Iowa Drainage Guide

Cooperative Extension Service
Iowa State University
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Contents

Introduction

The *Iowa Drainage Guide* was prepared to provide recommendations for drainage improvements installed on Iowa's agricultural land. It is intended to provide legal, soil management, and engineering information to farmers, engineers, contractors, farm planners, and others associated with drainage system planning, construction, and management.

There are three major parts to this guide: (1) legal implications to drainage of Iowa's lands; (2) drainage recommendations for Iowa's soils; and (3) engineering design, construction, and maintenance recommendations for various types of drainage systems.

The user is cautioned to use subsurface depth and spacing recommendations only as a guide. Recommendations are based on the best information available; but local conditions may vary so recommendations should be tempered with local experience and successful practice. These recommendations also may change as a result of future research and field experience. This document supersedes the *Iowa Drainage Guide,* Special Report 13 (Revised), published by Iowa State University, December, 1962.

The *Iowa Drainage Guide* represents a cooperative endeavor by federal and state agencies. The following committee developed this new guide: Stewart W. Melvin, extension agricultural engineer, Iowa State University; Douglas C. Seibel, state conservation engineer, SCS; Volney H. Smith, assistant state conservation engineer, SCS; Paul E. Lucas, Midwest National Technical Center, SCS; W. Donald Frevert, state construction engineer, SCS; and John R. Nixon, assistant state soil scientist, SCS; J. Clayton Herman, extension communication specialist, Iowa State University, editor.

This committee was assisted by several SCS and agricultural engineering extension employees in other states where similar guides are being developed. Special appreciation goes to C. J. W. Drablos, University of Illinois, for his assistance with the subsurface drainage chapter in this guide.

Chapter 1. Iowa Drainage Laws

General Laws

Iowa is governed by laws contained in the *Code of Iowa* (Code) as they are interpreted by the courts. The Iowa Code has several chapters on drainage. Chapter 465 applies to individual drainage rights including tile drainage. Chapter 455 applies to levee and drainage districts. Chapter 455B includes laws pertaining to the Department of Natural Resources.

There are two general rules of law governing drainage: (1) the Civil Law, which grants the right to the owner of the higher land to drain across a lower neighbor in a natural waterway without interference; and (2) the Common Law rule, which permits the lower owner to fight off the water of his upper neighbor. Iowa, Minnesota, and most midwestern states follow the Civil Law rule, which grants the upper owner almost unrestricted right to drain land in a natural waterway over their lower neighbor. In addition, all states have additional laws affecting the rights of landowners in connection with drainage.

Chapter 465, sections 1 through 18, covers laws governing outlets for private drainage. Special situations may be affected by other laws. Section 455B.270 excepts private drainage of lands from control by the Department of Natural Resources. However, other sections give the department rights over pollution, public damage, and other aspects.

This chapter is not intended to provide legal advice but, rather, to give general guidance on questions that arise frequently. An attorney should be consulted for legal problems that cannot be resolved by mutual agreement.

Agreements and Easements

Definition of an easement—An easement is a privilege or right that one person has in the lands of another. For the purpose of this guide, easement will be defined as a special right for a single use in the lands of another. Drainage easements are usually limited to the right to enter on the lands of another for the purpose of installing drainage measures and for repair and maintenance.

The following items should normally be included in a subsurface drainage easement:

1. Description of all lands involved;

2. Names of owners;

3. The right to enter and to install subsurface drains and outlets and to repair and maintain;

4. Size, location, and depth of proposed drain;

5. Manner of installation;

6. Area to be drained from upper lands;

7. Rights of lower owner as to use of the drain line and outlet;

8. A statement that the agreement, with drainage plat attached, is to be recorded, is to be permanent, and is to remain with the land;

9. The costs to each; and

10. Provision for repair and maintenance.

Importance of an agreement—When a project involves two or more owners, an agreement is important because it prevents misunderstandings. Not only should there be an agreement when more than one farm is involved, but it should be in writing, signed before a notary public, and recorded in the manner provided by law.

Effect of an easement—An easement for the purpose of installing a subsurface drain takes away the use of the land from the owner only while the drain is being installed. A properly executed easement is binding upon future owners of the lands involved.

Mutual Drainage Systems

Description—A mutual drainage system is where the owners of the land to be drained agree among themselves to a system of drainage that will properly drain all of their lands located in one watershed. There can be two owners or many. They have no connection with legal drainage districts or any municipal body unless they attach themselves to a legal drainage district. The owners remain in sole control.

Advantages over a legal drainage system—A mutual system is usually cheaper. Overhead is low and repairs and maintenance do not depend upon actions of a public body.

Legal Drainage Districts

Description—A legal drainage district is formed in accordance with the laws of the state. Chapter 455 of the 1983 Code applies to the formation of legal drainage districts in Iowa by the board of supervisors. Two or more landowners may petition for the formation of a drainage district and one landowner may petition for a subdistrict. When a district is established, installation and maintenance is under the direction and control of the board of supervisors or board of trustees for the drainage district (Section 462.1 of the 1983 Code).

Subdrainage district—An owner may file a petition for the establishment of a subdistrict to provide an outlet for an area within a drainage district that has been assessed for benefits, but is separated from the main ditch, drain, or watercourse by the land of others who do not wish to cooperate.

Forming a legal drainage district—The petition of the landowners is filed with the board of supervisors, along with a bond in a fixed amount to pay the costs of hearings and other expenses in the event the district is not formed. From that point on the supervisors take over, make surveys, hold hearings, and make a final determination about establishing the district. Anyone aggrieved can appeal directly to the District Court and from there to the State Supreme Court.

Advantages of a legal drainage district—The legal system is necessary where there are owners who have to be compelled to pay their share when they do not wish to do so. The board of supervisors can establish such a system on their own motion if they find it beneficial to the public. Converting a drainage system installed as a mutual drainage system into a legal drainage district is advantageous only when there are disagreements among the members of a mutual drainage system.

Watercourses

Definition—Section 455B.261 of the 1983 Code defines "watercourse" as any lake, river, creek, ditch, or other body of water or channel having definite banks and bed with visible evidence of the flow or occurrence of water except lakes or ponds without outlet to which only one landowner is riparian. The State Supreme Court does not require definite banks but holds that a watercourse is where water flows naturally.

Definition of a watershed—A watershed is the area that contributes the water supply to a watercourse.

Draining a depression—It is legal to use a tile to drain a depression that holds back surface water if it is drained to its natural watercourse.

Improving a watercourse—Where permits are not required, a landowner may tile, excavate, or straighten a watercourse that runs through the owner's land even though it increases the downstream rate of flow. It should be noted, however, that stream channel modifications can sometimes cause more problems than solutions. Changes can cause erosion problems subjecting the owner to a complaint under Section 467A.47 of the 1983 Code pertaining to soil loss.

Permits from the Department of Natural Resources—Approval by the department for construction, operation, and maintenance of channel changes are required in the following instances:

1. Rural areas (when the changes involve streams draining more than 10 square miles),

2. Urban areas (when the changes involve streams draining more than 2 square miles), and

3. Changes involving any protected stream.

Permits from the Corps of Engineers—A permit may be required from the Corps of Engineers when dredging or filling 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."

Protected streams—The Iowa Department of Natural Resources has designated certain cold water streams in Iowa as protected streams. This classification is based on water quality standards published by the Iowa Department of Natural Resources and prohibits channel changes or any other development that will have significant adverse effects on the surrounding habitat of these streams. A list of protected streams is included in Chapter 72.50 of the Department of Natural Resources rules.

Subsurface Drain Outlets

Definition—A subsurface drain outlet is a pipe or tile that carries water from a drainage system to a surface channel.

Distance from property line—There is no law setting the distance away from the property line for an outlet. It must be far enough back so that the water flows under the property line in approximately the same manner as it did before the drain was installed.

Connecting additional drains to an outlet that crosses a neighbor's property—If an outlet is owned on neighboring property, the owner can connect as many subsurface drain lines as desired unless an agreement has been made that specifies the number of connecting outlets. If an outlet is owned by a neighbor, permission will likely be required prior to connecting additional drains. A situation like this calls for more facts before a definite answer is given. An attorney should be contacted for advice.

Increasing flow by improving existing drainage system—It is legal to improve an existing subsurface drainage system on an upper farm even though it causes an increase in volume or rate of flow as long as the drainage area does not change.

Plugging a neighbor's outlet—A landowner cannot restrict or limit the use of an outlet that crosses his/her farm. Iowa law provides a penalty of twice the amount of damages for stopping a subsurface drain. If an old subsurface drain becomes blocked on a neighbor's property, the upper landowner with an easement has the right to make the repair so the water will run off properly. If there is no easement, there may be an easement by prescription (passage of time) and the upper landowner will still have the right to make the repair. An outlet by prescription is gained by 10 years of usage. However, there are many things to be considered before it can be stated flatly that 10 years gives the upper owner an unqualified right to such an easement.

Drain outletting into road ditch—A subsurface drain can be outletted into a road ditch if it is the natural outlet. Section 465.23 of the 1983 Code states, "When the course of natural drainage of any land runs to a public highway, the owner of such land shall have the right to enter upon such highway for the purpose of connecting his drain or ditch with any drain or ditch constructed along or across the said highway but in making such connections, he shall do so in accordance with specifications furnished by the highway authorities having jurisdiction thereof, which specifications shall be furnished to him on application. He shall leave the highway in as good condition in every way as it was before the said work was done."

Connecting to a county road tile—A landowner can connect farm subsurface drain to a tile in the county road right-of-way if the county road tile can carry the additional load and properly dispose of it. This should **never** be done without first contacting the board of supervisors and the county engineer. The same rule applies to tile in a state road right-of-way.

Outletting into a well—A permit is required from the Iowa Department of Natural Resources prior to establishing an outlet into a well. It is not likely that such a permit will be granted because of the known pollution problems associated with this practice.

Outletting into a sinkhole or other depression—A permit is required from the Iowa Department of Natural Resources prior to outletting into a sinkhole or other depression that has no surface outlet. Because of potential groundwater pollution problems, this type of permit is rarely, if ever, granted.

Outletting into a slant pipe or barrel—As long as water is not diverted from one watershed to another and the water flows across the property line in the same way as it has in the past, forcing the water to the surface with a slant pipe or barrel appears to be legal. However, this will not provide a free outlet and may cause the subsurface drain to fill with sediment.

Pump drainage—Written approval should be obtained from the downstream landowner prior to using a pump to gain an outlet. This is a change in the natural flow of the water. In any event, legal counsel should be sought prior to proceeding.

Forcing an outlet—An upper owner can force an outlet across a lower owner by following the law. Chapter 465 of the 1983 Code sets up the action that must be taken to do this.

Roadways

Contact person—When crossing a state road with a subsurface drain, the district engineer for the Department of Transportation should be contacted. When crossing a county road, the county engineer should be contacted.

Responsibility for installing a subsurface drain across a road—The county or state pays for crossing a road. Section 465.23 of the 1983 Code states, "If a tile line or drainage ditch must be projected across the right-of-way to a suitable outlet, the expense of both material and labor used in installing the tile line or drainage ditch across the highway and any subsequent repair thereof shall be paid from funds available for the highways affected."

Railroads

Contact person—The maintenance department of the railroad should be contacted at its headquarters when crossing a railroad.

Cost of crossing railroad property—Railroads are under the same laws as any property owner. If a landowner wishes to cross railroad property, the railroad must cooperate, but the landowner will probably have to pay the costs. When a legal drainage district crosses a railroad at the location of a natural watercourse, or the location provided by the railroad for water to cross, the railroad is required to pay for and construct needed bridges or culverts.

Potholes and Wetlands

Draining potholes and wetlands—Laws prevent state and federal agencies from providing assistance that would result in the drainage of certain types of wetlands.

Filling a pothole—A pothole can be filled even though it means that additional water will then flow across adjoining landowners.

Sewage Systems

Outletting a septic tank or sewer line into a subsurface drain—It is not legal to discharge sewage into a subsurface drain or any other waters of the state. Even though such a system has been in existence for a number of years, a lower owner can have the sewage system disconnected by complaining to the Department of Natural Resources.

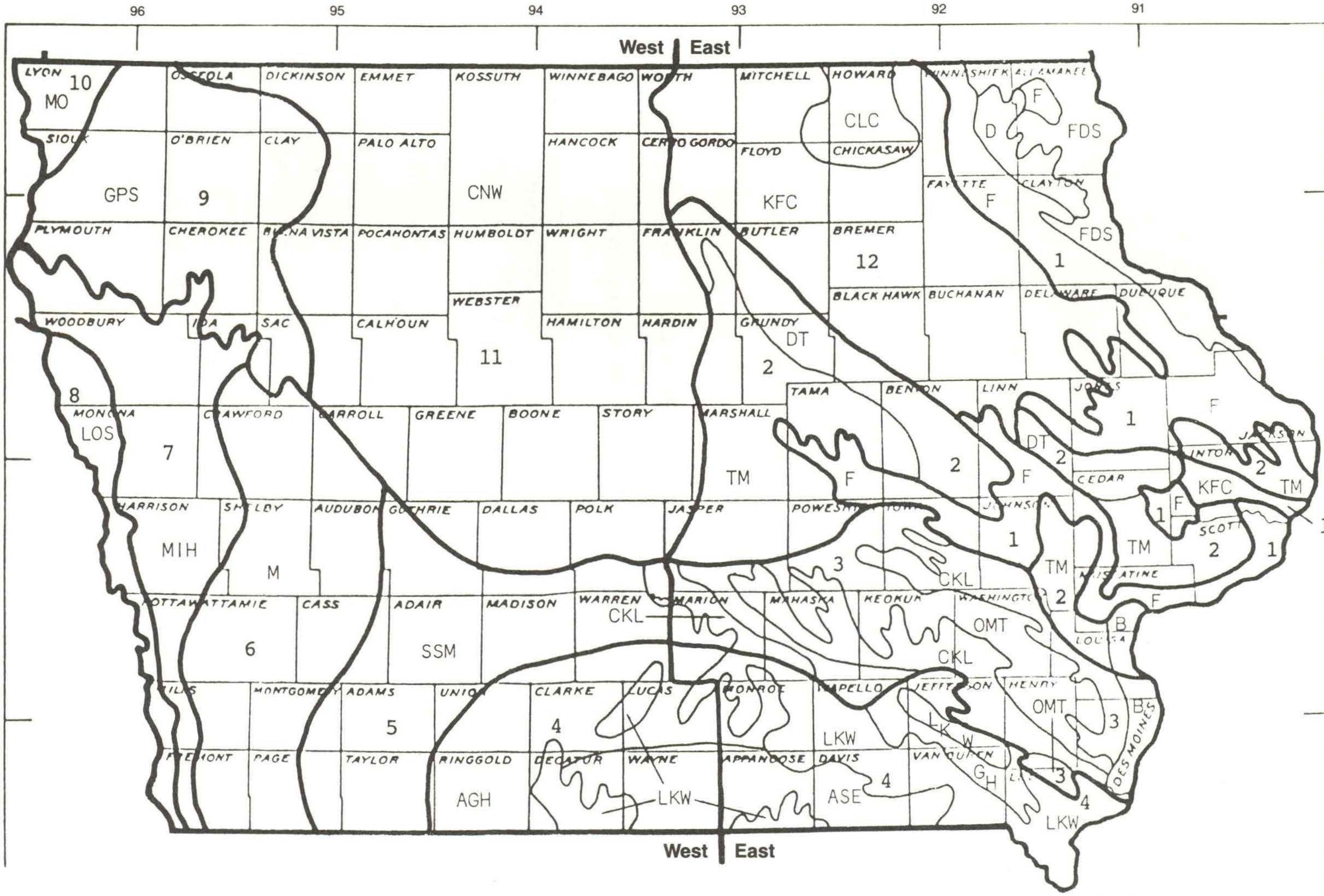
Chapter 2. Drainage Guidelines for Iowa Soils

There are approximately 375 different soil series mapped in Iowa. Slightly more than half of these have problems with excess water. There are also more than six million acres of cropland in Iowa with a capability class of IIw, which means that wetness is a factor limiting productivity. In addition, there are many areas of wet pastureland in the state that would benefit from drainage.

This guide gives recommendations for drainage of all soils mapped in Iowa. These recommendations are based upon field tests, mathematical equations, and experience gained from past drainage of these soils. Some soils readily adapt to subsurface drains. Others are most economically drained by surface methods. Still others may benefit from a combination of surface and subsurface systems while some soils do not need drainage. The remarks given for each soil in table 2-2 reflect its drainage needs.

Figure 2-1 shows the principal soil association areas of Iowa. Table 2-1 is a listing of all soils mapped in Iowa with soil identification numbers in numerical order. Table 2-2 is an alphabetical listing of each soil giving its natural drainage class, recommended tile spacing at 36- and 48-inch depths using a drainage coefficient of ⅜ inch in 24 hours, and remarks on type and extent of drainage needed.

To use this chapter, determine the soil type from published county soil survey reports, from the owner's conservation plan, or from unpublished soil maps available in the local soil conservation district office. Some small areas of wet soils cannot be delineated on the map at the scale commonly used for soil surveys. Therefore, these recommendations may need to be used in conjunction with an on-site review and detailed investigations.



AGH:	Adair-Grundy-Haig	DT:	Dinsdale-Tama	LOS:	Luton-Onawa-Salix
ASE:	Adair-Seymour-Edina	F:	Fayette	M:	Marshall
B:	Bottomland	FDS:	Fayette-Dubuque-Stonyland	MIH:	Monona-Ida-Hamburg
CKL:	Clinton-Keswick-Lindley	GPS:	Galva-Primghar-Sac	MO:	Moody
CLC:	Cresco-Lourdes-Clyde	GH:	Grundy-Haig	OMT:	Otley-Mahaska-Taintor
CNW:	Clarion-Nicollet-Webster	KFC:	Kenyon-Floyd-Clyde	SSM:	Shelby-Sharpsburg-Macksburg
D:	Downs	LKW:	Lindley-Keswick-Weller	TM:	Tama-Muscatine

Figure 2-1. Map of Iowa delineating the 21 principal soil association areas (coded by letters) and the 12 major soil areas (coded by numbers) (modified from Fenton et al., 1971).

Table 2-1. Listing of Iowa soils by soil identification number.

1 Ida silt loam

2 Hamburg silt loam
Hamburg-Ida silt loam

3 Castana silt loam

4 Knoke silty clay loam

5 Ackmore-Colo complex
Kennebec-Ackmore complex

6 Okoboji silty clay loam
(Glencoe silty clay loam prior to 1968)

7 Wiota silt loam
Wiota silty clay loam
(Audubon, Marshall, Washington)

8 Judson silty clay loam
Judson silt loam (Adams, Cass, Cedar, Iowa, Jasper, Polk, Shelby)

9 Marshall silty clay loam

10 Monona silt loam

11 Colo-Judson complex
Colo-Ely complex

12 Napier silt loam

13 Olmitz-Vesser-Colo complex
Nodaway-Vesser silt loam

14 Castana loam

17 Napier-Nodaway-Colo complex

18 McPaul-Kennebec silt loam

19 Kennebec-McPaul silt loam

20 Killduff silty clay loam

21 Muck, shallow

22 Dow silt loam

23 Arispe silty clay loam

24 Shelby loam
Shelby clay loam (Adair, Audubon, Dallas, Marshall, Mills, Monroe, Page, Union, Warren)
Shelby cobbley loam (Crawford)

25 Chute loamy fine sand (Woodbury)
Chute fine sandy loam (Crawford)

26 Kennebec silty clay loam

27 Terril loam

28 Dickman fine sandy loam
Dickman sandy loam (Carroll)

29 Clarion-Nicollet complex

30 Corley-Judson complex

31 Afton silty clay loam

32 Spicer silty clay loam

33 Steinauer clay loam
Steinauer loam (Fremont, Sac, Shelby)

34 Estherville sandy loam

35 Steinauer-Shelby complex

36 Salix silty clay loam

38 Blake-Haynie silt loam

40 Fayette silt loam, Karst (Clayton)

41 Sparta loamy fine sand
Sparta fine sandy loam (Crawford)
Sparta loamy sand (Lee)

42 Granby sandy loam

43 Bremer silty clay loam

44 Blencoe silty clay

46 Keg silt loam

48 Knoke mucky silt loam

49 Waubonsie fine sandy loam

51 Vesser silt loam

52 Bode clay loam

54 Zook silty clay loam

55 Nicollet loam
Nicollet clay loam (Clay, Pocahontas)

(Table 2-1 continued)

56 Cantril loam
Cantril silt loam (Polk)

57 Rushville silt loam

58 Douds loam

59 Burchard clay loam (Carroll)

60 Malvern silty clay loam

62 Storden loam

63 Chelsea loamy fine sand
Chelsea fine sand (Iowa)
Chelsea sand (Bremer)

64 Benclare silty clay loam

65 Lindley loam
Lindley silt loam (Dallas)
Lindley clay loam (Benton, Clinton, Delaware, Marion)

66 Luton silty clay
Luton clay (Woodbury)

67 Woodbury silty clay

68 Napa clay

69 Clearfield silty clay loam

70 McPaul silt loam

71 Dickman-Marshall complex
Sparta-Marshall complex

72 Estherville loam

73 Salida sandy loam
Salida gravelly coarse sandy loam (Hardin)
Salida gravelly sandy loam (Boone, Buena Vista, Clay, Dickinson, Franklin, Kossuth, Palo Alto)
Salida gravelly loam (Crawford)
Salida gravelly loamy sand (Sac, Dickinson)

74 Rubio silt loam

75 Givin silt loam

76 Ladoga silt loam
Ladoga silty clay loam (Dallas, Washington)

77 Sac silty clay loam

78 Sac silty clay loam, clay loam substratum (Buena Vista, Sac)

80 Clinton silt loam
Clinton silty clay loam (Dallas, Johnson, Monroe, Washington)

81 Clinton silt loam, bedrock substratum

83 Kenyon loam

84 Clyde silty clay loam
Clyde clay loam (Black Hawk, Bremer, Buchanan, Clayton, Delaware)
Clyde loam (Dubuque)
Clyde silt loam (Winneshiek)

86 Runnels silt loam

87 Colo-Zook complex

88 Nevin silty clay loam
Nevin silt loam (Adams, Johnson)

89 Sac silty clay loam, gray subsoil

90 Okoboji mucky silt loam

91 Primghar silty clay loam

92 Marcus silty clay loam

93 Shelby-Adair complex

94 Mystic-Caleb complex

95 Harps loam
Harps clay loam (Kossuth, Pocahontas, Webster)

96 Turlin loam
Turlin silt loam (Mitchell, Winneshiek)

97 Huntsville-Colo complex
Lawson-Huntsville silt loams

98 Huntsville silt loam

99 Exira silty clay loam

103 Gravity silty clay loam

104 Dodgeville silt loam, moderately deep, 20-30″ of loess over limestone bedrock

107 Webster silty clay loam
Webster clay loam (Greene, Pocahontas, Story)

(Table 2-1 continued)

108 Wadena loam, moderately deep

109 Backbone fine sandy loam
Backbone loamy sand (Bremer, Winneshiek)

110 Lamont fine sandy loam
Lamont sandy loam (Bremer, Winneshiek)

112 Strahan silt loam (Mills)

116 Graceville silt loam

117 Garwin-Sperry complex

118 Garwin silty clay loam

119 Muscatine silty clay loam
Muscatine silt loam (Cedar, Clinton, Delaware, Dubuque, Johnson, Polk)

120 Tama silty clay loam
Tama silt loam (Butler, Cedar, Clayton, Clinton, Delaware, Dubuque, Johnson, Polk)

121 Tama Variant silt loam

122 Sperry silt loam
Sperry silty clay loam (Clay, O'Brien)

127 Wiota silt loam, sandy substratum

129 Arenzville-Chaseburg silt loam

130 Belinda silt loam

131 Pershing silt loam

132 Weller silt loam

133 Colo silty clay loam

134 Zook silty clay

135 Coland silty clay loam (Grundy, Hardin, Johnson, Marshall, Mitchell, Worth)
Coland clay loam

136 Ankeny sandy loam
Ankeny fine sandy loam (Cass, Clayton, Story, Webster)

137 Haynie silt loam

138 Clarion loam

139 Perks loamy fine sand

140 Sparta Variant loamy fine sand

141 Watseka loamy fine sand
Watseka loamy sand (Pocahontas)

142 Chaseburg silt loam

143 Brady sandy loam (Clinton)
Brady silt loam (Cedar)

144 Blake silty clay loam

145 Onawa silt loam

146 Onawa silty clay

147 Modale silty clay loam

148 Winneshiek Variant loam, shaley subsoil

149 Modale silt loam

150 Hanska loam

151 Marshan clay loam, moderately deep

152 Marshan clay loam, deep
Marshan loam (Dubuque, Johnson)

153 Shandep clay loam, depressional (Butler, Cerro Gordo)
Shandep loam (Franklin)
Marshan silty clay loam, depressional (Delaware)

154 Ainsworth-Lamont complex

155 Albaton silty clay loam

156 Albaton silty clay

157 Albaton silt loam

158 Dorchester silt loam

159 Finchford loamy sand

160 Walford silt loam

161 Walford-Atterberry silt loam

162 Downs silt loam

163 Fayette silt loam
Fayette silty clay loam, eroded

164 Traer silt loam

(Table 2-1 continued)

165 Stronghurst silt loam

166 Bremer Variant silty clay loam

167 Ames loam
Ames silt loam (Boone)

168 Hayden loam

169 Clarion loam, long slopes (Worth)

170 Napier-Castana silt loam

171 Bassett loam
Bassett silt loam (Winneshiek)

172 Wabash silty clay

173 Hoopeston fine sandy loam
Hoopeston sandy loam (Des Moines, Lee)

174 Bolan loam

175 Dickinson fine sandy loam
Dickinson sandy loam (Washington)

176 Burkhardt sandy loam

177 Saude loam
Saude sandy loam (Howard)

178 Waukee loam
Waukee silt loam (Mitchell)

179 Gara loam
Gara silt loam (Marion)

180 Keomah silt loam

181 Clarion-Dickinson complex

183 Dubuque silt loam, moderately deep
Dubuque silty clay loam, moderately deep, eroded (Clayton)

184 Klinger silty clay loam
Klinger silt loam (Cedar, Clinton)

185 Bauer silt loam

188 Kensett loam (Cerro Gordo, Hardin)
Kensett silt loam (Mitchell, Worth)

189 Omadi silt loam

192 Adair clay loam
Adair loam (Henry, Wayne)
Adair silty clay loam (Washington)

193 Camden silt loam

195 Radford-Huntsville silt loam

196 Volney silt loam and loam
Volney channery silt loam (Clayton)

198 Floyd loam

201 Coland-Terril complex
Coland-Spillville complex

202 Cylinder loam, moderately deep
Cylinder clay loam, moderately deep (O'Brien, Pocahontas)

203 Cylinder loam, deep
Cylinder clay loam, deep (Pocahontas)
Cylinder silty clay loam, deep (O'Brien)

204 Dodgeville silt loam, deep

205 Whalan loam, moderately deep

207 Whalan loam, deep

208 Klum fine sandy loam

210 Boone loamy fine sand (Webster)
Boone fine sandy loam (Keokuk, Mahaska)

211 Edina silt loam

212 Kennebec silt loam

213 Rockton loam, deep

214 Rockton loam, moderately deep

215 Goss loam

216 Ripon silt loam, moderately deep

217 Ripon silt loam, deep

219 Jackson silt loam

220 Nodaway silt loam

221 Palms muck

222 Clarinda silty clay loam

(Table 2-1 continued)

223 Rinda silt loam (Des Moines, Lee)
Rinda silty clay loam, eroded
(Henry, Monroe, Wapello, Washington)

224 Linder loam
Linder sandy loam (Boone)

225 Lawler loam, moderately deep

226 Lawler loam, deep

230 Arispe-Clearfield silty clay loam

233 Corley silt loam

234 Nishna silty clay loam (Mills, Sac)
Nishna silty clay (Fremont)

235 Coland-Turlin complex

236 Lester loam

237 Sarpy loamy fine sand

238 Sarpy fine sandy loam

239 Lester-Colo complex

240 Storden-Colo complex, steep

241 Burkhardt-Saude complex

244 Blend silty clay

245 Blend silty clay loam

246 Curran silt loam

248 Wabash silty clay loam

249 Zwingle silt loam

250 Clarion silty clay loam

251 Nicollet silty clay loam

253 Farrar fine sandy loam

255 Cooper silty clay loam

256 Lester-Storden loam

258 Biscay clay loam, moderately deep
Biscay loam, moderately deep (Greene)

259 Biscay clay loam, deep
Biscay loam, deep (Carroll, Greene)

260 Beckwith silt loam

261 Appanoose silt loam

263 Okaw silt loam

264 Ainsworth silt loam

265 Bixby loam

267 Bixby Variant loam

268 Knox silt loam

269 Humeston silt loam
Humeston silty clay loam
(Union, Washington, Wayne)

270 Spillville loam, sandy substratum

273 Olmitz loam
Olmitz sandy loam (Polk)

274 Rolfe silt loam
Rolfe silty clay loam (Dickinson)
Rolfe loam (Humboldt, Polk, Sac, Story)

275 Moville silt loam

276 Ladoga-Hedrick complex

279 Taintor silty clay loam
Taintor silt loam (Marion, Monroe)

280 Mahaska silty clay loam

281 Otley silty clay loam

282 Ransom silty clay loam

284 Flagler sandy loam
Flagler fine sandy loam (Delaware, Mahaska)

285 Burkhardt sandy loam

286 Colo-Judson-Nodaway complex

287 Zook-Colo-Ely silty clay loam

288 Ottosen clay loam (Kossuth, Story)
Ottosen silty clay loam (Calhoun)

289 Colo silty clay loam, silty clay substratum

(Table 2-1 continued)

290 Dells silt loam

291 Atterberry silt loam

292 Dorchester silt loam, deep

293 Chelsea-Lamont-Fayette complex

294 Ladoga-Billett complex

295 Clinton-Lamont-Chelsea complex

297 Crocker loamy fine sand

299 Minden silty clay loam

302 Coggon loam

303 Pinicon loam (Mitchell)
Pinicon silt loam (Howard)

307 Dundas silt loam (Boone, Webster)
Dundas silty clay loam (Humboldt)

308 Wadena loam, deep

310 Galva silty clay loam

311 Galva silty clay loam, stratified substratum

312 Seymour silt loam
Seymour silty clay loam (Wayne)

313 Gosport silt loam

315 Klum-Perks-Nodaway complex

317 Galva-Wadena complex

318 Clanton silt loam

319 Dunbarton silt loam

320 Arenzville silt loam

321 Boots mucky peat

323 Terril loam, sandy substratum
Terril loam, sandy loam substratum (Delaware)

324 Dickman fine sandy loam, loam substratum

325 Le Sueur loam
Le Sueur silt loam (Hardin)

326 Dorchester silt loam, moderately shallow

329 Webster-Nicollet complex

330 Kingston silt loam
Kingston silty clay loam
(Dickinson, Kossuth, Pocahontas)

331 Madelia silty clay loam

332 Clarion loam, thin solum

333 Colo silty clay loam, silty clay substratum

335 Harcot loam

336 Orio fine sandy loam

338 Garmore silt loam (Humboldt)
Garmore loam (Pocahontas)

339 Truman silt loam

340 Sogn loam

341 Chute-Moody complex

343 Okoboji Variant silt loam

345 Plattville loam

348 Fieldon silty clay loam
Fieldon loam (Kossuth)

349 Darfur silty clay loam
Darfur loam (Kossuth)

350 Waukegan silt loam

351 Atterberry silt loam, sandy substratum

352 Whittier silt loam

353 Tell silt loam

355 Luther loam

356 Hayden-Storden complex

361 Dorchester-Sarpy complex

362 Haig silt loam

363 Haig silty clay loam

(Table 2-1 continued)

364 Grundy silty clay loam
Grundy silt loam (Henry, Lee)

366 Luton silty clay loam

368 Macksburg silty clay loam

369 Winterset silty clay loam

370 Sharpsburg silty clay loam
Sharpsburg silt loam (Polk)

371 Sharpsburg-Nira silty clay loam

373 Tallula silt loam (Franklin)
Tallula-Downs complex
Timula silt loam

374 Kensett Variant sandy loam, deep

377 Dinsdale silty clay loam
Dinsdale silt loam (Buchanan, Cedar, Clinton, Delaware)

380 Mahaska silt loam

381 Klinger-Maxfield silty clay loam

382 Maxfield silty clay loam

383 Marna silty clay loam
Marna silty clay (Clay)

384 Collinwood silty clay loam

385 Guckeen clay loam (Boone, Webster)
Guckeen silty clay loam (Clay, Greene)

386 Cordova silty clay loam (Webster)
Cordova clay loam (Story)
Cordova loam (Greene)

387 Kamrar clay loam

388 Kossuth silty clay loam

389 Waldorf silty clay loam, silty substratum (Kossuth)

390 Waldorf silty clay loam

391 Clyde-Floyd complex

393 Sparta loamy fine sand, till or loamy substratum

394 Ostrander loam

396 Letri silty clay loam (calcareous)

397 Letri silty clay loam

398 Tripoli silty clay loam (Butler, Cerro Gordo, Franklin, Linn, Mitchell)
Tripoli clay loam (Benton, Black Hawk, Bremer, Buchanan, Clay, Fayette)

399 Readlyn loam
Readlyn silty clay loam (Butler)

401 Crofton silt loam

403 Hayfield Variant loam

404 Thorp silt loam

406 Kennebec-Amana silt loam

407 Schley loam (Benton, Buchanan, Cerro Gordo, Clinton, Delaware, Fayette, Linn)
Schley silt loam (Butler, Franklin, Howard, Mitchell, Worth)

408 Olin fine sandy loam

409 Dickinson fine sandy loam, loamy substratum

410 Moody silty clay loam

411 Egan silty clay loam

412 Sogn loam

413 Sogn-Gosport-Clanton complex

414 Calmar clay loam

415 Montieth loamy sand (Guthrie)
Montieth sandy loam (Hardin)

416 Hesch sandy loam

417 Hesch loam

418 Hixton fine sandy loam

419 Vanmeter silt loam (Dallas)
Vanmeter silty clay loam (Monroe)

420 Tama silt loam, benches

422 Amana silt loam
Amana silty clay loam (Mahaska)

(Table 2-1 continued)

423 Bucknell silty clay loam

424 Lindley-Keswick complex

425 Keswick loam
Keswick silt loam (Washington)

426 Aredale loam
Aredale silt loam (Delaware)

427 Ladoga-Chelsea complex

428 Ely silty clay loam
Ely silt loam (Benton, Butler, Cedar, Clinton, Dubuque, Iowa, Johnson, Linn)

430 Ackmore silt loam
Ackmore silty clay loam (Adair, Lyon)

433 Storden clay loam

434 Arbor loam
Arbor silty clay loam (Adair)

435 Coland Variant clay loam (Winnebago)

436 Lakeport silty clay loam

437 Cooper loam

438 Carr fine sandy loam (Fremont)

439 Madelia silt loam

441 Sparta-Clarion complex

442 Dickinson-Sparta-Tama complex

443 Jacwin Variant loam, deep

444 Jacwin silty clay loam (Cerro Gordo, Howard)
Jacwin loam (Boone, Clayton, Fayette, Franklin, Webster, Winneshiek)

446 Burcham silt loam

447 Cott loam

448 Cott clay loam

449 Waubonsie silty clay loam

451 Caleb loam

452 Lineville silt loam
Lineville silty clay loam (Washington)

453 Tuskeego silt loam

455 Wilmonton clay loam

456 Wilmonton silty clay loam (Dickinson)

457 DuPage silt loam (Cerro Gordo, Hardin)
DuPage loam (Butler)

459 Spillville Variant-Hanlon complex, calcareous

462 Downs silt loam, benches

463 Fayette silt loam, benches

466 Solomon clay (Fremont)
Solomon silty clay (Harrison)

467 Radford silt loam
Radford silty clay loam (Plymouth)

468 Olin Variant sandy loam (Delaware)

470 Lamoni-Shelby complex

471 Oran loam
Oran silt loam (Cerro Gordo, Worth)

473 Gilford sandy loam

474 Bolan loam

478 Gosport-Rock outcrop complex
Nordness-Rock outcrop complex

480 Orwood silt loam

482 Racine loam (Howard, Winneshiek)
Racine silt loam (Mitchell)

483 Frankville silt loam, moderately deep

484 Lawson silt loam
Lawson silty clay loam (Marshall)

485 Spillville loam

486 Davis loam

487 Otter-Huntsville silt loam

488 Newvienna silt loam

489 Ossian silt loam

490 Caneek silt loam

(Table 2-1 continued)

491 Renova loam

495 Fayette-Renova-Roseville complex

496 Dorchester-Volney complex

497 Fayette-Dubuque-Jacwin complex

498 Lamont Variant sandy loam, dark, till substratum, 15-30 inches to till

499 Nordness silt loam
Nordness loam (Buchanan, Madison)

505 Sperry silt loam

506 Wacousta silt loam (Franklin, Hardin, Humboldt, Webster, Worth)
Wacousta silty clay loam (Clay, Calhoun, Kossuth, Palo Alto, Pocahontas, Sac, Story)
Wacousta mucky silt loam (Buena Vista)

507 Canisteo silty clay loam
Canisteo clay loam (Greene, Kossuth, Pocahontas, Story)

508 Calcousta silty clay loam

509 Marshall silty clay loam, benches

510 Monona silt loam, benches

511 Blue Earth mucky silt loam
Blue Earth mucky silty clay loam (Pocahontas)
Blue Earth silty clay loam (Sac)

512 Marlean loam
Marlean sandy loam (Dubuque)

513 Grable silty clay loam

514 Grable silt loam

515 Percival silty clay

516 Vore silty clay loam

520 Coppock silt loam

531 Kniffin silt loam

532 Rathbun silt loam

534 Carlow silty clay (Appanoose)
Carlow silty clay loam (Van Buren)

536 Hanlon fine sandy loam
Hanlon sandy loam (Mitchell)

538 Carr fine sandy loam (Woodbury)
Carr very fine sandy loam (Harrison)

539 Perks sandy loam (Johnson)

541 Estherville-Salida complex

549 Modale very fine sandy loam

551 Calamine silty clay loam
Calamine loam (Clayton)

552 Owego silty clay

553 Forney silty clay (Harrison)
Forney clay (Woodbury)

555 Percival Variant silty clay

558 Talcot clay loam, moderately deep

559 Talcot clay loam, deep
Talcot silty clay loam, deep (Carroll, Clay, Dickinson)

561 Rozetta silt loam

562 Fayette-Shale substratum
Rozetta-Eleroy silt loam

566 Moingona loam

570 Nira silty clay loam

571 Hedrick silt loam
Hedrick silty clay loam (Poweshiek, Washington)

572 Inton silt loam

573 Hoopeston loam (Louisa)

574 Bolan-Dickman-Ocheyedan complex

575 Dickinson-Ostrander complex

576 Dickinson-Racine complex

577 Everly clay loam

578 Waukee loam

581 Otley-Nira complex

(Table 2-1 continued)

583 Minnetonka silty clay loam

585 Coland-Spillville complex
Spillville-Colo complex

587 Chequest silty clay loam

589 Otter silt loam

591 Clyde-Floyd-Schley complex

592 Mystic silt loam
Mystic clay loam (Poweshiek)
Mystic loam (Madison)

594 Galland loam

595 Harpster silty clay loam

599 Nordness-Shale complex

606 Lanyon silty clay (Webster)
Lanyon silty clay loam (Buena Vista, Sac)

607 Salix Variant silty clay loam

608 Dempster silt loam, moderately deep

609 Omadi-Alluvial land complex

610 Lamont-Renova complex

611 Rossfield Variant silty clay loam

612 Mottland loam
Mottland silt loam (Clayton)

613 Rossfield loam

614 Jacwin Variant loam

615 Colo-Spillville complex, channeled

620 Port Byron silt loam

621 Houghton muck

636 Buckney fine sandy loam

638 Clarion-Storden loam

639 Storden-Salida complex

651 Faxon silty clay loam (Cerro Gordo, Worth)
Faxon silt loam (Pocahontas)

653 Tuskeego silt loam, sandy substratum (Louisa)

654 Corwith loam

655 Crippin loam

658 Mayer loam, moderately deep

659 Mayer loam, deep

662 Mt. Carroll silt loam

663 Seaton silt loam

670 Rawles silt loam

675 Dickinson-Sharpsburg complex

683 Liscomb loam (Marshall)

684 Elrick sandy loam

687 Watkins silt loam

688 Koszta silt loam

692 Mayberry clay loam

695 Tilfer silty clay loam

696 Tilfer loam

705 Downs Variant silt loam (Hardin)

706 Cerlin silt loam

708 Fairhaven silt loam, 24-32" to sand/gravel

709 Fairhaven silt loam, 32-40" to sand/gravel

710 Wentworth silty clay loam

712 Schapville silt loam

713 Winneshiek loam, deep

714 Winneshiek loam, moderately deep

715 Nodaway-Perks complex

717 Napier-Gullied land complex

720 Racoon silt loam

725 Hayfield loam, moderately deep

(Table 2-1 continued)

726 Hayfield loam, deep

727 Udolpho loam, deep

728 Udolpho loam, moderately deep

729 Ackmore-Nodaway silt loam
Nodaway-Martinsburg silt loam

730 Nodaway-Cantril complex

731 Pershing silty clay loam

732 Weller silty clay loam

733 Calco silty clay loam

734 Holly Springs silty clay loam

735 Havelock clay loam

736 Lester loam, long slopes (Dallas)

739 Steinauer-Salida complex (Cherokee)

742 Martinsburg silt loam

744 Revere silty clay loam

751 Northboro silt loam (Page)
Northboro silty clay loam (Page)

752 Lineville Variant silt loam, dark

755 Nicollet loam, long slopes

759 Fruitfield sand

760 Ansgar silt loam

761 Franklin silt loam

763 Exette silt loam

764 Grundy silty clay loam, benches
Grundy silt loam, benches (Henry, Van Buren)

771 Waubeek silt loam

772 Donnan Variant loam

775 Billett fine sandy loam

776 Lilah sandy loam

777 Wapsie loam

778 Sattre loam
Sattre silt loam (Johnson, Mitchell)

779 Kalona silty clay loam

781 Lourdes loam

782 Donnan loam
Donnan silt loam (Benton, Franklin, Mitchell, Worth)

783 Cresco loam

784 Riceville loam
Riceville silt loam (Clayton, Mitchell)

785 Spillco loam

787 Vinje silty clay loam

791 Primghar Variant silty clay loam, calcareous

792 Armstrong loam
Armstrong clay loam (Henry)

793 Bertrand silt loam

795 Ashgrove silt loam
Ashgrove silty clay loam (Des Moines, Henry, Wapello)

797 Jameston silty clay loam

798 Protivin loam
Protivin clay loam (Butler)

804 Ashdale silt loam

805 Roseville loam

807 Schley Variant sandy loam

808 Dempster silt loam

809 Bertram sandy loam
Bertram fine sandy loam (Black Hawk, Buchanan, Delaware)

810 Galva silty clay loam, benches

811 Muskego muck (Winnebago)

812 Moody silty clay loam, benches

813 Atkinson loam

(Table 2-1 continued)

814 Rockton loam, 20-40" to limestone

815 Dorchester silt loam, frequently flooded

820 Dockery silt loam

821 Dockery silty clay loam

822 Lamoni silty clay loam
Lamoni clay loam (Madison, Monroe)
Lamoni clay (Adair)

823 Ridgeport sandy loam

826 Rowley silt loam

827 Zenor-Estherville complex

828 Zenor sandy loam

829 Zenor-Storden complex

831 Pershing silty clay loam, benches

832 Weller silty clay loam, benches

834 Titus silty clay loam

836 Kilkenny silty clay loam (Worth)
Kilkenny clay loam (Cerro Gordo)

844 Blake silt loam

845 Colo silt loam, calcareous overwash

849 Kenmoor fine sand (Harrison)
Kenmoor loamy fine sand (Mills)

850 Blend silty clay loam, overwash

851 Forney silty clay loam, calcareous overwash

852 Owego silt loam, calcareous overwash

855 Shorewood silty clay loam

863 Fayette silt loam, Karst (Clayton)

864 Grundy Variant silty clay loam

865 Salix silty clay loam, overwash

866 Luton silty clay, thin surface

870 Sharpsburg silty clay loam, benches

876 Ladoga silt loam, benches

878 Ocheyedan loam

879 Fostoria loam (Clay, Dickinson, Kossuth)
Fostoria clay loam (Clay)

880 Clinton silt loam, benches

881 Otley silty clay loam, benches

882 Palsgrove silt loam

883 Cresken clay loam

887 McPaul-Kennebec silt loam

888 Terril-Castana complex

890 Moody silty clay loam, loam substratum

892 Mystic Variant silty clay loam

893 Gara-Rinda complex

895 Lemond loam

896 McPaul-Albaton-Blake complex

897 Solomon-Luton silt loam, calcareous overwash

899 Davis silt loam

902 Luana silt loam (Clayton)

904 Nasset silt loam

907 Schley loam, sandy substratum (Delaware)

910 Trent silt loam

913 Waucoma silt loam (Mitchell)
Waucoma loam (Winneshiek)

914 Winneshiek loam

915 Rollingstone silt loam

916 Downs silt loam, sandy substratum (Muscatine)

917 Fayette silt loam, sandy substratum (Muscatine)

918 Garwin silty clay loam, sandy substratum

919 Muscatine silt loam, sandy substratum

(Table 2-1 continued)

920 Tama silt loam, sandy substratum

923 Coyne fine sandy loam

924 Burchard-Adair clay loam

925 Toolesboro loam

926 Canoe silt loam

930 Orion silt loam

933 Sawmill silty clay loam

936 Coland-Hanlon complex
Coland-Spillville-Hanlon complex

942 Colo-Alluvial land complex, channeled

943 Spillville-Colo complex, channeled

945 Albaton clay, depressional

949 Zwingle Variant silty clay (Clinton)

950 Niota silty clay loam
Niota Variant silty clay loam (Des Moines)

951 Medary silt loam (Clinton)
Medary Variant silt loam (Clayton)

952 Denrock Variant silt loam

954 Darwin silty clay

955 McPaul silt loam, frequently flooded

956 Okoboji-Harps complex

958 Spillville loam, frequently flooded

960 Shaffton loam

961 Ambraw silty clay loam (Clinton)
Ambraw loam (Des Moines)

962 Elvira silty clay loam

963 Elvers silt loam

964 Fayette-Rock outcrop complex

974 Bolan loam, loamy substratum (Johnson)

976 Raddle silt loam (Butler)

977 Richwood silt loam

978 Festina silt loam

980 Gullied land-Ely-Colo complex
Gullied land-Judson complex

981 Worthen silt loam

983 Castana-gullied land complex

993 Gara-Armstrong loam

994 Galland-Douds clay loam

998 Jameston-Provitin complex

1005 Ackmore-Kennebec complex, channeled

1013 Vesser-Humeston-Ackmore complex (Davis)

1032 Spicer silty clay loam

1043 Bremer silty clay loam, sandy substratum

1048 Knoke mucky silt loam, ponded
Knoke mucky silty clay loam, ponded (Greene)

1057 Rushville silt loam, benches

1058 Douds-Lindley complex (Louisa)

1063 Chelsea-Douds complex (Louisa)

1074 Rubio silt loam, benches

1075 Givin silt loam, benches

1088 Nevin silty clay loam, sandy substratum

1096 Turlin loam, channeled

1118 Garwin silty clay loam, benches

1119 Muscatine silty clay loam, benches
Muscatine silt loam (Johnson)

1122 Sperry silt loam, benches

1130 Belinda silt loam, benches

1131 Pershing silt loam, benches

1132 Weller silt loam, benches

1133 Colo silty clay loam, channeled

(Table 2-1 continued)

1134 Zook silty clay loam, channeled

1135 Coland clay loam, channeled
Coland silty clay loam, channeled (Greene)

1142 Chaseburg silt loam, channeled

1158 Dorchester silt loam, channeled

1160 Walford silt loam, benches

1164 Traer silt loam, benches

1165 Stronghurst silt loam, benches

1173 Hoopeston Variant sandy loam (Franklin)

1178 Waukee Variant loam (Story)

1180 Keomah silt loam, benches

1181 Keomah silt loam, bedrock substratum

1202 Cylinder Variant loam, moderately deep (Dickinson)

1203 Cylinder Variant loam, deep

1212 Kennebec silt loam, channeled

1219 Canoe Variant silt loam

1220 Nodaway silt loam, channeled

1221 Palms muck, undrained (Dickinson)

1233 Corley silt loam, benches

1235 Coland-Turlin complex, channeled

1259 Biscay Variant clay loam, deep (Boone)

1260 Beckwith silt loam, benches

1273 Olmitz Variant loam (Des Moines)

1279 Taintor silty clay loam, benches
Taintor silt loam, benches (Monroe)

1280 Mahaska silty clay loam, benches

1291 Atterberry silt loam, benches

1299 Minden silty clay loam, benches

1308 Wadena Variant loam, deep (Boone, Greene)

1314 Hanlon-Spillville complex, channeled

1315 Klum-Perks-Nodaway complex, channeled
Spillville-Landes complex

1320 Arenzville silt loam, channeled

1362 Haig silty clay loam, benches
Haig silt loam, benches (Henry)

1368 Macksburg silty clay loam, benches

1369 Winterset silty clay loam, benches

1384 Collinwood Variant silty clay loam (Dickinson)

1422 Amana silt loam, channeled

1430 Ackmore silt loam, channeled

1458 Millington loam, channeled

1467 Radford silt loam, channeled

1484 Lawson silt loam, channeled

1485 Spillville loam, channeled
Spillville-loamy fluvents complex, channeled

1490 Caneek silt loam, channeled

1507 Brownton silty clay loam

1511 Blue Earth muck, ponded

1536 Hanlon fine sandy loam, channeled

1585 Spillville-Coland complex, channeled

1587 Dolbee silt loam

1589 Otter silt loam, channeled

1595 Harpster silt loam

1636 Buckney fine sandy loam, channeled

1658 Terril-Colo complex, channeled

1688 Koszta silt loam, sandy substratum

1735 Havelock clay loam, channeled (Pocahontas)

1777 Wapsie Variant loam

1779 Kalona silty clay loam, benches

(Table 2-1 continued)

1785 Spillco loam, channeled

1826 Snider loam

1936 Coland-Hanlon complex, channeled
Coland-Spillville-Hanlon complex, channeled

1950 Niota Variant silty clay loam

1954 Darwin silty clay, channeled

1977 Richwood Variant loam

2075 Nira-Givin complex

2090 Okoboji mucky silt loam, sandy substratum

2108 Wadena Variant loam, moderately deep (Calhoun)

2208 Klum fine sandy loam, calcareous (Des Moines)

2225 Blue Earth muck, sandy loam substratum (Hancock)

2226 Elrin loam

2484 Lawson silt loam, frequently flooded

2485 Spillville-Buckney complex

2636 Hanlon-Ackmore complex, channeled (Muscatine)

2826 Rowley-Lawson silt loam overwash

2636 Hanlon-Ackmore complex, channeled (Muscatine)

2826 Rowley-Lawson silt loam overwash

4001 Ida-Urban land complex

4010 Monona-Urban land complex

4011 Colo-Ely-Urban land complex

4012 Napier-Urban land complex

4041 Sparta-Dickinson-Urban land complex

4043 Bremer-Marshan-Urban land complex

4046 Keg-Urban land complex

4055 Nicollet-Urban land complex

4083 Kenyon-Clyde-Urban land complex

4107 Webster-Urban land complex

4110 Lamont-Urban land complex

4119 Muscatine-Urban land complex

4120 Tama-Urban land complex

4133 Colo-Urban land complex

4138 Clarion-Urban land complex

4156 Albaton-Urban land complex

4158 Dorchester-Urban land complex

4159 Finchford-Flagler-Urban land complex

4163 Fayette-Urban land complex

4170 Castana-Urban land complex

4171 Bassett-Chelsea-Urban land complex

4177 Saude-Lawler-Urban land complex

4237 Sarpy-Urban land complex

4255 Cooper-Urban land complex

4446 Burcham-Urban land complex

4507 Canisteo-Urban land complex

Table 2-2. Drainage guidelines for Iowa soils.

Soil name	Natural soil drainage[1]	Tile spacing, ft.[2] 36″ depth	48″ depth	Remarks
Ackmore	Somewhat poor and poor	80-90	100-110	Common flooding. May need protection.
Adair	Moderately well and somewhat poor	30-40	50-60	Wetness usually due to seepage. Use interceptor tile at loess-till contact. May need erosion control measures.
Afton	Poor	70-80	80-100	Common flooding. May need protection.
Ainsworth	Moderately well			Drainage not needed. May need erosion control measures.
Albaton	Poor			Tile outlets rarely available. Some areas may flood. Use surface drains. Land grading generally required.
Albaton (depressional)	Very poor			Frequent flooding. Tile not recommended. Use random field ditches.
Amana	Somewhat poor	80-90	90-110	Common flooding. May need protection.
Ambraw	Poor	80-90	90-110	Frequent flooding. May need protection. Tile outlets rarely available. May need filter or envelope on tile. Use surface drains.
Ames	Poor	50-70		Tile may not be satisfactory. Use surface drains and tile if depressional.
Ankeny	Well			Drainage not needed. May need erosion control measures.
Ansgar	Poor	70-80	90-100	May need interceptor tile for seepage or supplemental surface drains.
Appanoose	Poor			Tile not recommended. Use surface drains.
Arbor	Well and moderately well			Drainage not needed. May need erosion control measures.
Aredale	Well			Drainage not needed. May need erosion control measures. Channel tile may be needed for terraces.
Arenzville	Well			Frequent flooding. May need protection. Drainage not needed.

[1]Natural soil drainage refers to degree of natural soil drainage prior to artificial drainage.
[2]Drain spacing recommendations are for field slopes less than 5%.

(Table 2-2. continued)

Soil name	Natural soil drainage[1]	Tile spacing, ft.[2] 36″ depth	Tile spacing, ft.[2] 48″ depth	Remarks
Arispe	Moderately well and somewhat poor			Drainage not needed. May need erosion control measures.
Armstrong	Moderately well and somewhat poor	30-40	50-60	Wetness usually due to seepage. Use interceptor tile at loess-till contact. May need erosion control measures.
Ashdale	Well			Drainage not needed. Bedrock at 4-5 ft. May need erosion control measures.
Ashgrove	Poor and somewhat poor			Tile not recommended. May need interceptor tile at loess-till contact. May need erosion control measures. Drainage not needed. May need erosion control measures.
Atkinson	Well			Drainage not needed. May need erosion control measures.
Atterberry	Somewhat poor	70-90	90-110	Tile may help in timely field operations. May need erosion control measures.
Backbone	Well			Drainage not needed. Bedrock at 2-3 ft. May need erosion control measures.
Bassett	Moderately well	60-80	80-90	Tile may help in timely field operations. May need erosion control measures. Channel tile may be needed for terraces.
Bauer	Moderately well			Drainage not needed. May need erosion control measures.
Beckwith	Poor			Tile not recommended. Use surface drains.
Belinda	Poor			Tile not recommended. Use surface drains.
Benclare	Moderately well			Occasional flooding. May need protection. Drainage not needed.
Bertram	Well to somewhat excessive			Drainage not needed. Bedrock at 2-3 ft. May need erosion control measures.
Bertrand	Well			Drainage not needed. May need erosion control measures.
Billett	Well			Drainage not needed. May need erosion control measures.
Biscay	Poor	70-90	80-110	Sandy substratum. May need filter or envelope on tile. If continuous, coarse sand layers are present, spacing may be 200-300 ft.

Bixby	Well			Drainage not needed. May need erosion control measures.
Blake	Somewhat poor	100-120	130-150	Occasional flooding. May need protection. Tile outlets rarely available. Use surface drains. Land grading generally required.
Blencoe	Somewhat poor	80-90	100-110	Some areas may flood. Tile outlets rarely available. Use surface drains. Land grading generally required.
Blend	Poor			Tile not recommended. Use surface drains.
Blue Earth	Very poor	50-70	70-90	Surface intakes to tile are desirable. Diversions and surface drains may be needed.
Bode	Well			Drainage not needed. May need erosion control measures.
Bolan	Well			Drainage not needed. May need erosion control measures.
Boone	Excessive			Drainage not needed. Bedrock at 3-4 ft. May need erosion control measures.
Boots	Very poor	140-150	180-200	Depressional topography. May need surface intakes to tile, pumping, or protection from runoff.
Brady	Somewhat poor	100	100	Wet in spring. Droughty in summer. May need water control structures. Filter or envelope may be needed for tile. May need erosion control measures.
Bremer	Poor	67-75	90-100	Occasional flooding. May need protection.
Bucknell	Somewhat poor	20-30	30-40	Wetness due to seepage. Use interceptor tile. Relief tile should supplement a good surface drainage system.
Buckney	Well			Occasional flooding. May need protection. Drainage not needed.
Burcham	Moderately well	40-50	50-60	Some areas may flood. Drainage not needed. May need diversions.
Burchard	Well			Drainage not needed. May need erosion control measures.
Burkhardt	Somewhat excessive to excessive			Drainage not needed. May need erosion control measures.
Calamine	Poor to very poor			Tile usually not satisfactory. Bedrock at 4-5 ft. Use random surface drains. Land grading may be helpful. May need erosion control measures.

[1]Natural soil drainage refers to degree of natural soil drainage prior to artificial drainage.
[2]Drain spacing recommendations are for field slopes less than 5%.

(Table 2-2. continued)

Soil name	Natural soil drainage[1]	Tile spacing, ft.[2] 36″ depth	48″ depth	Remarks
Calco	Poor	65-85	80-110	Common flooding. May need protection.
Calcousta	Very poor	80-90	90-110	Use surface intakes to tile in depressions.
Caleb	Moderately well			Drainage not needed. May need erosion control measures.
Calmar	Moderately well to well			Drainage not needed. May need erosion control measures.
Camden	Well			Drainage not needed. May need erosion control measures.
Caneek	Somewhat poor to poor	70-90	90-110	Frequent flooding. May need protection.
Canisteo	Poor	70-80	90-100	May need diversions, random surface drains, and surface intakes to tile.
Canoe	Somewhat poor	70-90	90-110	May need diversions or interceptor tile.
Cantril	Somewhat poor	80-90	100-110	May need diversions or interceptor tile. May need erosion control measures.
Carlow	Poor to very poor			Common flooding. May need protection. Tile not recommended. Use surface drains.
Carr	Well to moderately well			Occasional flooding. May need protection. Drainage not needed.
Castana	Well			Drainage not needed. May need erosion control measures.
Cerlin	Moderately well to somewhat poor	25-35	25-35	Tile may not be satisfactory. May need diversions or interceptor tile. May need erosion control measures.
Chaseburg	Well to moderately well	70-90	90-110	Common flooding. May need protection. Use interceptor tile for seepage. May need erosion control measures.
Chelsea	Excessive			Drainage not needed. May need erosion control measures.

Chequest	Poor	40-50	50-60	Common flooding. May need protection.
Chute	Excessive			Drainage not needed. May need erosion control measures.
Clanton	Moderately well			Drainage not needed. May need erosion control measures.
Clarinda	Poor			Wetness usually due to seepage. Use interceptor tile. May need erosion control measures.
Clarion	Well			Drainage not needed. May need erosion control measures.
Clearfield	Poor to somewhat poor	50-60	70-80	Wetness usually due to seepage. Use interceptor tile at loess-till contact. May need erosion control measures.
Clinton	Moderately well			Drainage not needed. May need erosion control measures. May need interceptor tile at loess-till contact.
Clyde	Poor to very poor	60-80	70-100	Usually seepy. Interceptor tile may be useful in some areas.
Coggon	Moderately well			Drainage generally not needed but interceptor tile may be beneficial. May need erosion control measures.
Coland	Poor	70-90	80-110	Common flooding. May need protection. May need erosion control measures.
Collinwood	Moderately well to somewhat poor	30-40	40-60	Tile may help in timely field operations. May need diversions or interceptor tile. May need erosion control measures.
Colo	Poor	60-85	70-100	Common flooding. May need protection.
Cooper	Somewhat poor	30-40	40-50	Many areas do not need drainage. Silty clay substratum below 30 inches. Place tile on or above silty clay substratum. Tile outlets rarely available.
Coppock	Somewhat poor to poor	70-80	80-90	Common flooding. May need protection.
Cordova	Poor	70-80	90-100	May need diversions, interceptor tile, or supplemental surface drains.
Corley	Poor	80-90	100-110	Use surface drains and tile if depressional.

[1]Natural soil drainage refers to degree of natural soil drainage prior to artificial drainage.
[2]Drain spacing recommendations are for field slopes less than 5%.

(Table 2-2. continued)

Soil name	Natural soil drainage[1]	Tile spacing, ft.[2]		Remarks
		36″ depth	48″ depth	
Corwith	Somewhat poor	80-90	90-110	May need diversions or interceptor tile.
Cott	Moderately well			Drainage not needed. Rare flooding. May need protection.
Coyne	Well			Drainage not needed. May need erosion control measures.
Cresco	Moderately well	50-70	60-80	Tile may help in timely field operations. Tile may be needed for hillside seepage. May need erosion control measures.
Crippin	Somewhat poor	70-80	90-100	Most areas do not need tile.
Crocker	Well			Drainage not needed. May need erosion control measures.
Crofton	Well to excessive			Drainage not needed. May need erosion control measures.
Curran	Somewhat poor	90-100	100-120	Occasional flooding. May need protection. Sandy substratum. May need filter or envelope on tile. If continuous sand layers are present, spacing may be 200-300 ft. Highly corrosive to concrete.
Cylinder	Somewhat poor	80-90	100-110	Some areas may not need tile. Sandy substratum. If continuous coarse sand layers are present, spacing may be 200-300 ft. May need filter or envelope on tile.
Darfur	Poor	140-160	180-200	Some areas may not need tile. May need diversions or interceptor tile.
Darwin Variant	Poor to very poor			Frequent flooding. May need protection. Tile not recommended. Use surface drains. Bedrock at 1-2 ft.
Darwin	Poor to very poor			Tile not recommended. Use surface drains. Bedrock at 3-4 ft.
Davis	Well to moderately well			Occasional flooding. May need protection. Tile may help in timely field operations. May need erosion control measures.
Dells	Somewhat poor	90-100	100-120	Tile may help in timely field operations. May need diversions or surface drains. Sandy substratum. May need filter or envelope on tile.
Dempster	Well			Drainage not needed. May need erosion control measures.

Denrock	Somewhat poor			Tile outlets rarely available. Use surface drains. Occasional flooding. May need protection.
Dickinson	Well to somewhat excessive			Drainage generally not needed. Occasional seepy areas may need interceptor tile. May need erosion control measures.
Dickman	Well			Drainage not needed. May need erosion control measures.
Dinsdale	Well to moderately well			Drainage not needed. May need erosion control measures.
Dockery	Somewhat poor	80-90	90-100	Occasional flooding. May need protection. Tile outlets rarely available. Tile may help in timely field operations.
Dodgeville	Well			Drainage not needed. May need erosion control measures. Bedrock at 3-4 ft.
Dolbee	Poor	80-90	100-110	Common flooding. May need protection.
Donnan	Somewhat poor to moderately well	20-30	40-60	Tile may not be satisfactory. Wetness usually due to seepage. Use interceptor tile. May need erosion control measures.
Dorchester	Well to moderately well	70-90	90-110	Rare to frequent flooding. May need protection. Tile may help in timely field operations.
Douds	Moderately well			Drainage not needed. May need erosion control measures.
Dow	Well			Drainage not needed. May need erosion control measures.
Downs	Well	70-90	90-110	Tile may help in timely field operations. May need interceptor tile for seepage. May need erosion control measures.
Downs Variant	Moderately well	70-90	90-110	Tile may help in timely field operations. May need interceptor tile for seepage. May need erosion control measures.
DuPage	Moderately well			Occasional flooding. May need protection.
Dubuque	Well			Drainage not needed. Bedrock at 2-3 ft. May need erosion control measures.
Dunbarton	Well			Drainage not needed. Bedrock at 1-2 ft. May need erosion control measures.

[1]Natural soil drainage refers to degree of natural soil drainage prior to artificial drainage.
[2]Drain spacing recommendations are for field slopes less than 5%.

(Table 2-2. continued)

Soil name	Natural soil drainage[1]	Tile spacing, ft.[2] 36″ depth	48″ depth	Remarks
Dundas	Poor to somewhat poor	60-70	80-90	May need diversions or surface intakes to tile.
Edina	Poor	20-30	40-50	Use surface drains. Tile should supplement a good surface drainage system. Tile may not be satisfactory.
Egan	Well			Drainage not needed. May need erosion control measures.
Eleroy	Moderately well	50-60	70-80	Wetness due to seepage. Use interceptor tile at loess-shale contact. May need erosion control measures.
Elrin	Somewhat poor			Drainage not needed.
Elvers	Poor to very poor	100-110	120-130	Frequent flooding. May need protection. Tile outlets may not be available. May need filter or envelope on tile.
Elvira	Poor	140-160	300-320	Frequent flooding. May need protection. Tile outlets may not be available. May need filter or envelope on tile.
Ely	Somewhat poor	60-85	70-100	May need diversions or interceptor tile. May need erosion control measures.
Estherville	Well to somewhat excessive			Drainage not needed. May need erosion control measures.
Everly	Well to moderately well			Drainage not needed. May need erosion control measures.
Exette	Well			Drainage generally not needed. May need interceptor tile for seepage. May need erosion control measures.
Exira	Well			Drainage not needed. May need erosion control measures.
Fairhaven	Well			Drainage not needed. May need erosion control measures.
Farrar	Well			Drainage not needed. May need erosion control measures.
Faxon	Poor to very poor	30-40		Occasional flooding. May need protection. Bedrock at 2-3 ft.

Fayette	Well			Drainage generally not needed. May need interceptor tile for seepage. May need erosion control measures.
Festina	Well			Drainage not needed. May need erosion control measures.
Fieldon	Poor	290-310	340-350	Tile may help in timely field operations. May need filter or envelope on tile.
Finchford	Excessive			Drainage not needed. May need erosion control measures.
Flagler	Excessive			Drainage not needed. May need erosion control measures.
Floyd	Somewhat poor	60-90	70-100	May need diversions or interceptor tile.
Forney	Poor			Common flooding. May need protection. Tile not recommended. Use surface drains. May need diversions.
Fostoria	Somewhat poor	80-90	100-110	May need diversions or interceptor tile.
Franklin	Somewhat poor	70-80	80-100	Tile may not be needed in some areas. May need diversions or interceptor tile. May need erosion control measures.
Frankville	Well			Drainage not needed. Bedrock at 2-3 ft. May need erosion control measures.
Galland	Moderately well			May need diversions or interceptor tile. May need erosion control measures.
Galva	Well			Drainage not needed. May need erosion control measures.
Gara	Moderately well to well			Drainage not needed. May need erosion control measures.
Garmore	Moderately well			Drainage not needed.
Garwin	Poor	60-80	80-100	
Givin	Somewhat poor	50-70	60-80	Some areas do not need tile. May need erosion control measures.
Gosport	Moderately well			Tile may not be satisfactory. Wetness usually due to seepage. Use interceptor tile. May need erosion control measures.
Goss	Well			Drainage not needed. May need erosion control measures.

[1]Natural soil drainage refers to degree of natural soil drainage prior to artificial drainage.
[2]Drain spacing recommendations are for field slopes less than 5%.

(Table 2-2. continued)

Soil name	Natural soil drainage[1]	Tile spacing, ft.[2] 36″ depth	Tile spacing, ft.[2] 48″ depth	Remarks
Grable	Well to somewhat excessive			Common flooding. May need protection. Drainage not needed.
Graceville	Well			Drainage not needed.
Granby	Poor to very poor			Tiling not generally recommended. Use surface drains for low areas.
Grundy	Somewhat poor	40-50	50-60	Most areas do not need tile. Tile should supplement a good surface drainage system. May need erosion control measures.
Guckeen	Moderately well to somewhat poor	60-70	80-90	Some areas may not need drainage. May need erosion control measures.
Haig	Poor	40-50	50-60	Tile may not be satisfactory. Tile outlets may not be available. May need surface drains.
Hamburg	Somewhat excessive			Drainage not needed. May need erosion control measures.
Hanlon	Moderately well			Common flooding. May need protection. Drainage not needed.
Hanska	Poor	260-280	280-300	Waterbearing sands make tile placement difficult. May need filter or envelope on tile. May need diversions and surface drains.
Harcot	Poor	340-360	420-440	Waterbearing sands make tile placement difficult. May need filter or envelope on tile. May need diversions.
Harps	Poor	70-80	80-100	
Harpster	Poor	70-80	80-90	
Havelock	Poor	80-90	90-110	Common flooding. May need protection.
Hayden	Well			Drainage not needed. May need erosion control measures.
Hayfield	Moderately well to somewhat poor		80-100	Some areas do not need tile. Sandy substratum. May need filter or envelope on tile.

Haynie	Well to moderately well			Common flooding. May need protection. May need erosion control measures.
Hedrick	Moderately well			Drainage not needed. May need erosion control measures.
Hesch	Well			Drainage not needed. May need erosion control measures.
Hixton	Well			Drainage not needed. Bedrock at 3-4 ft. May need erosion control measures.
Holly Springs	Poor to very poor			Common flooding. May need protection. Tile outlets rarely available.
Hoopeston	Somewhat poor			Drainage not normally needed. Sandy substratum. May need filter or envelope for tile.
Houghton	Very poor	60-80	80-110	Frequent ponding. High organic matter makes tile difficult to maintain. May have iron ochre problems. Water level needs to be maintained to prevent subsidence.
Humeston	Poor to very poor	20-30	30-40	Common flooding. May need protection. Tile may not be satisfactory. Tile should supplement a good surface drainage system. May need surface intakes.
Huntsville	Well			Common flooding. May need protection. Drainage not needed. May need erosion control measures.
Ida	Well			Drainage not needed. May need erosion control measures.
Inton	Moderately well			Drainage not needed. May need erosion control measures.
Jackson	Moderately well	60-80	80-100	Most areas do not need tile. May need erosion control measures.
Jacwin	Somewhat poor	20-30		Bedrock at 3-4 ft. May need diversions or interceptor drains. May need erosion control measures.
Jameston	Poor	50-60	60-70	Tile may not be satisfactory. Tile should supplement a good surface drainage system.
Judson	Well to moderately well			Most areas do not need tile. May need interceptor tile for seepage. May need erosion control measures.

[1]Natural soil drainage refers to degree of natural soil drainage prior to artificial drainage.
[2]Drain spacing recommendations are for field slopes less than 5%.

(Table 2-2. continued)

Soil name	Natural soil drainage[1]	Tile spacing, ft.[2] 36″ depth	48″ depth	Remarks
Kalona	Poor	60-80	80-100	
Kamrar	Moderately well			Drainage not needed. May need erosion control measures.
Kato	Poor	260-280	340-360	Waterbearing sands make tile placement difficult. May need filter or envelope on tile.
Keg	Well to moderately well		80-100	Tile generally not needed. May need surface drainage.
Kenmoor	Moderately well			Occasional flooding. May need protection. Tile outlets rarely available. Use surface drains.
Kennebec	Moderately well			Common flooding. May need protection. Drainage not needed. May need erosion control measures.
Kensett	Somewhat poor	40-50		Occasional flooding. May need protection. Bedrock at 3-4 ft.
Kenyon	Moderately well to well	60-80	80-90	Tile may help in timely field operations. Most areas do not need tile. May need erosion control measures. Channel tile may be needed for terraces.
Keomah	Somewhat poor	60-70	80-90	Some areas do not need tile. May need erosion control measures.
Keomah Bedrock Substratum	Somewhat poor	60-70	80-90	Bedrock at 5-6 ft. Some areas do not need tile. May need erosion control measures.
Keswick	Moderately well	30-40	50-60	Wetness usually due to seepage. Use interceptor tile at loess-till contact. May need erosion control measures.
Kilkenny	Well			Drainage not needed. May need erosion control measures.
Killduff	Well to moderately well			Drainage not needed. May need erosion control measures.
Kingston	Moderately well to somewhat poor	70-80	90-100	May need diversions. Many areas may not need tile. May need erosion control measures.

Klinger	Somewhat poor	70-80	80-100	Many areas do not need tile. May need erosion control measures.
Klum	Moderately well			Frequent flooding. May need protection. Drainage not needed.
Kniffin	Somewhat poor			Tile not recommended. May need erosion control measures.
Knoke	Very poor	50-60	70-80	Depressional. Ponded areas may need surface intakes to tile or surface drains.
Knox	Well			Drainage not needed. May need erosion control measures.
Kossuth	Poor	70-80	90-100	May need surface drains.
Koszta	Somewhat poor	80-90	100-110	Some areas do not need tile. May need diversions.
Ladoga	Moderately well			Most areas do not need tile. May need erosion control measures.
Lakeport	Somewhat poor	80-90	100-110	Tile outlets rarely available. May need diversions.
Lamoni	Somewhat poor	20-30	30-40	Wetness may be due to seepage. Use interceptor tile. May need erosion control measures.
Lamont	Well			Drainage not needed. May need erosion control measures.
Landes	Well to moderately well			Drainage not needed. May need erosion control measures.
Lanyon	Very poor	40-50	70-80	Frequent flooding. May need protection
Lawler	Somewhat poor	70-90	80-100	Some areas may not need tile. Sandy substratum. If continuous coarse sand layers are present, spacing may be 200-300 ft. May need filter or envelope on tile. May need erosion control measures.
Lawson	Somewhat poor	70-90	90-110	Common flooding. May need protection.
Lemond	Poor		80-100	Some areas may not need tile. Sandy substratum. If continuous coarse sand layers are present, spacing may be 200-300 ft. May need filter or envelope on tile.

[1]Natural soil drainage refers to degree of natural soil drainage prior to artificial drainage.
[2]Drain spacing recommendations are for field slopes less than 5%.

(Table 2-2. continued)

Soil name	Natural soil drainage[1]	Tile spacing, ft.[2] 36″ depth	48″ depth	Remarks
Lester	Well			Drainage not needed. May need erosion control measures.
Le Sueur	Moderately well to somewhat poor	60-70	80-90	Most areas do not need tile.
Letri	Poor	40-50	60-70	Tile may not be satisfactory. May need diversions and interceptor drains.
Lilah	Excessive			Drainage not needed. May need erosion control measures. Highly corrosive to concrete.
Linder	Somewhat poor		100-110	Some areas may not need tile. If continuous coarse sand layer is present, spacing may be 200-300 ft. May need filter or envelope on tile. May need diversions.
Lindley	Well to moderately well			Drainage not needed. May need erosion control measures.
Lineville	Moderately well to somewhat poor			Tile not recommended. May need interceptor tile. May need erosion control measures.
Liscomb	Well			Drainage not needed. May need erosion control measures.
Littleton	Somewhat poor	80-90	100-110	May need diversions or interceptor drains. May need erosion control measures.
Lourdes	Moderately well	50-70	60-80	Tile may help in timely field operations. Tile may be needed for hillside seepage. May need erosion control measures.
Luana	Well			Drainage not needed. May need erosion control measures.
Luther	Somewhat poor	60-80	80-100	Many areas do not need tile.
Luton	Poor to very poor			Occasional flooding. May need protection. Tile outlets rarely available. Land grading generally required.
Macksburg	Somewhat poor	80-90	90-100	Many areas do not need tile. May need erosion control measures.
Madelia	Poor	70-80	80-100	

Mahaska	Somewhat poor	80-90	90-100	Many areas do not need tile. May need erosion control measures.
Malvern	Moderately well to somewhat poor			Wetness due to seepage. Use interceptor tile. May need erosion control measures.
Marcus	Poor	70-80	80-100	May need surface drains.
Marlean	Well			Drainage not needed. May need erosion control measures.
Marna	Poor	50-60	70-80	
Marshall	Well			Drainage not needed. May need erosion control measures.
Marshan	Poor	70-90	80-100	Waterbearing sands make tile placement difficult. May need filter or envelope on tile. If continuous coarse sand layer is present, spacing may be 200-400 ft.
Martinsburg	Well to moderately well			Drainage not needed. May need interceptor tile for seepage. May need erosion control measures.
Maxfield	Poor	70-80	80-100	May need diversions or interceptor tile.
Mayberry	Moderately well	30-40	50-60	Wetness due to seepage. Use interceptor tile. May need erosion control measures.
Mayer	Poor to very poor	80-90	100-110	May need filter or envelope on tile. If continuous coarse sand layer is present, spacing may be 200-400 ft.
McPaul	Well to moderately well			Common flooding. May need protection. Drainage not needed. May need erosion control measures.
Medary	Moderately well			Drainage not needed. May need erosion control measures.
Millington	Poor	80-90	100-110	Frequent flooding. May need protection.
Minden	Somewhat poor	80-90	100-110	Not all areas need tile.
Minnetonka	Poor	70-80	90-100	May need diversions and interceptor drains.

[1]Natural soil drainage refers to degree of natural soil drainage prior to artificial drainage.
[2]Drain spacing recommendations are for field slopes less than 5%.

(Table 2-2. continued)

Soil name	Natural soil drainage[1]	Tile spacing, ft.[2] 36″ depth	48″ depth	Remarks
Modale	Moderately well to somewhat poor			Common flooding. May need protection. Tile outlets rarely available. Use surface drains.
Moingona	Moderately well			Drainage not needed. May need erosion control measures.
Monona	Well			Drainage not needed. May need erosion control measures.
Moody	Well			Drainage not needed. May need erosion control measures.
Mottland	Well			Drainage not needed. May need erosion control measures.
Moville	Somewhat poor			Common flooding. May need protection. Tile outlets rarely available. Use surface drains.
Mt. Carroll	Well			Drainage not needed. May need erosion control measures.
Muscatine	Somewhat poor	60-80	80-100	Many areas do not need tile. May need erosion control measures.
Muscatine Sandy Substratum	Somewhat poor	80-90	100-110	Many areas do not need tile. Sandy substratum at 4-8 ft.
Mystic	Moderately well to somewhat poor			Tile not recommended. May need interceptor tile for seepage. May need erosion control measures.
Napa	Poor to very poor			Tile not recommended. Use surface drains.
Napier	Well			Drainage not needed. May need erosion control measures.
Nasset	Well			Drainage not needed. Bedrock at 3-4 ft. May need erosion control measures.
Nevin	Somewhat poor	80-90	100-110	Most areas do not need tile. May need erosion control measures.
Nevin Sandy Substratum	Somewhat poor	90-100	110-120	Most areas do not need tile. Sandy substratum at 4-5 ft.
Newvienna	Moderately well	70-90	90-110	Tile may help in timely field operations. May need interceptor tile for seepage. May need erosion control measures.

Nicollet	Moderately well to somewhat poor	70-80	90-100	Most areas do not need tile.
Niota	Poor			Occasional flooding. May need protection. Tile not recommended. Use surface drains. Highly corrosive to concrete.
Nira	Moderately well	70-80	80-100	Wetness usually due to seepage. Interceptor tile may be needed on or near loess-till contact. May need erosion control measures.
Nishna	Poor	30-50	40-60	Common flooding. May need protection. Tile may not be satisfactory. Tile should supplement a good surface drainage system.
Nodaway	Moderately well	70-80	90-100	Common flooding. May need protection. Most areas do not need tile.
Nordness	Well			Drainage not needed. Bedrock at 1-2 ft. May need erosion control measures.
Northboro	Moderately well			Drainage not needed. May need erosion control measures.
Ocheyedan	Well			Drainage not needed. May need erosion control measures.
Okaw	Poor to very poor			Common flooding. May need protection. Tile not recommended. Highly corrosive to concrete. Use surface drains. May need diversions. May need erosion control measures.
Okoboji	Very poor	50-60	70-80	Depressional. Ponded areas may need surface drains or surface intakes to tile.
Olin	Well to somewhat excessive			Drainage not needed. May need erosion control measures.
Olmitz	Well to moderately well			Drainage not needed. May need erosion control measures. May need interceptor tile for seepage.
Omadi	Well			Occasional flooding. May need protection. Drainage not needed. May need erosion control measures.
Onawa	Somewhat poor to poor			Common flooding. May need protection. Tile outlets rarely available. Tile may not be satisfactory.
Oran	Somewhat poor	70-90	80-100	Tile may help in timely field operations. May need erosion control measures.

[1]Natural soil drainage refers to degree of natural soil drainage prior to artificial drainage.
[2]Drain spacing recommendations are for field slopes less than 5%.

(Table 2-2. continued)

Soil name	Natural soil drainage[1]	Tile spacing, ft.[2] 36″ depth	48″ depth	Remarks
Orion	Somewhat poor	70-90	90-110	Frequent flooding. May need protection.
Orwood	Well			Drainage not needed. May need erosion control measues.
Ossian	Poor	70-90	90-110	Frequent flooding. May need protection.
Ostrander	Well	70-90	80-100	Drainage may not be needed. May need erosion control measures.
Otley	Moderately well			Drainage not needed. May need erosion control measures. May need interceptor tile at loess-till contact.
Otter	Poor	70-90	90-110	Frequent flooding. May need protection. Surface intakes to tile may be needed in depressions.
Ottosen	Somewhat poor	70-80	90-100	Many areas do not need tile.
Owego	Poor to somewhat poor			Common flooding. May need protection. Tile outlets rarely available. Use surface drains. Land grading generally required.
Palms	Very poor	60-80	80-110	Frequent ponding. Surface intakes to tile may be needed in depressions. High organic matter makes tile difficult to maintain.
Palsgrove	Well			Drainage not needed. Bedrock at 3-4 ft. May need erosion control measures.
Percival	Somewhat poor			Common flooding. May need protection. Tile outlets rarely available. Use surface drains.
Perks	Excessive			Common flooding. May need protection. Drainage not needed. May need erosion control measures.
Pershing	Moderately well to somewhat poor	40-50	50-60	Tile may not be satisfactory. May need diversions and surface drains. May need erosion control measures.
Pinicon	Somewhat poor	70-80	80-100	May need erosion control measures.
Plattville	Well to moderately well			Drainage not needed. Bedrock at 3-4 ft. May need erosion control measures.

Port Byron	Well to moderately well			Drainage not needed. May need erosion control measures.
Primghar	Somewhat poor	80-90	100-110	Most areas do not need tile. Tile may be helpful in timely field operations. May need erosion control measures.
Protivin	Somewhat poor	50-60	60-70	Tile may not drain all areas. May need erosion control measures.
Racine	Well to moderately well			Drainage not needed. May need erosion control measures.
Racoon	Poor	30-40	50-60	Occasional flooding. May need protection. Surface intakes to tile may be needed in depressions. Highly corrosive to concrete. Tile should supplement a good surface drainage system.
Raddle	Well			Drainage not needed. May need erosion control measures.
Radford	Somewhat poor	80-90	90-100	Common flooding. May need protection.
Ransom	Moderately well and somewhat poor	80-90	90-100	Many areas do not need tile.
Rathbun	Somewhat poor			Tile not recommended. Use surface drains. May need erosion control measures.
Rawles	Moderately well	80-90	90-100	Common flooding. May need protection. Tile may help in timely field operations. May have iron ochre problems.
Readlyn	Somewhat poor	60-80	80-100	Some areas may not need tile. May need erosion control measures.
Renova	Well			Drainage not needed. May need erosion control measures.
Riceville	Somewhat poor	40-50	50-60	Tile may not drain all areas. May need erosion control measures.
Richwood	Well			Drainage not needed. May need erosion control measures.
Ridgeport	Somewhat excessive			Drainage not needed. May need erosion control measures.
Rinda	Poor to somewhat poor			Wetness usually due to seepage. Use interceptor tile. May need erosion control measures.

[1]Natural soil drainage refers to degree of natural soil drainage prior to artificial drainage.
[2]Drain spacing recommendations are for field slopes less than 5%.

(Table 2-2. continued)

Soil name	Natural soil drainage[1]	Tile spacing, ft.[2] 36″ depth	48″ depth	Remarks
Ripon	Well			Drainage not needed. May need erosion control measures.
Rockton	Well			Drainage not needed. Bedrock at 2-3 ft. May need erosion control measures.
Rolfe	Very poor	40-60	70-90	Tile may not drain all areas. Use surface intakes to tile in depressions.
Roseville	Well			Drainage not needed. Bedrock at 3-4 ft. May need erosion control measures.
Rossfield	Well			Drainage not needed. May need erosion control measures.
Rowley	Somewhat poor	80-110	100-180	Occasional flooding. May need protection. Sandy substratum. May need filter or envelope on tile. May need erosion control measures.
Rozetta	Moderately well	70-90	90-110	Tile may help in timely field operations. May need interceptor tile for seepage. May need erosion control measures.
Rubio	Poor to very poor	40-50	50-60	Tile may not drain all areas. Tile should supplement a good surface drainage system. Use surface intakes to tile in depressions.
Rushmore	Poor	50-60	60-70	
Rushville	Poor to very poor	30-40	40-50	Tile may not drain all areas. Use surface drains. Highly corrosive to concrete.
Sac	Well			Drainage not needed. May need erosion control measures.
Salida	Excessive			Drainage not needed. May need erosion control measures.
Salix	Moderately well	80-90	90-100	Most areas do not need tile. Tile outlets rarely available.
Sarpy	Excessive			Occasional flooding. May need protection. Drainage not needed.
Sattre	Well			Drainage not needed. May need erosion control measures.
Saude	Well			Drainage not needed. May need erosion control measures.
Sawmill	Poor	65-85	80-100	Frequent flooding. May need protection.
Schapville	Moderately well to well			Drainage not needed. May need erosion control measures.

Schley	Somewhat poor	70-80	80-100	Highly corrosive to concrete. May need interceptor tile for seepage.
Schley Variant	Somewhat poor	80-90	100-110	May need filter or envelope on tile.
Seaton	Well			Drainage not needed. May need erosion control measures.
Seymour	Somewhat poor			Tile not recommended. May need erosion control measures.
Shaffton	Somewhat poor	80-100	300-320	Frequent flooding. May need protection. Tile outlets may not be available. Highly corrosive to concrete. May need filter or envelope on tile.
Shandep	Very poor	120-140	280-300	Frequent flooding. May need protection. Surface intakes to tile may be needed in depressions. May need filter or envelope on tile.
Sharpsburg	Moderately well	70-80	90-100	Most areas do not need tile. May need erosion control measures.
Shelby	Moderately well to well			Wetness usually due to seepage. Use interceptor tile at loess-till contact. May need erosion control measures.
Shorewood	Moderately well to somewhat poor	70-80	90-100	May need erosion control measures.
Snider	Somewhat poor	80-90	100-110	
Sogn	Somewhat excessive			Drainage not needed. May need erosion control measures. Bedrock at 1-2 ft.
Solomon	Poor			Common flooding. May need protection. Tile outlets rarely available. Tile not recommended. Use surface drains.
Sparta	Excessive			Drainage not needed. May need erosion control measures.
Sperry	Very poor to poor	40-50	50-60	Tile may not drain all areas. Use surface intakes to tile in depressions.
Spicer	Poor	80-90	100-110	
Spillco	Moderately well to somewhat poor	80-90	90-100	Common flooding. May need protection. Tile may help in timely field operations.
Spillville	Moderately well to somewhat poor	70-90	80-100	Common flooding. May need protection. May need erosion control measures.

[1]Natural soil drainage refers to degree of natural soil drainage prior to artificial drainage.
[2]Drain spacing recommendations are for field slopes less than 5%.

(Table 2-2. continued)

Soil name	Natural soil drainage[1]	Tile spacing, ft.[2]		Remarks
		36″ depth	48″ depth	
Steinauer	Well to excessive			Drainage not needed. May need erosion control measures.
Storden	Well			Drainage not needed. May need erosion control measures.
Strahan	Well			Drainage not needed. May need erosion control measures.
Stronghurst	Somewhat poor	70-80	90-100	Some areas may not need tile. May need erosion control measures.
Taintor	Poor	60-80	80-100	
Talcot	Poor	80-90	100-110	Waterbearing sands make tile placement difficult. May need filter or envelope on tile. If continuous coarse sand layer is present, spacing may be 200-400 ft.
Tallula	Well to moderately well			Drainage not needed. May need erosion control measures.
Tama	Well	80-90	100-110	Most areas do not need tile. Tile may help in timely field operations. May need erosion control measures.
Tell	Well			Drainage not needed. May need erosion control measures. May need interceptor tile for seepage.
Terril	Moderately well			Drainage not needed. May need erosion control measures.
Thorp	Poor			Waterbearing sands make tile placement difficult. Depressional. Use surface drains.
Tilfer	Poor to very poor			Occasional flooding. May need protection. Bedrock at 2-3 ft.
Traer	Poor to very poor	65-75	80-100	Tile may not drain all areas. Use surface intakes to tile in depressions.
Trent	Moderately well			Drainage not needed. May need erosion control measures.
Tripoli	Poor to somewhat poor	60-70	80-90	
Truman	Well			Drainage not needed. May need erosion control measures.

Turlin	Somewhat poor	70-80	80-100	Common flooding. May need protection. Tile may help in timely field operations. May need erosion control measures.
Tuskeego	Poor			Tile not recommended. Use surface drains.
Udolpho	Somewhat poor to poor	80-90	90-100	Waterbearing sands make tile placement difficult. May need filter or envelope on tile. If continuous coarse sand layer is present, spacing may be 200-400 ft.
Vesser	Somewhat poor to poor	80-90	90-100	Common flooding. May need protection.
Volney	Well to somewhat excessive			Drainage not needed. May need erosion control measures.
Vore	Moderately well			Common flooding. May need protection. Tile outlets rarely available. Use surface drains.
Wabash	Very poor			Common flooding. May need protection. Tile not recommended. Use surface drains.
Wacousta	Very poor	70-80	80-100	Use surface intakes to tile in depressions.
Wadena	Well			Drainage not needed. May need erosion control measures.
Waldorf	Poor	60-80	80-100	
Walford	Poor to very poor	65-75	90-100	Tile may not drain all areas. Tile should supplement a good surface drainage system.
Wapsie	Well			Drainage not needed. May need erosion control measures.
Watkins	Well to moderately well			Drainage not needed. May need erosion control measures.
Watseka	Somewhat poor			Drainage generally not needed.
Waubeek	Well to moderately well			Drainage not needed. May need erosion control measures. May need interceptor tile for seepage.

[1]Natural soil drainage refers to degree of natural soil drainage prior to artificial drainage.
[2]Drain spacing recommendations are for field slopes less than 5%.

(Table 2-2. continued)

Soil name	Natural soil drainage[1]	Tile spacing, ft.[2] 36″ depth	48″ depth	Remarks
Waubonsie	Moderately well to somewhat poor	50-60	70-80	Common flooding. May need protection. Tile outlets rarely available. Use surface drains.
Waucoma	Well			Drainage not needed. May need erosion control measures.
Waukee	Well			Drainage not needed. May need erosion control measures.
Waukegan	Well			Drainage not needed. May need erosion control measures.
Webster	Poor	60-80	80-100	May need surface drains or intakes to tile.
Weller	Moderately well	50-60	60-70	Tile may not be satisfactory. Highly corrosive to concrete. Tile should supplement a good surface drainage system. May need erosion control measures.
Wentworth	Well			Drainage not needed. May need erosion control measures.
Whalan	Well			Drainage not needed. Bedrock at 2-3 ft. May need erosion control measures.
Whittier	Well			Drainage not needed. May need erosion control measures.
Wilmonton	Moderately well to somewhat poor	40-50	60-70	Many areas do not need tile.
Winneshiek	Well			Drainage not needed. Bedrock at 2-3 ft. May need erosion control measures.
Winterset	Poor	40-50	60-70	
Wiota	Well to moderately well			Drainage not needed. May need erosion control measures.
Woodbury	Poor to somewhat poor	70-80	90-100	Common flooding. May need protection. Tile outlets rarely available. Use surface drains.
Worthen	Well			Drainage not needed. May need erosion control measures.

Zenor	Somewhat excessive			Drainage not needed. May need erosion control measures.
Zook	Poor	30-50	40-60	Common flooding. May need protection. Tile may not be satisfactory. Tile should supplement a good surface drainage system.
Zwingle	Poor			Tile not recommended. May need erosion control measures.

[1]Natural soil drainage refers to degree of natural soil drainage prior to artificial drainage.
[2]Drain spacing recommendations are for field slopes less than 5%.

Chapter 3. Subsurface Drainage

Subsurface drainage is used where soils are permeable enough for economical spacing of the drains and productive enough to justify the investment. A subsurface drain should provide trouble-free service for many years if correctly installed and built with high-quality material.

Drainage Outlet

A subsurface drainage system will function only as well as the outlet. Therefore, when planning a drainage system, it is essential that a suitable outlet is available or there is an opportunity to develop an outlet. It is essential that outlets are deep enough and have sufficient capacity to provide a free outlet and adequate cover for all outletting mains and laterals. When a subsurface drain outlets into an open ditch, the end of the drain should always be protected against undermining, prolonged submergence, and entry of rodents or other animals into the drain.

Existing mains used as outlets for the proposed subsurface drainage system should be carefully evaluated. To be adequate as an outlet, an existing main should:

1. Be free from breakdowns, fractured tile, excessive sedimentation, or root clogging;

2. Appear to be working properly and have a free outlet as described above;

3. Have sufficient capacity to remove drainage water from the portion of the watershed needing subsurface drainage at the rate of ¼ inch in 24 hours; and

4. Have sufficient depth to provide the minimum recommended cover for all new drains to be installed.

Pump outlets may be considered when no suitable gravity outlet is available and it is not practical to improve an existing ditch. For pump capacities and design, see Chapter 6. Pump outlets may require legal easements from downstream owners.

Physical Features

Topography—Because of the depth limitation of trenching machines and the soil cover required over the drains, the topography of the site to be drained must be determined. The amount of surveying needed to obtain topographic information depends on the lay of the land. Where land slopes are obvious, limited survey data are needed to locate drains. On flat and slightly undulating land, proper location of drains is not obvious and a topographic survey is necessary. Sufficient topographic information should be obtained for the complete job in advance of the installation. Insufficient data often results in a piecemeal system that eventually may be very costly.

Soil—The soils in an area to be drained greatly influence the type of system that will be installed and indicate if special problems can be anticipated. Soil survey reports available at the local office of the Soil Conservation Service and the Cooperative Extension Service can be used as guides in planning drainage systems. Soil borings or test pits are used to supplement the information from maps when necessary. The additional information is especially important for interceptor drains and in locations where bedrock is anticipated.

Types of Subsurface Drainage

Relief drainage lowers the water table or removes excess water percolating through the soil over the drained area. Drains are uniformly placed in the area and connected to a main that leads to one or more outlets. If soil is homogeneous, drawdown will be the same on both sides of the drain. Flow from the drain is generally intermittent.

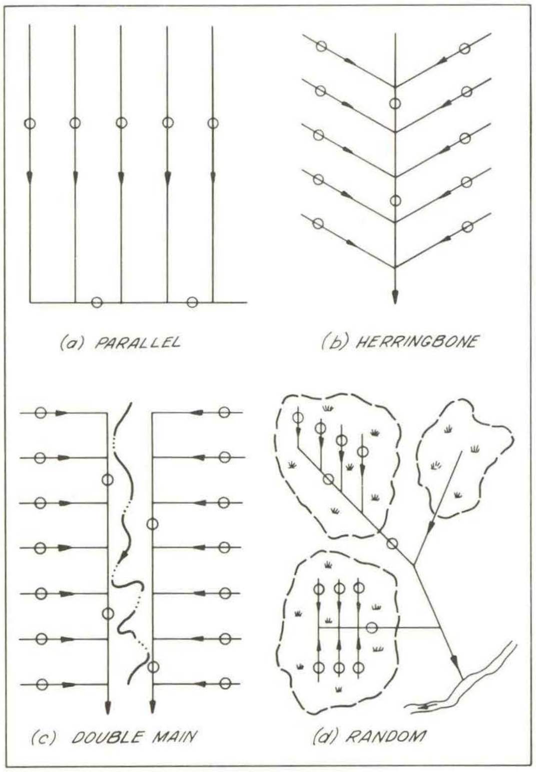
Interceptor or cutoff drainage is useful in wet areas resulting from seepage out of adjoining highlands. Subsurface drains should be installed at nearly right angles to the direction of groundwater flow and placed near or in the seep planes in the soil profile. Seep planes can be located by backhoe test pits or soil borings. The drain must intercept the seep planes continuously, have adequate soil cover, and be on a continuous grade toward the outlet. One or two properly spaced subsurface drains will usually dry up a wet area.

Patterns of Subsurface Drainage Systems

To plan a subsurface drainage system, select a pattern that best fits the topography and groundwater conditions. Some of the basic systems are illustrated in figure 3-1.

Random system—A random system is used where the topography is undulating or rolling and contains isolated wet areas. For efficiency, the main drain follows natural low ground in the swales rather than in deep cuts through ridges. If wet areas are large, submains and laterals for each area may be arranged in a gridiron or herringbone pattern to provide the required drainage.

Figure 3-1. Types of drainage collection systems.



Herringbone system—The herringbone system consists of parallel laterals that enter the main at an angle, usually from both sides. This system is used for long, relatively narrow wet areas such as those next to flat drainageways. This pattern may be used with other patterns in small or irregular areas. Its disadvantages are double drainage and higher cost because junctions with the main are required. However, herringbone systems provide the extra drainage needed for the heavier soils that are sometimes found in narrow depressions.

Parallel or gridiron system—The parallel or gridiron system is similar to the herringbone system except that the laterals enter the main from only one side. This system is used on flat, regularly shaped fields and on uniform soil. Variations of the system are often used with other patterns.

Double-main system—The double-main system is a modification of the gridiron and herringbone systems. It is used where a depression, which is frequently a natural watercourse, divides the field where drains are to be installed. Sometimes the depressional area may be wet because of seepage coming from the higher ground. Placing a main on each side of the depression serves two purposes: (1) the main intercepts the seepage water, and (2) provides an outlet for the laterals.

If the depression is deep and unusually wide and if only one main is used in the center, a break in the gradeline of each lateral may be necessary before it reaches the main. A main on each side of the depression permits a more uniform lateral gradeline.

Materials for Subsurface Drainage Systems

Material specifications for drains are important to both the drainage contractor and landowner since they provide a basis for manufacturing a consistent product with the assurance that the product will be strong, durable, and perform adequately. Materials used for subsurface drains include clay, concrete, bituminized fiber, metal, plastic, or other materials of acceptable quality. Current specifications listed in table 3-1 should be used in determining the quality of the drain conduit.

Clay Drain Tile

ASTM Standard Specification C-4 gives physical test requirements for standard, extra quality, and heavy duty clay drain tile. Standard drain tile is satisfactory where the tile is laid in trenches of moderate depth and width and where it will not be exposed to severe conditions. Extra quality and heavy duty tile should be used for more severe conditions.

Generally, color and salt glazing are not reliable indicators of tile quality. Clay tile is not affected by acids or sulfates. Low temperatures normally will not damage clay tile if it is carefully handled and stored during freezing weather.

Some clay or shale drain tile may be damaged by frost. Do not "string out" or stack tile on wet ground during periods of freezing and thawing.

Concrete Drain Tile

Quality concrete drain tile will give long and satisfactory service under most field conditions. There are four quality classes of concrete drain tile: standard, extra, heavy duty, and special.

Standard quality tile is intended for drainage of ordinary soils where the tile is laid in trenches of moderate depth and width. Tile of this quality is limited to internal diameters of 12 inches or less.

Extra quality tile is intended for drainage of ordinary soils where the tile is laid in trenches of considerable depth, width, or both.

Heavy duty, extra quality tile is intended for drainage of ordinary soils where the tile is laid in trenches of relatively great depth, width, or both.

Table 3-1. Materials for subsurface drainage.

Type of material	Specification[1]
Clay drain tile	ASTM[2]—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 drainage	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

[1]This information is from "Subsurface Drain, Standards and Specifications (606)," *National Handbook of Conservation Practices,* United States Department of Agriculture, Soil Conservation Service.
[2]Specifications can be obtained from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pa. 19103.

Special quality tile is intended for drainage where special precautions are necessary—for example, where the tile is laid in soils that are markedly acidic or that contain unusually high quantities of sulfates, and where it is laid in trenches of considerable depth, width, or both.

Certain constituents of portland cement in tile react with the acids in some soils. The extent of the reaction depends principally on the degree of soil acidity and the permeability of the tile walls. When the pH value drops below 6.0, a soil is considered to be acidic. Concrete tile installed in soils with pH in the range of 5.0 to 6.0 should be of special quality. Concrete tile should not be used when pH is lower than 5.0.

Plastic Drain Tubing

High-density polyethylene is the most commonly used material for subsurface drains in the United States. Plastic tubing is not affected by acids and chemicals normally found in the soil at drainage depth. Plastic may become stiff and brittle at very low temperature and the pipe stiffness is reduced during exposure to the sun on a hot day. This temperature-related characteristic of plastic will be a problem only when handling and is not encountered once it is installed and buried. If plastic tubing must be installed during unusually cold conditions, the manufacturer should be consulted for recommendations.

Designs of Subsurface Drainage Systems

The purpose of drainage is to lower the water table to a point below the ground surface where it will not interfere with plant root growth and development. The degree of drainage required is dependent on (1) the maximum allowable height of the water table, (2) the minimum rate at which the water table must be lowered, or (3) the maximum allowable duration and frequency of ponding. The designer of the subsurface drainage system selects an appropriate degree of drainage for the site to fit the different crop requirements.

Drainage Coefficient

The drainage coefficient is the rate at which water can be removed and is expressed as the equivalent depth of water covering the surface that can be removed in 24 hours. Table 3-2 can be used to determine the minimum recommended drainage coefficient for various conditions.

If surface or blind inlets must be used to drain depressional areas where adequate surface drainage does not exist, the drain must have capacity to remove runoff from the entire contributing watershed area. An exception may be made for small depressions if surveys are available and the volume of the potholes can be determined accurately. In this case, the tile should be able to remove the appropriate drainage coefficient from the land area that needs tile drainage plus the water in the potholes within 24 hours. If the drainage area to pothole area ratio is large, it may not be practical to drain the pothole within 24 hours. The pothole area, perhaps, should become a sacrifice area rather than spend large sums for a tile water removal system that would drain it within 24 hours.

Drain Pipe Size

The size of the main is based on the size of the area drained, the grade, the specified drainage coefficient, and the internal roughness of the drain. Mains should be large enough to drain all areas in the watershed that need drainage, using the appropriate drainage coefficient. They should have a free outlet and be deep enough to provide outlets for all laterals to be installed.

Figures 3-2 and 3-3 can be used to determine drain size. Select the appropriate drainage coefficient at the bottom right-hand corner of the chart. In the column find the acreage that will be drained by the subsurface drain. Move horizontally to the left until you intersect the grade of the drain. This point locates the size of the drain and the velocity of the water moving inside the drain when it is flowing at capacity. Manning's roughness coefficient ("n") is given in table 3-3 for different drain materials.

Do not exceed the hydraulic capacity of the drain at the design slope. The smallest drain generally recommended for laterals is 4 inches. A 3-inch corrugated plastic drain may be installed in certain locations where the grade is 0.003 feet per foot or more. A minimum 5-inch drain should be used for sandy soils and organic soils with short laterals. Normally a 6-inch diameter is minimum for drains in organic soils and for mains. For rigid drains exceeding 10 inches in diameter, it is preferable to use 2-foot or longer lengths to maintain alignment.

Table 3-2. Drainage coefficients for subsurface drains in Iowa.

Crops and degree of surface drainage	Drainage coefficient[1] (in. of water per day)	
	Mineral soil	Organic soil
Field crops		
Good surface drainage[2]	3/8 to 1/2	1/2 to 3/4
Blind inlets[3]	1/2 to 3/4	3/4 to 1
Surface inlets[3]	1/2 to 1	1 1/2 to 2
Truck crops		
Good surface drainage[2]	1/2 to 3/4	3/4 to 1 1/2
Blind inlets[3]	3/4 to 1	1 1/2 to 2
Surface inlets[3]	1 to 1 1/2	2 to 4

[1]Drainage coefficients will vary with related factors. Obtain professional help where needed in determining required capacity.
[2]Consider only the area that will be tiled or that could be tiled as the drainage area. It is assumed that surface water is removed by field ditches or watercourses. For fields having slopes of less than 0.2%, use the higher end of the drainage coefficient range.
[3]Use the entire contributing watershed as the drainage area.

Figure 3-2. Corrugated plastic tubing drainage chart.

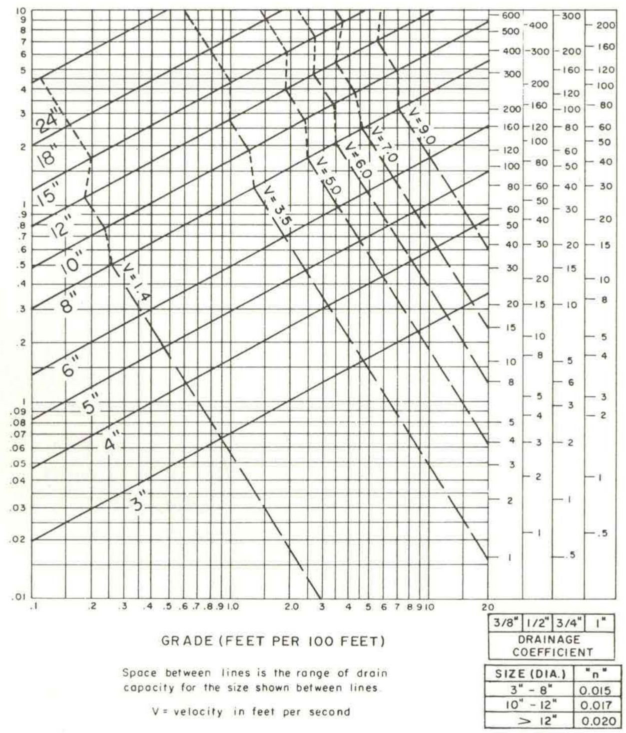


Figure 3-3. Clay and concrete tile drainage chart.

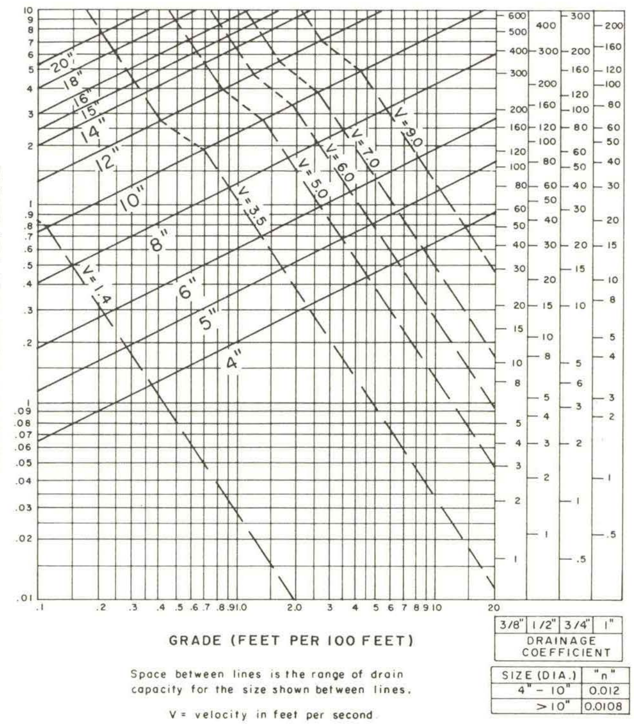


Table 3-3. Recommended coefficients of roughness for drain materials.

Type of conduit	Nominal diameter (inches)	"n" value
Clay or concrete drain tile	4-10	0.012
Clay or concrete drain tile	12-48	0.0108
Corrugated plastic tubing	3-8	0.015
Corrugated plastic tubing	10-12	0.017
Corrugated plastic tubing	>12	0.020
Corrugated metal pipe	3-30	0.025
Smooth wall pipe (tongue and groove or bell spigot joints)	3-30	0.012

Table 3-4. Maximum lengths of corrugated plastic tubing. (Based on 100-ft. spacing and a drainage coefficient of 3/8-in. per day).

	Maximum length (ft.) for various drain diameters (in.)			
Grade (ft./ft.)	3	4	5	6
0.0005	470	1,000	1,800	2,800
0.001	660	1,400	2,600	4,000
0.002	830	1,900	3,600	5,500
0.003	1,000	2,300	4,300	6,600
0.005	1,400	3,000	5,800	8,800

Table 3-5. Maximum lengths of clay and concrete drain tile. (Based on 100-ft. spacing and a drainage coefficient of ⅜-in. per day.)

	Maximum length (ft.) for various drain diameters (in.)			
Grade (ft./ft.)	3	4	5	6
0.0005	520	1,160	2,100	3,450
0.001	750	1,650	3,000	4,900
0.002	830	2,200	4,100	6,900
0.003	1,000	2,700	5,000	8,300
0.005	1,660	3,600	6,600	10,800

Table 3-6. Length adjustment factors for various drainage coefficients and drain spacings.[1]

Drainage coefficient (in. per day)	Factor	Drain spacings (ft.)	Factor
¼	1.5	30	3.33
⅜	1.0	40	2.50
½	0.75	60	1.67
¾	0.5	66	1.52
1	0.3	70	1.43
—	—	80	1.25
—	—	100	1.00

[1]Convert to different drainage coefficients and drain spacings by multiplying the lengths given in tables 3-4 and 3-5 by the conversion factors given.

Table 3-7. Minimum grade.[1]

Inside diameter (in.)	Minimum grade for drains not subjected to fine sand or silt[2]		Minimum grade for drains where fine sand or silt may enter the drain[3]	
	Tile	Tubing	Tile	Tubing
		ft.		
3	0.0009	0.001	0.006	0.009
4	0.0006	0.0008	0.0041	0.0065
5	0.0004	0.0006	0.003	0.0045
6	0.0003	0.0004	0.0024	0.0034

[1]Minimum grade determined at full flow.
[2]Grades for minimum cleaning velocity of 0.5 ft. per second.
[3]Grades for minimum cleaning velocity of 1.4 ft. per second.

Length of Lateral Drain

The length of laterals made of corrugated plastic tubing and concrete and clay tile should not exceed the values given in tables 3-4 and 3-5, assuming that the drains are spaced 100 feet apart and that the drainage coefficient is ⅜ inch. Table 3-6 provides an adjustment factor for other drainage coefficients with different lateral spacings.

Drain Grades and Velocities

General—Subsurface drains are placed at uniform depths where possible. As a result, the topography of the land influences the grades available. It is often possible to orient the drains within the field to obtain a desirable grade. The grades should be sufficient to result in a nonsilting velocity yet be flat enough that the maximum allowable velocities are not exceeded and the drain is not subjected to excessive pressure flow. Too much flow will cause erosion around the drain.

Minimum recommended grade for drains—The grade should be as great as possible on flatlands without sacrificing adequate depth. The minimum grade of small size drains should be limited as shown in table 3-7.

When grades flatter than those in table 3-7 are used for main lines, observe these precautions in designing the system to reduce the amount of sediment.

1. Make sure the system has a free outlet so backwater will not further reduce velocities.

2. Provide sediment traps and clean-out system.

3. Provide breathers and relief wells for venting and to ensure full hydraulic head operations.

4. Protect the entire system from sedimentation by using filters and envelopes to prevent piping or erosion of the drain blinding material.

Table 3-8. Maximum velocities without protective measures.

Soil texture	Velocity (ft. per second)
Sand and sandy loam	3.5
Silt and silt loam	5.0
Silty clay loam	6.0
Clay and clay loam	7.0
Coarse sand or gravel	9.0

Maximum recommended grades for drains—For long laterals and mains, the maximum permissible velocities without protective measures should be limited to those shown in table 3-8.

Protective measures where specified should include one or more of the following.

1. Select rigid butt end pipe or tile with straight, smooth sections and square ends to obtain tight-fitting joints.

2. Wrap open joints of the pipe or tile with tar impregnated paper, burlap, or special fabric-type filter material.

3. Place the conduit in a sand and gravel envelope or blind with the least erodible soil available.

4. Seal joints or use a watertight pipe or nonperforated continuous tubing.

5. Enclose continuous, perforated pipe or tubing with fabric-type filter material or properly graded sand and gravel.

Depth and Spacing of Drains

Depth and spacing of the tile should be such that the depth of groundwater between tile lines can be lowered within 24 hours after a rain to a level that will not cause crop injury. Generally, most field crops are not injured if the water table is lowered to at least 6 inches below the ground surface in the first 24 hours after a rain. During the second day after a rain the groundwater level should be lowered to approximately 1 foot and on the third day to 1.5 feet.

Spacing—Spacing between laterals depends on the permeability of the soil, the permissible depth, and the depth to the barrier. The proper drain spacings for humid regions and for various soil types are generally determined through experience. The general range of tile spacing for Iowa soils is shown in table 2-2, Chapter 2.

Drain depth and soil permeability—The spacing of the drain is related to its depth. In general, spacing can be increased with increasing depth of the drain. The depth and spacing required to give the desired depth of water table are influenced by the conductivity of soil layers, the amount and frequency of rainfall, seepage, capillary movement, and topography. In general, drains in moderate to moderately permeable mineral soils should be installed at a depth of 3 to 5 feet. Drains should be no deeper than 4 feet in very sandy soils because capillary fringe is limited. In slowly permeable clay soils, the rate of lateral water movement does not increase with depth. Therefore, the drain is usually placed approximately 1 foot below the desired water table depth.

Other conditions that determine drain depth—These are conditions other than soil permeability that determine the depth of drains.

1. Severity and depth of frost action—If possible, place drains below the frost line to obtain optimum year-round drainage and to prevent damage to the drain.

2. Impact loads from heavy equipment—A minimum average depth of 3.0 feet is recommended in mineral soils to protect a well-bedded subsurface drain from breakage by heavy equipment.

3. When 3-inch drains are used for combined drainage and subirrigation of shallow rooted crops, the minimum depth may be 1.5 feet if heavy machinery is not used in the cropped areas.

4. The minimum depth of cover in organic soils should be 2.5 feet for normal field levels after initial subsidence. If controlled drainage is not provided to hold subsidence to a minimum, the depth of cover should be increased to 3 feet.

5. Depth and adequacy of outlet—The outlet should be deep enough for the lateral drain to be positively graded and have adequate cover at the extreme upper end.

6. Adequacy of cover—When it is possible to secure minimum cover for protection, use metal or some other continuous high-strength pipe.

Loading Requirements

Subsurface drains should be installed so that the load does not fracture the tile or cause excess deflection of flexible tubing. The loads on clay concrete drain tile can be determined from formulas developed by A. Marston at Iowa State College in 1930. The maximum allowable trench depths for drain tile are listed in table 3-9.

Plastic drain tubing should be installed so that it does not deflect more than 20 percent of its nominal diameter. The maximum trench depths for tubing buried in loose, fine-textured soils are listed in table 3-10.

To prevent overloading in deep and wide ditches, it is sometimes feasible to construct a subditch, either with a trenching machine or by hand, in the bottom of a wide ditch that has been excavated by a bulldozer, dragline, power shovel, or backhoe. The width of the subditch measured at the top of the drain determines the allowable load. The width of the excavation above this point is not important.

In deep trenches, it is a good idea to backfill in several stages to allow time for settlement between fillings. Calculate the live load and add it to the soil load when determining the class of drain and type of bedding. Table 3-11 shows the percent of wheel loads transmitted to the drain.

When the calculated load requirements exceed the crushing strengths for standard quality tubing or tile, specify the required material quality such as special quality concrete or heavy duty tubing.

When the calculated load requirements exceed the crushing strengths for special quality concrete, heavy duty clay drain tile, or heavy duty tubing in applicable specifications, specify pipe that is capable of supporting the required loads.

Interceptor Drain

Description—Interceptor drains are usually installed to intercept water that flows in a pervious layer on top of an impervious subsoil strata. To ensure cutoff, the drain is generally located one-half to one diameter in depth into the impervious layer or seepage plane at right angles to the line of seepage travel. The line is usually buried near the upstream boundary of the wet area. Proper location of the interception drainage system is very important. (See figure 3-4.)

Capacity and size—When a drain is used to intercept seepage or springs, adequate field investigations must be made to determine the amount of seepage. Locate the drain so it intercepts seep planes continuously. Cover the drain adequately with soil and establish a grade to an available outlet.

To determine the size of drain for a particular set of conditions, use table 3-12 and figures 3-2 and 3-3. Table 3-12 provides estimates of inflow rates for different soil textures. With this information, the tile size can be determined by referring to figures 3-2 and 3-3.

Table 3-9. Maximum allowable trench depths, rigid conduits.

Tile size	Tile quality	Trench width at top of tile (in.)								
		15	18	21	24	27	30	36	42	48
4 & 5	Stand.	I	8.8	7.3	7.3	7.3				
	E.Q.	I	I	10.5	9.8	9.8				
	H.D.	I	I	18.5	11.6	11.6				
6	Stand.	I	8.9	6.3	6.3	6.3	6.3			
	E.Q.	I	I	10.6	8.3	8.3	8.3			
	H.D.	I	I	17.6	10.0	9.6	9.6			
8	Stand.	—	9.2	6.4	5.4	5.4	5.4	5.4		
	E.Q.	—	I	10.8	7.8	7.1	7.1	7.1		
	H.D.	—	I	17.8	10.3	8.1	8.1	8.1		
10	Stand.	—	9.5	6.6	5.4	4.8	4.8	4.8	4.8	
	E.Q.	—	I	11.0	8.0	6.5	6.2	6.2	6.2	
	H.D.	—	I	25.0	14.3	9.7	8.0	7.9	7.9	
12	Stand.	—	—	6.8	5.6	5.0	4.7	4.7	4.7	
	E.Q.	—	—	11.2	8.2	6.7	5.8	5.8	5.8	
	H.D.	—	—	I	14.2	10.0	8.4	7.2	7.2	
14	E.Q.	—	—	—	8.2	6.8	5.8	5.3	5.3	
	H.D.	—	—	—	23.2	13.5	10.5	7.9	7.5	
16	E.Q.	—	—	—	8.6	7.1	6.2	5.2	5.2	5.2
	H.D.	—	—	—	I	19.8	13.2	9.3	7.9	7.9
18	E.Q.	—	—	—	—	8.0	7.0	5.6	5.4	5.4
	H.D.	—	—	—	—	I	17.2	10.9	8.6	7.6
20	E.Q.	—	—	—	—	—	8.0	6.4	5.7	5.5
	H.D.	—	—	—	—	—	22.6	12.5	9.9	8.5
22	E.Q.	—	—	—	—	—	—	6.9	6.0	5.8
	H.D.	—	—	—	—	—	—	14.9	10.7	9.5
24	E.Q.	—	—	—	—	—	—	7.8	6.8	6.2
	H.D.	—	—	—	—	—	—	18.6	12.8	10.3

Stand. = Standard quality tile.
E.Q. = Extra quality tile.
H.D. = Heavy duty clay or heavy duty extra quality concrete tile.
I = Infinite depth (no limit).
Standard quality tile is not recommended above 12 in. in diameter.

Based on ordinary bedding (Class C), which is provided when the tile is supported by a suitably rounded ditch bottom of undisturbed or compacted earth for a width of at least 50 percent of the tile diameter and care is used to fill the space at the sides of the tile with granular material by shovel tamping. Soil weight is 120 lb. per cu. ft. and factor of safety is 1.5.

Table 3-10. Maximum trench depth for tubing buried in loose, fine-textured soil.

Nominal diameter of tubing (in.)	Quality of tubing[1]	Maximum trench depth (ft.) for various trench widths (in.) at top of tubing			
		12	16	24	32 or greater
3, 4	Standard[2]	12.8[4]	6.9	5.6	5.2
	Heavy duty[3]	—[5]	9.8	6.9	6.2
5, 6	Standard[2]	10.2	6.9	5.6	5.2
	Heavy duty[3]	—[5]	9.5	6.6	6.2
8	Standard[2]	10.2[5]	7.2	5.6	5.2
	Heavy duty[3]	—[5]	9.8	6.9	6.2
10	—[3]	—[5]	9.2	6.6	6.2
12	—[3]	—	8.9	6.6	6.2
15	—[3]	—	—	6.9	6.2

[1]ASTM designations.
[2]Pipe stiffness is 13 psi (90 KN/m^2) for 20% deflection.
[3]Pipe stiffness is 18 psi (124 KN/m^2) for 20% deflection.
[4]It is assumed that $E' = 50$ psi, (345 KN/m^2) that $D = 3.4$, that $K = 0.096$ (bedding angle of 90°), that $w = 109$ pcf, (1,750[1]kg/m^3) and that $y = 1.1$ x.
[5]Any depth is permissible for this width or less.

This table is revised from A. D. Fenemor, B. R. Bevier, and G. O. Schwab. 1979, "Prediction of Deflection for Corrugated Plastic Tubing," Transactions of the ASAE, pp 1338-1343.
Note: The commercial tubing supplied by 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 3-11. Percent of wheel loads transmitted to underground tile.

Depth of backfill over top of tile (ft.)	Percent of wheel loads for various trench widths at top of tile (ft.)						
	1	2	3	4	5	6	7
1	17.0[1]	26.0[1]	28.6[1]	29.7[1]	29.9[1]	30.2[1]	30.3[1]
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[2]	1.0	2.3	3.7	4.7	5.5	6.2	7.0

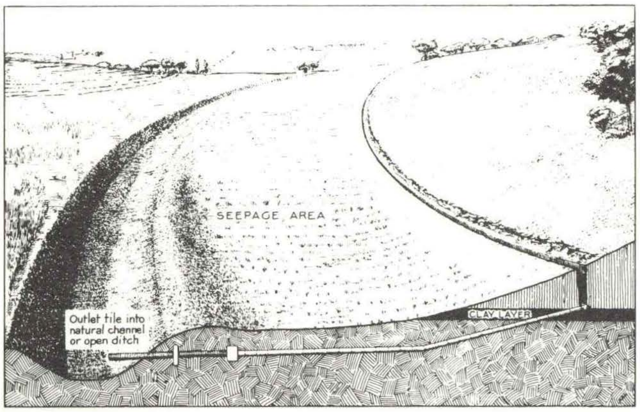
[1]These percentages include both live load and impact transmitted to 1 lineal ft. of tile.
[2]Live loads transmitted are practically negligible below 6 ft.

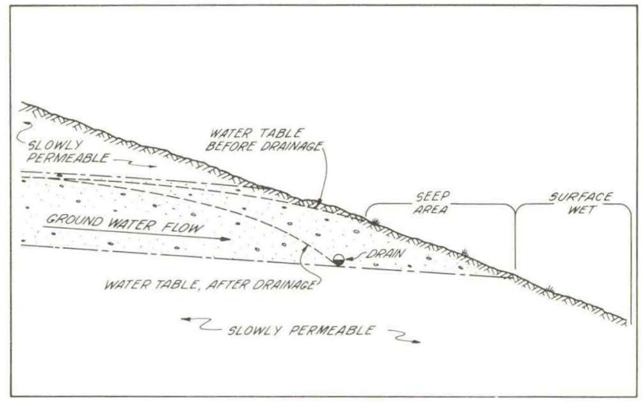
Table 3-12. Inflow rates for interceptor lines.

Soil texture	Inflow rate per 1,000 ft. of line (cfs)[1 2 3]
Coarse sand and gravel	0.15 to 1.00
Sandy loam	0.07 to 0.25
Silty 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% for slopes of 2-5%, by 20% for slopes of 5-12%, and 30% for slopes of more than 12%.
[3]For interception areas with considerable seepage, the minimum tile size should be 6 in.

Figure 3-4. Interception of seepage under barrier conditions with a cross section (bottom) of the interceptor drain.





Changes in Direction

Changes in horizontal direction of drain lines can be made by:

1. A gradual curve in the trench on a radius of curvature that the trenching machine can dig and still maintain grade;

2. A gradual curve on a radius of curvature such that joint spacings for tile do not exceed 1⁄16 to 1⁄8 inch and provide a minimum water inlet area of 0.75 square inch per foot of drain;

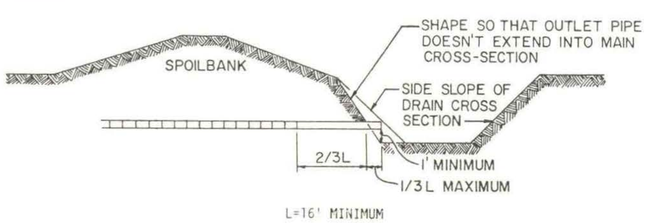
3. Using corrugated plastic tubing, manufactured bends, or fittings; and

4. Using junction boxes or manholes where drain lines make an abrupt change in direction or where two or more large drains join.

Drainage Appurtenances

Drain outlet pipes—As illustrated in figures 3-5 and 3-6, drain outlet pipes should be installed on the end of all drains that outlet into a ditch to protect them from erosion and undermining.

Figure 3-5. Recessed pipe outlet to open drain.



The most practical and economical subsurface drain outlet is a length of continuous pipe that does not have perforations or open joints. The pipe should be at least 16 feet long to ensure that there will be no seepage around the drain that could cause erosion at the outlet. At least two-thirds of the pipe should be embedded in the bank to provide the required cantilever support. The flowline of the outlet pipe should be at least 1 foot above the normal flow in the outlet ditch. When sufficient depth of cover cannot be obtained at the drain outlet, as shown in figure 3-6, several methods may be used to protect the drain.

Where surface water enters the ditch at the location of the drain outlet, some type of structure should be used to safely lower the surface flow to the ditch. When there is no spoil bank, a straight-drop spillway is generally recommended. If a spoil bank is present and sufficient temporary storage on the land is possible and permissible, a pipe drop-inlet structure is usually the best and most economical alternative. Sometimes it may be possible to move the drain outlet out of the waterway or divert the surface water to another location at least 60 to 75 feet away and lower the surface flow into the ditch over a sodded chute.

Animal guards—As illustrated in figure 3-7, animal guards such as rods, flap gates, finger type flap gates, or similar structures should be used on the outlets of all drains that are accessible to small animals. Fixed bars should not be used on drain lines where debris may directly enter the system through broken tile or surface inlets.

Figure 3-6. Drain outlets.

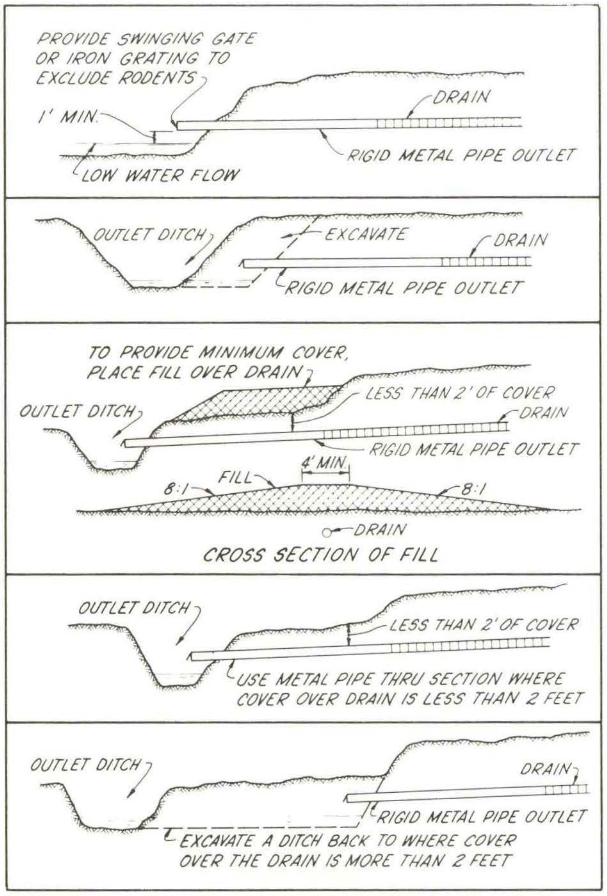


Figure 3-8. Drain crossing.

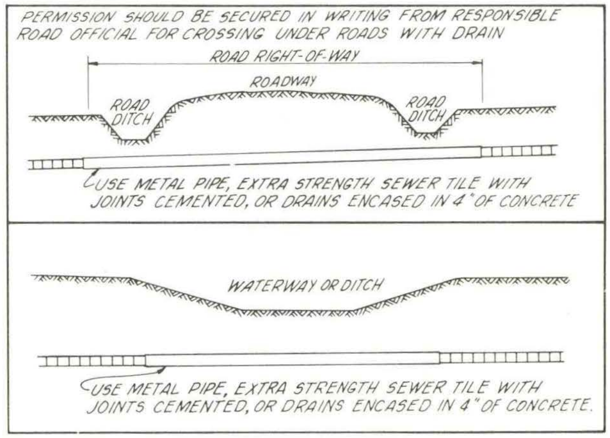
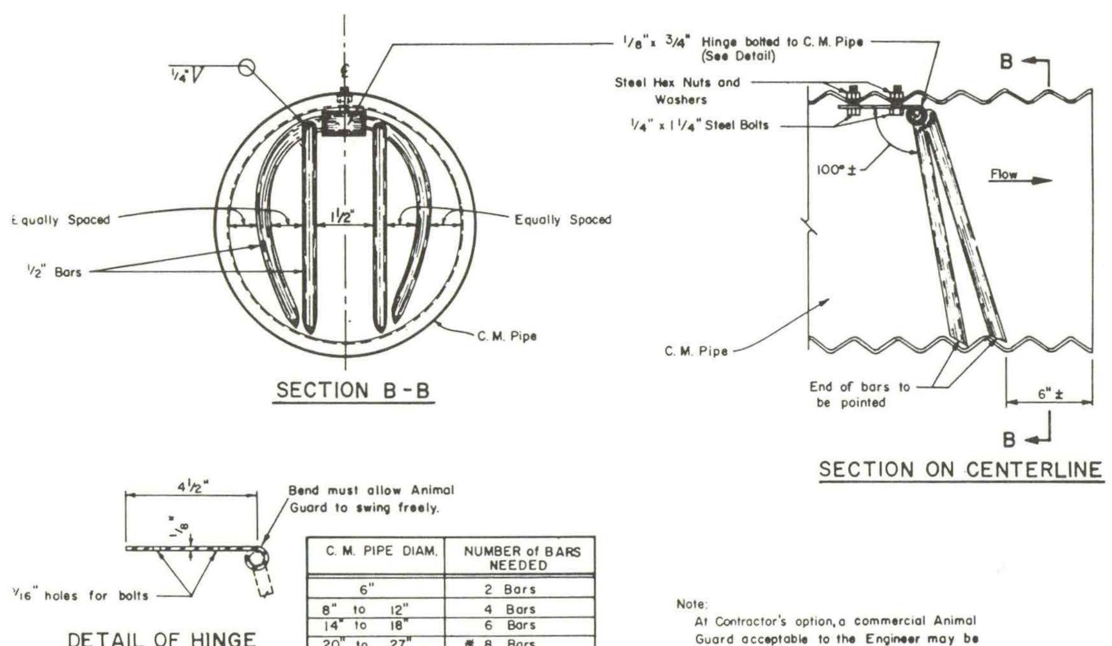


Figure 3-7. Rodent protection for outlet pipe.



C. M. PIPE DIAM.	NUMBER of BARS NEEDED
6"	2 Bars
8" to 12"	4 Bars
14" to 18"	6 Bars
20" to 27"	* 8 Bars

* Use two hinges

Note:
At Contractor's option, a commercial Animal Guard acceptable to the Engineer may be installed in lieu of the Animal Guard shown.

DETAILS OF ANIMAL GUARD - FORK TYPE

Drain crossings—Watertight conduits should be used where subsurface drains cross under waterways or other ditches. Conduits under roadways should be designed to withstand expected loads and should meet the requirements of the appropriate railroad or highway authority (figure 3-8). See tables 3-9, 3-10, and 3-11. Shallow drains through depressional areas and near outlets should be protected against hazards of farm and other equipment, as well as freezing and thawing.

Junction boxes—Junction boxes are used where two or more drains join at different elevations or where abrupt changes in direction are necessary. They may also be used as sediment traps. Junction boxes should be located in permanent fence rows or in noncultivated areas with the cover above ground to provide easy access for inspection. In cultivated fields, the box should be constructed so that the top is at least 18 inches below the ground surface (figure 3-9).

Catch basins or sediment traps—As illustrated in figure 3-10, catch basins or sediment traps are used downstream from surface water inlets to catch sediment and trash entering the line. They also permit direct entry into the line for inspection and maintenance and serve as junction boxes.

Pressure relief well—Pressure relief wells relieve pressure in the line that might otherwise cause the line to blow out. A relief well can be constructed by placing a Tee connection in the line and fitting a pipe vertically into the Tee.

The pipe should outlet at or near the ground surface. The exposed end of the pipe should be covered with heavy wire mesh or grating. The size of the riser should be equal to or greater than the diameter of the line. Relief wells should be located where the drain line might become overloaded for short periods of time, or when full flow changes to partial flow because of increasing grade. Relief wells are also needed on lines that have surface inlets, particularly downstream from large inlets.

Breathers—As shown in figure 3-11, breathers are constructed in the same way as pressure relief wells and may serve the same purposes. Breathers allow air to enter the drain for the purpose of venting the line. Breathers are usually installed where the line changes from a flat to a steep grade and full flow conditions exist in the line with the flat grade or when the line is longer than ¼ mile.

Figure 3-9. Junction box for drains.

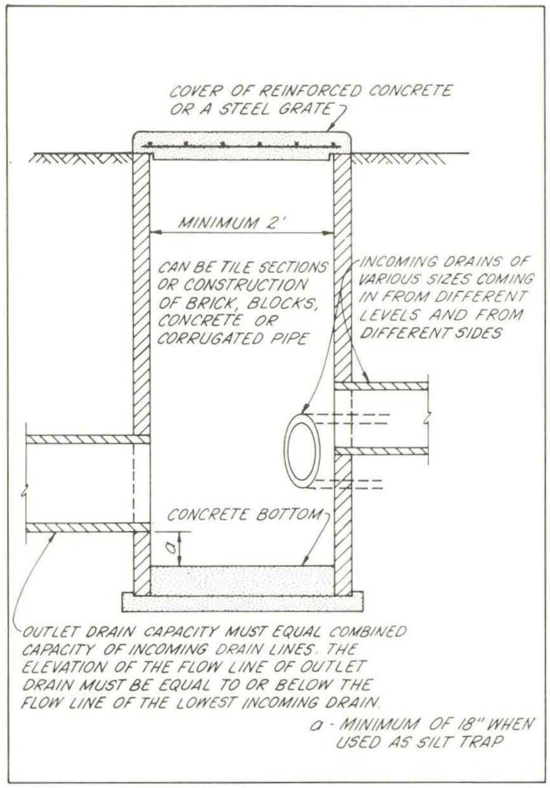


Figure 3-10. Manhole catch basin or sediment trap.

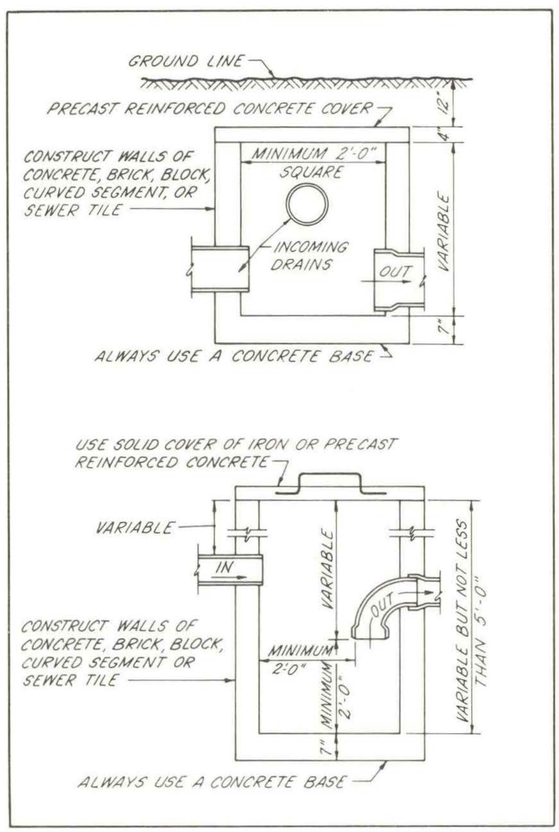


Figure 3-11. Breather or vent. When used as a breather, the riser should be 4 in. in diameter for tile line up to and including 15-in. tile and 6 in. for tile over 18 in.

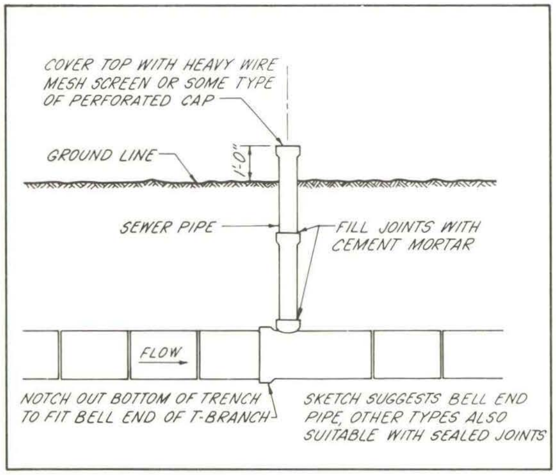


Figure 3-12. Blind inlet.

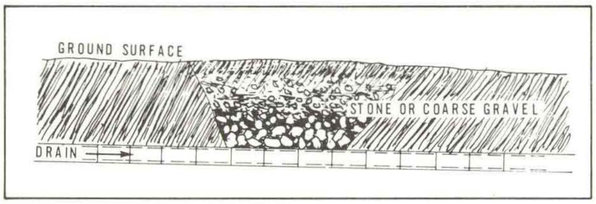
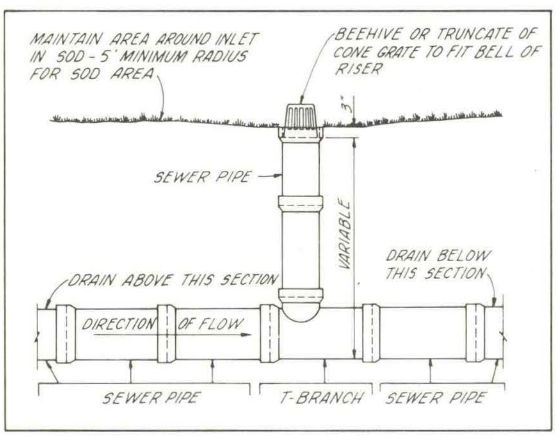


Figure 3-13. Surface water inlet.



Blind inlet or french drains—Following is one method of constructing a blind inlet (figure 3-12). Fill a section of the trench above the drain with broken brick or tile, stone, gravel, crushed rock, corn cobs, or a combination of these materials. Select the fill carefully and place it around and about 6 inches above the drain to meet envelope requirements. Above this point, up to within 12 or 18 inches of the ground surface, grade the material upward from coarse to fine and cover it with topsoil. For faster intake of water and in areas where silting is a problem, use pea gravel, small stones, or coarse sand instead of topsoil. The blind inlet may also be constructed of graded gravel. The length of time for which the blind inlet will be useful depends on proper installation, the fill material, and the amount of sediment that reaches the inlet.

Blind inlets are used to remove both surface and subsurface water. They are most useful in open fields because they do not hinder farming operations. The rate at which blind inlets remove impounded water is much slower than that of surface inlets which should be used where there is a large amount of impounded water.

Surface inlets—Surface inlets (figure 3-13) let surface water enter a drain. Because of the high cost of carrying surface water in buried drains, this structure is recommended only for draining low areas where a surface drainage system is not feasible. When surface inlets are used, two or three lengths of sewer pipe should be placed on each side of the riser. The riser should be installed as recommended for relief wells.

A cone grate is a desirable means of providing protection because it tends to float the flood debris and prevents the debris from closing over the entrance. Metal or plastic pipes that have holes at or slightly above ground level may be used as inlets. In some locations, a top cover over the pipe prevents debris from going down the pipe, and a trash screen prevents lodging against the pipe.

Where it is likely that a substantial amount of sediment will enter the surface water inlet, it is advisable to use a manhole catch basin and sediment trap. Since surface water inlets may be a source of weakness in a drainage system, offset the inlet to one side of the line to reduce the hazard to the main line. One method of protecting the main line is to place the surface water inlets on a short lateral so that any damage to the inlet will not disturb the main.

Connections—Manufactured connections should be used for joining two tile lines at a junction. If connections are not available, the junction should be chipped, fitted, and sealed with cement mortar.

Manufactured couplers or fittings should be used with corrugated plastic tubing at all joints and at all changes in direction where the centerline radius is less than three times the tubing diameter, at changes in diameter, and at the end of the line. All connections must be compatible with the tubing. Where certain fittings are not available, hand-cut holes are acceptable, providing they are reinforced with cement mortar or other material that will make a tight joint. However, when making the connection, care must be taken not to create a means of obstructing flow or catching debris inside the conduit or allowing soil to enter the line.

Mains should be laid deep enough so the centerline of laterals can be joined at or above the approximate centerline of the main.

Trees—Where possible, water-loving trees such as willow, elm, soft maple, and cottonwood should be removed for a distance of approximately 100 feet on either side of a subsurface drain line. A clearance of at least 50 feet should be maintained for other species of trees. If the trees cannot be removed or the line rerouted, the lines should be constructed with sealed, watertight joints or nonperforated tubing throughout the tree root zone.

Buried cables, pipelines, highways, and other facilities—Buried utilities and highways complicate the design and installation of drainage systems. If a new utility line or highway is to cross an area, the affected landowners should have sufficient engineering design work completed to ensure that the installation will have minimum interference with present and future drainage needs.

The crossing of existing buried cables, pipelines, and other facilities with drains should be avoided whenever possible. The number of crossings should be kept to a minimum by installing interceptor lines parallel to the facilities. **Before installing a drainline across a buried cable or pipeline, contact the owner for the exact location and depth and possible supervision while working in the vicinity of the line.** A special permit may be necessary when crossing a county, state, or federal highway.

In addition to the safety hazard of construction around a buried pipeline or cable, the landowner and the contractor may be liable for the cost of interrupted service and repair if a buried utility is damaged and the utility owner was not properly notified.

Filters and filter materials—Suitable filters should be used around drains when required by site conditions to prevent the accumulation of sediment in the drain. Typical soil types that may require filters are sand, silt, and some organic soils. The filters may be sand-gravel envelopes designed to serve as a filter or manufactured filter material. The need for a filter or envelope should be determined by the characteristics of the soil material at drain depth and the velocity of flow in the conduit.

Manufactured filters should have adequate opening size, strength, durability, and permeability to provide constant filtering action in the soil material and to protect the drain throughout the expected life of the system. The manufacturer of the material should certify that it is suitable for underground use.

Envelopes and envelope materials—Envelopes should be used around drainlines when required to improve the flow of subsurface water to the drain or to provide support for the drain.

When the sand-gravel envelope is to also serve as a filter, it is recommended that a minimum of 3 inches of material be placed under and on each side of the drain. If less than 3 inches of filter material is placed over the top of the drain, it should be covered with a plastic sheet to separate the filter from the backfill. The sand-gravel filter material should be selected to prevent the soil in which the installation is made from entering the conduit. Not more than 10 percent of the filter should pass the #60 sieve. Organic materials such as hay, straw, corncobs, and other products may serve as filters. The use of organic materials as filters will depend on their availability and local experience as to their suitability for the given conditions.

Materials to be used for envelopes do not need to meet the same gradation requirements as that of filters, but they should be suited for bedding of the conduit and not contain materials that will cause an accumulation of sediment in the conduit. Envelope material should consist of sand or gravel, all of which passes a 1½ inch sieve, 90 to 100 percent passes a ¾ inch sieve, and not more than 10 percent passes a #60 sieve.

See figure 3-14 for unified soil classification of soils needing filters or envelopes.

Figure 3-14. 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 ft./sec.
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		Optional May be needed with flexible drain tubing	None for soils with little or no fines 1.40 ft./sec. for soils with appreciable 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			
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, dated 8/3/70.

Plans
The designer should prepare a plan and construction notes for the contractor. These plans and notes should be corrected for any modifications made during construction. In cases where the system design can be made in the field, a final "as built" plan and notes should be prepared.

The plans should include a map showing the locations, sizes, and grades of all lines and appurtenances. Profiles or construction notes of all mains and submains should be included. It is important that the map be adequately referenced to existing permanent physical features to facilitate location for any future maintenance and repairs.

One or more copies of the final plan and notes, with any construction modifications, should be given to the landowner. It is recommended that the owner file one copy of the plan with the legal papers of the land and that a working copy be kept with the farm records.

Installation
Introduction—A subsurface drain must be installed correctly if it is to perform properly. With good design and selection of quality materials, proper installation greatly reduces future maintenance problems and prolongs the life of the subsurface drainage system.

Construction plans—All construction work should follow a definite plan that 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 facilities on which this installation depends are satisfactory. Permission should be obtained well in advance of construction to cross other land, easements, highways, and railroads. Buried cables, pipelines, or other utilities should be noted and the public utility concerned should be notified and requested to mark the exact location of such buried obstacles at points where drains are to be constructed. When construction is completed, the contractor should leave a plan of the work as installed in the field with the landowner.

Inspection and handling of material—The contractor should inspect drain materials 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. Ensure that plastic tubing installed is perforated, except as otherwise specified.

Storage—Drain materials should be protected from hazards and they should be handled carefully to avoid damage to the material. The storage area should be dry with good drainage and be free of rodents and vegetation. The area should have a protected floor area (pea gravel 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. Excessive exposure to ultraviolet rays from sunlight can be harmful to tubing. Therefore, protection from sunlight is required when tubing is subjected to long periods of storage. Coils and reels of tubing should be protected from damage and deformation by being laid flat when stored for extended periods of time. Coils of tubing should not be stacked more than four high. Reels should not be stacked.

Safety—Safety standards for people and machines should be observed. Workers in trenches should be protected from cave-ins and they should not work alone. OSHA regulations require special procedures for trenches 5 feet or more in depth. Moving parts of machines should be protected by proper guards. Casual observers should not be permitted near excavating operations.

Grade control—All drains should be installed to a predetermined grade. Accurate grade control must be constantly maintained during installation. This can be accomplished by using equipment designed for drainage installation. If a backhoe or other equipment must be used, considerable hand labor and checking may be necessary to properly shape the trench and control the grade. Grade is normally maintained by use of targets or electronic, optical grade control devices (lasers).

Trench Method
Beginning point—Trench construction should normally begin at the outlet and proceed upgrade.

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

Trench width—Trench width at the top of the drain should be the minimum required to permit installation and provide bedding conditions suitable to support the load on the drain but with not less than 3 inches of clearance on each side of the drain.

Trench bottom—Tile should be bedded with 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 or use a specially shaped bucket.

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 may be semicircular, trapezoidal, or a 90° V. The 90° V-groove of sufficient depth **is satisfactory for 3- to 6-inch tubing.**

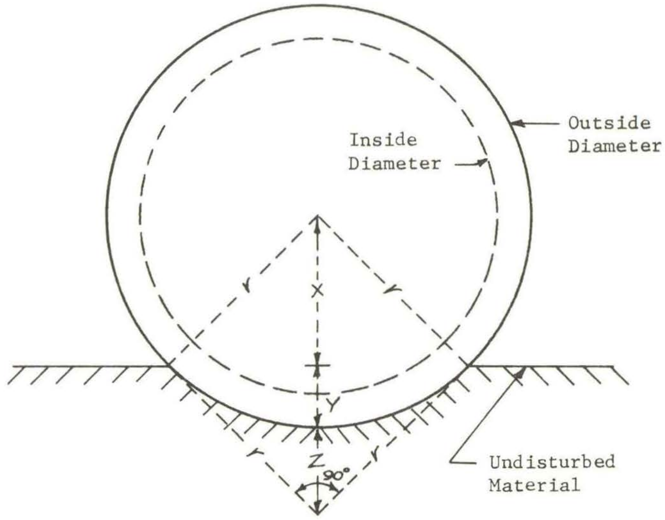
The void under the tubing is advantageous for load bearing but may cause undermining by erosion on steep grades such as terrace outlets. Under steep grade conditions, the bottom of the trench should be shaped to closely fit the tubing. The groove can be formed or cut in a number of ways. In all cases, some type of a forming tool should be 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.

Figure 3-15 shows dimensions for a 90° V-groove. When the same 90° V-groove is used for sizes from 3- to 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 or larger tubing, a curved bottom that more nearly fits the tubing is recommended rather than the 90° V-groove.

Correction for overdigging grade—If the trench is excavated below the designed grade, it should be filled to grade with gravel or well-pulverized soil and tamped sufficiently to provide a firm foundation. The bottom of the trench must be planed and shaped to grade.

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

Figure 3-15. Dimensions for a 90° 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	1.272	0.527	0.745
4	4.8	2.4	1.697	0.703	0.994
5	6.0	3.0	2.121	0.879	1.242
6	7.2	3.6	2.545	1.055	1.490

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

Unstable trench walls—Unstable or fluid soil conditions encountered in the trench wall, or base, such as may be found by excavation below the groundwater level or in a saturated sand, may cause 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 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.

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

The following procedures should be considered when draining such soils:

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

2. Use stabilizing envelope materials under the drain;

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

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

5. If the drain is tile, install to secure a snug fit of the joints; and

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

If unstable soil material is encountered, it may be removed and replaced with a foundation and bedding of processed stone or processed gravel, suitably graded to act as an impervious mat into which the unstable soil will not penetrate. The depth of this processed material used for foundation and bedding will depend on the severity of the trench-bottom soil condition. Install such special foundation and bedding material in a maximum of 6-inch layers and compact. 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° rigid-V prefabricated foundation cradle with the top width 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 should be used that can maintain a continuous forward motion that disturbs the in-place material as little as possible.

Filters and filter material—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 3-16 and 3-17). If this type of filter material is not available, artificial prefabricated filter material can be used. Protective filters are seldom required for agricultural drainage systems in Iowa because soils are generally stable. However, a filter is required for base materials such as uniform fine to medium sands where high velocities can develop that will move the sands into the drain. Gravel envelopes are not normally designed as filters, but, because they consist of a well-graded material related to the gradation of the base material, they do act as partial filters. Most artificial prefabricated filter material such as fiberglass, spun-bonded or knitted synthetic fabrics, and plastic filter cloth act as protective filters and with time may partially clog up and decrease the inflow into the drain. Where fiberglass filter material is used, it must be manufactured from borosilicate-type glass with the manufacturer's certification that it is suitable for underground use. The fibers should be of variable size, with some larger fibers intertwined in the mat in a random manner. During installation, the material should span all open joints and perforations without excessive stretch. Care should be taken not to damage the material during installation. Any damaged areas should be replaced before backfilling.

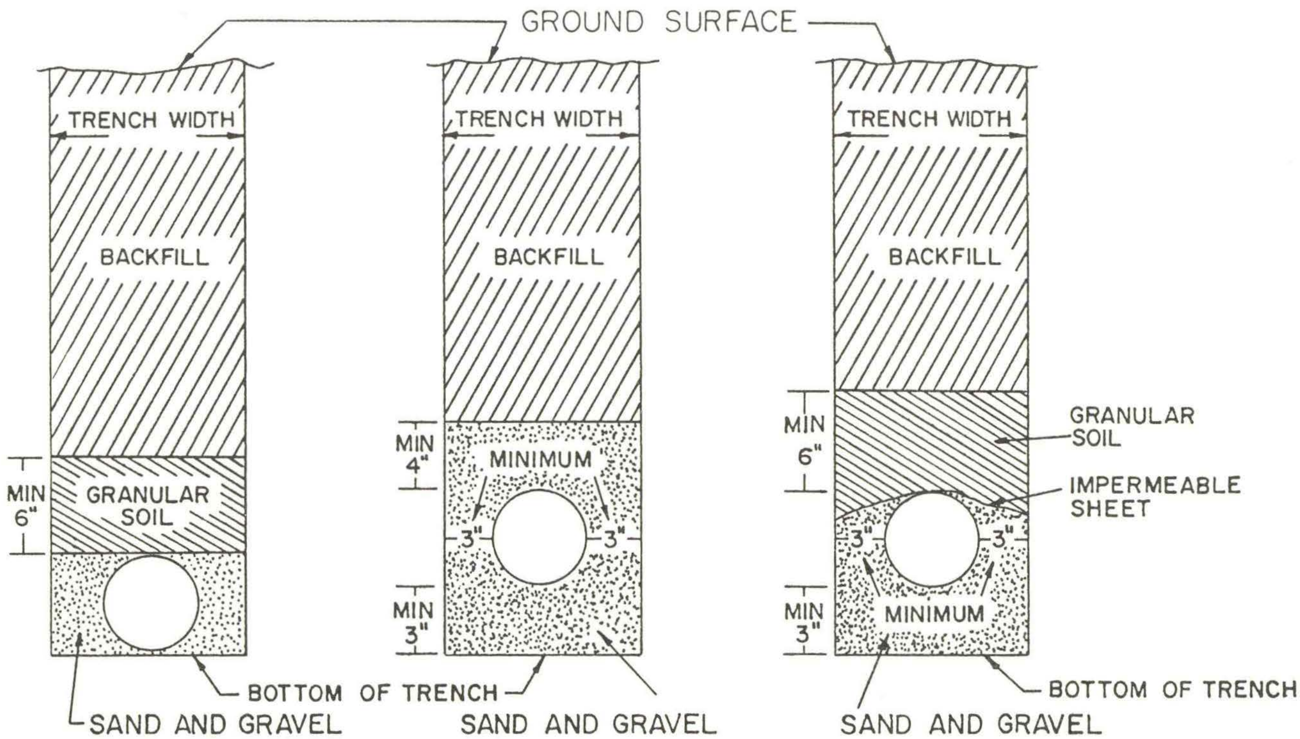


Figure 3-16. Tubing encased in sand and gravel envelope for support.

Figure 3-17. Tubing encased in sand and gravel envelope designed as a filter.

Figure 3-18. Tubing encased in sand and gravel envelope designed as a filter with an impermeable sheet such as plastic.

Envelopes and envelope material—An envelope material installed around subsurface drains ensures proper bedding support and improves the flow of the groundwater 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.

Figures 3-16, 3-17, and 3-18 show the different placement of envelope materials used with tubing. Figure 3-16 shows the envelope being used where drain support is required for either tile or tubing. Installation as shown in figures 3-17 and 3-18 show the shape of the envelope used where fines are present in the soil. 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.

The envelope material should be placed to form an even, firm bedding under the drain, and the remainder of the material should be carefully placed so as not to disturb the grade or alignment of the drain. Care should 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 the gravel envelope is necessary except as required for ensuring a firm and even bedding for the drain.

Allowable variation from grade—The constructed grade must be such that the drain will provide the required capacity. A variation of 0.1 foot from grade is allowable. No reverse grade is allowed.

Installing the Drains

1. Laying conduit should normally begin at the lower end of the drain and progress upgrade. Laying the conduit inside the shoe casing of the drainage machine during the trenching operation is preferred.

2. Conduits should be laid in the groove and on the planned grade on a firm bed, free of loose soil.

3. All soil or debris should be removed from the conduit before installation.

4. Drain conduit should be free from clinging wet or frozen material that would hinder the laying of conduit on grade.

5. The upper end of all drain conduits should be closed tightly with an end plug.

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

7. Automatic conduit-laying devices are acceptable, provided requirements of this guide are met.

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

9. 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.

10. Drains within 100 feet of trees should be of continuous pipe.

Stretch during installation—Stretch 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 as to reduce its stiffness to less than the allowable minimum pipe stiffness. Stretch is expressed as a percent increase of length and should not exceed 5 percent. The use of a power feeder is recommended for all sizes.

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 by 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 usually is within 5 minutes or less after installation.

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 tendency to coil, which causes difficulty in laying flat and level and necessitates extra care. Check with the manufacturer concerning recommendations for handling the material under cold conditions.

Floating in water—Plastic tubing will float in water. If it floats during installation, it is difficult to get backfill material around and over the tubing without getting the material underneath it, causing misalignment. Therefore, precautions must be taken to prevent floating. This can be accomplished by mechanically holding the tubing in place until blinding is completed.

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 areas where chemical deposits in and around the drain area are a problem, blinding should be done with friable topsoil 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 immediately 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 that can be mounted on 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.

1. **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 if the soil is suitable.

2. **Blinding for tubing**—Blinding will ensure proper alignment of the tubing in the groove and protect it when the remaining excavated material is placed in 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 backfilling when the impact of rocks and hard clods could damage it.

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

Backfilling—At the conclusion of each day's work, the end of the drain line should be blocked 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, or conveyor methods. The backfill materials should be placed in the trench so 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 the tubing feels warm to the touch (100°F), delay backfilling until the tubing reaches the soil temperature.

Trenchless Plow Method

The trenchless method, using a drainage plow, can be used to install corrugated plastic drain tubing. 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.

In the trenchless plow method, tubing is placed at a prescribed depth in an open channel beneath a temporarily displaced wedge or column of soil. The

Figure 3-19. Soil disturbance caused by trenchless plow working relatively shallow (28 in.).

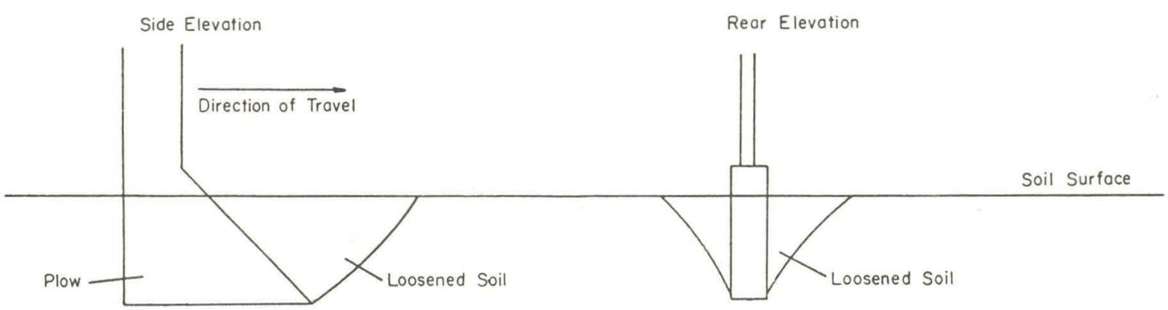
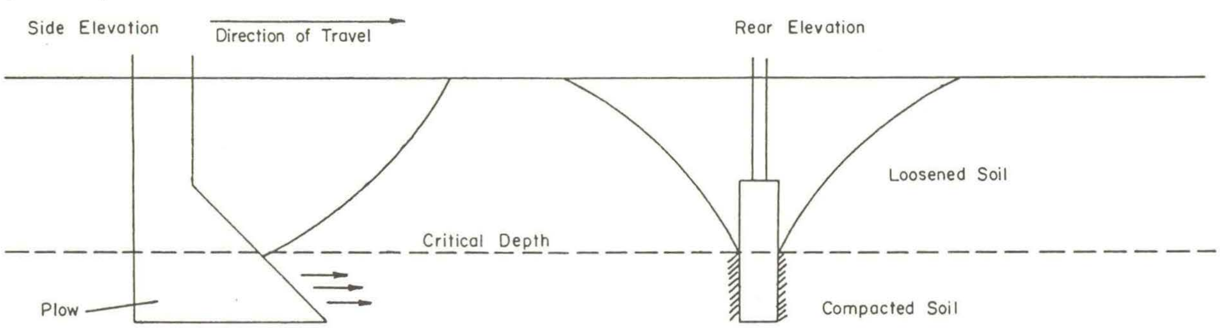


Figure 3-20. Soil disturbance caused by trenchless plow working relatively deep (5½ ft.).



trenchless plow 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 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 slot should be fissured and loosened rather than compacted. The size of the shoe and drain placing attachment should conform to the outside diameter of the drain.

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 3-19. The soil is broken loose at the base of the plow. It heaves forward and upward ahead of the tine and falls 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 (5½ feet) in the same dry soil will tend to move the soil as shown in figure 3-20.

Disturbance near the soil surface is similar to figure 3-19, but below a certain depth, the soil is compressed sideways resulting in compaction with a reduction in soil permeability. Between these two extremes of working depth there is a certain depth, termed critical depth, where the transition occurs between one type of soil disturbance and the other. This critical depth represents the maximum working depth of a trenchless plow if compaction around the pipe is to be avoided. The position of the critical depth depends upon the following factors: forward inclination of tine, tine width, soil moisture content, and 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 more moist at depth, the critical depth will reduce to about 10 times the tine width. The critical depth can sometimes be lowered by loosening the surface layers of the soil to a depth between 8 to 16 inches in a strip approximately 1½ times 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 above 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.

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 with textures ranging from sand 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 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 that 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.

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 are. The operator should flag locations where rocks are encountered at the time of contact 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 large rocks are above or near grade, the plow tends to bounce over them and disrupt 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 an adverse deviation in grade, the point of deviation should be marked. The drain is to be excavated at this point and the grade corrected.

Blinding—Trenchless plows should be fitted with a device 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 sand if a filter is not used. With a filter, a covering of medium to coarse sand around the tubing could enhance inflow.

Stringing tubing—Because of relatively high plow speeds, stringing 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. Spools mounted on the machine can be used as an alternative to stringing.

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 stiffness. The permitted stretch during installation should not exceed 5 percent. It is recommended that trenchless plows be equipped with a power feeder to reduce stretch during the installation process.

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

Grade control—The laser automatic grade control method should 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 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 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 of the type of conservation practice that could be used on the contributing watershed area to reduce soil movement.

Cleaning 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 jeopardize 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 line 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 manufactured 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 the traps need to be checked 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. 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 recessing the channel bank and setting the pipe within the recessed 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—A flap gate or fixed pin guard can be used to prevent rodents and other small animals from entering and blocking outlets.

Fixed pins are suitable for lines without surface inlets. The pins are inserted horizontally through the end of the pipe, not more than 1½ 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 should be used for lines that have surface inlets. Small material that continually washes through inlets into the line can plug a fixed pin guard. Flap gates should be made of noncorrosive material.

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. 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. Jetting the drain with an acid solution has been used successfully in some areas, but this remedy is very costly.

Chapter 4. Surface Drainage

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

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 or even eliminate the need for them under certain conditions.

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 may be 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 Drains or Ditches

The principal means to convey water in a surface drainage system is by field drain, field lateral, and farm main. Field drains need not be designed to contain the quantities of flow as indicated by drainage curves (see Chapter 5: Open Channels) since their primary purpose is to remove residual surface water after volume runoff has passed out of the field.

Field drains are shallow graded channels, usually with relatively flat side slopes, that collect water within a field. Figure 4-1 shows typical field drains.

Field drains may require cleaning after tillage operations. When field drains are not cultivated, weed growth should be controlled by mowing, spraying, or burning.

Figure 4-1. Field drains.

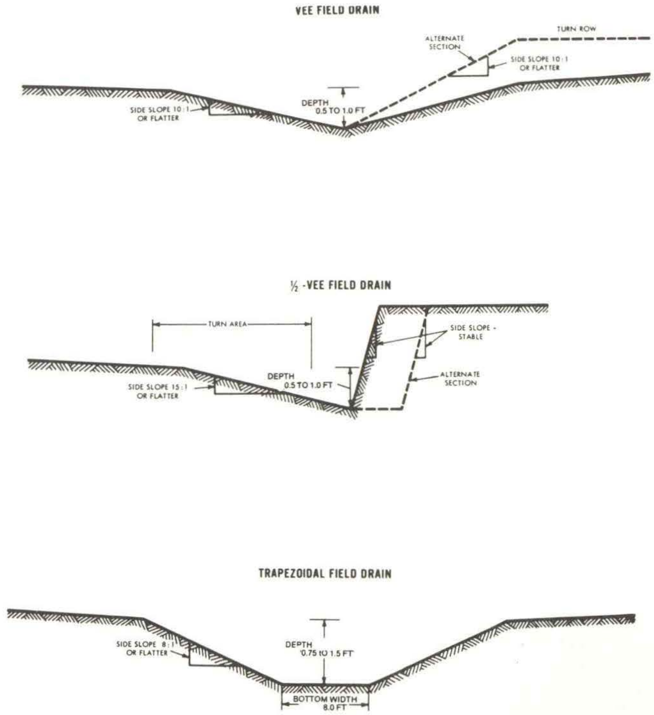


Table 4-1 shows field drain dimensions. Tables 4-3, 4-4, or 5-3 may be used to size field drains. (**Note:** Table 5-3 was developed for an "n" of 0.040 (maintained grass). For bare channels or other cover, design for approximate "n." See the tables for correction factors.

Field lateral is the principal ditch for adjacent fields or areas on a farm. Field laterals receive water from field drains, and, in some areas, from field surfaces, and carry it to the farm mains. Figure 4-2 shows typical field laterals.

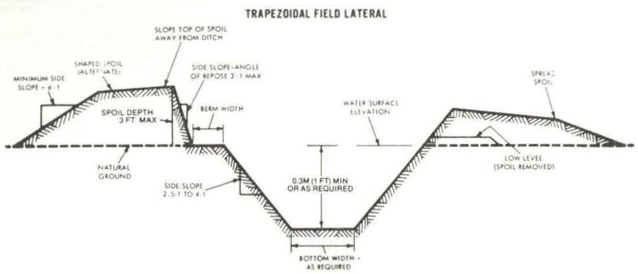
Field laterals should be designed to discharge the rates of flow indicated by the drainage curves. Field laterals occupy productive land and are costly to construct and maintain. They should be spaced as widely apart as field conditions permit. Draglines and backhoes are used to construct and maintain field laterals. Table 4-2 shows field lateral dimensions.

Table 4-1. Recommended minimum field ditch dimensions.

Type	Depth (ft.)	Bottom width (ft.)	Side slopes
Vee	0.5 to 1.0	0	10:1 or flatter[1]
One-half vee	0.5 to 1.0	-	15:1 or flatter
Trapezoidal	0.75 to 1.5	8	8:1 or flatter

[1]10 horizontal to 1 vertical.

Figure 4-2. Field lateral.



Sizing for field laterals may be done from both the open channel tables (table 5-3) or from the field drainage tables (tables 4-3 and 4-4).

Field laterals require periodic maintenance. Suitable chemical weed and brush 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 of livestock is a good method. Laterals require cleanout where excess deposition has occurred.

Table 4-2. Recommended field lateral side slopes.

Type	Depth	Recommended side slopes	Minimum side slopes
Trapezoidal	1.0 to 3.0	4:1	2:1
Trapezoidal	3.1 and over	2.5:1	1:1

Table 4-3. Vee-shaped field drainage ditches. 10:1 Side Slopes n = 0.025

				Slope (%) .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

(Table 4-3 continued) — 10:1 Side Slopes n = 0.025

	Slope (%) .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 (%) .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

10:1 Side Slopes
n = 0.025

Table 4-4. Vee-shaped field drainage ditches. 10:1 Side Slopes n=0.040

				Slope (%) .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 (%) .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 (%) .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

10:1 Side Slopes
n=0.040

Farm main is the outlet ditch serving an individual farm (see Chapter 5: Open Channels, for design, construction, and maintenance).

In some situations, where erosion may be a problem or in an urban setting, it may be more desirable to use a "vegetated" surface drain or waterway.

Methods

The principal surface drainage methods are land smoothing, land grading, random system, parallel system, interceptor drain, and diversion. 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 drains.

The smoothing operation 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 drains and/or laterals should be installed in the remaining low areas. Figure 4-3 shows a typical 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 drain. Land grading, by carefully designed cutting and filling operations, provides excellent surface drainage.

Areas to be graded should be planned for a minimum number of field drains with the drains located, where possible, at right angles to field laterals and crop rows.

Surface drainage will be adequate if all reverse row grades that form depressions are eliminated. Minimum grade limits should include a tolerance in construction that will permit the elimination of all depressions either in original construction or the postconstruction touchup. Reverse row grades can be eliminated with relative ease on fields designed with 0.2 percent minimum grades. Unusual precision in construction is required with 0.1 percent and flatter grades.

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

Figure 4-3. Land smoothing operation.

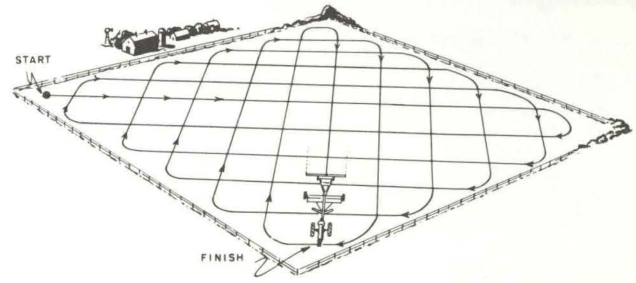
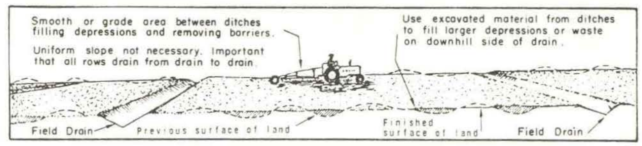
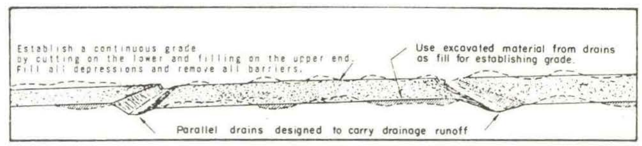


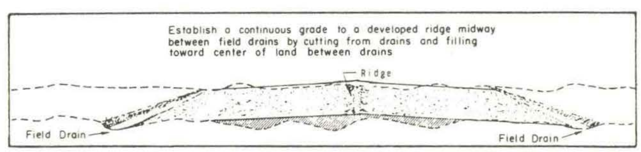
Figure 4-4. Methods of grading land surfaces for drainage.



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

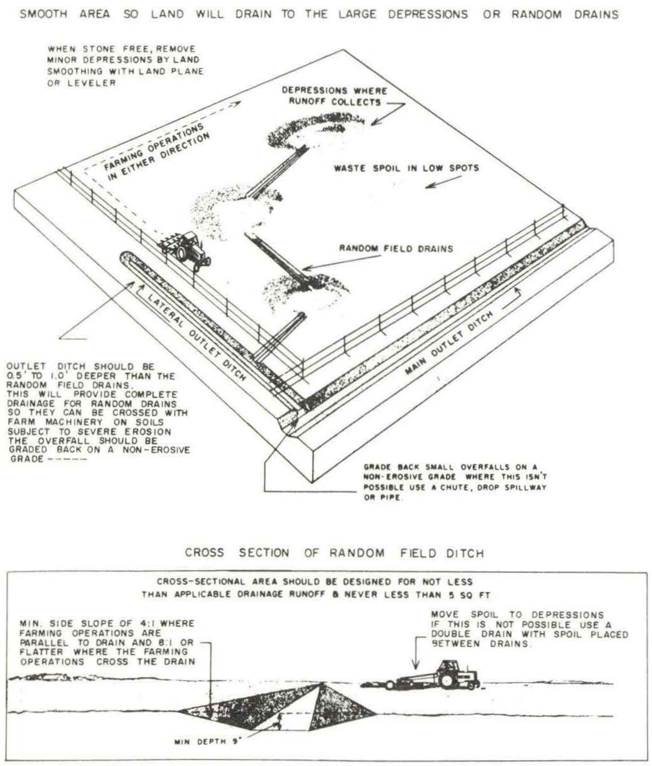


TYPICAL CROSS SECTION OF GROUND SURFACE THAT HAS LITTLE OR NO GENERAL SLOPE AND IS COVERED WITH MANY SMALL DEPRESSIONS AND POCKETS

Cross slopes normally should not exceed 0.5 percent. Reverse cross slopes are satisfactory if field drains have the minimum required grades and drainage outlets are adequate.

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

Figure 4-5. Random system of surface drainage.



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. Fields should be scarified prior to construction if there are hardpans. The field surface should be firm when surveyed so that rod readings taken at stakes will reflect the true elevations. Fields **should not be graded when wet** because this impairs the physical condition of the soil.

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

Fields should be scarified either before or after the final land smoothing operations to loosen the cut surfaces and to blend the fill material with the underlying soil.

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 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 must be in the direction of the crop rows.

Random system is a system of meandering field drains or field laterals that are located in and drain depressions in a field. The random system is adapted to slowly permeable soils having depressional areas too large to be eliminated by land smoothing or grading. These ditches connect the various low spots 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 4-5 shows a typical random layout.

Double field drains, 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 drains. Recommended minimum distances between the centerlines are 50 feet for drains 0.5 feet deep, plus 10 feet for each additional 0.1 foot of depth. Lesser distances may be necessary at the outlet ends because of construction requirements. Figure 4-6 shows a "W" ditch layout.

Parallel system is a system of parallel laterals with most of the field drains at right angles 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 drains are constructed between parallel field laterals. This permits farm equipment to travel greater distances without turning. Field surfaces between field laterals should be improved by land smoothing or land grading for maximum benefits.

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

Figure 4-6. Layout of the "W" ditch.

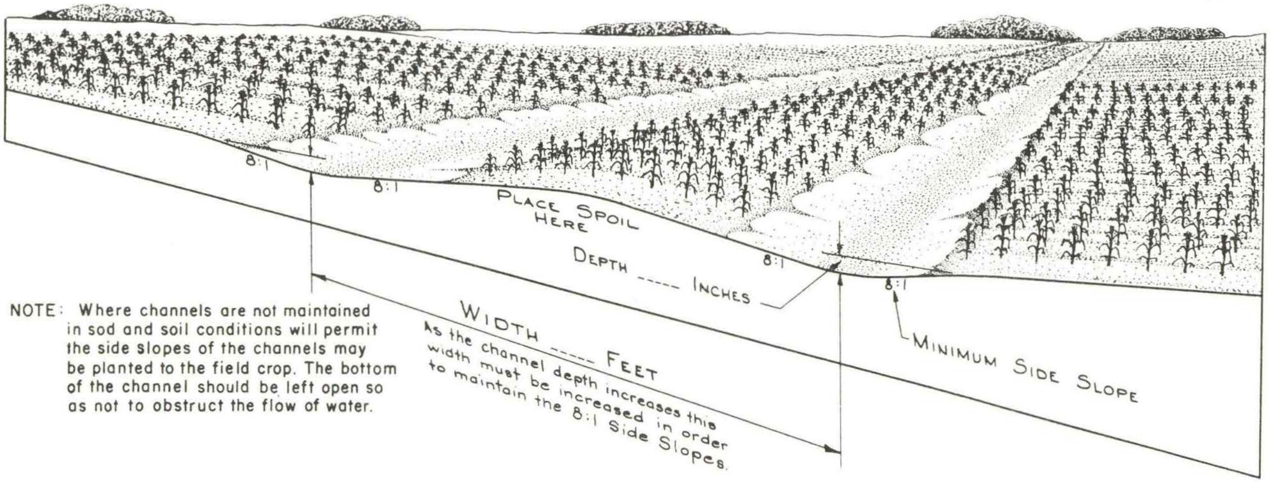
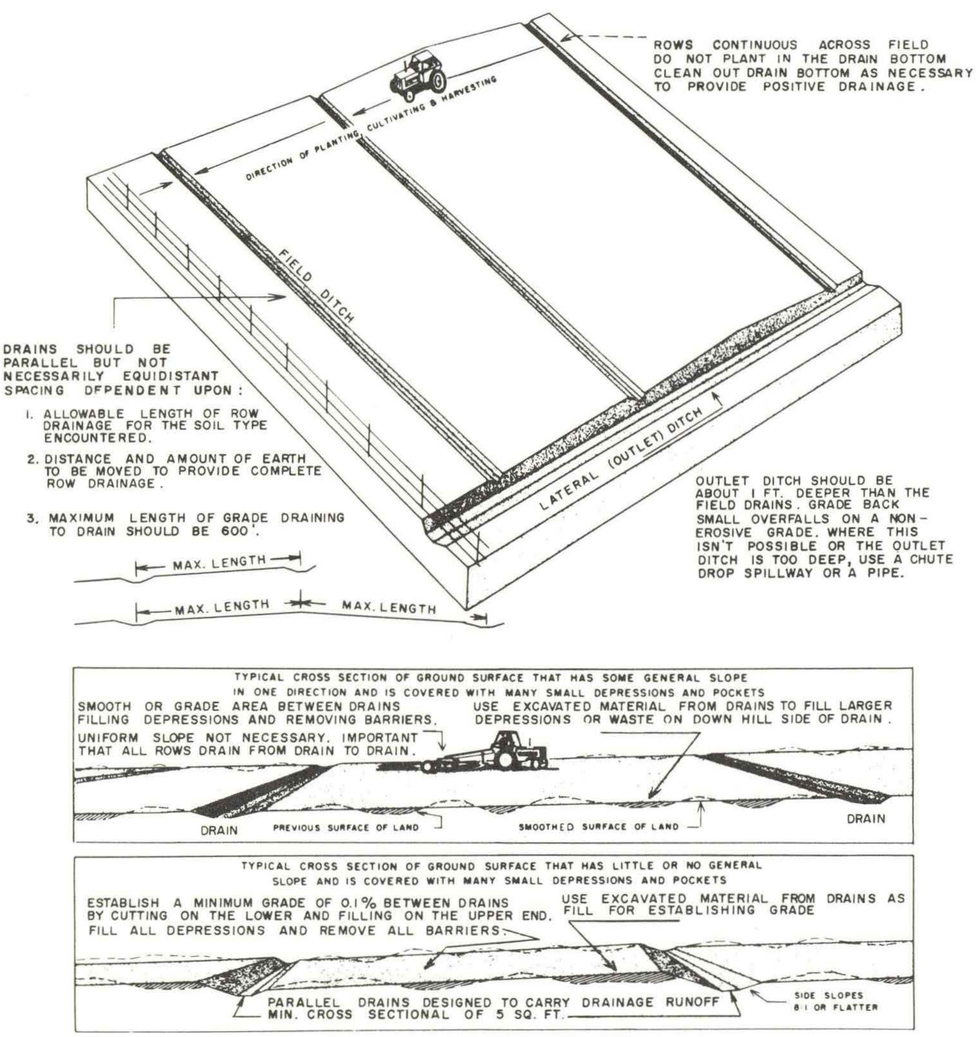


Figure 4-7. Parallel system of surface drainage.

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



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

2. Lay out collection ditches across the slope but never with less grade than 0.05 feet in 100 feet. Grade the surface between the ditches, if necessary, to have all rows drain to the ditch.

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

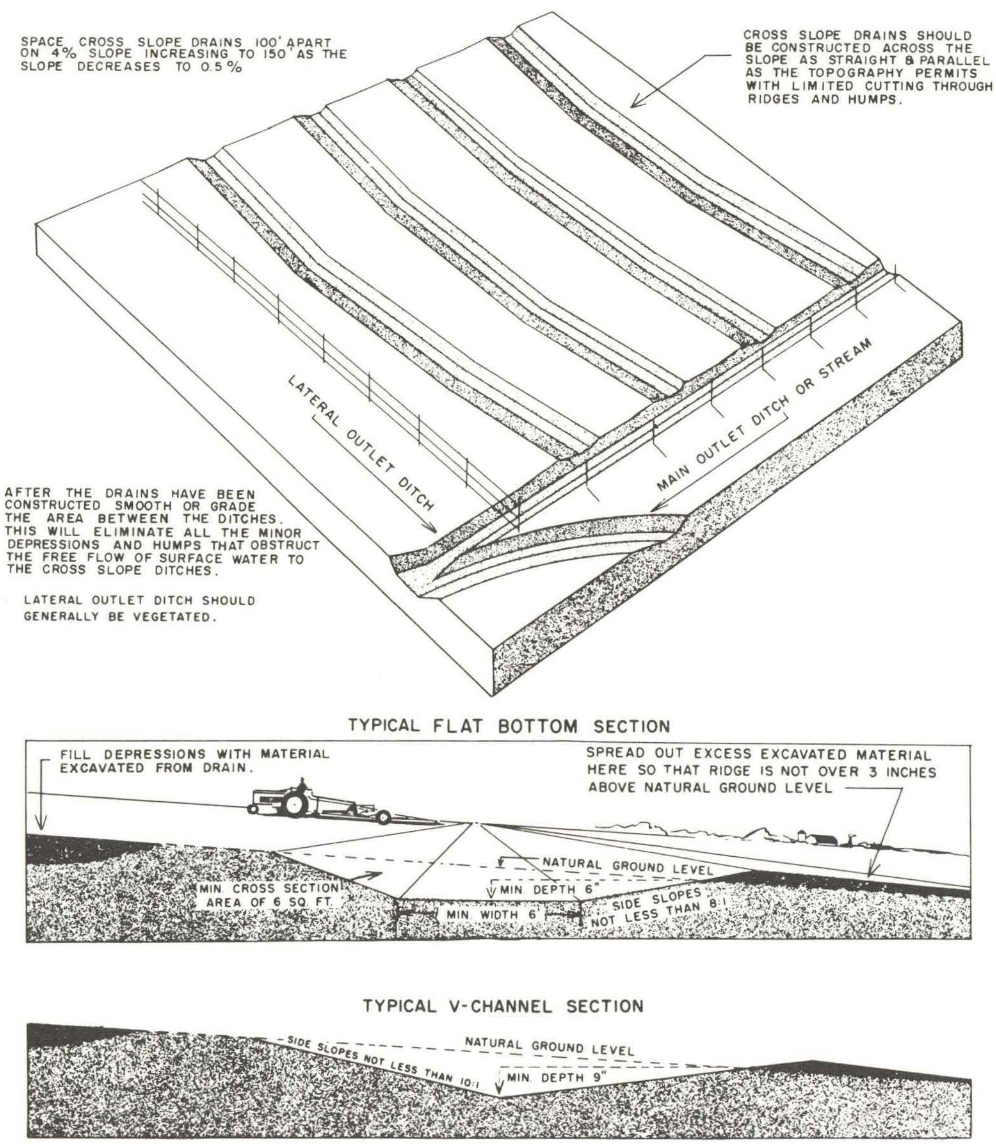
4. Plow the field in the direction of greatest slope. Dead furrows should be on a continuous slope to avoid ponding of water.

5. Use land smoothing every 2 to 3 years to maintain a continuous grade between collection ditches.

Figure 4-7 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 drains 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 drains convey water to a collector field lateral by drop structures or other means at the field drain outlets. If the grade is too erosive for the field lateral, a grassed waterway may have to be utilized. The collector ditches are located to one side of the field to permit continuous cultivation. Crop rows are still normally laid out in the direction of greatest slope.

Figure 4-8. Cross slope system of surface drainage.



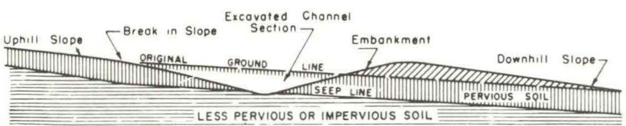
Field drains in the cross-slope system should be as straight as topography permits with limited cutting through ridges and humps. Spacing for each field should be designed to control erosion losses and permit adequate drainage. Drain slopes should be between 0.05 and 0.5 feet per 100 feet and the cross-sectional area of the drain should be not less than 6 square feet.

The spoil should be spread over the field and placed in depressions on the slopes between drains. 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 ditches. Figure 4-8 illustrates the cross-slope system.

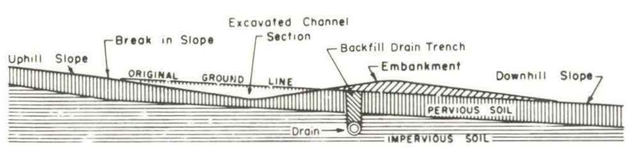
Interceptor drains are channels located across the flow of groundwater and installed to collect subsurface flow before it resurfaces. Surface water may also be collected and removed. They are used on long slopes with 1 percent or steeper grades and shallow, permeable soils overlying relatively impermeable subsoils. Interceptor drains should be designed to meet the field conditions as disclosed by soil borings and topography. Figure 4-9 illustrates typical layouts for an interceptor drain. Draglines and backhoes are used to construct and maintain interceptor drains.

Diversions are channels constructed across the slope to intercept surface runoff and conduct it to a safe outlet. Diversions 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 cost of drainage systems for bottomlands. The diversion will be designed on grades that will not carry water to exceed the maximum allowable velocity suggested for open ditches. It will normally be designed to carry the 10-year frequency storm event. Figure 4-10 illustrates a typical diversion layout. Bulldozers are suitable for the construction of diversions.

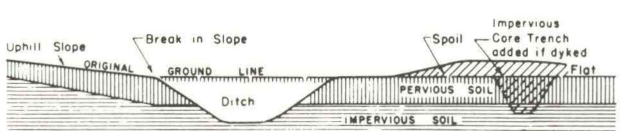
Figure 4-9. Typical interceptor installations.



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

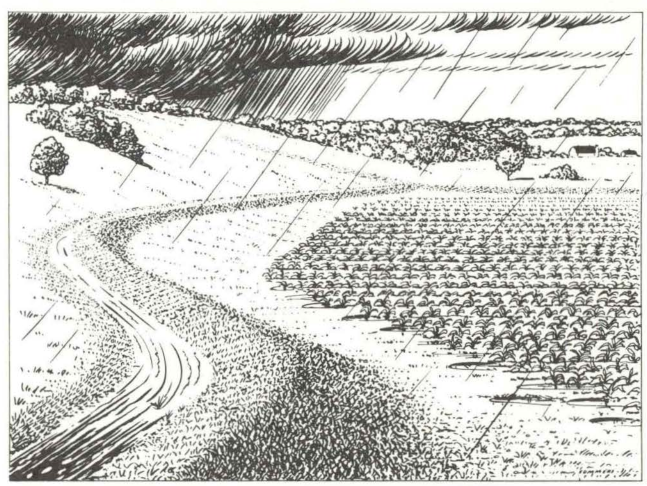


CROSS SECTION SHOWING DITCH AS SURFACE WATER DIVERSION WITH DRAIN AS SUB-SURFACE INTERCEPTOR



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

Figure 4-10. Diversion.



Chapter 5: Open Channels

Open channels serve as outlets for other conservation practices that are installed to dispose of excess surface and subsurface water required for flood prevention, drainage, or other water management purposes.

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

Design and Construction

Adequacy of Outlets

All drainage systems require outlets of adequate capacity, depth, and stability to meet design requirements. If the outlet is inadequate, the effectiveness of the entire drainage system can be greatly reduced or lost.

Characteristics of a stable channel are:

1. It neither aggrades nor degrades beyond tolerable limits,

2. The channel banks do not erode to the extent that the channel cross section is changed appreciably,

3. Excessive sediment bars do not develop,

4. Excessive erosion does not occur around culverts and bridges or elsewhere, and

5. Gullies do not form or enlarge due to the entry of uncontrolled surface flow to the channel.

All channel construction and modification (including clearing and snagging) must be in accord with a design that can be expected to result in a stable channel that can be maintained at reasonable cost. Vegetation, riprap, revetments, linings, structures, or other measures should be used where necessary to ensure stability.

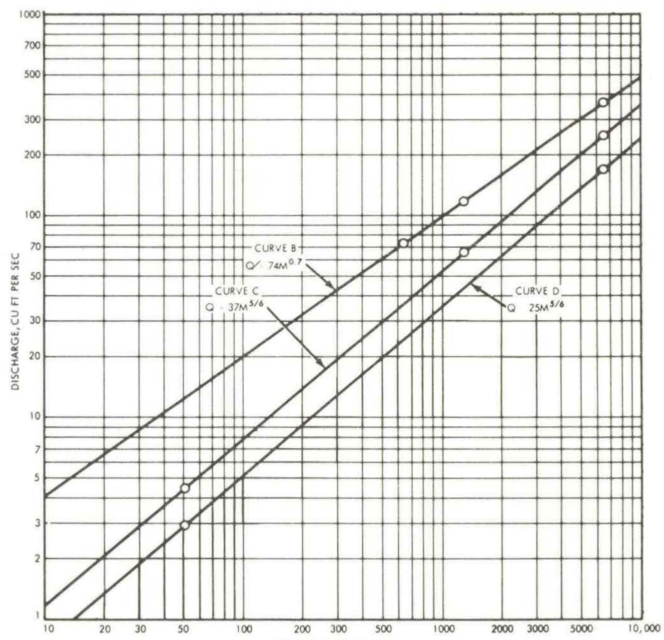
Installation of channels, or improvement of existing channels, usually increases peak discharges downstream from the end of the improvement. Care should be taken to prevent increased stages downstream from creating significant damage. The channel must be stable when there is flow at design capacity. Where the drainage area exceeds 1 square mile, USDA Soil Conservation Service Technical Release No. 25, *Design of Open Channels,* covers procedures to evaluate channel stability.

Excavation or other channel work must not cause significant erosion, flooding, or sedimentation. The landowner or operator must be advised that it is their responsibility to secure necessary state permits and to comply with applicable federal and state laws and regulations (see Chapter 1).

Required Capacities

The required capacity of the open channel may be developed from drainage curves or from flood routings of the drainage area. Drainage design criteria are based on the fact that crops can tolerate a limited amount of flooding but must not be flooded for long periods of time, usually no longer than 24 to 48 hours. The intensity of drainage desired is expressed in terms of drainage curves (figure 5-1). These empirical curves were developed from a large number of field measurements of drainage flow rates and observation of the adequacy of drainage. The curves will not provide for peak flows from large storms. Excess runoff will be discharged as overland flow that temporarily floods adjacent lands.

Figure 5-1. Drainage curves for grain crops in Iowa.



Curve B for flood plain where there is a combination of hills and flood plain.
Curve C for major portion of state outside areas described in curves B and D.
Curve D for lake regulated, sandy topography, or pothole areas. Applicable to drainage areas having average slopes of less than 25 feet per mile.

If the total runoff (R), in inches, from a 2-year, 48-hour storm can be determined, the required capacity of the open channel can be determined as follows:

$$Q = (16.39 + 14.75 \frac{R}{2}) M^{5/6}$$

In the curve equations, Q is the design flow rate in cubic feet per second and M is the drainage area in square miles.

Hydraulic Design and Construction

Having determined the required channel capacities, it is necessary to design a channel of adequate size to convey the desired flow without exceeding a predetermined water surface elevation and at velocities that are neither erosive nor so slow as to cause large amounts of sediment deposition. Basic hydraulic concepts necessary to accomplish these ends are described in the following text.

Water Surface Elevation-Hydraulic Gradient

The hydraulic gradient represents the surface of the water when the ditch is operating at the design flow. The design of the hydraulic gradient for drainage ditches should be determined from control points including elevation, significant low areas served by the ditch and hydraulic gradients of any tributary ditches, and the outlet. The hydraulic gradient is drawn through or below as many control points as possible based on their importance and after studying: (1) the profile of the natural ground surface, (2) critical elevations established by surveys, and (3) channel restrictions such as culverts and bridges.

If control point elevations are estimated rather than computed from survey data, the hydraulic gradient should be no less than:

1. One foot below fields that will receive normal drainage for ditches draining more than 640 acres,

2. 0.5 foot for ditches draining 40 to 640 acres, and

3. 0.3 foot for ditches draining less than 40 acres.

For lands to be used only for water-tolerant crops, such as trees and grasses, these requirements may be modified and the hydraulic gradeline set at ground level. These guidelines do not apply to channels where flow is contained by dikes.

Permissible Velocities

Velocities must be high enough to prevent siltation but low enough to avoid erosion. Table 5-1 provides a guide to maximum allowable velocities for drainage areas of 640 acres or less. Velocities less than 1.5 feet per second should be avoided since siltation will take place and permit growth of mosses and weeds as well as reducing channel cross section.

Table 5-1. Maximum allowable velocities for given soil textures.

Soil on channel bottom and sides			
Descriptive term or name	**Soil classification: USDA**	**Soil classification: Unified**	**Velocity, fps**
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	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 gravels, cobbles, flaggy, unweathered shales and hardpans	Clean gravels (D_{50}>3/4″), cobbles, unweathered shales and hardpans	6.00

The Flow Formula—Manning's Equation

The most-used formula for open channel design was developed by Robert Manning in 1890 and is known as Manning's Formula. It is written as follows.

$$V = \frac{1.486}{n} r^{2/3} s^{1/2}$$

V = Average velocity of flow in feet per second;
n = A coefficient of roughness;
r = Hydraulic radius in feet. $r = \frac{A}{p}$

A = Area of cross section in square feet
p = Wetted perimeter, or length of cross section on which water impinges
s = Slope of hydraulic gradient, in feet per foot (Although s is actually the slope of the water surface, or even more precisely, of the "energy" gradient, for designs within the scope of this guide, s is usually taken as the slope of the channel bottom.)

After V is determined, capacity (Q), is calculated from the equation:

$$Q = AV$$

Q = Capacity in cubic feet per second
A = Area of cross section in square feet
V = Velocity in feet per second determined from Manning's equation

Table 5-2 provides a quick method for computing velocity and capacity for 0.040 roughness coefficient and often used side slopes (2:1 and 4:0).

The following references contain many useful tables to aid in the solution of Manning's equation.

King, Horace W., *Handbook of Hydraulics,* 3rd, 4th, 5th, or 6th edition.
Corps of Engineers, *Hydraulic Tables,* 2nd edition, 1944.
Bureau of Reclamation, *Hydraulic and Excavation Tables,* 11th edition, 1957.

Table 5-2. Values of V and Q for drainage ditches.

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	
					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	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
	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
	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
	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				
	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								
	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
	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
	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
	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						
	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										
	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
	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
	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
	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						
	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										
	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
	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
	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		
	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																

CORRECTION FACTORS FOR V AND Q n
0.025 - 1.60
0.030 - 1.33
0.035 - 1.14
0.040 - 1.00
0.045 - 0.89
0.050 - 0.80
0.055 - 0.73
0.060 - 0.67
0.065 - 0.62
0.070 - 0.57
0.075 - 0.53
0.100 - 0.40
0.125 - 0.32
0.150 - 0.27
0.175 - 0.23
0.200 - 0.20
0.250 - 0.16
0.300 - 0.13

2:1 Side Slopes
n=0.040

Table 5-2. Values of V and Q for drainage ditches (continued).

DITCH SIZE					PERCENT SLOPE																	
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	
					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
	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
	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
	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
	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
	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
	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
	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
	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
	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
	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
	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
	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
	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
	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
	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
	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
	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
	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	3.98	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

CORRECTION FACTORS FOR V AND Q
n
0.025 - 1.60
0.030 - 1.33
0.035 - 1.14
0.040 - 1.00
0.045 - 0.89
0.050 - 0.80
0.055 - 0.73
0.060 - 0.67
0.065 - 0.62
0.070 - 0.57
0.075 - 0.53
0.100 - 0.40
0.125 - 0.32
0.150 - 0.27
0.175 - 0.23
0.200 - 0.20
0.250 - 0.16
0.300 - 0.13

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.

2:1 Side Slopes
n = 0.040

Table 5-2. Values of V and Q for drainage ditches (continued).

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	
					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
	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
	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
	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				
	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								
	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
	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
	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
	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						
	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										
	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
	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
	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		
	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								
	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										
	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
	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
	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				
	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																

CORRECTION FACTORS FOR V AND Q
n
0.025 - 1.60
0.030 - 1.33
0.035 - 1.14
0.040 - 1.00
0.045 - 0.89
0.050 - 0.80
0.055 - 0.73
0.060 - 0.67
0.065 - 0.62
0.070 - 0.57
0.075 - 0.53
0.100 - 0.40
0.125 - 0.32
0.150 - 0.27
0.175 - 0.23
0.200 - 0.20
0.250 - 0.16
0.300 - 0.13

4:1 Side Slopes
n=0.040

Table 5-2. Values of V and Q for drainage ditches (continued).

Ditch Size: Bottom Width Ft.	Depth Ft.	Top Width Ft.	Area Sq.Ft.	r - Ft.	Percent Slope 0.02 V	0.02 Q	0.04 V	0.04 Q	0.06 V	0.06 Q	0.08 V	0.08 Q	0.10 V	0.10 Q	0.15 V	0.15 Q	0.20 V	0.20 Q	0.25 V	0.25 Q	0.30 V	0.30 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
	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
	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
	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
	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
	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
	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
	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
	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
	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
	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
	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
	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
	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
	4.5	26.0	76.50	2.72	1.02	78	1.45	111	1.78	136	2.05	157	2.28	174	2.80	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
	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
	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
	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
	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	0.88	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	0.72	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	0.81	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	597
	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

Correction Factors for V and Q: n	
0.025	1.60
0.030	1.33
0.035	1.14
0.040	1.00
0.045	0.89
0.050	0.80
0.055	0.73
0.060	0.67
0.065	0.62
0.070	0.57
0.075	0.53
0.100	0.40
0.125	0.32
0.150	0.27
0.175	0.23
0.200	0.20
0.250	0.16
0.300	0.13

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.

4:1 Side Slopes
n = 0.040

Roughness Coefficient

The coefficient "n" is a factor that must take into account all retarding influences in a channel, not just roughness alone. Vegetation, meanders, obstructions, etc., all affect channel flow. For a design within the scope of this guide, a value of n=.04 is commonly used for the aged condition and many design tables are based on this value. However, the designer should consider all retarding influences and select a value that will represent conditions that will exist after the channel is "aged" and assuming the level of maintenance expected.

Generally, "n" tends to decrease as the hydraulic radius increases. Table 5-3 provides recommended values of "n" based on the hydraulic radius of the channel for the solution of the Manning Formula for mains and laterals with good alignment.

Table 5-3. Value of roughness coefficient.

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

Channel Depth

Open channels that serve as outlets for subsurface drains should be designed for a normal water surface at or below the invert of the outlet end of the closed drain. The clearance between a subsurface drain invert and the ditch bottom should be at least 1 foot for ditches that fill with sediment at a normal rate. Larger clearances are to be specified when unusual site conditions occur, such as organic and sandy soils. The normal water surface is defined as the elevation of the usual low flow during the growing season.

Cross Section

The design ditch cross section (see figure 4-2, Chapter 4: Surface Drainage) should be set below the design hydraulic grade line and should meet the combined requirements of capacity, limiting velocity, depth, side slopes, bottom width, and, if needed, allowances for initial sedimentation. Side slopes should be stable, meet maintenance requirements, and be designed according to site conditions. Based upon soil conditions, side slopes should be no steeper than:

1. Silt 2:1,
2. Clay and other heavy soils 1½:1,
3. Peat and muck 1:1, and
4. Sand 3:1.

Construction equipment and maintenance requirements influence the bottom width and should be established to suit site conditions. In some situations, ditches may need to be crossed in the farming operation and will require a 6 to 1 or flatter side slope. A 3 to 1 or flatter side slope should be used where vegetation is mowed.

Location

Where possible, outlet channels should be located near or parallel to field boundaries or property lines so as not to interfere with cropping patterns. However, it will often be desirable to follow existing natural drainage courses to minimize excavation.

Channel Alignment

Straight lines and gentle curves are recommended in laying out open channels. Table 5-4 shows recommended minimum radii of curvature without bank protection. Bank protection should be provided if necessary changes in alignment are sharper than those listed.

Table 5-4. Minimum radii of curvature without bank protection.

Width of ditch top (ft.)	Fall per mile	Minimum radius curvature, ft.	Approximate ° of curve
Small ditches less than 15 ft.	Under 3 ft.	300	19°
	3 ft. to 6 ft.	400	14°
Medium size ditches 15 to 35 ft.	Under 3 ft.	500	11°
	3 ft. to 6 ft.	600	10°
Large ditches greater than 35 ft.	Under 3 ft.	600	10°
	3 ft. to 6 ft.	800	7°

Berms and Spoil Banks
Adequate berms should be provided and shaped, as required, to provide access for maintenance equipment, to eliminate the need for moving spoil banks in future operations, to provide for work areas and facilitate spoilbank spreading, to prevent excavated material from washing or rolling back into ditches and to lessen sloughing of ditchbanks caused by heavy loads too near the edge of the ditchbanks. Table 5-5 gives recommended minimum berm widths, except where spoil is spread.

Table 5-5. Minimum recommended berm width.

Ditch depth (ft.)	Minimum berm width (ft.)
2-6	8
6-8	10
More than 8	15

If spoil material is to be placed in banks along the ditch rather than spread over adjacent fields, the spoilbanks must have stable side slopes. Provision must be made to channel water through the spoil and into the ditch without causing serious erosion.

In cropland areas, it is often desirable to spread the spoil. Spreading may begin at or near the channel bank or a berm may be left. If spreading begins at the channel bank, it should be carried upward at a slope not steeper than 3 to 1 to a depth not to exceed 3 feet. From the point of maximum depth, the spoil should be graded to slope away from the channel at a slope not steeper than 6 to 1 if it is to be farmed (see figure 4-2, Chapter 4: Surface Drainage).

Junctions of Lateral Ditches
Where there is a significant drop from a lateral to a main ditch or other outlet, the lateral should be cut back on a level grade as specified and then graded back on a slope. This level area is to store sediment and protect the outlet ditch until the lateral stabilizes. Satisfactory results may usually be obtained by excavating the lateral on a level grade flush with the bottom of the outlet ditch for a distance of 50 to 300 feet; then use a bottom grade out of the recessed area of from 0.5 to 1.0 percent until it intersects the normal grade of the lateral. Where the drop from the lateral to the main is too great to control by the above method, structural protection must be provided.

Related Structures and Ditch Protection
Mains and laterals should be protected against erosion by chutes, drop structures, pipe drops, other suitable structures or grassed waterways, or specially graded channel entrances where surface water or shallow ditches enter deeper ditches. Where sufficient storage is available to store runoff, these installations should provide for the removal of water in accordance with the design runoff based on area and selected drainage runoff curve contained in figure 5-1. Where there is insufficient storage, the structure should be designed to handle peak flows.

Grade control structures, bank protection, or other suitable measures should be used if necessary to reduce velocities and control erosion.

Culverts and Bridges
Culverts and bridges that are modified or added as part of channel projects should meet reasonable standards for the type of structure, and have a minimum capacity equal to the design discharge or state or local agency design requirements, whichever is greater. When the design discharge is based on floods that occur frequently, such as floods of 1- or 2-year frequency, it may be desirable to increase the capacity of culverts and bridges above the design discharge.

Culverts and bridges across ditches should be designed after loads are carefully determined from the weight of farm machinery, trucks, and other vehicles expected to use them. Designs should facilitate ditch maintenance around the abutments, and the openings must be large enough to avoid reduction of ditch flow capacity. Where bridges and culverts are not feasible, fords with suitable ramps for livestock and machinery may be used.

Environmental Considerations
In the location and design of channels, careful consideration should be given to minimizing water pollution, damage to fish and wildlife habitat, protection of forest resources, and the quality of the landscape. Considering requirements for construction and operation and maintenance, selected woody plants must be preserved. Selection should consider the overall landscape character, prominent views, and the fish and wildlife habitat requirements.

Planned measures necessary to mitigate unavoidable losses to fish or wildlife habitat should be included in the project. Quality of the landscape should be maintained by both location of channel works and plantings as appropriate.

The alignment of channels undergoing modification should not be changed to the extent that the stability of the channel or laterals thereto is endangered.

Vegetation of Channels
Channel side slopes should be seeded with permanent, short-stem grasses as soon as possible after excavation. Use daily seeding if possible. Correct for acidity, alkalinity, and fertility as necessary to ensure vegetative growth. It may be necessary to use temporary seeding, anchored mulch, and soil stabilizers to reduce erosion and achieve seeding.

The grass on ditch banks, berms, and spoil banks may need occasional mowing. Care should be taken to avoid destruction of wildlife. Brush and weeds may be controlled by herbicide sprays. **Always check local, state, and federal regulations on the use of herbicides. Read and follow instructions on the label.**

Aquatic weeds should be kept out of ditch bottoms, since they delay drainage by reducing flow rates and causing sediment deposits. The weeds may be controlled by herbicides, but their application will depend on downstream uses of water and legal liability. Legal liability on use of herbicides should be investigated before use. Herbicide use must be consistent with the uses listed on the label. Sediment deposits and accumulations of debris should be removed from outlet ditches to maintain their design capacity.

A 10-foot grass strip should be maintained along the ditch to reduce erosion and provide access for proper maintenance.

Operation and Maintenance

Open ditches rapidly lose their effectiveness unless they are properly maintained. A good maintenance program is just as necessary as proper design and construction. Drainage systems often become clogged with uncontrolled growth of vegetation and partially fill with sediment soon after installation. Since maintenance is so important for successful drainage, every effort should be made to work out a maintenance program with the drainage enterprise, group, or landowner responsible for the system.

Operation and Maintenance Plan
An operation and maintenance plan should be developed for each channel system. Minimum requirements for operation, maintenance, and replacement are to be established consistent with the design objectives. This includes consideration of fish and wildlife habitat, quality of the landscape, water quality, mitigation features, methods, equipment, costs, stability, function for design life, frequency, and time of year for accomplishing the work. Detailed provisions for operation and maintenance must be made where complex features such as water level control structures and pumping plants are involved.

Uncontrolled grazing can cause serious damage to channel slopes and vegetation. Livestock traffic in and out of the channel should be only at controlled access points for both channel erosion and water quality considerations.

Maintenance Access
Travelways for maintenance should normally be provided as a part of all channel work. This requirement may be met by providing ready access points to sections of channel where this will permit adequate maintenance in conformance with the operation and maintenance plan.

A travelway should be provided on each side of large channels if necessary for use of maintenance equipment. Travelways must be adequate for movement and operation of equipment required for maintenance of the channel. The travelway may be located adjacent to the channel on a berm or on the spread spoil. In some situations the channel itself may be used as the travelway. The travelway, including access points, should blend into the topography and landscape.

Chapter 6: Pump Drainage

Pumps may be used to remove excess surface or groundwater if it is impossible or uneconomical to obtain gravity outlets for drainage. Pumps are also used at locations that have adequate outlets except during periods of prolonged high water along large streams. Dikes are often required in conjunction with the pump installation.

The recommendations given here are for small drainage plants involving watershed areas of less than 1,500 acres.

Each drainage problem involving pumping has individual and varied requirements. The pumping capacity, pump location, associated dikes, gravity outlet conduits, and the type of pump and its appurtenances are a few items to consider. The location of the problem in the watershed, the soils, crops, economic protection, and the method to be employed in the solution of the problem must also be considered.

When a drainage problem may involve gravity drainage or pump drainage, or a combination of the two, the economics of all practical solutions should be determined. A gravity outlet may require a high capital outlay, but low operation and maintenance costs can be expected. For pumps, the reverse is usually true with low capital outlay but generally high operation and maintenance costs.

The pumping plant should be planned and designed as an integral part of the drainage system. The reconnaissance or preliminary survey will determine the condition of the drainage outlet and whether pumping is required. A drainage system where the pumping plant is designed into the system usually will function much more efficiently than one where the pumping facilities are added because the outlet is found to be inadequate after the system is installed.

First consideration should be given to disposing of all the runoff water possible by diversion around the area and to providing for all possible gravity flow through floodgates. The pumping plant must be designed to pump the balance of the water that will give adequate drainage against the total head expected.

Disposal of interior drainage water should be provided through the dike in conduits protected by gates that prevent backflow during high exterior water stages and permit outflow during low water stages.

In the event the pumped area is to be isolated by dikes, a situation needs to be anticipated where the dikes are overtopped and the entire diked area is flooded to the top of dike. If warranted, emergency pumping facilities or a gated emergency spillway will have to be provided for.

The plant should be located to best serve the purposes while considering such plant requirements as foundation conditions, the need for service access, proximity to power sources, and locations that might be susceptible to vandalism. In areas where significant sump storage is available, the pumping plant should be located to take maximum advantage of the storage provided. A location should be selected that will permit safe discharge into the outlet with a minimum of construction outside the diked area.

If possible, the plant should be located in an easily accessible place. Ordinarily, the dike can be widened to accommodate vehicular traffic to the plant. It is desirable to have an all-weather access road.

The requirements for a stable foundation are often in conflict with the other requirements of location. Borings should be made and the location selected that has the best foundation conditions consistent with other site requirements. An unstable foundation material can considerably increase the cost of a pumping plant. A more intensive investigation before selecting the plant location will often yield big dividends in reduced costs of providing a stable foundation.

Protecting the pumped area against overflow or backwater from the outlet should be provided by perimeter dikes designed against damage from overtopping wave action, erosion, and instability from high water stages.

The outlet channel from the pumped area must be adequate for handling the discharge.

Pump Capacity

Minimum suggested pump capacities are provided in table 6-1.

Table 6-1. Minimum suggested pump capacities.

Type of drainage inflow	Pumping rate (minimum)
Subsurface water only	Drainage system capacity + 20%
Subsurface and surface waters, field crops	Minimum ½ in. per 24 hr.
Specialty crops	1½-4 in. per 24 hr.
Seepage, where it becomes important	Additional capacity to cover need

When special or high-value crops are to be grown, the pump capacity will vary, depending upon the storage of runoff water in the ditches and in the watershed and the degree of protection desired.

The following relationship may be used to determine pump capacity in gallons per minute.

$$Q = 18.9 \times C \times A$$

Q = Gallons per minute
C = Drainage coefficient (in inches per 24 hours)
A = Area of the watershed (in acres)

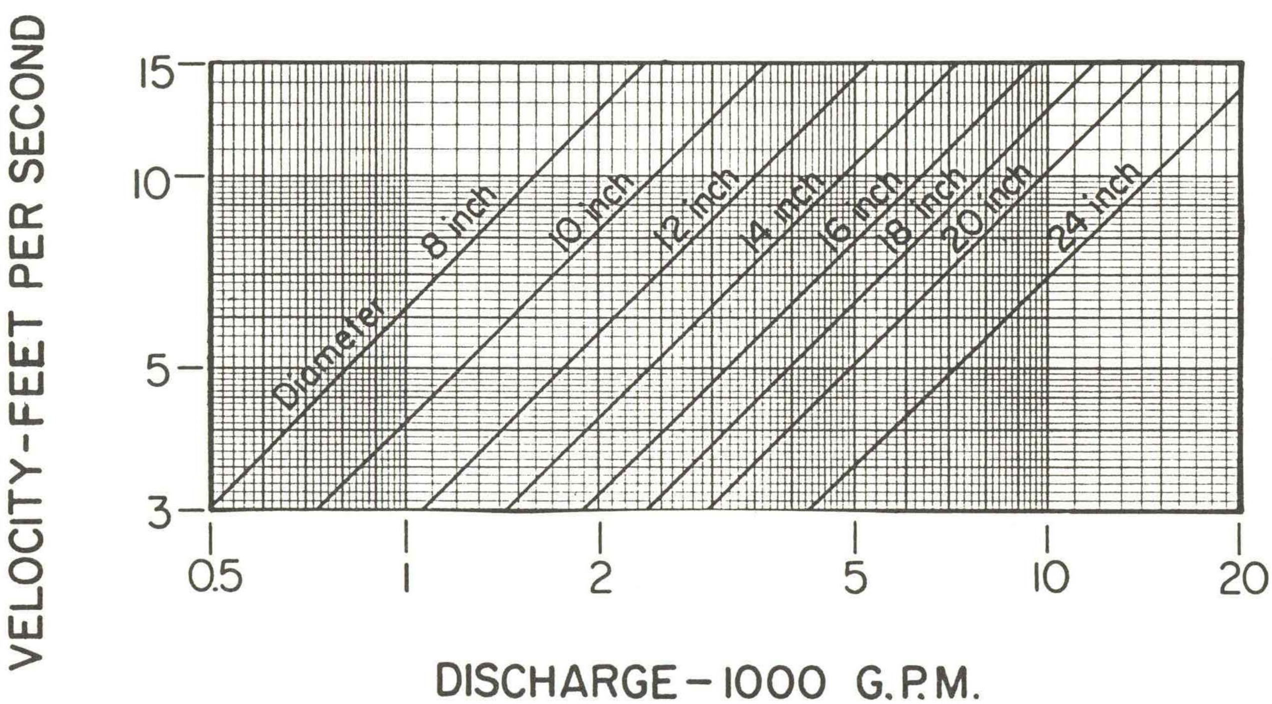
Pump Selection

When selecting pumps, consider the type, characteristics, capacity, head, and number of pumps in conjunction with kind and source of power, shape, and size of pump, housing, and method of plant operation.

Pumps used for drainage are of the high-volume, low-head class. This class includes axial-flow propeller pumps and certain centrifugal pumps. For areas smaller than 5 acres, commercial sump or marine bilge pumps can be used. Pumping volumes and heads must be determined carefully, since efficiency is adversely affected by values other than those recommended by the manufacturer.

Electric power has the advantage of permitting automatic operation, and the elimination of daily fueling or servicing activities. A 10-horsepower motor usually is the largest that can be used on single phase 230-volt lines. Larger motors can be operated on three-phase power that is available in some areas or where phase converters can be used on single phase power lines. Where electricity is planned as the power source for pump drainage installations, 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. Belt or power takeoff drives may be used to couple farm tractors to the pump.

Figure 6-1. Velocity-discharge relationship.



The size of pumps depends upon total head and quantity of water pumped. The rated size is usually designated by the pipe column diameter at the discharge end of the pump. The design column velocity at a propeller pump may range between 7 and 12 feet per second with highest efficiency usually occurring at values of 8 to 10 feet per second.

Figure 6-1 will give guidance on the size of pump needed for a particular velocity-discharge relationship. Final pump selection should be based on manufacturer's recommendation.

Power Requirements

The power required to move the designed pumping rate depends on the head against which the water must be pumped and the efficiency of the plant.

The horsepower required to move a given quantity of water against a specific head can be calculated using the following formula.

$$HP = \frac{Q \times H}{3960 \times N}$$

HP = Horsepower required to move the water
Q = Pumping rate (in gallons per minute)
H = Total head (in feet, which includes the difference in elevation between inlet water level and discharge water level, as well as friction losses in the pump and fittings)
N = Efficiency of unit—The plant efficiency is equal to the pump efficiency times the drive efficiency. Pump efficiencies may vary from 50 to 75 percent and drive efficiencies from 90 to 100 percent.

The horsepower determined in this manner will be the continuous duty requirement. For electric motors, this will be the nameplate rating. For internal combustion engines, the minimum size engine will be the calculated horsepower plus power required to operate accessories. The approximate efficiency of internal combustion engines is as follows:

75 percent of rated HP for gasoline water cooled engines,

80 percent of rated HP for diesel water cooled engines, and

60 percent of rated HP for air cooled engines.

Storage Required

Space for temporary water storage must be provided to prevent excessive starting of the pump and motor. On small areas an enclosed sump or pump bay may provide sufficient storage. Enclosed sumps may be constructed of silo staves, manhole blocks, or a series of large sewer or metal pipe sections. For subsurface systems serving more than 100 acres and where surface water must be pumped, an open ditch or large pit will generally provide the best storage.

For automatic operation, water storage should be provided so the maximum number of cycles of operation will be limited to 10 per hour. The required storage may be estimated from the following formulas.

Active storage in cubic feet =

$$\frac{\text{pump capacity in gpm (gallons per minute)}}{5.0}$$

Storage area in square feet in sump or ditch =

$$\frac{\text{pump capacity in gpm}}{5.0\ d\ \text{(feet)}}$$

("d" is the depth of storage or the distance between water levels that will start and stop pump operation.)

For manual operation, active water storage must be greater than for automatic operation and it depends upon the number of times the operator is willing to start the pump. Where the number of starts is limited to two a day, the following formulas may be used to estimate the active storage desirable.

Active storage in cubic feet = pump capacity in gpm × 25.

Storage area in sump =

$$\frac{25 \times \text{pump capacity in gpm}}{d\ \text{(feet)}}$$

"d" is the depth of the ditch for water storage in feet.

The depth of storage (distance between water levels) should be about 2 feet for sumps and 1 foot for ditches. This will reduce changes in operating characteristics of the pump caused by the change in water level. Sumps should be made with a paved base and with weep holes in the walls. The base provides a solid footing for the sump wall and will support the weight of the pump and the sump cover. Weep holes will prevent flotation of the sump.

Pump Bay
Proper clearance and submergence for the pump selected must be provided in the pump bay. Manufacturers give recommendations for these dimensions and the sump or bay should be designed after the pump has been selected. The pump and motor should be protected at all times from flooding. See figure 6-2.

Operation and Cycling
Although pumping may be cyclic in design, electric motors (if used as pump motors) should have continuous load ratings to take care of sustained inflows. Electric motor operation can be easily controlled by float 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 cutoffs will eliminate the need for an operator during most of the period the engine is running. Safety cutoffs (engine temperature, engine oil pressure, and pump pressure) should be attached to any engine if it is to be left running unattended for any length of time.

Housing
The type of housing for a pump depends upon importance and size of the plant, type of power used, and pump location. Several factors influence the need for housing such as air temperature, wind, moisture from humidity, precipitation, and flooding, fuel storage, safety, vandalism, and plant appearance. The materials used for housing should be fire resistant, water proofed, durable, and easily maintained. Provisions should be made for removing the pump when required.

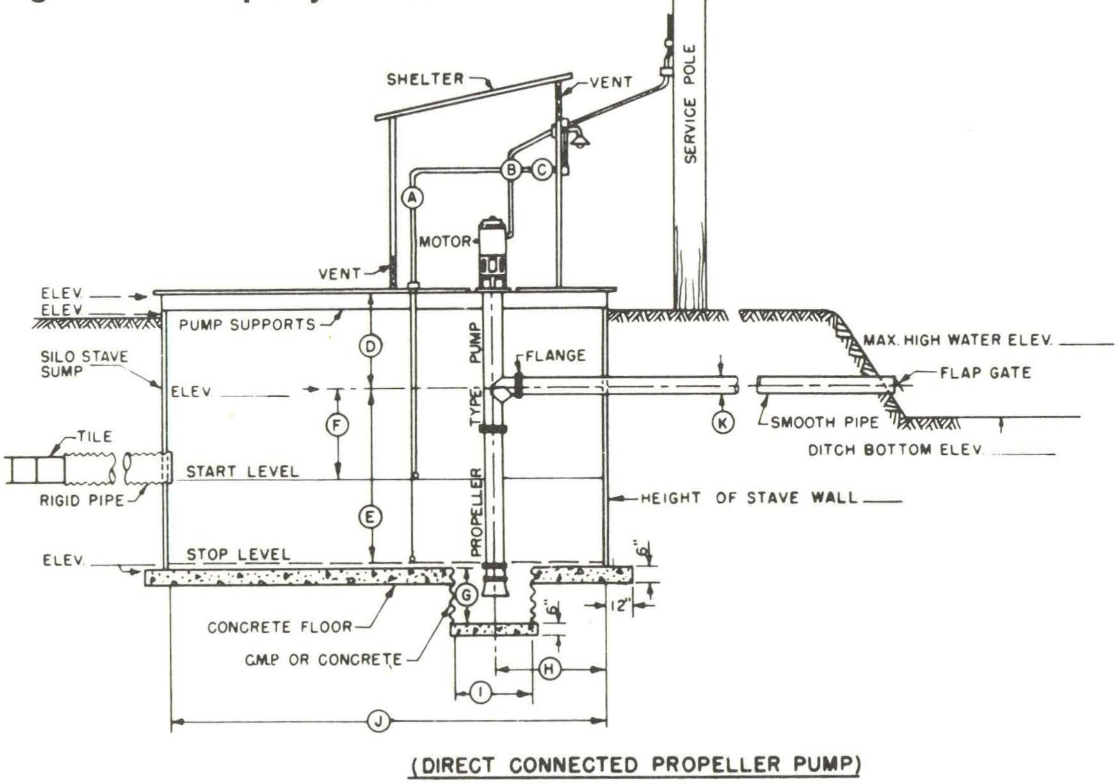
Trash Racks
Trash racks or protective screening must be provided to prevent entry of floating debris into sumps where damage to pumps might otherwise occur. The velocity of flow through a trash rack should not exceed 2 feet per second. The recommended trash rack bar spacing is as follows:

Pump diameter (in.)	Bar spacing (in.)
16	¾
18-24	1-1½
30-42	2
48	2⅓-3

A trash rack should be shaped so cleaning by hand is easily done, or it must be equipped with mechanical cleaners. Where trash racks are not feasible, galvanized basket strainers may be used on small pumps to prevent entry of small gravel and debris.

Detailed information on the design of drainage pumping plants is available in Chapter 7 of the SCS publication, *Drainage of Agricultural Land (Sec. 16, SCS National Engineering Handbook)*.

Figure 6-2. Pump bay details.



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