.2	7.2	7.9	9.1	10	11	12	13	14	14	16	18	19	20
29"x18"		4.4	6.2	7.6	8.7	9.7	11	12	14	15	16	17	18	19	22	24	26	27
36"x22"		6.8	9.7	12	14	15	17	19	22	24	26	27	29	31	34	37	41	43
43"x27"		10	15	18	21	23	25	29	33	36	39	41	44	46	52	57	60	66
50"x31"		14	19	24	28	31	34	39	44	48	52	55	58	62	69	76	81	88
58"x36"		20	28	34	39	44	48	56	62	68	74	78	84	88	98	109	117	125
65"x40"		25	35	43	50	56	60	70	78	86	94	100	105	110	125	138	149	159
72"x44"		30	42	52	60	67	74	84	94	100	110	120	130	135	150	165	179	190
		Velocity				4		5		6		7		8	9	10		

DIAMETER IN INCHES		CUBIC FEET PER SECOND																
		Head on Pipe in Feet																
		0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.5	3.0	3.5	4.0
18"x11"	Length = 40 Feet	1.2	1.7	2.0	2.4	2.7	2.9	3.4	3.8	4.1	4.5	4.8	5.0	5.3	6.0	6.6	7.0	7.6
22"x13"		1.8	2.6	3.2	3.6	4.1	4.5	5.1	5.7	6.3	6.8	7.2	7.6	8.0	9.0	10	11	12
25"x16"		2.7	3.9	4.7	5.5	6.1	6.7	7.8	8.6	9.4	10	11	12	12	14	15	16	17
29"x18"		3.8	5.3	6.6	7.6	8.4	9.2	11	12	13	14	15	16	17	19	20	22	24
36"x22"		6.0	8.6	11	12	14	15	17	19	21	23	24	26	27	30	33	36	39
43"x27"		9.4	13	16	19	21	23	27	30	33	35	37	40	42	47	51	55	59
50"x31"		12	17	22	25	28	31	35	40	43	47	50	53	56	63	69	74	80
58"x36"		18	26	32	36	40	45	51	57	62	68	72	76	80	90	99	108	115
65"x40"		23	33	40	46	52	57	66	72	80	86	92	98	105	115	128	139	149
72"x44"		28	39	48	56	62	68	80	89	97	105	110	120	125	140	155	168	180
		Velocity					4		5		6		7		8	9	10	

DIAMETER IN INCHES		CUBIC FEET PER SECOND																
		Head on Pipe in Feet																
		0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.5	3.0	3.5	4.0
18"x11"	Length = 60 Feet	1.0	1.4	1.8	2.0	2.3	2.5	2.9	3.2	3.5	3.8	4.1	4.3	4.6	5.1	5.6	6.0	6.2
22"x13"		1.6	2.2	2.7	3.2	3.6	3.9	4.5	5.0	5.5	6.0	6.4	6.8	7.0	8.0	8.6	9.4	10
25"x16"		2.4	3.4	4.2	4.8	5.4	5.9	6.8	7.6	8.4	9.0	9.6	11	11	12	13	14	15
29"x18"		3.3	4.7	5.8	6.7	7.4	8.2	9.4	11	12	13	14	14	15	17	18	20	21
36"x22"		5.5	7.7	9.4	11	12	13	15	17	19	21	22	23	25	27	30	32	35
43"x27"		8.6	12	15	17	19	21	24	27	30	32	35	36	38	43	47	51	55
50"x31"		11	16	20	23	26	28	33	36	40	43	46	49	52	57	63	68	72
58"x36"		17	24	30	34	38	42	49	55	60	64	68	72	76	86	94	100	109
65"x40"		22	31	39	44	50	55	63	70	76	84	88	94	100	110	120	130	140
72"x44"		26	37	46	53	59	65	75	84	92	100	105	110	120	130	145	159	169
		Velocity					4		5		6			7	8	9		

$$H = \frac{2.460(1+Ke)}{(BD)^2} + \frac{350.7n^2L}{(BD)^2D^{2/3}}\Bigg)\left(\frac{Q}{10}\right)^2 \qquad n = 0.024 \quad Ke = 0.9$$

From Bureau of Public Roads Hydr. Circular #5

USDA-SCS-MINNESOTA
12-5-63

TABLE 6-11

CAPACITY OF CONCRETE PIPE CULVERTS
OUTLET CONTROL (WITHOUT HEADWALLS - SOCKET END UPSTREAM)

D In Inches	H in feet 0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
				L = 20 feet				
12	3	5	6	7	8	8	9	10
18	8	12	14	16	18	20	22	23
24	15	21	26	30	34	37	40	42
30	24	34	41	48	53	59	63	68
36	35	49	60	70	78	85	92	99
42	48	68	83	96	107	117	127	135
48	63	89	109	126	141	154	166	178
54	80	113	138	160	179	196	212	226
60	99	140	172	198	222	243	262	282
velocity	4 5 6	7	8	10		12		
				L = 30 feet				
12	3	4	5	6	7	8	8	9
18	8	11	13	16	17	19	21	22
24	14	20	25	29	32	35	38	41
30	23	33	40	46	52	57	61	66
36	34	48	59	68	76	83	90	96
42	47	66	81	94	105	115	124	133
48	62	88	107	124	138	152	164	175
54	79	112	137	158	176	193	209	223
60	98	138	170	196	219	240	259	277
velocity	4 5 6	7	8	10		12		
				L = 40 feet				
12	3	4	5	6	7	7	8	8
18	7	10	13	15	17	18	20	21
24	14	20	24	28	31	34	37	40
30	23	32	39	45	51	55	60	64
36	33	47	58	67	75	82	88	94
42	46	65	80	92	103	113	122	130
48	61	86	106	122	136	149	161	172
54	78	110	135	156	174	191	206	220
60	97	137	168	194	216	237	256	274
velocity	4 5 6	7 8		10		12		
				L = 50 feet				
12	3	4	5	6	6	7	7	8
18	7	10	12	14	16	17	19	20
24	14	19	23	27	30	33	36	38
30	22	31	38	44	49	54	58	62
36	33	46	57	65	73	80	86	92
42	45	64	78	91	101	111	120	128
48	60	85	104	120	134	147	159	170
54	77	109	133	154	172	188	203	217
60	96	135	166	191	214	234	253	270
velocity	4 5 6	7 8		10		12		

$$H = \left(\frac{2.520\,(1+ke)}{D^4} + \frac{466.2\,n^2L}{D^{14/3}}\right)\left(\frac{Q}{10}\right)^2 \qquad n = .012 \qquad Ke = 0.2$$

From Bureau of Public Roads
Hydraulic Circular #5

USDA-SCS-MINNESOTA
11-15-63

TABLE 6-12

CAPACITY OF CULVERTS
INLET CONTROL (Without Headwalls)

Circular Corrugated Metal Pipe

Diameter in Inches	Cubic Feet Per Second												
	H on Pipe Inlet in Feet												
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0
12	2.0	3.2	4.1	4.7	5.3	5.8	6.3	6.7	7.2	7.5	8.0		
15	2.6	4.5	6.0	7.2	8.0	8.9	9.5	10	11	11	12	12	13
18	3.1	5.5	8.0	9.8	11	12	13	14	15	16	17	18	18
21	3.4	6.8	10	13	15	17	18	19	20	22	23	24	25
24	3.8	7.5	11	15	18	21	23	25	26	28	29	31	32
27		8.5	13	18	22	25	28	31	33	35	37	39	40
30		9.0	15	20	26	30	33	37	40	42	45	47	50
36		10	17	24	31	38	45	50	55	60	64	67	70
42			19	28	37	46	55	63	70	76	81	86	91
48			21	32	42	54	62	77	86	92	101	110	115
54				33	47	60	73	86	99	111	122	131	140
60				37	51	66	82	96	110	130	142	155	165

Circular Concrete Pipe - Socket End Upstream

Diameter in Inches	Cubic Feet Per Second												
	H on Pipe Inlet in Feet												
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0
12	2.5	4.0	5.2	6.0	6.8	7.4	8.0	8.6	9.1	9.6	10		
15	3.1	5.6	7.5	9.0	10	11	12	13	14	15	16	16	17
18	3.5	7.0	9.0	12	14	15	17	18	20	21	22	23	24
21	4.0	8.0	12	15	18	20	22	24	26	27	29	30	32
24	4.3	9.1	14	19	22	26	29	31	33	35	38	40	42
27		9.8	16	22	27	32	35	38	40	43	46	48	52
30		10	17	25	32	37	42	46	50	53	56	59	62
36		12	20	29	38	47	55	62	68	72	79	82	85
42			22	33	44	57	67	76	85	93	100	107	113
48			24	38	50	65	80	92	105	115	125	135	145
54				38	55	73	90	105	120	135	150	162	175
60				42	58	78	95	115	135	155	172	190	202

Pipe Arch - Corrugated Metal Pipe

Span and Rise	Cubic Feet Per Second												
	H on Pipe Inlet in Feet												
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0
18"x11"	3.2	4.8	6.0	6.8	7.5	8.2							
22"x13"	4.0	6.5	8.0	9.5	11	12	13						
25"x16"	4.7	8.0	11	13	15	16	17	18					
29"x18"	5.5	10	13	16	19	21	22	24	26	27	28		
36"x22"	6.7	12	18	22	26	30	33	35	38	40	43	45	47
43"x27"	7.8	15	22	30	37	42	46	51	55	58	61	65	67
50"x31"	9.4	17	26	36	45	53	59	66	71	76	80	84	88
58"x36"		20	31	43	55	65	75	83	90	98	105	111	116
65"x40"		21	34	47	62	75	87	98	108	118	125	133	141
72"x44"		24	38	53	70	85	100	115	128	138	150	160	170

Values given in tables above were taken directly from appropriate nomographs in Bureau of Public Roads Hydraulic Engr. Circular No. 5

USDA-SCS-MINNESOTA
November 1, 1963

CHAPTER 7

PUMP DRAINAGE

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PUMP DRAINAGE

General

Drainage pumping plants may be used where it is impossible or uneconomical to obtain gravity outlets for drainage waters. In such pumping plants, water collects in a ditch or sump until it reaches a specified level at which time the pump starts. Pumping action continues until the water surface in the sump recedes to a minimum level and the pump stops. Most drainage pumps are powered by electric motors and have automatic controls for starting and stopping. Figure 7-1 shows a typical installation of a drainage pumping plant using a sump as the storage collector.

Items to consider in planning for a pump drainage plant include soil foundation charateristics, pump location and capacity, outlet requirements, degree of protection required, mode of pump plant operation and type of power. Each pump drainage problem has its individual and varied requirements, thus all facets of the problem should be investigated to acquire the design that will be most economically feasible.

Location of the Pump

The drainage pumping plant should be in a location that provides satisfactory outlet conditions, adequate storage, stable soil for its foundation, and reasonable access to a power supply. Such a plant should also be located so as to be easily accessible for inspection and maintenance, but not susceptible to vandalism. Since electric power, when available, is the most satisfactory type of power for use in automatic pump operations, the local electric power company should be contacted to determine how, where, and at what cost an electric power line could be extended to the various pump locations being considered. Soil borings are necessary to determine the suitability of the foundation materials to be encountered at any given site. The pump controls and motor should be located above the site's high water elevation if possible.

Pump Capacity

A pumping drainage plant must be able to pump the amount of water necessary to provide adequate drainage against the total head expected. The pump should have a capacity slightly greater than the maximum flow expected to enter the sump or ditch. To reduce cost, consideration should be given to the disposal of all the surface runoff water, if possible, by diversion around the pump plant area, rather than emptying it into the pumping system. Installations designed to pump subsurface drain water only should have a pump capacity equal to the maximum drainage system capacity plus a safety factor of about 10%.

When both subsurface and surface waters are to be pumped for field crops, the pump should have a capacity to remove at least one-half inch of water from the area, and up to one inch for areas of 100 acres or less, in a 24-hour period. For areas growing high-valued specialty crops,

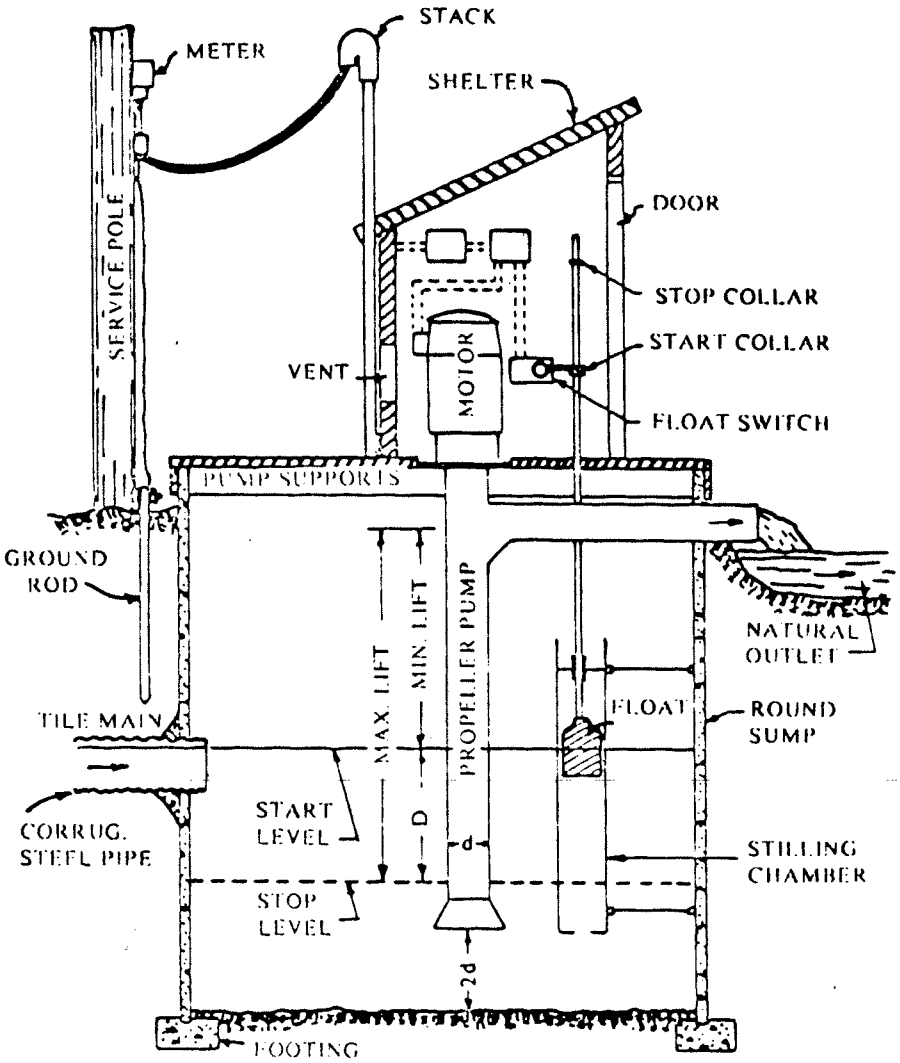

Figure 7-1. Typical Pumping Plant for Subsurface Drains

the pump capacity should be increased to one and a half to two inches of water per 24 hours, if both surface and subsurface waters are to be pumped.

Sump Storage Requirements

With automatic pump operation, sufficient active storage capacity should be provided in the sump, or collection ditch, to avoid having excessive cycling of the pump. Design specifications in the past have limited the number of pump cycles to ten cycles per hour, in order to reduce wear on the electic controls and equipment. Recent data from electrical equipment manufacturers, however, indicate that more frequent pump cycling can be tolerated without risk of major damage to the equipment. Starting an idle pump requires extra energy and also increased maintenance. While a reduction in sump storage capacity can be attained by increasing the cycling frequency of the pump, such savings may be offset by the increase in such operational costs. Thus, in choosing the rate of cycling of a pump, consideration should be given to the economical factors for each installation.

The selection of a pump having a capacity greatly in excess of that required for given sump and outlet conditions should also be avoided. With such over-capacity pumps, the drawdown limits within the sump (active storage) which control pump operation are quickly reached. With rapid drawdown rates, it is often difficult for water being held in more distant storage areas, such as open ditches or pits, to move toward the pump fast enough to maintain continuous pump operation. Constrictions in pipes, trash rack structures or other channels through which the water must flow to reach the pump may force the pump to cycle at unnecessarily high and damaging frequency.

Active storage capacity of the sump, in cubic feet, for an automatically operating pump should be two times the pump capacity (gpm) divided by the number of pump cycles per hour (N).

$$\text{Active storage (cubic feet)} = \frac{\text{pump capacity (gpm)} \times 2}{\text{"N" (cycles per hour)}}$$

Where a pumping bay is placed in a storage pit or channel, the openings to the bay should be able to transmit at least twice the pump capacity. If trash racks are installed, plugging of part of the rack should be considered in the design of the entrance to the pumping bay.

Trash Racks

Trash racks or protective screening must be provided to prevent entry of floating debris into sumps where damage to pumps might otherwise occur. The velocity of flow through a trash rack should not exceed 2 feet per second. The recommended trash rack bar spacings are as follows:

Pump Diameter (inches)	Bar Spacing (inches)
16	3/4
18 - 24	1 - 1 1/2
30 - 42	2
48	

A trash rack should be shaped to permit cleaning by hand, or equipped with mechanical cleaners. Where trash racks are not feasible, such as with small pumps, galvanized basket strainers may be used to prevent entry of gravel and debris.

The vertical distance (D) between the start and stop levels shown in Figure 7-1 represents the change in lift or head under which the pump must operate. With the class of pumps used in drainage work, the distance (D) should not exceed two feet. Knowing the sump volume and the distance (D), the area of the sump can be determined. A storage ditch used in conjunction with the sump is an alternative to a large pumping sump.

When a drainage pumping plant is to be operated manually, the active storage should be much greater than that for automatic operation and depends to a large extent on the number of times the landowner is willing to start the pump each day.

Types of Pumps and Pump Drives

Pumps used for pump drainage are of the high-volume, low-head class. This class of pumps includes the axial-flow propeller pumps and certain types of centrifugal pumps. For areas smaller than five acres, commercial sump or marine bilge pumps can be used. Pumping volumes and heads must be determined carefully, since friction factors become critical at settings other than those recommended by the manufacturer. Pump data is used by the manufacturer's representative in chosing the appropriate pump model. The designer should check with the manufacturer to verify that an appropriate pump is available.

Electric power has the advantage of permitting automatic operation and elimination of the need for daily fueling or servicing activities. Usually, a 10-horsepower motor is the largest that can be used on single phase 230-volt lines. Motors of higher horsepower can be operated where three-phase power is available, or where phase converters can be used on single phase power lines. In those cases where electric power is planned, the power supplier should be consulted for suggestions and recommendations on the most feasible arrangement. If electric power is not available, diesel, gasoline, or LP gas stationary power units can be used to operate the pump. A farm tractor, with belt or power takeoff drive, may be used to operate the drainage pump in an emergency.

Pump Operation

Although in actual operation pumps used in drainage outlets may be cyclic, electric motors should have continuous load ratings to take care

of sustained inflows. Electric motor operation can be easily controlled by automatic switches. Internal combustion engines will require manual control for set periods, or some means of throttle or clutch control to make them automatic. Automatic safety cutout will eliminate the need for an operator during most of the period that the engine is running. Safety cutouts (engine temperature, engine oil pressure, and pump pressure) should be attached to any engine if it is to be left running unattended.

Detailed information on the design of drainage pumping plants is available in the American Society of Agricultural Engineer's Standards (ASAE EP 369) entitled, "Design of Agricultural Drainage Pumping Plants."

Example: A pumping plant is needed at the outlet of a tile drainage system. The system drains 70 acres, the drainage coefficient is 3/8", and the design outflow is 1.1 c.f.s. Determine the pump capacity and sump size.

Solution: The pump capacity should be equal to the maximum outflow plus 10% safety factor:

$$\text{Pump Capacity} = 110\% \times 1.1 \text{ c.f.s.}$$

$$= 1.2 \text{ c.f.s} = 544 \text{ gallons per minute}$$

The required sump active storage capacity can be found using the formula. Assume the above pump will cycle 10 times per hour.

$$\text{Active Storage} = \frac{2 \times 544 \text{ g.p.m.}}{10 \text{ cycles/hour}} = 109 \text{ cu. ft.}$$

If the drawdown distance (D) is set at 2 feet, the required plan area of the sump is:

$$\text{Area} = \frac{109 \text{ cu. ft.}}{2 \text{ ft.}} = 55 \text{ sq. ft.}$$

An 8-foot square or 6-foot by 10 foot sump will provide enough storage.

CHAPTER 8

DRAINAGE OF ORGANIC SOILS

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DRAINAGE OF ORGANIC SOILS

GENERAL

Investigations, design and development of drainage systems for organic soils generally follow the same basic procedures used in mineral soils. However, due to the properties and inherent problems related to organic soils, modifications and adjustments are needed for drainage systems installed in these soils. Characteristics of organic soils that effect the design and construction of drainage systems are depth of organic soils, type of organic materials, permeability, subsidence, shrink and swell, combustibility, erosion, available outlets, etc.

CLASSIFICATION OF ORGANIC SOILS

Organic soils have commonly been referred to as peat and mucks. Peats have distinguishable plant fibers and mucks have little or no definable plant fiber with mineral sediments mixed in. The Soil Survey has adopted a broad classification based upon distinguished plant fibers; Fibric, Hemic, Sapric and Limnic. Fibric, Hemic, and Sapric are "peats". Fibric has the most plant fibers and Sapric is the most decomposed organic soil. Limnics ("muck") have no distinguishable fibers and are a mixture normally of organic and sedimentary mineral soils having very low strength.

In drainage work, organic soils have been classified according to ignition loss. Peats are defined as containing 50 percent or more organic matter and mucks as containing less than 50 percent. There are some soils classified as mineral soils that have a relatively high percent of organics that act more like a mineral soil yet have some of the organic soil traits. These are normally identified in soil survey with a modifier such as mucky silt loam. Generally, of the organics, mucks are the more desirable soil for draining since they shrink less, work easier and need less fertilizer.

PLANNING AND DESIGN CONSIDERATIONS

Due to some inherent problems related to organic soil properties, consideration must be given to the adverse effects of the soil on the drainage system.

SUBSIDENCE. Subsidence affects both the surface and part of the subsurface. The shrinking of the soil can cause problems with dikes, tile lines, structures, etc., Subsidence is caused by several things. Some of the causes are listed below.

1. Lowering the water table allows air to replace the water and allows an environment for oxidation and settlement to take

place. Oxidation is the deterioration of the organic matter by aerobic bacteria. Settlement results as the upper soil compacts the lower layers as they are drained.

2. Farm equipment and other structures or traffic also contribute to the compaction of the organic soils as they are drained.

3. Some subsidence is due to direct erosion of materials and possibly burning of the organic matter.

The resulting subsidence can cause damage to structures, tile lines, dikes, etc. and in some cases the lower surface eliminates gravity outlets and pump stations may be needed. Design of a drainage system must consider the subsidence of the soil during the expected life of the system.

Subsidence rates are not available. Subsidence has to be based on local experience, consideration of the type of organic material, the depth of the soil, the depth of drainage and land use. For estimating long term subsidence on undrained sites, consider 25 to 35 percent of the drain depth as an average for subsidence (as much as 50% of the depth has been observed in some organic soils), and for previously drained soils, an estimate of 10 percent of the tile depth can be used. In shallow organics underlain with sands or other firm mineral soils, subsurface drains can be installed if it can rest on the mineral soil. In deep organic soils, subsidence is a major design consideration. Since subsidence below the tile line cannot be estimated, a two-phase construction is suggested. Phase 1 would be open ditches to approximately tile depth for 3-4 years. Phase 2 would be after 3-4 years and after subsidence has taken place. Then, tile could be installed in the ditches and covered. Long lengths of tile or plastic tile should be considered to reduce the number of joints that could displace and cause a failure in the system.

Depth of tile in organic soils should be at or below the frost line to prevent freezing and heaving due to ice lense and frost action. Generally 4 to 5 feet in Minnesota is considered minimum.

EROSIVENESS. Once organic soils (particularly the more fiberous soils) become drained and dried, both wind and water erosion can take place. Many organic soils when dried are very light weight and when pulverized for farming become very susceptible to wind erosion and can also float away with storm runoff. Tillage and cropping practices can effectively control this loss.

BURNING. Many organic soils high in plant matter can burn when dried, destroying the soil and resulting in subsidence of the surface. Controlling the watertable and taking safety precautions are methods of reducing the chance of burning.

SHRINK AND SWELL. Fibrous organic soils have a high potential for swelling when wetted and shrinking when dried. This can cause problems

with uneven movement of surfaces that can damage drainage structures, dikes, tiles, etc. To minimize this, these organic materials should be kept at an even moisture by covering them with a protective layer or controlling watertable fluctuation to a minimum.

OCHRE FORMATION. Many organic soils have problems with ochre formation in subsurface drain lines. Refer to Chapter 4 for information.

CHAPTER 9

WATER LEVEL CONTROL

WATER LEVEL CONTROL

Water level control in a drainage system is accomplished by including outlet structures, junction boxes, and other devices that can control the outlet elevation of the water from a system. This can be accomplished in both a gravity and a pumping system. Water level control capabilities extends the potential and versatility of the drainage system where other benefits can also be realized. Other potential benefits could be:

1. A simple means of subsurface irrigation at small cost and yet not hindering field operations. Then during harvest season the watertable can be lowered for better trafficability during harvest operations.

   For speciality crops such as wild rice, a controlled system can allow for flood irrigation for wild rice and draining for harvest, as well as providing drainage for the rotation crop to control disease.

   For soils that would be droughty when drained, such as high watertable sands, controlled drainage can be beneficial to crop production.

   In dry years when rainfall is short, the capability of controlling the available ground water level can be highly beneficial for crop production.

2. Controlling and limiting subsidence in organic soils by controlling the rate of groundwater removal and depth to the watertable. In addition to a controlled water supply available to plant growth, a controlled watertable reduces oxidation of organics by limiting the time they are drained completely, reduces fire hazards by keeping the organics moist, and can be used to reduce the range of shrink and swell in some organic materials.

3. Provide the opportunity to maintain and manage wildlife habitat in conjunction with man's cropping and utilization of the land.

4. Reduce wind erosion during the spring by keeping the water level near the surface keeping it moist to reduce blowing and stimulate seed and plant growth.

5. Allows for management of ground water level during excessive rainfall periods.

There can be some drawbacks to controlled water level drainage systems that the planner should be aware of in planning such a system. In some soils and watertable conditions, "drainage-irrigation" tile may have to

be placed closer which will mean additional system cost. If the system is designed to distribute irrigation water also, it will require larger volumes of water than a sprinkler system. In areas where salts in the soils can cause problems with plant growth, a controlled water level drainage system can cause more salt accumulation in the soil and create a new problem. With proper planning and investigation, these areas can be avoided and proper designs developed.

Water level control can be accomplished in both pump and gravity outlet systems. In pumping systems, water level can be controlled by regulating the start and stop levels of the pumps.

Where fall across the fields is so great that control of the watertable cannot be regulated across the entire field in an effective manner, auxiliary structures along the tile lines may be needed. The auxiliary structures, like the outlet structure for gravity systems, can be simple structures using flash board systems to control water level, or more elaborate structures using irrigation-type gates.

The objective of the controlled system needs to be determined in the early planning stage before design is begun. For normal irrigation, maximum water levels are usually 18 inches for grasses and shallow-rooted crops and 30 inches for deep-rooted crops such as corn. Water levels higher than that may be needed in the spring for erosion control or other reasons.

Owners of such a system should be aware that, to gain the most benefit from the system, a higher level of management and operation will be needed.

A computer model, called DRAINMOD, has been developed to evaluate and design water management systems for soils with natural or induced high water tables. DRAINMOD is a program developed by Dr. R. W. Skaggs of North Carolina State University at Raleigh, North Carolina. It can be used to evaluate conventional drainage, controlled drainage, watertable management (subsurface irrigation) systems, and waste water irrigation systems. For more information, refer to the DRAINMOD Users Manual.

A P P E N D I X

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APPENDIX I: GLOSSARY OF TERMS

BERM: Strip or area of land, usually level, between the spoil bank and edge of a ditch or canal.

BLIND: Placement of loose soil around a tile or conduit to prevent damage or misalignment when the trench is backfilled. Allows water to flow more freely to the tile.

BLIND DRAIN: Type of drain consisting of an excavated trench, refilled with pervious materials such as coarse sand, gravel or crushed stones, through whose voids water percolates and flows toward an outlet. Often referred to as a French drain because of its initial development and widespread use in France.

BLINDING MATERIAL: Material placed on top of and around a closed drain to improve the flow of water to the drain and to prevent displacement during backfilling of the trench.

BLIND INLET: Surface water inlet to a drain in which entrace of water is by percolation rather than open flow channels.

BLOW OUT: Common reference to a rupture in an underdrain usually attributed to hydraulic pressure from within the line and resulting in displacement of pipe and in washout of supporting and covering earth materials. Also "break throughs" or ruptures in soil behind levees associated with sand boils.

BOTTOM CLEARANCE: Vertical distance from the inlet of the pump suction pipe to the bottom of the sump.

BREAK GRADE: To change grade; as in a tile line, ditch or field.

BREATHER: See Vent.

CHANNEL: A natural or man made open surface drain or stream used to remove excess surface water. Depending upon size and intended use; it may be called a field ditch, lateral or main.

CHANNEL IMPROVEMENT: Improvement of the hydraulic flow characteristics of channels by increasing the cross section, straightening, or clearing in order to increase its carrying capacity.

CHANNEL STABILIZATION: Erosion prevention and stabilization of velocity distribution in a channel by use of jetties, drops, revetments, vegetation and other measures.

CLAY: Soil particles less than 0.002 mm in diameter according to USDA classification.

CLEAN OUT: Removal of vegetative growth, silt and debris from an open or closed drain or other conduit without change in size or section.

CLOSED DRAIN: Subsurface drain, tile or perforated pipe, which receives surface water through surface inlets.

COEFFICIENT OF ROUGHNESS: Factor in fluid flow formulas expressing the character of a channel surface and its frictional resistance to flow.

CUBIC FOOT PER SECOND: Flow rate measurement equal to 1 cubic foot per second. Optional usage: c.f.s., Second Foot.

DITCH: Constructed open channel for conducting water. See Drain.

DIVERSION: Channel constructed across the slope for the purpose of intercepting surface runoff; changing the accustomed course of all or part of a stream.

DOUBLE DITCH OR DRAIN: See W-ditch.

DOUBLE-MAIN SYSTEM: Gridiron system of subsurface drainage with two closely spaced parallel mains. Normally used where a waterway or depression is deep enough to make it impractical to cross with tile lines to reach one main and have one main deep enough to allow this crossing.

DRAIN: A subsurface drain, closed drain, ditch or channel system for removal of surplus ground or surface water.

DRAINAGE: Process of removing excess surface or subsurface water from a soil or area.

DRAINAGE AREA: The area from which drainage water is collected and delivered to an outlet.

DRAINAGE COEFFICIENT: Design rate at which water is to be removed from a drainage area. It may be expressed in inches of depth per day or in terms of flow rate per unit of area.

DRAINAGE PUMPING PLANT: One or more pumps, power units and appurtenances for lifting drainage water from a collecting basin to a gravity outlet.

DRAINAGE SYSTEM: Collection of open and/or closed surface and subsurface drains, together with structures and pumps used to collect and dispose of excess surface or subsurface water.

FRENCH DRAIN: See Blind Drain.

INTERCEPTOR DRAIN: Surface or subsurface drain, or a combination of both designed and installed to intercept flowing water.

JUNCTION: Point of intersection of two open or closed drains; accessory used to effect a junction between two tile lines.

JUNCTION BOX: Box. manhole or other structure which serves to join one or more drains.

LAND LEVELING: Process of shaping the land surface for better movement of water and machinery over the land. Also called land forming, land shaping, or land grading.

LAND SMOOTHING: Process of eliminating minor surface irregularities without changing the general contours of the land; the finishing operation in land leveling.

LATERAL: Secondary or side channel, ditch or conduit. Also called branch line or drain, spu, lateral ditch, group lateral.

MAIN: Principal drain which collects drainage water from the lateral drains, field drains, and submains and conducts the drainage water to an outlet. Also called major drain, outlet drain, trunk drain.

MOLE DRAIN: Drain formed by pulling a bullet-shaped cylinder through the soil. No tubing or tile is installed with this method.

OUTLET: Point of water disposal from a stream, river, lake, tidewater, or artificial drain.

PUMP DRAINAGE: Drainage system which pumps the water into an outlet.

RELIEF DRAIN: A drain designed to remove water from the soil in order to lower the water table and reduce hydrostatic pressure.

SILT: Small, 0.05 to 0.002 mm in diameter, mineral soil grains intermediate between clay and sand; waterborne sediment with diameters of individual grains approaching that of silt; soil material containing 80 percent or more silt and less than 12 percent clay.

SLOPE: Degree of deviation of a surface from the horizontal, usually expressed in percent or degrees. Also, is a ratio of the horizontal distance to the vertical drop in that distance (e.g. 3:1 means 3 feet horizontal to each foot of vertical drop).

SUBIRRIGATION: Applying irrigation water below the ground surface either by raising the water table within or near the root zone, or by use of a buried perforated or porous pipe system which discharges directly into the root zone.

SUBMERGED OUTLET: Outlet for discharging water below a free water surface.

SUBSURFACE DRAINS: A system of underground conduits and/or blind drains used primarily to remove subsurface water from soil; however, in some cases, surface water may also be removed by the underground system by utilizing surface water inlets and blind drain inlets. Other commonly used names are under drains, internal drains, tile drains, closed drains, or tile.

SUMP: Pit, tank, or reservoir in which water is collected or stored for withdrawal by a pump.

SUMP STORAGE: Volume of water that can be stored in the sump between start and stop levels of pumping.

SURFACE DRAINAGE: Removal of surplus water from the surface of agricultural land by a system of surface drains.

SURFACE WATER INLETS (or SURFACE INLETS): This is normally an open pipe from the surface to the subsurface drain to remove excess surface water from depressions. Inlets are normally perforated or equipped with a trash rack.

VENT: Open vertical pipe riser from a tile or irrigation line which allows air to enter or escape from the pipe system.

APPENDIX II: AMERICAN-METRIC CONVERSION CONSTANTS.

LENGTH and DISTANCE	In.	Ft.	Yd.	Statute Miles	Cm	Meters	Km
1 in. equals	1	0.083	0.027	-	2.54	-	-
1 ft	12	1	0.333	-	30.48	0.305	-
1 yd	36	3.0	1	-	91.44	0.914	-
1 statute mile	-	5280	1760	1	-	1609	1.61
1 cm	0.394	0.0328	0.0109	-	1	0.01	-
1 meter	39.37	3.281	1.094	-	100	1	0.001
1 km	-	3281	1094	0.6214	-	1000	1

USEFUL APPROXIMATIONS: 5 cm = 2 in.; 10 cm = 4 in.; 30 cm = 1 ft; 10 meters = 33 ft; 10 im = 6 miles; 16 km = 10 miles; 1 fathom = 6 ft; 120 fathoms = 1 cable length

AREAS	In.^{2}	Ft^2	Yd^2	Ac	Cm^2	Meters^2	Ha
1 in.^{2}	1	0.007	-	-	6.45	0.00064	-
1 ft^2	144	1	0.1111	-	-	0.0929	-
1 yd^2	1296	9	1	-	-	0.8361	-
1 ac	-	43,560	4840	1	-	4050	0.405
1 cm^2	0.155	-	-	-	1	0.0001	-
1 m^2	1550	10.76	1.20	-	10,000	1	0.001
1 ha	-	107.600	11.955	2.47	-	10,000	1

USEFUL APPROXIMATIONS: 1 ha = 2½ ac; 1 in.^{2} = 6½ cm^2; 1 m^2 = 11 ft^2; a hectare 328 feet on each side.

VOLUME and CAPACITY	In.^{3}	Ft^3	Gallons	M^3	Liters	Quarts
1 cu. inch	1	0.00057	0.0043	-	0.0163	0.0173
1 cu. foot	1728	1	7.48	0.0283	28.3	29.9
1 gallon	231	0.134	1	0.0038	3.78	4
1 cu. meter	61,030	35.3	264.2	1	1000	1057
1 liter	61.03	0.0353	0.264	0.001	1	1.057

USEFUL APPROXIMATIONS: 16.4 cc = 1 in.^{3}; 35 ft^3 in a m.^{3}; 1 register ton = 100 ft^3; 1 U.S. shipping ton = 40 ft^3 or 32.14 U.S. bu or 31.14 Imp bu (From O. W. Israelsen and V. E. Hansen, Irrigation Principles and Practices, 3rd ed., John Wiley & Sons, New York, 1962.)

APPENDIX III

USDA TEXTURE CLASSES AND SYMBOLS

Texture modifier:

BY	Bouldery
BYV	Very bouldery
BYX	Extremely bouldery
CB	Cobbly
CBA	Angular cobbly
CBV	Very cobbly
CBX	Extremely cobbly
CN	Channery
CNV	Very channery
CNX	Extremely channery
CR	Cherty
CRC	Coarse cherty
CRV	Very cherty
CRX	Extremely cherty
FL	Flaggy
FLX	Extremely flaggy
FLV	Very flaggy
GR	Gravelly
GRC	Coarse gravelly
GRF	Fine gravelly
GRV	Very gravelly
GRX	Extremely gravelly
MK	Mucky
PT	Peaty
RB	Rubbly
SH	Shaly
SHV	Very shaly
SHX	Extremely shaly
SR	Stratified
ST	Stony
STV	Very stony
STX	Extremely stony
SY	Slaty
SYV	Very slaty
SYX	Extremely slaty

Texture terms:

COS	Coarse sand
S	Sand
FS	Fine sand
VFS	Very fine sand
LCOS	Loamy coarse sand
LS	Loamy sand
LFS	Loamy fine sand
LVFS	Loamy very fine sand
COSL	Coarse sandy loam
SL	Sandy loam
FSL	Fine sandy loam
VFSL	Very fine sandy loam
L	Loam
SIL	Silt loam
SI	Silt
SCL	Sandy clay loam
CL	Clay loam
SICL	Silty clay loam
SC	Sandy clay
SIC	Silty clay
C	Clay

Terms used in lieu of texture:

CE	Coprogenous earth
CEM	Cemented
CIND	Cinders
DE	Diotomaceous earth
FB	Fibric material
FRAG	Fragmental material
G	Gravel
GYP	Gypsiferous material
HM	Hemic material
ICE	Ice or frozen soil
IND	Indurated
MARL	Marl
MPT	Mucky-peat
MUCK	Muck
PEAT	Peat
SG	Sand and gravel
SP	Sapric material
UWB	Unweathered bedrock
VAR	Variable
WB	Weathered bedrock

APPENDIX III

UNIFIED SOIL CLASSIFICATION SYSTEM

GROUP	TYPICAL NAMES	IDENTIFICATION PROCEDURE
GW	Well-graded gravels, gravel-sand mixtures, little or no fines.	Wide range in grain sizes and substantial amounts of all intermediate particle sizes.
GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.
GM	Silty gravels, gravel-sand-silt mixtures.	Nonplastic fines or fines with low plasticity. (for identification procedures see ML below)
GC	Clayey gravels, gravel-sand-clay mixtures.	Plastic fines (for identification procedures see CL below).
SW	Well-graded sands, gravelly sands, little or no fines	Wide range in grain sizes and substantial amounts of all intermediate particle sizes.
SP	Poorly-graded sands, gravelly sands, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.
SM	Silty sands, sand-silt mixtures.	Nonplastic fines or fines with low plasticity. (for identification procedures see ML below)
SC	Clayey sands, sand-clay mixtures.	Plastic fines (for identification procedures see CL below).

		Identification Procedures on Fraction Smaller than No. 40 Sieve Size		
		Dry Strength (Crushing) characteristics)	Dilatancy (Reaction to shaking)	Toughness (Consistency) near PL)
ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.	None to Slight	Quick to Slow	None
CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.	Medium to High	None to Very Slow	Medium
OL	Organic silts and organic silty clays of low plasticity.	Slight to Medium	Slow	Slight
MP	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic.	Slight to Medium	Slow to None	Slight to Medium
CH	Inorganic clays of high plasticity, fat clays.	High to Very High	None	High
OH	Organic clays of medium to high plasticity, organic silts.	Medium to High	None to Very Slow	Slight to Medium
Pt	Peat and other highly organic soils.	Readily identified by color, odor, spongy feel and frequently by fibrous texture.		

APPENDIX IV

REFERENCES

The references listed below were used to develop this guide, and should be referred to for more information on drainage.

SCS National Engineering Handbook, Section 16, Drainage of Agricultural Land.

SCS Engineering Field Manual, Chapter 14, Drainage.

SCS National Handbook of Conservation Practices.

SCS Minnesota Technical Guide, Section 4, Standards for Conservation Practices.

SCS DRAINMOD Users Manual, Interim Technical Release.

1983-1984 Agricultural Engineers' Yearbook of Standards, ASAE Engineering Practices:

ASAE EP260.3, Design and Construction of Subsurface Drains in Humid Areas.

ASAE EP302.2, Design and Construction of Surface Drainage Systems on Farms in Humid Areas.

ASAE EP369, Design of Agricultural Drainage Pumping Plants.

ASAE EP407, Agricultural Drainage Outlets-Open Channels.

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