NEW JERSEY WATER MANAGEMENT GUIDE

United States Department of Agriculture
Natural Resources Conservation Service
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Acknowledgment

Cover Photo of drainage ditches in Great Meadows, Warren County, by James Kleindienst, Civil Engineering Technician, Hackettstown Service Center.

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NEW JERSEY
WATER MANAGEMENT GUIDE
CONTENTS

Contents:

Chapter 1 General

Contents **NJ650.1401**

NJ650.1401 General

a) Introduction

The New Jersey Water Management Guide (NJWMG) has been adapted from the July, 1987 New Jersey Drainage Guide. The material has been developed to assist New Jersey NRCS field personnel and others working with New Jersey landowners to provide general planning, design, and management guidance on various methods of water management, primarily drainage techniques, commonly used in the State. The NJWMG has been expanded to include guidance for the restoration of wetlands through the interruption or removal of previously installed drainage practices.

Today, NRCS assistance on drainage practices is largely limited to the restoration of existing drainage systems or their modification to enhance water quality objectives. In some instances, the conversion to higher value agriculture in marginal areas or disease concerns lead to the installation of new systems. When a new system is designed or an old system is restored, the conservation planner must be aware of the potential impacts on adjacent wetland areas. Likewise, when the goal is the restoration of a wetland area through the removal of drainage practices, consideration must be given to the impacts on neighboring properties due to a rise in ground water levels or reduction in the efficiency of surface water removal.

The New Jersey Water Management Guide includes in an appendix recommendations for drainage of many of the soil series found in New Jersey that commonly require drainage. The recommendations are largely historical in nature and based on experience with the particular soil or a similar soil. The recommendations are intended to serve as guidance. More site specific methods for the design of drainage systems can be found in National Engineering Handbook Part 642, Drainage, Chapter 4, and Part 650, Engineering Field Handbook, Chapter 14.

b) Types of drainage systems

Drainage is the removal of excess surface or subsurface water. Excess water may be due to on-site conditions such as a high ground water table, or may originate from off-site sources related to either surface or subsurface flow, or both.

Removal of excess water is accomplished by installing drainage practices or a system of practices planned considering the source of the excess water and desired conservation goals. Surface water generally is removed by a combination of practices of open ditches, land forming, and underground outlets. Subsurface flows are removed or controlled by open ditches or buried conduits. A lateral drain, or system of lateral drains, is generally located to lower the water table. Water control structures such as flashboard weirs installed in drainage conduits or open ditches can be added to the drainage system to provide for management of water table levels. Even though most references relate to agricultural settings, the applicability includes urban areas as well.

Solutions for all drainage problems may not require structural practices. In some cases, surface ponding or saturation may be due to development of compacted or tight layers at or near the soil surface that may be treated with agronomic practices such as deep tillage or through the planting of deep rooting warm season grasses.

Surface drainage

Surface drainage involves removal of excess surface water by developing a continuous positive slope to the free water surface or by pumping. It may be accomplished by open ditches, land grading, underground outlets, pumping, or any combination of these that facilitates water movement to a suitable outlet. Drainage by this method applies to nearly level topography where:

- Soils are slowly permeable throughout the profile.
- Soils are shallow, 8 to 20 inches deep, over an impermeable layer.
- Topography consists of an uneven land surface that has pockets or ridges which prevent or retard natural runoff.

- Surface drainage supplements subsurface drainage.

Subsurface drainage

Subsurface drainage is the removal of excess ground water within the soil profile. It is also used to facilitate the leaching of salts from the soil and maintenance of a salt balance. Typically, perforated plastic tubing is used, while older systems may include clay and concrete tile, or mole drains. Open ditches constructed to an adequate depth and properly located may also be used to remove excess ground water. Subsurface drainage is applicable to wet soils having sufficient hydraulic conductivity for drainage where a suitable outlet is available or an outlet can be obtained by pumping.

Interception drainage

Interception drainage systems remove excess water originating upslope, deep percolation from irrigation or rainfall, and water from old, buried stream channels. Interception drains are open ditches or buried conduits located perpendicular to the flow of ground water or seepage. They are installed primarily for intercepting subsurface flow moving down gradient. Although this method of drainage may intercept and divert both surface and subsurface flows, it generally refers to the removal of subsurface water.

Water table management

Water table control systems can be an alternative to single purpose drainage systems. The basic premise is to install certain structural measures and to operate them in a manner that controls the water table at a predetermined elevation. The structural practices can range from installing a flashboard or stop-log structure in the outlet ditch to installing a complete system consisting of land forming, subsurface drain tubing, water control structures, well and pump to provide supplemental water, and observation wells for monitoring.

Drainage pumping

Pumps or pumping systems have many applications in drainage systems. Pumps may be used as outlets for surface or subsurface drainage when gravity outlets are not available or the available outlet is not deep enough to satisfy minimum depth requirements. Additional information can be found in the National Engineering Handbook Part 624, Drainage, Chapter 7.

Pumps for water supply are often needed for sub-irrigation or water table management systems. Wells and pumps for wells are also described in NEH Part 623, Irrigation, and Part 650 EFH, Chapter 12.

c) Investigations and planning

When drainage is considered, an investigation is necessary to determine the nature and extent of the problem. Planners need to evaluate the cause of the problem and develop practical alternatives to achieve the desired objectives. Environmental considerations must be a part of the planning process and investigations necessary for habitat enhancement or mitigation, and for environmental protection, should be an integral part.

In making a field investigation, the following items should be noted:

- Location and extent of any wetlands.
- Areas in which crops show damage or area of surface ponding or saturation.
- Observations of unique landscape features, ecologically significant areas, land use patterns, operation (land management) aspects, and site visibility.
- Topography and size of the watershed area.
- Size, extent, and ownership of the area being considered for drainage.
- Location of the drainage outlet and its condition.
- Presence of cultural resources.

- Potential impacts outside the area being evaluated.
- General character of soil throughout the area needing drainage, including land capability, land use, crops and yields. Log soil borings and record locations.
- High-water marks or damaging floods and dates of floods.
- Sources of excess water from upslope land or stream channel overflow and possible disposal areas and control methods.
- Condition of areas contributing outside water and possible treatment needed in these areas to reduce runoff or erosion.
- Condition of any existing drainage system and reasons for failure or inadequacy. Old subsurface drainage systems that have failed because of broken or collapsed sections may well be the cause of a wet area.
- Location, condition, and approximate size of existing conservation practices.
- Utilities, such as pipelines, roads, culverts, bridges, and irrigation facilities and their possible effect on the drainage system.
- Estimate of surveys needed.
- Additional considerations to comply with applicable environmental permits.

The intensity of this investigation and the makeup of the investigation party depend upon the size of the area and complexity of the problem. In all cases, as much information as possible should be obtained from local farmers and residents. The investigation must be extensive enough to provide a clear picture of the size and extent of the drainage problem.

The environmental values of an area must be fully considered when planning to develop a new drainage system or improve an existing system. Alternatives and options should be evaluated from the perspective of the landowner, neighbors, and the community. Alternatives should aim towards balanced and sustainable systems that fit within the natural setting. Agricultural developments, natural resource conservation, biodiversity, wildlife habitat, water quality, economics, health, and social considerations may all play a role in the decision-making process, and appropriate evaluations should be made.

Additional information on investigations and planning can be found in NEH Part 650, EFH, Chapter 14.

Planning considerations and design requirements for specific conservation practices are found in Section IV of the Field Office Technical Guide. Drainage related conservation practices include:

Code 310 Bedding,
Code 356 Dike,
Code 554, Drainage Water Management,
Code 466 Land Smoothing,
Code 462 Precision Land Forming,
Code 533 Pumping Plant,
Code 587 Structure for Water Control,
Code 606 Subsurface Drain,
Code 607 Surface Drain, Field Ditch, and
Code 608 Surface Drain, Main or Lateral.

Chapter 2 Surface Drainage

Contents **NJ650.1402**

NJ650.1402 Surface Drainage

a) General

Surface drainage is the orderly removal of excess water from the land surface and the root zone by means of channels or ditches supplemented, if necessary, by shaping and grading of the land surface to provide slope toward the channels.

A surface drainage system is designed to remove excess water at a rate which will prevent long periods of standing water or flooding without excessive erosion, so that crops will have adequate moisture conditions for growth. The design capacity of drainage systems depends on several interrelated factors including rainfall patterns, soil characteristics and crops grown.

For the northern humid region of the country that includes New Jersey, a series of drainage runoff curves were developed that define the rate at which runoff is to be removed based on the value of the crop or land protected. These curves generally apply to flatland areas, which for New Jersey typically includes land having a grade of one percent or less and where the contributing upland watershed has an average slope of ten percent or less.

The drainage runoff curves establish the efficiency at which excess water is removed from the landscape. It is expected that out of bank flooding will occur with the flood waters to be removed in a period of time necessary to avoid crop damage.

Runoff Curve D provides fair agricultural drainage and is applied to areas of low value crops, pasture, and woodland where excess water is to be removed within 24 to 48 hours.

Runoff Curve C provides good agricultural drainage and is applied to field crop areas where excess water is to be removed within 12 to 24 hours.

Runoff Curve B provides for excellent agricultural drainage of high value crops such as vegetables and turf grass where excess water is to be removed in 6 to 12 hours.

Runoff Curve A provides for good protection from overflow, but will not eliminate flood runoff.

Appendix A contains an exhibit that provides the acres drained per quantity of flow for the four drainage runoff curves.

b) Types of channels

Field ditches

Field ditches are shallow graded channels usually having flat side slopes that collect water in a field and convey the water to a channel. Cross sections are typically “V” or trapezoidal and may be farmed or vegetated. The steepest side slope for a farmed field ditch is 8H:1V. If not farmed or crossed by equipment, the steepest recommended side slope for a field ditch in a cropped field is 4H:1V and 3H:1V in a pasture.

Field ditches may require cleanout following tillage operations. When field ditches are not cropped, weed growth must be controlled by mowing or spraying.

Lateral ditches

Field ditches convey water to lateral ditches. The lateral receives this water and sometimes water from the filled surface and conveys it to the main ditch. Lateral ditches require periodic maintenance to control vegetation on the bottom and side slopes. Sides slopes of 3H:1V or flatter are recommended for ease of mowing. Where excessive sediment deposition occurs in a lateral, occasional cleanout will be required.

Main ditches

The main ditch is the outlet for the drainage system. It receives flow from lateral ditches and sometimes other mains.

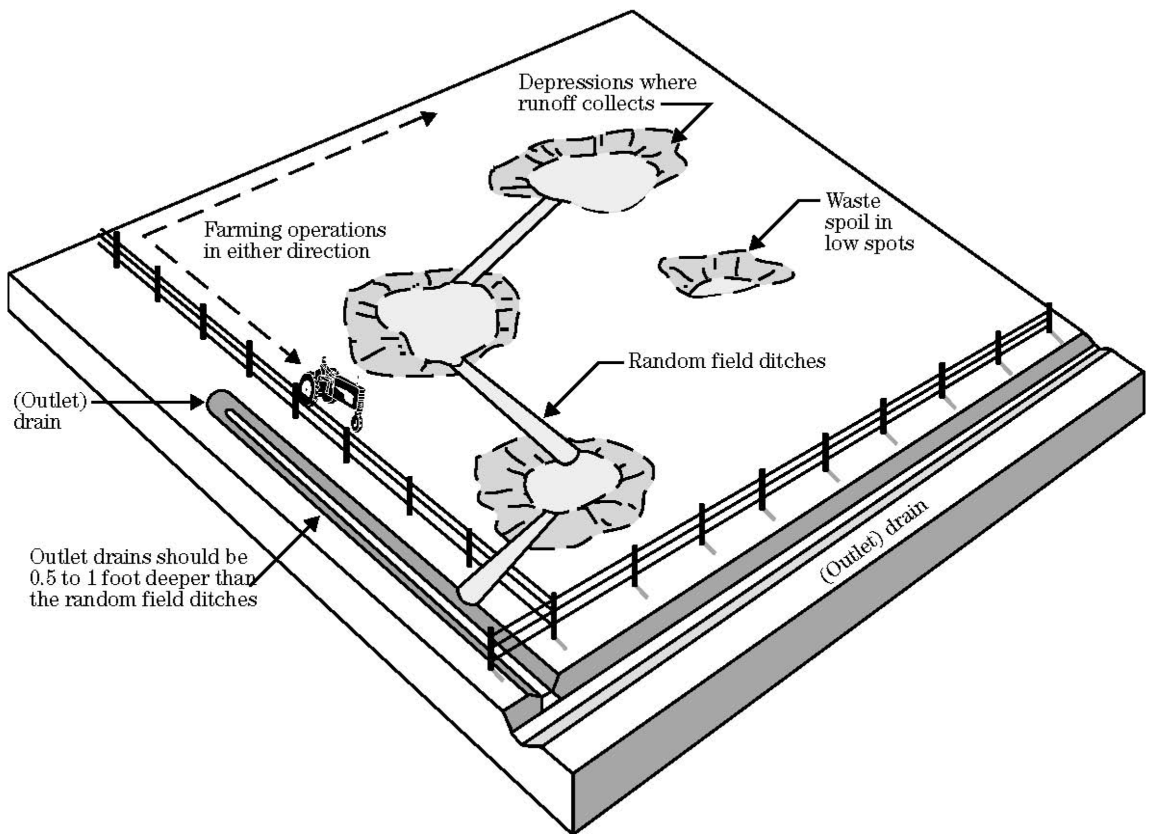
c) Types of open drain systems

Drains should be located to fit the farm or other land use operations and should have capacity to handle the runoff and not cause harmful erosion. The drain system should cause excess water to flow readily from the land to the disposal drain. Five common drain systems are described in this section.

(1) Random drain system

This type system is adapted to drainage systems on undulating land where only scattered wet areas require drainage. The ditches should be located so they intercept depressions and provide the least interference with farming operations (fig. 2–1). The ditches should be shallow and have side slopes flat enough for farm equipment to cross. Precision land forming and smoothing help to assure the removal of surface water from less permeable soil.

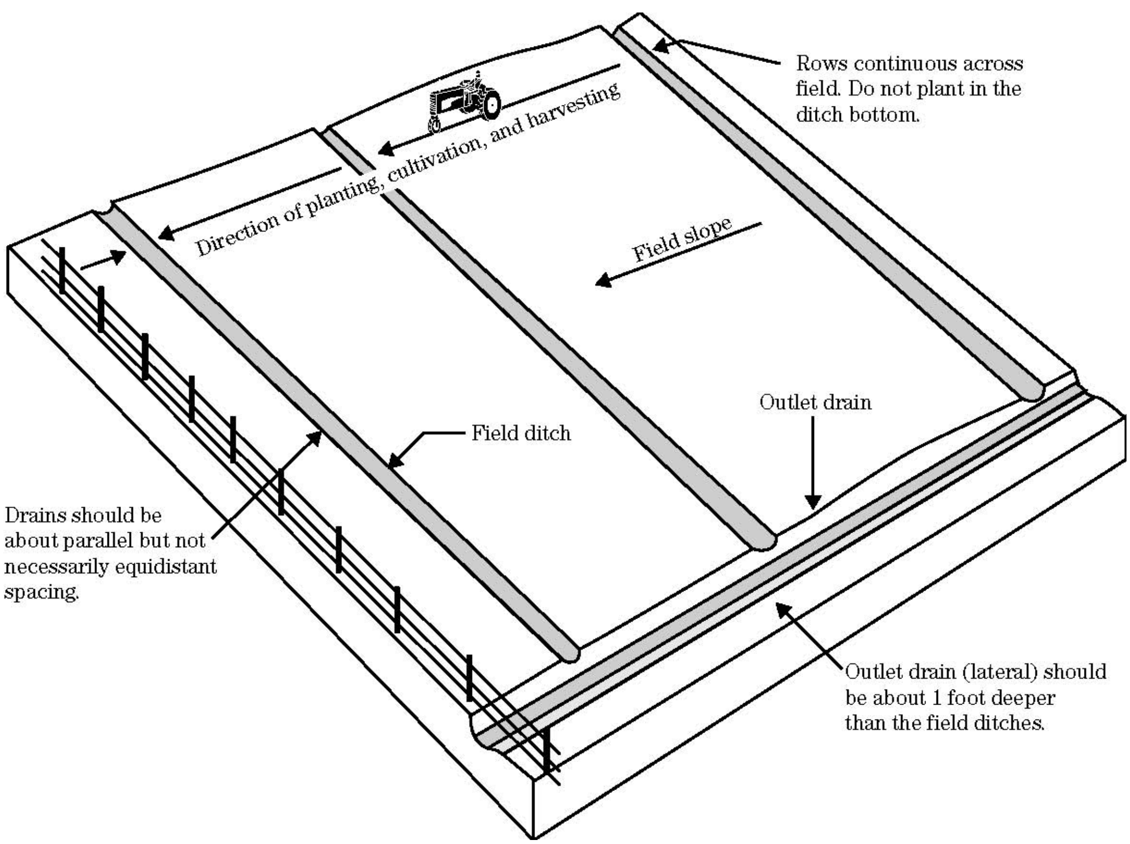
Figure 2–1 Random drains



(2) Parallel drain system

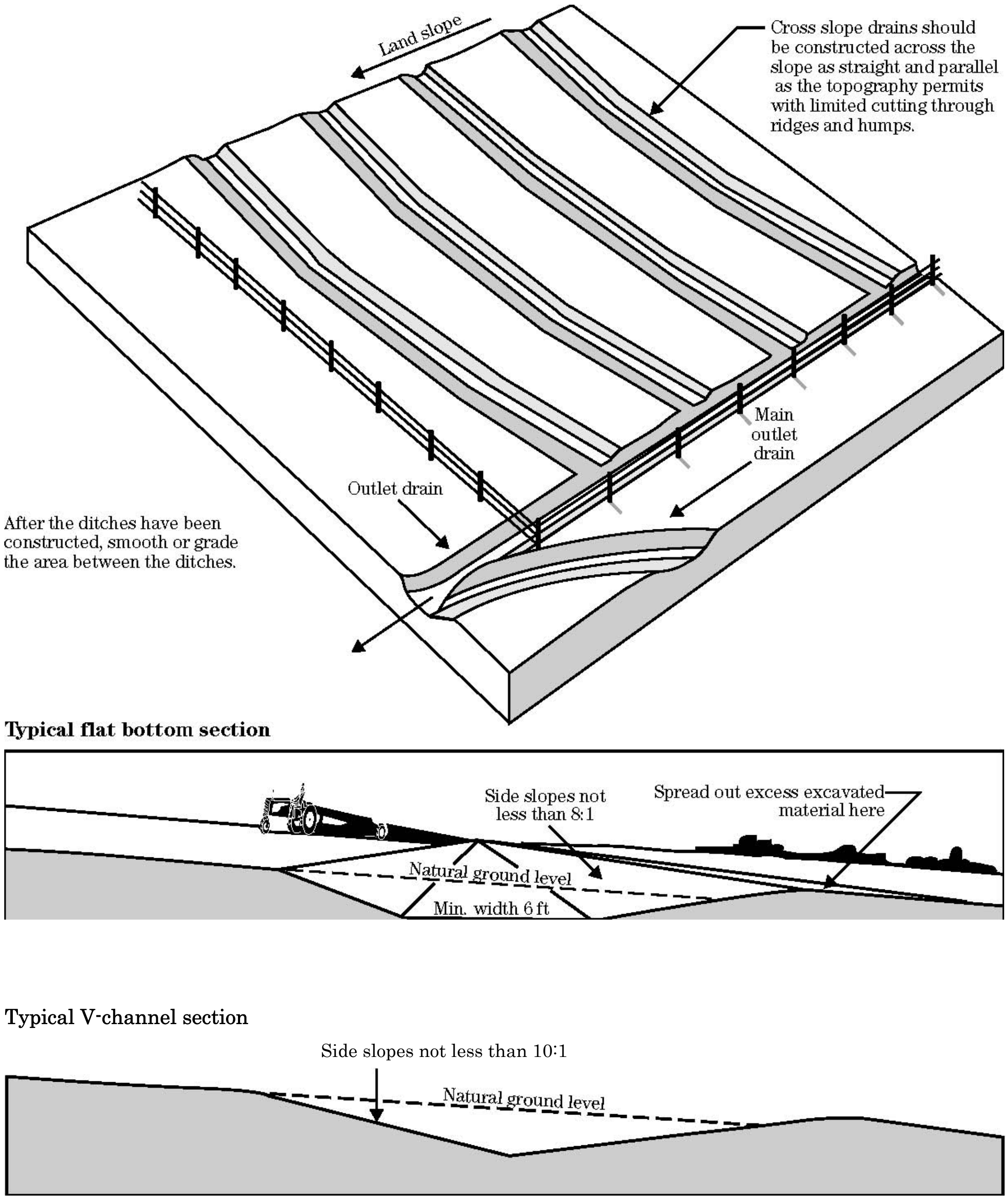
This type system is applicable to land where the topography is flat and regular and where uniform drainage is needed. The ditches are established parallel but not necessarily equidistant, as shown in figure 2–2. The direction of the land slope generally determines the direction of the ditches. Field ditches are generally perpendicular to the slope, and laterals run in the direction of the slope. The location of diversions, cross slope ditches, and access roads for farming equipment can also influence the drain location. Spacing of the field ditches depends upon the water tolerance of crops, the soil hydraulic conductivity, and the uniformity of the topography. Land forming can reduce the number of ditches required by making the topography more uniform. Where possible, spacing should be adjusted to fit the number of passes of tillage and harvesting equipment.

Figure 2-2 Parallel surface drains



(3) Cross slope drain system

Figure 2–3 Reconstructing cross slope drain system



A cross slope drain system is used to drain sloping land, to prevent the accumulation of water from higher land, and to prevent the concentration of water within a field. The field ditches work best on slopes of less than 2 percent. The drain is located across the slope as straight as topography will permit (fig. 2–3). The spacing of these ditches varies with the land slope and should be based on recommendations contained in this guide. The excavated material should be placed in low areas or on the downhill side of the drain. Land forming or smoothing between the ditches improves operation of the system by preventing the concentration of flow and the occurrence of ponding.

(4) Bedding

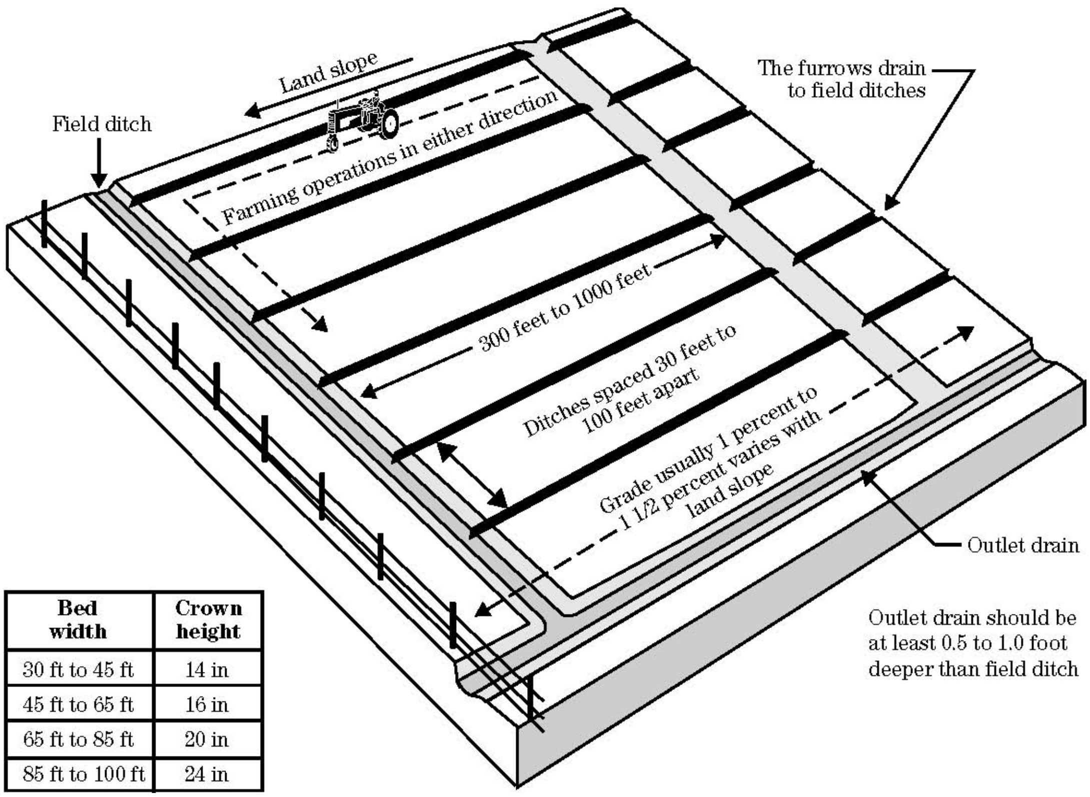
Bedding resembles a system of parallel field ditches with the intervening land shaped to a raised, rounded surface (fig. 2–4). This drainage system generally is used where slopes are flat and the soil is slowly permeable and where other types of drainage are not economically feasible. A bedding system generally is in small land areas and is installed using farm equipment.

Beds are established to run with the land slope or in the direction of the most desirable outlet. Local information should be used to determine the width of beds, the crown height, construction method, and maintenance.

(5) Narrow raised beds

A narrow bed system has a raised bed wide enough for single or double cropping rows to provide an aerated surface profile. This system facilitates surface water movement and aeration of the shallow root zone. When used with plastic covers for weed control, evaporation control, and nutrient management, the narrow bed system can be extremely effective for some cropping systems.

Figure 2–4 Surface drainage bedding



Bed width	Crown height
30 ft to 45 ft	14 in
45 ft to 65 ft	16 in
65 ft to 85 ft	20 in
85 ft to 100 ft	24 in

d) Land forming

Land forming refers to the reshaping of the land surface to facilitate the movement of surface water. Land smoothing and precision land forming are used in surface drainage to improve the effectiveness of the drainage system.

Land smoothing

Land smoothing is the elimination of minor depressions and irregularities without changing the general topography. Equipment needed is usually a land plane or land leveler. The purpose is to provide a more uniform surface for runoff to move toward field ditches.

The operation of land smoothing on land with more than 0.1 percent grade can usually be accomplished without a detailed survey or plan. However, in critical portions of a field where visual observations do not provide the accuracy required, a survey is necessary.

Precision land forming

Precision land forming is the process of reshaping the land surface to predetermined grades, such that each point on the field has positive drainage. Precision land forming, by carefully designed cutting and filling operations, can provide excellent surface drainage. Areas to be graded are planned with a minimum number of field ditches, with ditches located, if possible, perpendicular to the laterals and to the field rows.

Minimum grade limits should include a tolerance for construction that will permit elimination of depressions. For most fields, a 0.2 percent grade will readily accomplish this goal. A grade of 0.1 percent or flatter will require unusual precision in construction. The recommended grades range from 0.1 percent to 0.5 percent with grades being uniform or varied.

The maximum allowable depth of cut will depend on the soil and economics. Soil borings are necessary for determining the maximum depth of cut. The degree of compaction imparted in fill areas should be sufficient to avoid future settlement problems but not exceed densities restrictive to root growth, especially in the rooting zone of the planned crop or vegetation. Fields must not be graded when soil moisture levels are high, as this will impair the physical structure of the soil. Topsoil should be salvaged from areas of deep cuts or fills for spreading on areas where deep cuts expose the subsoil.

In precision land forming, bulldozers and pans are used for rough grading. Final grading and smoothing is accomplished with land planes or land levelers. Typically, three passes of a land plane are recommended, one along each diagonal and the final in the direction of cultivation.

Maintenance is important during the first year or two after construction as fill settles with time. If depressions develop, additional planning may be necessary.

e) Drainage channel design

Main and lateral ditches are open channels that serve as outlets for drainage systems. These ditches can serve as outlets for other conservation practices as well as for the disposal of excess surface and subsurface drainage water.

Considerations

For new systems, the location of mains and laterals must be carefully planned because they will define field size and restrict farm traffic patterns. Culverts or bridges will usually be required for access across mains and laterals, so their number should be minimized to reduce installation and maintenance costs. Channel depth is important where surface drains are to serve as outlets for other practices such as subsurface drainage conduits. All systems require an adequate outlet whether discharge will be by gravity flow or pumping.

In the rehabilitation of existing mains and laterals, restoration is usually to reestablish the historic cross section and profile by removal of sediments. This can be accomplished through identification of control points, such as existing culvert inverts and subsurface drain outlets, along with probing to determine sediment depths. Consideration should be given to preserving existing stabilizing vegetation, especially along the channel side slopes. Where banks must be disturbed, excavation should be limited as much as practical to one side of the channel. Tree canopy that provides shading to the ditch should also be preserved.

Whether new construction or restoration is planned, consideration must be given to the environmental impacts including effects on wetlands, fisheries, wildlife habitat, water quality, and aesthetics.

Required Capacity

In agricultural areas, the required capacity of a ditch may be determined from the drainage runoff curves consistent with the land use. Other hydrologic procedures for determining runoff rates and volume may be necessary or required where flooding may impact roads, structures, or adjacent properties.

For New Jersey, the minimum design capacity for a surface drainage system can be determined from the drainage runoff curve exhibit in Appendix A. In evaluating if the minimum capacity is sufficient, consider the potential for damages resulting from out of bank flow.

The drainage runoff curves are generally used in agricultural areas where the natural land slope is one percent or less, although steeper slopes may be present. Typically, rolling or rugged watersheds do not fit the intent of the drainage runoff curves. Drainage runoff curves may be used where the watershed contributing runoff to a flatland area are ten percent or less. Where the contributing watershed is steeper than ten percent, design storm events are to be used for determining capacity (see New Jersey Conservation Practice Standard Code 608, Surface Drainage, Main or Lateral).

20-40 Rule

Runoff is determined above and below the outlet of contributing ditches and streams, at points of change in the channel slope, at culverts and bridges, and at the outlet.

Runoff calculations generally begin at the upper end of the drain and proceed downstream. An empirical procedure, termed the 20-40 rule, should be used in computing the required capacity for a drain below a junction with a lateral. For large drainage areas, the application of the procedure may have considerable effect on the drain design. In small areas the change in required drain capacity may be so small that the procedure need not be applied. Experience in applying the 20-40 rule will guide the designer in its use. The rules for computing the required capacity for a drain are:

Rule 1—Where the watershed area of one of the ditches is 40 to 50 percent of the total watershed area, the required capacity of the channel below the junction is determined by adding the required design capacity of each drain above the junction. This is based upon the assumption that the flows from two watersheds of about the same size may reach the junction at about the same time, and that therefore the drain capacity below the junction should be the sum of the two flows. This rule should be used in all cases for watershed areas of less than 300 acres.

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

Rule 3—Where the watershed area of a lateral is from 20 to 40 percent of the total watershed area, the discharge is proportioned from the smaller discharge at 20 percent to the larger discharge at 40 percent. In this range the discharges should be computed by both methods and the difference in cubic feet per second obtained. The design discharge for the channel below the junction should then be obtained by interpolation. See the following example.

Example

A lateral ditch draining 100 acres joins a main draining 300 acres, making a total drainage area below the junction of 400 acres. The lateral represents 25 percent of the total watershed. Excellent agricultural drainage is desired, so B drainage runoff curve is selected.

	Watershed Area Acres	Runoff Q cfs
Rule 1	100	17
	300	48
	Total	65
Rule 2	400	62

The difference between Rule 1 and 2 is 3 cfs.

The difference between 20 and 40 percent is 20 percent. Twenty-five percent is 5/20 of the difference between 20 and 40 percent. 5/20 of 3 cfs is 0.75 cfs. Round up to 1 cfs and add to 62 to arrive at a capacity of 63 cfs for the main below the junction.

If the 20-40 Rule increases the required capacity of the ditch below the junction above that required by rule 2, the enlarged section is carried downstream without changing size until the total drainage area increases until the point that rule 2 applies.

Velocity

The velocity in a channel must be high enough to prevent sediment deposition (at least 1.4 feet per second), yet low enough to avoid erosion. Channel stability determined by the allowable velocity procedure presented in this guide is acceptable for channels having a contributing drainage area under one square mile. Stability of channels draining over one square mile shall be evaluated in conformance with Conservation Practice Standard Code 582, Open Channel.

Table 2-1 provides the allowable velocity at design flow depth for various soils and materials. The most critical soil type, or that having the lowest allowable velocity, is usually selected as the maximum allowable velocity for design.

Table 2-1 Allowable velocity for drainage channels

Soil texture or material	Velocity ft/s
sand, sandy loam (noncolloidal)	2.5
silt loam, loam	3.0
sandy clay loam	3.5
clay loam	4.0
clay, fine gravel, graded loam to gravel	5.0
Graded silt to cobbles (colloidal)	5.5
Shale, hard pan, and coarse gravel	6.0

Velocity for design of surface drains is commonly determined using Manning's Equation:

$$V = \frac{1.486}{n} R^{2/3} S^{1/2}$$

where: V = velocity (ft/s)
n = roughness coefficient
R= hydraulic radius, A/P
S = slope of hydraulic grade line (ft/ft)
A= cross sectional flow area (ft^2)
P = wetted perimeter (ft)

Roughness coefficient

The roughness coefficient, n, is a factor that accounts for the retarding influences on channel flow such as surface irregularities, vegetation, meander, obstructions, and variation in cross section. For most ditch designs where good maintenance is expected, an n value of 0.04 is commonly used to determine capacity. For newly constructed channels, it is recommended that an n value of 0.025 (bare earth condition) be used to check velocity to avoid erosion. Table 2-2 provides guidance for determining the n value of a channel with good alignment and grassed vegetation based on hydraulic radius.

Table 2-2 Value of Manning's *n* for drainage ditch design

Hydraulic radius	*n*
Less than 2.5	0.040 – 0.045
2.5 to 4.0	0.035 - 0.040
4.0 to 5.0	0.030 - 0.035
More than 5.0	0.025 – 0,030

Hydraulic grade line

The slope of the hydraulic grade line (water surface) is important in determining flow velocity. In the design of most small unobstructed ditches in uniform topography, the hydraulic grade line is assumed parallel to the ditch bottom.

Proper location of the grade line is more important as drain flows become greater. The profile of the channel should be plotted showing the location and elevation of control points. The control points help to select the maximum elevation of the hydraulic grade line desired for the drain. They may include, but are not limited to, the following:

- Natural ground elevations along the route of the proposed drain.
- Location, size, and elevation of critical low areas to be drained. These are obtained from the topographic data.
- Hydraulic grade line for side ditches or laterals established from the critical areas to the design drain. Plot the elevation where the side drain hydraulic grade line meets the design drain as a control point.
- Where laterals or natural streams enter the design drain, use the same procedure as that for hydraulic grade line for side ditches.
- Bridges across drainage ditches should not reduce the area of the design cross section. Where feasible to do so, the hydraulic grade line should be placed 1 foot below the stringers of the bridge. The allowable head loss on culverts should be kept low.

On agricultural drainage the allowable head loss generally should not exceed 0.5 foot.

- Elevations of buildings or other property within the area to be protected from overflow.
- If the drain being designed is to outlet into an existing drain or natural stream, the elevation of the water in the outlet drain or stream against which the designed drain must discharge should be used as a control point. The water surface elevation in the outlet ditch may be determined from recorded data, historic observation, or high water marks. Another method of obtaining this elevation is to determine the depth of flow in the outlet ditch by applying the same flow design basis as that used for the proposed ditch. For small outlet ditches in rather flat topography, the water elevation may be estimated at the bankfull stage.

Control points should be connected with a line on the profile. The hydraulic grade line is drawn through or below the control points. The grades should be as long as possible and should be broken only where necessary to stay close to the control points.

If the hydraulic grade line has been well established, it will not be altered except at structures that have head losses. At these control points, the head loss will be shown upstream from the structure as a backwater curve. This will change the hydraulic gradient, although generally for only a short distance
.

In cases where the water surface must be determined accurately, computer software developed for backwater analysis should be used.

Cross section, depth, and side slopes

The most economical ditch cross-section approaches that of a semicircle. A deep, narrow ditch generally carries more water than a wide, shallow ditch of the same cross-sectional area. An excessively wide, shallow ditch tends to develop sand or silt bars, which cause ditch meandering and bank cutting, and a fairly deep, narrow ditch tends to increase velocities and reduce sediment deposition and meandering. Because the cross-section selected is a matter of judgment, all factors involved should be considered. Ditches shall be designed to be stable. In some cases economy and hydraulic efficiency must be sacrificed in the interest of ditch stability and maintenance.

Factors that must be considered in establishing the depth of a ditch are:

- Depth to provide the capacity for removing the surface runoff plus freeboard.
- Depth to provide outlet for subsurface drainage.
- Depth to clear bridges.
- Depth to allow for sufficient capacity after subsidence in organic soils.
- Depth to trap sediment below the elevation of a design flow line. (To be effective, a trap should be proportioned such that the ratio of the trap length times width divided by the ditch capacity should be greater than 100.)

The machinery used for construction of the ditch should be considered in the selection of ditch bottom width. A bulldozer or blade equipment is used to construct V-shaped ditches. Flat bottom ditches frequently are designed if scrapers, hydraulic hoes, or draglines are to be used to construct the ditch. Depth of ditch and soil conditions affect the type of equipment used. Specified minimum bottom widths are often based on the available equipment.

The side slope selected for design must be stable, meet maintenance requirements, and be designed according to site conditions. Special investigations and stability analysis may be required when seepage is present in the channel banks from high water table conditions, low strength soils are encountered, or where channel soils are erosive and could lead to undermining of the banks.

Depth and side slope recommendations based on soil type are contained in the Appendix of this guide.

Calculation of ditch capacity

The capacity of a ditch can be determined from the Continuity Equation:

$$Q = VA$$

where: Q = capacity (cfs)
V = velocity (ft/s)
A = cross sectional flow area (ft^2)

Various curves, tables, and computer spreadsheets and software have been developed to assist in determining ditch capacity.

Culverts and bridges

Culverts and bridges should be designed for the expected loads from farm equipment, construction equipment, or vehicles that will use the crossing. The hydraulic capacity of the culvert or bridge should be large enough to avoid a reduction in the channel capacity. Wet crossings, or fords, may also be considered for livestock or for farm equipment where infrequent use is expected.

When a culvert or bridge is installed in a channel, it has the effect of backing up water or increasing head at the inlet. The amount of this rise in water level is determined by the entrance losses, friction losses, and exit losses. The amount of head loss needs to be considered in the design to insure that the upstream water surface is not so high as to prevent good drainage or to cause an increase in flood levels on adjacent properties.
The velocity through a bridge and at the outlet of a culvert should be checked to determine if scour protection is needed. Riprap may be required when allowable velocities are exceeded. Preformed scour holes may be used to stabilize conduit outlets.

Culverts and bridges for farm field access lanes should have a design capacity consistent with that of the channel. For drainage areas less than one square mile where the land slope is under one percent, the minimum capacity may be determined from the runoff drainage curves, otherwise the 2 year-24 hour storm should be used. Crossing for farmstead access lanes should be designed for the 10 year-24 hour event. The design capacity for public road crossings will be determined by the responsible unit of government. (See Conservation Practice Standard Code 560, Access Road, and Code 578, Stream Crossing)

Junctions

The bottom grades of ditches having about the same depth and capacity should be designed to meet at or near the same elevation. The bottom of a shallow, small capacity ditch may be designed to meet a larger ditch at or near the normal or low flow elevation of the larger ditch.

A transition is designed where a shallow ditch enters a much deeper ditch. Before beginning a transition, the grade of the shallow ditch generally is designed 10 to 100 feet upstream on a zero grade at the elevation of the deeper ditch. The transition should be on a non-erosive grade not to exceed 1 percent.

Where the difference in the elevation of the ditch grade lines is considerable and transition grades seem impractical, a structure should be used to control the drop from the shallow ditch to the deeper ditch. See EFH Chapter 6, Structures, for additional information.

Surface water entry

Provisions should be made to control surface water entering into a ditch to avoid erosion of the banks. Ideally, surface water enters a ditch only through lateral ditches graded to the bottom of the channel, or through structures including chutes, drop spillways, or pipe conduits. Collection ditches can be used to reduce the number of necessary structures. Excavated spoil can be spread or left in spoil banks along the channel with openings spaced to control surface water entry. A minimum berm width, or set-back, of eight feet should be provided between the spoil pile and the ditch bank to allow for maintenance and erosion control, and to prevent overloading of the bank slope.

f) Channel vegetation and maintenance

Field ditches that will not be cropped and the banks of all mains and laterals should be stabilized with a good vegetative cover of appropriate grasses. Channel beds may also be stabilized with vegetation where prolonged flows are not expected. The area adjacent to the channel should also be vegetated including spoil banks, berms, and buffer strips.

Surface drains have an estimated service life of 15 years. This can be achieved and prolonged through proper maintenance. Standardized operation and maintenance plans have been developed for surface drainage practices and can be found in the NRCS New Jersey electronic Field Office Technical Guide.

Chapter 3 Subsurface Drainage

Contents **NJ650.1403**

Tables

Figures

NJ650.1403 Subsurface Drainage

a) General

Plants require air as well as moisture and nutrients in the root zone. Excess water restricts the available air and inhibits plant growth. Artificial subsurface drainage increases productivity on land where high water table or soil moisture conditions prevent the gravitational movement of water from the root zone.

In addition to the aeration of the root zone for improved crop growth, subsurface drainage can increase the length of the growing season since earlier planting dates are possible. Drainage improves the soil moisture conditions for the operation of farming equipment and decreases the possibility of adversely affecting soil tilth by farm equipment operated when the soil has excess moisture. The removal of subsurface water results in the soil having a greater storage capacity for rainfall which will decrease runoff and thereby reduce possible erosion.

A properly planned system coordinates the subsurface drainage system with other conservation and management practices. Land grading and shallow surface ditches may be needed to eliminate ponded surface water and thus reduce the amount of water entering the soil.

The New Jersey Water Management Guide includes in an appendix recommendations for drainage of many of the soil series found in New Jersey that commonly require drainage. The recommendations are largely historical in nature and based on experience with the particular soil or a similar soil. The recommendations are intended to serve as guidance. More site specific methods for the design of drainage systems can be found in National Engineering Handbook Part 642, Drainage, Chapter 4, and Part 650, Engineering Field Handbook, Chapter 14.

b) Types of systems

Relief drains are those installed to remove excess ground water percolating through the soil or to control a high water table. They should systematically lower the water table for an area. The drains may be aligned parallel or perpendicular to the direction of ground water flow. Several general types of system layout or patterns may be considered depending on the topography and nature of the subsurface drainage problem.

Random system

A random field drainage system is used where the topography is undulating or rolling and has isolated wet areas. The main drain is generally placed in the lowest natural depression, and smaller drains branch off to tap the wet areas. Because such drains often become outlets for a more complete system established in the higher areas of the field, the depth, location, and capacity of the random lines should be considered as part of a complete drainage system. Generally, the logical location of these drains obviously fit the topography.

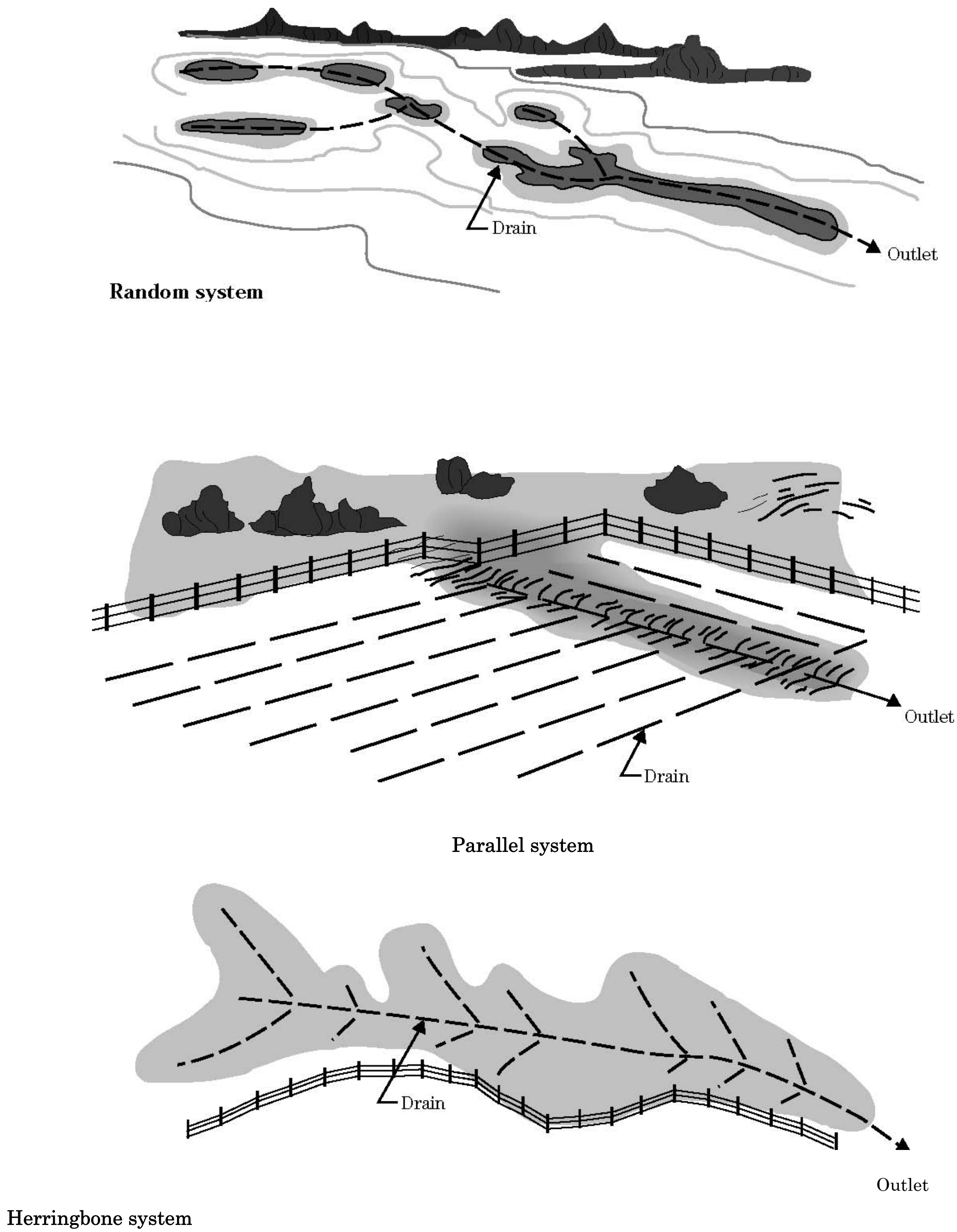
Parallel system

The parallel field drainage system consists of laterals that are perpendicular to the main drain. Variations of this system are often used with other patterns. In many cases, the parallel system is desirable because it provides intensive drainage of a given field or area. It can also be used in depressional or low areas that can be graded before installation of the system.

Herringbone system

The herringbone field drainage system consists of laterals that enter the main drain at an angle, generally from both sides. If site conditions permit, this system can be used in place of the parallel system. It can also be used where the main is located on the major slope and the lateral grade is obtained by angling the laterals upslope. This pattern may be used with other patterns in laying out a composite system in small or irregular areas.

Figure 3-1 Field drainage systems



c) Subsurface drainage design

A plan should be made of every subsurface drainage project. The size and detail of the plan will vary depending on the scope of the project, however, all plans should have the same basic information required for the construction of the subsurface drainage system.

Considerations

(1) Soils

Subsurface drainage is applicable to saturated soil conditions where it is physically and economically feasible to use buried conduits to remove or control free water from the root zone.

The need for and the design of subsurface drainage systems are related to the amount of excess water entering the soil from rainfall; the permeability of the soil and underlying subsoil material; and the crop requirements. In soils with slow permeability that causes water to flow slowly into the drain, the drains must be closely spaced. Consequently, installation may be considered too expensive for use of subsurface drains.

Soils must have sufficient depth and permeability to permit installation of an effective and economical subsurface drainage system. Some sandy soils and peat and muck have large pore spaces that allow rapid movement of water. Wetness occurs in these soils because of a high water table, particularly in the spring, late in summer, or during the irrigation period. For maximum crop yields, the wetness problem must be corrected by drainage. These soils can be successfully drained.

Some fine sand soils have insufficient colloidal material to hold the sand particles together. This can cause excessive movement of the particles into the drains. Special precautions, such as filters or envelopes, are often required.

In highly permeable, coarse sands and some peat soils, excessive lowering of the water table causes a moisture deficiency during periods of drought. Such soils have limited capillary rise and are unable to deliver water up into the plant root zone of certain crops if the water table falls much below the root zone. Water table control systems should be used for these conditions.

Other soil conditions make construction of drains hazardous or impractical. In some soils, boulders or stones make drainage costs prohibitive. In others, the topsoil is satisfactory, but it is underlain by unstable sand at the depth where drains should be installed, thus making installation more difficult.

(2) Biological and mineral clogging

The ferrous iron content of the ground water flowing into a drain is a reliable indicator of the potential for ochre development. Soluble ferrous iron flowing in ground water enters a different environment as it approaches the drain and passes through the drain envelope. If the level of oxygen is low, certain filamentous and rod-shaped bacteria can precipitate insoluble ferric iron and cause its incorporation into the complex called ochre. The amounts of iron in ground water that can stimulate bacteria to produce ochre can be as low as 0.2 ppm.

Laboratory and field methods are available to estimate the ochre potential for a given site. Of particular importance is whether ochre may be permanent or temporary. Temporary ochre occurs rapidly, usually during the first few months after drain installation. If the drains can be cleaned or maintained in functional order, the ochre problem may gradually disappear as the content of iron flowing to the drains is reduced. Such soil environments must be low in residual organic energy sources to prevent the continual release of iron during short-term flooding.

Permanent ochre problems have been found in profiles with extensive residual iron, such as cemented iron sub-horizons or rocks, and from iron flowing in from surrounding areas. Many factors influence ochre deposition, including the pH, type, temperature, and reducing conditions of the soil.

Certain onsite observations may give clues to potential ochre formation before a drainage system is installed. Surface water in channels may contain an oil-like film that is iron and may contain Leptothrix bacterial filaments. Gelatinous ochre may form on the ditch-banks or channel bottom. Ochre may also form within layers of the soil. Iron concretions, sometimes called iron rocks, are in some areas. The presence of spodic horizons (organic layers) suggests ochre potential; and most organic soils, such as mucks, have some potential for ochre problems.

If a site has potential for ochre deposits, certain planning and design practices should be followed to minimize this hazard to the system. No economical, long-term method for effectively controlling this problem is known. For sandy soils where a filter is necessary, a graded gravel envelope is best, although it can become clogged under conditions of severe ochre potential. When synthetic fabrics were evaluated for ochre clogging, the knitted polyester material showed the least clogging.

A submerged outlet may be successfully used to minimize ochre development with the entire drain permanently under water. The line should be completely under water over its entire length throughout the year. This may require that the drains be on flat grade. The depth of ground water over the drain should be at least one foot.

Herringbone or similar drain designs should have entry ports for jet cleaning.

Use drain pipe that has the largest slots or holes allowed within the limits of drain pipe and envelope standards. Slots or holes should be cleanly cut.

(3) Outlet

The starting point in planning a subsurface drainage system is normally the location of the outlet. Drains may discharge by gravity into natural streams, constructed open ditches, or into larger existing underground mains. Any of these outlets are suitable if they are deep enough and of sufficient capacity to carry all the drainage water from the entire drainage system. The adequacy of the outlet should be determined before proceeding with the design of the system.

The outlet ditch must have the capacity to remove the drainage runoff from its watershed quickly enough to prevent crop damage. It should be deep enough to allow at least 6 inches of clearance between the flow line of the drain and the normal low water stage in the ditch when drains are installed at the specified depth.

If existing subsurface drains are used for the outlet, they should be in good condition and working properly. The main drain should have sufficient capacity to handle the proposed drainage system in addition to other systems it serves, and it should be deep enough to permit the new system to be installed at the depth specified.

Where a gravity outlet is not available, pumping can be considered. Additional information can be found in this Guide or in the National Engineering Handbook Part 624, Drainage, Chapter 7.

(4) Environment

Whether a new drainage system is planned or an existing system is to be restored, consideration must be given to the environmental impacts especially effects on wetlands and water quality.

The lateral extent of the drainage system's influence on lowering the ground water level should be evaluated to ensure that adjacent wetland areas are not impacted.

Consider the potential for the rapid removal of applied nutrients in drainage water and possible impacts on downstream water quality. Additional measures to control the drainage rate or efficiency; or management of rate and timing of nutrient applications; may be necessary.

Drainage coefficient

Drains should have sufficient capacity to remove excess water from minor surface depressions and the major part of the root zone within 24 to 48 hours after rainfall ceases. The required amount of water to be removed in some specified time is the drainage coefficient. For field drainage, it is expressed as inches of water depth to be removed over a safe period of time, generally 24 hours.

Drainage coefficients historically used in New Jersey are shown in table 3-1. In practice, the selection of the drainage coefficient should be based largely on a knowledge of past cropping and farm operational problems in the area, combined with the judgment of the designer.

Table 3-1 Drainage coefficients

Soil	Field crops	Truck crops
	(inches to be removed in 24 hours)	
Mineral	3/8 – 1/2	1/2 – 3/4
Organic	1/2 – 3/4	3/4 – 1 1/2

The drainage coefficient assumes that surface drainage is adequate and applies to the entire area being drained. If the surface runoff from an upland area spreads over the area to be drained and is likely to increase the drainage problem, the acres used in determining the drain line size should be proportionally increased. The drain line size need not be increased if runoff from the upland area is diverted from the drained location.

Where high value crops such as vegetables may be damaged by shallow surface water ponding in depressional areas, surface inlets should be installed. If surface water is admitted into a subsurface drainage system through surface inlets, the drainage coefficient is to be increased as shown in table 3-2. The selected drainage coefficient will apply to the entire watershed contributing runoff to the surface inlet, except where only a small amount of runoff will be impounded at the location of the inlet. For the latter case, the drain line shall be large enough to remove the impounded water in 24 hours, plus provide capacity for the required drainage.

Table 3-2 Drainage coefficients for systems with surface inlets

Soil	Field crops	Truck crops
	(inches to be removed in 24 hours)	
Blind inlets		
Mineral	1/2 – 3/4	3/4 - 1
Organic	1/2 – 1	3/4 – 2
Open inlets		
Mineral	1/2 – 1	1 – 1 1/2
Organic	1/2 – 1 1/2	2 – 4

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

Depth and spacing

The depth and spacing requirements for a subsurface drain system are based on soil characteristics, type and value of crops, outlet conditions, and the presence or absence of impervious soil layers in the upper portion of the soil profile. Generally, the greater the depth of a field drain, the wider the spacing can be between drains.

Drains should be deep enough to provide protection against tillage operations, equipment loading, and frost. Initial settlement in organic soils should be considered in depth selection. Main and submain drains must be deep enough to provide the specified depth for outlets of lateral drains. Also, the maximum depth at which drains can be laid to withstand trench loading varies with the width of the trench and the crushing strength of the drain to be used.

All subsurface drains in mineral soils should have at least twenty four inches of cover for protection against overloading from heavy machinery. Subsurface drains in organic soils should have at least thirty inches of cover. Cover is measured from the top of the drain conduit to the ground surface. Less cover may be used if plastic drain lines are replaced with metal of other high strength durable pipe where drain lines cross under ditches, waterways, or small depressional areas not subject to heavy equipment travel. Additional protection against crushing may be required in the vicinity of the outlet, under lanes and in other special situations.

In most cases subsurface drains should not be placed under an impermeable layer, and they should be located within the most permeable layer.

Appendix B gives recommended depths and spacing for subsurface drains for many New Jersey soils benefiting from drainage. The recommended spacing ranges from less than 20 feet to over 300 feet. Typically, drain lines are not spaced closer than 40 feet in agricultural work due to excessive cost associated with the close spacing. For very high value crops and for special use areas such as athletic fields, closer spacing can be justified.

Grade and velocity

The design grade must be sufficient to provide the capacity required to drain the area. In areas where sedimentation is not a hazard, the minimum grade shall be based on site conditions and a velocity not less than 0.5 fps. If a hazard exists, a velocity of not less than 1.4 fps shall be used to establish the minimum grades if site conditions permit. Otherwise, provisions shall be made for preventing sedimentation by:

- use of filters,
- collecting and periodically removing sediment from installed traps, or
- periodic cleaning of the lines with high pressure jetting systems.

Steep grades may produce high velocities in the conduit that can induce piping of the surrounding soil material into the drain line. Protective measures are required where flow velocity exceeds the values given in Table 3-3.

Table 3-3 Maximum subsurface drain line velocity by soil texture

Soil texture	Maximum velocity fps
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

Protective measures include enclosing continuous perforated pipe or tubing with a geotextile or properly graded sand and gravel envelop, or by using non-perforated pipe with soil tight joints for the high velocity section. Open air risers or air releases may be required at steep changes in grade.

Size of drains

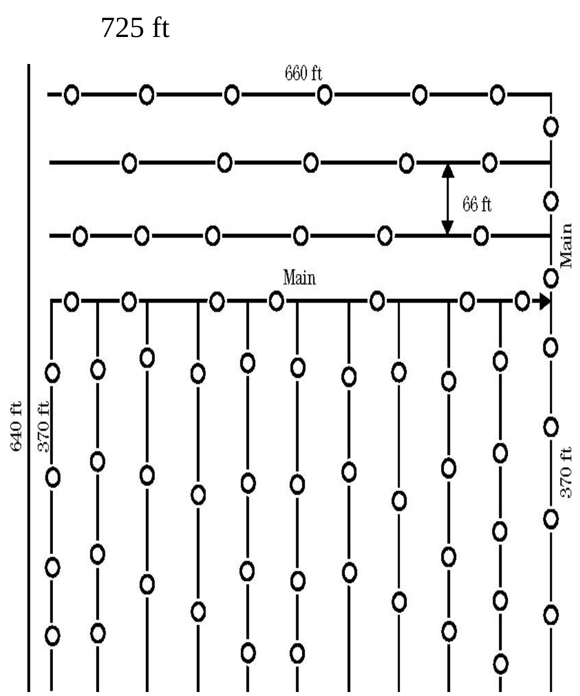
The size of drains depends upon the required flow and the grade on which they are laid. The required flow is determined from the drainage coefficient and the area or length of drains contributing flow, plus any allowances for concentrated flow entering from the surface, springs, or other sources. The contributing drainage area for a complete drainage system is about the same as the total length of all contributing lines multiplied by the spacing between such lines.

Random drains in poorly drained depressions are often used later as main drains for a more complete drainage system. Where such expansion is likely, the additional area that such drains would serve should be included in determining the size of the initial random line. Where surface water is admitted directly into a drain by surface inlets, the entire watershed contributing to the inlet should be included. Flow from such watersheds often can be reduced by diversion ditches.

(1) Main drain

The required discharge can be determined using figure 3–3 for a given drainage coefficient and area (acres). The required size of the corrugated plastic drainage tubing can be determined directly from figure 3–4. The size required for all types of drains can be calculated using Manning's equation with the appropriate roughness coefficients (table 3–4). The following example illustrates the use of these charts for the subsurface drainage system shown in figure 3-2.

Figure 3–2 Subsurface drainage system



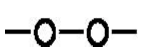

Subsurface pipe drain

Table 3–4 Values of Manning's *n* for subsurface drains and conduits

Description of pipe	Values of *n*
Corrugated plastic tubing	
3 to 8 inch diameter	0.015
10 to 12 inch diameter	0.017
>12 inch diameter	0.020
Smooth plastic, unperforated	0.010 – 0.012
Smooth plastic, perforated	0.010 – 0.012
Annular corrugated metal	0.021 – 0.025
Helical corrugated	0.015 – 0.020
Concrete	0.012 – 0.017
Vitrified sewer pipe	0.013 – 0.015
Clay drainage tile	0.012 – 0.014

Example for main drain (see Figure 3-3):

Given:

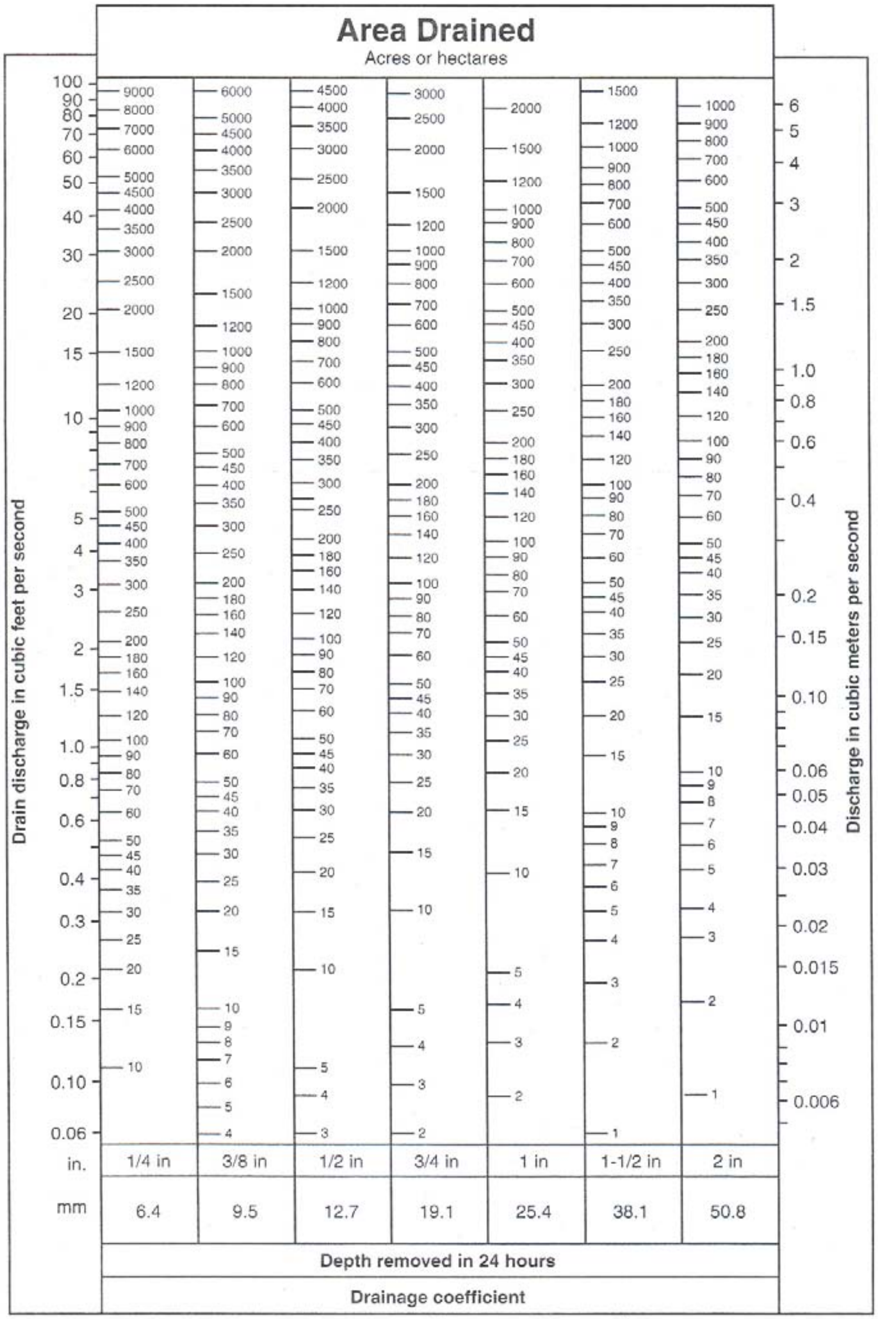
A tract of land about 640 by 725 feet is to be drained for general crops. The drainage area is 10.65 acres. The drainage coefficient is 3/8 inch in 24 hours (0.0156 inch/hour). A parallel system that has laterals spaced 66 feet apart, requires 4 lines, 660 feet long; 11 lines, 370 feet long; and 1 line, 200 feet long; making a total of 6,910 feet of drain. The main, as shown from a plotted profile, is on a grade of 0.08 percent and is to be corrugated plastic tubing.

Required:

Size of the corrugated plastic main at the outlet and its capacity.

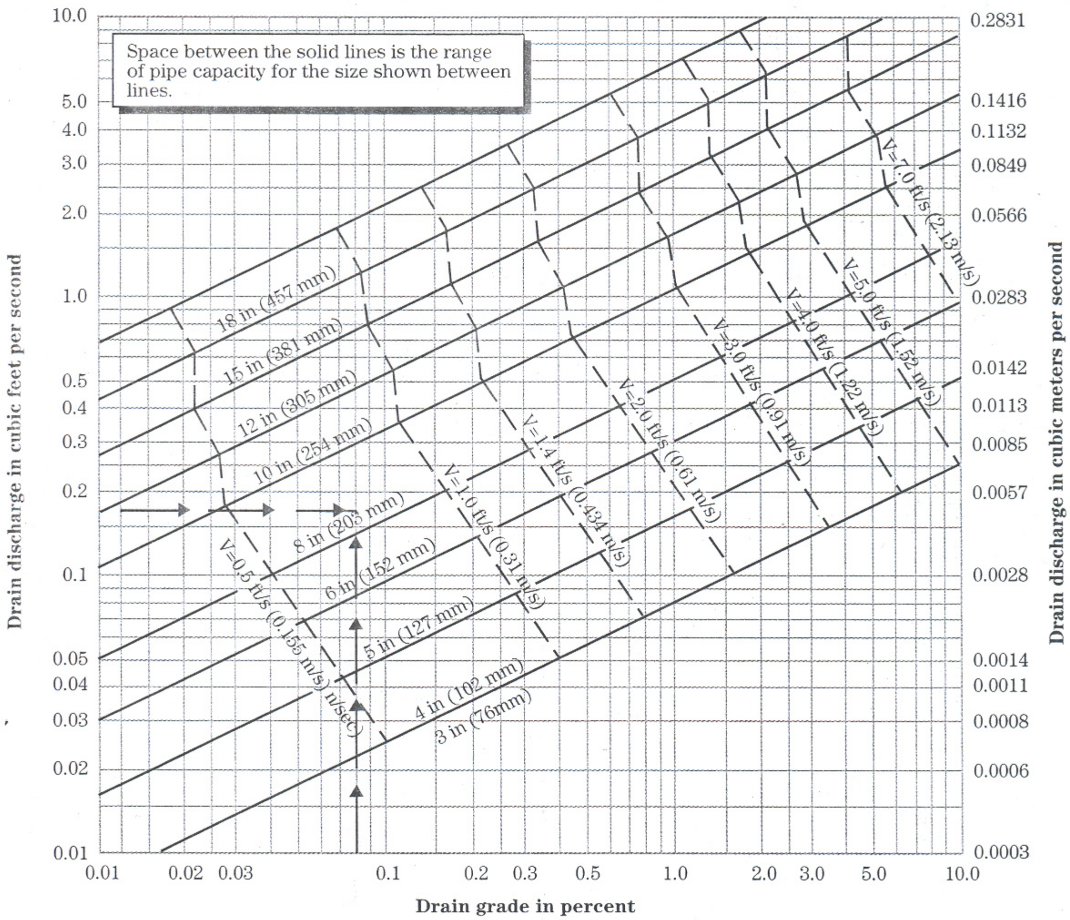
Using figure 3–3, find 10.65 acres in the 3/8 inch coefficient column under Area Drained to determine the discharge of 0.17 cubic feet per second. Using this discharge, enter figure 14–34 and a slope of 0.08 vertical grade line. The point of intersection lies within the range for an 8-inch drain. The top line of the space marked 8 represents the 8-inch drain flowing full when the hydraulic grade is the grade of the drain. From the intersection of the top of 8-inch range and grade of

Figure 3-3 Subsurface drain discharge from drainage coefficient



Note: Use acres with ft^3/s and hectares with m^3/s
(Source-ASAE Standard EP260.4)

Figure 3-4 Subsurface drain discharge for corrugated plastic pipe



Drain grade = hydraulic gradient
Percent = ft per 100 ft, or m per 100 m
V = velocity in ft/s (m/s)

3 to 8 in (76 to 203 mm) : n = 0.015
10, 12 in (254, 305 mm) : n = 0.017
15, 18 in (381, 457 mm) : n = 0.02

(Source-ASAE Standard EP260.4)

0.08 percent, produce a line horizontally to intersect the vertical on the left. The drain flowing full will discharge 0.3 cubic feet per second, which shows that the drain selected will not be flowing full.

(2) Field or drain lateral
To compute the size of a lateral, first determine the required discharge for the lateral. The following formula or figure 3-5 can be used. When the discharge is determined, use figure 3–2 to determine the drain size for plastic pipe.

In the case of parallel drains, the area served by the drain is equal to the spacing times the length of the drain plus one-half the spacing. The discharge can be expressed by the following formula:

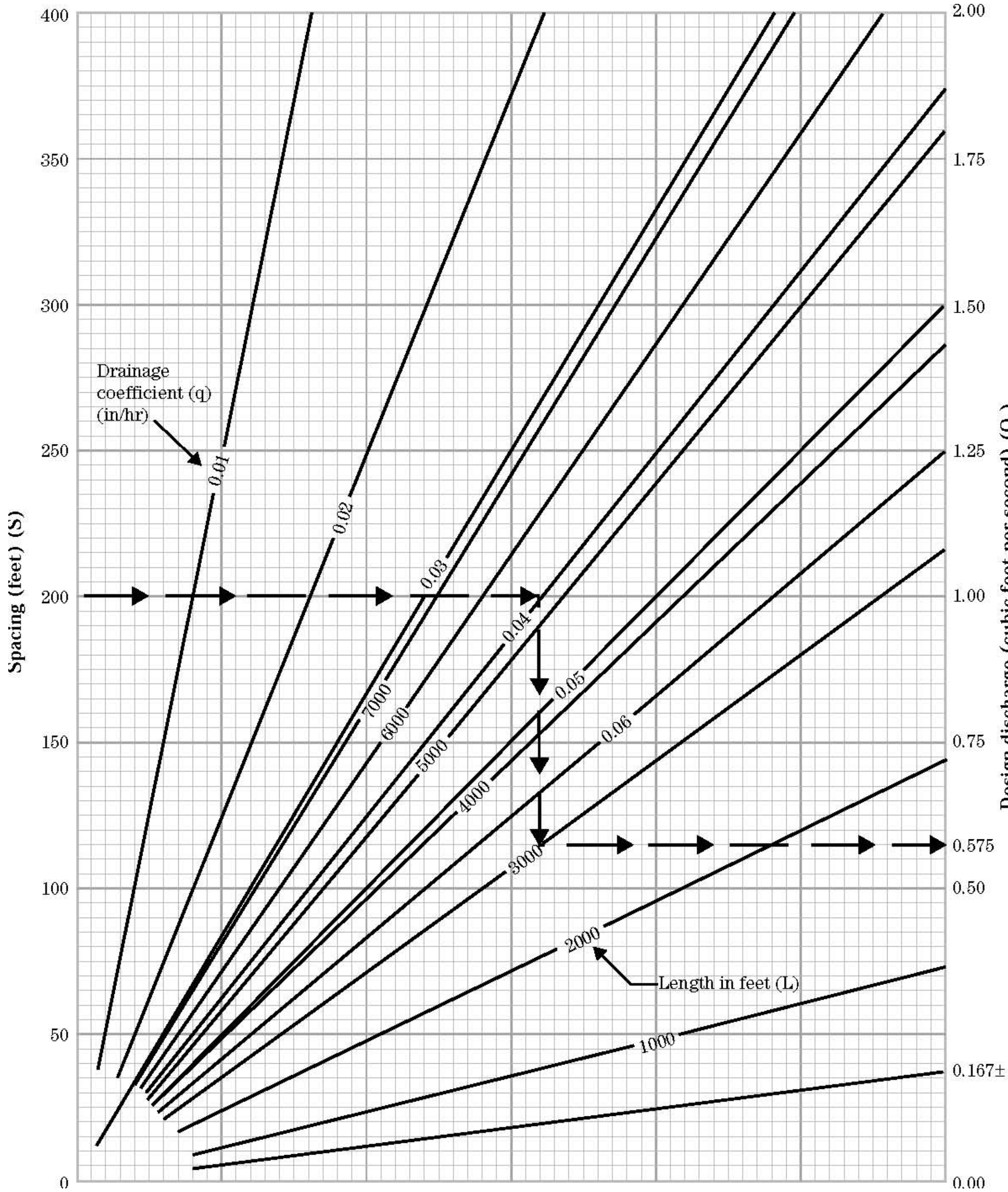
$$Q_r = \frac{qS\{L + (S/2)\}}{43,200}$$

where:
Q_r = Relief drain discharge, ft^3/s
q = Drainage coefficient, in/hr
S = Drain spacing, ft
L = Drain length, ft

Example:
Drain spacing – 200 feet (S)
Drain length – 3,000 feet (L)
Drain coefficient – 0.04 inches/hour (q) (1 inch/day)
Drain grade – 0.30 percent

Using figure 3–5, find spacing of 200 feet on the vertical scale on the left; follow horizontally to the right to intersect with the drainage coefficient curve 0.04. From that point follow vertically to intersect the length curve of 3,000 feet, then go horizontally to the right to read the discharge of 0.575 cubic feet per second. Using figure 3–4 for plastic tubing, find the above discharge on the vertical scale on the left and look horizontally to intersect the grade of 0.30 percent. An 8-inch drain will be required.
The drain chart has velocity lines. In the example, the velocity in the drain is between 1.4 and 2.0 feet per second, thus, minimizing sediment accumulation. In a drainage system, different sizes of drains may be needed. Required drain size may change at breaks in grade and changes in tributary area.

Figure 3–5 Curves to determine discharge, Q_r, for subsurface drain



$$Qr = \frac{qS\,(L+2)}{43{,}200}$$

d) Drain envelope

Drain envelope is used here as a generic term that includes any type of material placed on or around a subsurface drain for one or more of the following reasons:

- To stabilize the soil structure of the surrounding soil material, more specifically a **filter envelope**.
- To improve flow conditions in the immediate vicinity of the drain, more specifically a **hydraulic envelope**.
- To provide structural bedding for the drain, also referred to as **bedding**.

Soils in which drains are prone to mineral clogging are commonly referred to as problem soils because the soil particles tend to migrate into the drain. In practice, all very fine sandy or silty soils with low clay content are probable problem soils and will require filter envelopes (fine SP, fine SM, and ML or SM with P.I. less than 7). Finer textured soils, even with high clay content if the soil is considered dispersed, may present clogging problems in addition to being difficult to drain.

Drain envelope materials

Drain envelope materials used to protect subsurface drains include almost all permeable porous materials that are economically available in large quantities. Based on the composition of the substances used, they can be divided into three general categories: mineral, organic, and geotextile envelope materials.

Mineral envelopes consist of coarse sand and fine gravel. The envelope material may be pit run coarse sand and fine gravel containing a minimum of fines. Properly designed or selected sand-gravel drain envelopes can fulfill all the mechanical, soil stabilizing, and hydraulic functions of a filter envelope.

Organic envelopes include prewrapped loose plant materials, fibers, chips, or granules. The service life and suitability of organic materials as drain envelopes for subsurface drains cannot be predicted with certainty. Organic matter placed as a drain envelope may also affect chemical reactions in the soil that result in biochemical clogging problems. Where ochre clogging of drains is expected, organic matter should be used with caution.

Synthetic materials are geotextile fabrics specifically manufactured for use in drainage and soil stabilization. A geotextile is a permeable, polymetric material that may be woven, nonwoven, or knitted. Geotextiles are made of polyester, polypropylene, polyamide, polystyrene, and nylon. The materials vary in weight, opening size, fiber diameter, thickness, and uniformity.

Drain envelope materials are most effective when placed completely around the pipe. Typical drain envelope installations are shown in figure 3–6.

The practice of blinding or covering subsurface drains with a layer of topsoil before backfilling the trench actually provides many humid area drains with permeable envelope material. Humid area surface soils tend to have a well developed, stable, and permeable structure that functions well as a drain envelope. In stratified soils, drains are blinded by shaving the coarsest textured materials in the soil profile down over the pipe.

Design of drain envelopes

(1) Sand-gravel filter envelope design
The general procedure for designing a sand-gravel filter envelope for a given soil is:

- Make a mechanical analyses of both the soil and the proposed filter envelope material.
- Compare the two particle size distribution curves.
- Use criteria to determine whether the filter envelope material is satisfactory.

The criteria include:

- The D_{15} (defined below) size of the filter material should be at least 4 times the diameter of the d_{15} of the base material. (This would make the filter material roughly more than 10 times more permeable as the base material.)

- The D_{15} of filter material should not be more than 4 times larger than the d_{85} of the base material. (This prevents the fine particles of the base material from washing through the filter material.)

The following gradation limits are recommended:

- Upper limit of D_{100} is 38 mm (1.5 inches)
- Upper limit of D_{15} is the larger of 7 times d_{85} or 0.6 mm.
- Lower limit of D_{15} is the larger of 4 times d_{15} or 0.2 mm.
- Lower limit of D_5 is 0.075 mm (#200 sieve).

D_{100} represents the particle size in the filter material for which 100 percent, by weight, of the soil particles are finer (similarly for D_{15} and D_5). The d_{85} and d_{15} represent the particle size in the surrounding base material for which 85 percent and 15 percent, by weight, of the soil particles are finer. In the case of drainage, the base material is the soil.

Procedures for determining filter gradation design limits are found in NEH, Part 633, Chapter 26, Gradation Design of Sand and Gravel Filters.

Research on filter envelopes show that:

- If a filter envelope does not fail with the initial flow of water, it is probably permanently safe.
- The size ratios are critical.
- Materials with a D_{15}/d_{85} ratio greater than nine always fail.
- Well graded materials are more successful than uniform sized materials.
- A well-graded gravelly sand is an excellent filter or filter envelope for very uniform silt or fine uniform sand.
- It is not necessary for the grading curve of the filter envelope to be roughly the same shape as the grading curve of the soil.

(2) Sand-gravel hydraulic envelope design
The criteria for a sand-gravel hydraulic envelope are less restrictive than for a sand-gravel filter envelope as follows:

- Upper limit of D_{100} is 38 mm (1.5 inches).
- Upper limit of D_{30} is 0.25 mm (#60 sieve).
- Lower limit of D_5 is 0.075 mm (#200 sieve).

Pit run coarse sand and fine gravel containing a minimum of fines often meet these criteria. Sand gradations used for concrete as specified by ASTM C-33 (fine aggregate) will satisfy these hydraulic envelope criteria and will meet the filter envelope requirements for most soils.

(3) Geotextile filter envelope design
In filter envelope applications, the geotextile must physically survive installation, allow adequate flow of water, and basically retain the soil on its hydraulically upstream side. Both adequate flow capacity (requiring an open geotextile structure) and soil retention (requiring a tight geotextile structure) are required simultaneously. Therefore, critical geotextile parameters for filter envelope applications are permittivity, survivability, and soil retention.

Non-woven geotextiles are recommended for most drainage situations. In general, non-woven geotextiles retain more soil fines than do woven geotextiles. The structure of the mechanically bonded needle-punched fabric helps to decrease the internal clogging potential of the fabric. Non-woven fabrics also have very good oermeability and permittivity characteristics.

Minimum requirements for non-woven geotextiles satisfactory for most installations include:

- Tensile strength: 90 pounds, ASTM D 4632
- Bursting strength: 180 psi, ASTM D 3786
- Elongation at failure: >50%, ASTM D 4632
- Puncture: 40 pounds, ASTM D 4833
- AOS: Maximum #40 sieve, ASTM D

4751

- Permitivity: 0.70 , ASTM D 4491

e) Appurtenances

Surface inlets

Surface inlets should be used in low areas where surface drainage otherwise cannot be provided. They must be properly constructed to prevent washouts and silting of the line. Surface inlets should be avoided wherever possible. If silt is a hazard, place a silt trap (figure 3–7) at a convenient location immediately downstream from the inlet or use a blind inlet (figure 3–8). Blind inlets allow entry of surface water from small ponded areas into the drain without an open riser. The sand-gravel material for the porous medium must be appropriately designed to keep out sediment and prevent piping of base soil material, yet provide free water movement into the drain.

Junction boxes

Junction boxes should be used where two or more main or sub-main drains join or where several laterals join at different elevations. If the junction is in a cultivated field, the box should be constructed so that the top is at least 18 inches below the surface of the ground. It can be capped and covered and its position referenced for future relocation (figure 3–7).

Vents and relief wells

Vents, or breathers, are used to alleviate vacuum or negative pressure in the line. Breathers should be used where the line changes abruptly from a flat section to a steep section. Permanent fence crossings are good locations for installation. Relief wells relieve pressure in the line. They should be installed where steep sections change to flat sections unless the flatter section has about 25 percent greater capacity than the steeper section. They should be used on lines that have surface inlets, particularly when such inlets are large (figure 3-9).

Outlet protection

Where drains outlet into an open ditch or natural stream, the end of the drainage line should be protected from erosion, damage from periodic submergence, and from entry of rodents into the drain. Protection against erosion can be provided by using a length of continuous, non-perforated, rigid pipe at the outlet. Typical materials include corrugated metal pipe, or smooth PVC pipe. The rigid pipe should be a minimum of ten feet in length, with no more than 1/3 of the pipe length extending from the channel bank. The outlet should be six inches above the normal flow level in the ditch or one foot above the ditch bottom. Drainage systems that outlet into a pond may discharge at the water surface if there is a control structure at the pond’s outlet that provides at least one foot of drop to the downstream channel.

When there is a likely fire hazard due to burning vegetation at the outlet, a fire resistant material such as corrugated metal pipe should be used. Headwall structures should be considered where mowing could damage the outlet section. Where ice or floating debris may damage the outlet pipe, the outlet should be recessed from the bank or a headwall structure should be used.

Animal guards should be installed on the ends of all outlet pipes. Flap gates, hinged-rod gates, screens, and bar gratings are commonly used. Some different styles are shown in figure 3-10. Flap gates or hinged-rod gates should be used on drains that connect to surface water inlets to allow passage of debris that may enter the system.

Where surface water enters the ditch at the location of the drain outlet, some type of structure or precaution is needed to facilitate the transport of the water into the ditch without damage from erosion. The type of structure required is related to the drainage area size, discharge, site topography and soil. For disperse flows that may concentrate as fill settles in the pipe trench, a berm may be constructed across the trench at the ditch bank to divert flow to vegetated areas. For concentrated flows, a stabilized chute or drop structure may be necessary.

Generally, drainage systems will not require conduit outlet protection in the form of a riprap apron or preformed scour hole, however, the need should be evaluated where high exit velocities are expected or the system includes surface inlets.

f) Installation

Trenching and placement

Corrugated plastic drainage tubing has relatively little inherent load-bearing strength. Its ability to support soil loads is derived from the lateral pressure induced as the sides of the tubing deflect outward against the soil. Flexible tubing must be installed in the trench in a way that insures good soil support around the conduit.

The conduit should not be placed on exposed rock or stones more than 1.5 in. in diameter. Where such conditions are present the trench must be over-excavated a minimum of 6 inches and refilled to grade with a suitable bedding material.

The conduit must be placed on a firm foundation to insure proper alignment. If installation will be below a water table or where unstable soils are present, special equipment, installation procedures, or bedding materials may be needed. These special requirements may also be necessary to prevent soil movement into the drain or plugging of the envelope if installation will be made in such materials as saturated fine sands or silts.

.

For trench installations of corrugated plastic tubing 8 inches or less in diameter, one of the following bedding methods will be specified:

- A shaped groove or 90^{o} V-notch in the bottom of the trench for tubing support and alignment.
- A sand-gravel envelope, at least 3 in. thick, to provide support
- Compacted soil bedding material beside and to 3 in. above the tubing.

For trench installations of corrugated plastic tubing larger than 8 inches, the same bedding requirements will be met except that a semi-circular or trapezoidal groove shaped to fit the conduit will be used rather than a V-shaped groove.

For rigid conduits installed in a trench, the same requirements will be met except that a groove or notch is not required.

All trench installations should be made when the soil profile is in its driest possible condition in order to minimize problems of trench stability, conduit alignment, and soil movement into the drain.

For trench installations where a sand-gravel or a compacted bedding is not specified, the conduit should be blinded with selected material containing no hard objects larger than 1.5 in. in diameter. Blinder should be carried to a minimum of 3 in. above the conduit.

Drain crossings and outlets

Special considerations should be made where drains are installed under waterways and roads. Figure 3-11 provides some guidance for these crossings. The figure also provides guidance for drain installation where shallow depth of cover exists at the drain outlet. Alternatives include:

- adding fill to obtain the required minimum depth of cover,
- installing a rigid pipe rated for less than two feet of cover, or
- excavating an open ditch back to a point where the required minimum depth of cover can be provided.

Protection against biological clogging

1) Roots

Water-loving trees, such as willow, red maple, elm, poplar, and cottonwood, should be avoided when locating a drain line. Roots will clog the drain if they are allowed to enter. A minimum distance of 100 feet should be maintained from these trees unless non-perforated pipe is used. Drain lines should be located a minimum of 50 feet from other types of trees. When the proximity to trees cannot be avoided and drainage must still be provided, a sand and gravel envelope should be installed along the length of non-perforated pipe.

Where crop or grass roots may cause clogging, facilities may be installed to provide a means for submerging the conduit or elevating the water table above the drain to inhibit root growth from extending to the system.

2) Iron ochre

If drains are to be installed in sites where iron ochre problems are likely to occur, provisions should be made to provide access for cleaning the lines. Each drain line should outlet directly into an open ditch and/or should have entry ports as needed to provide access for cleaning equipment. Riser pipes for flushing the line shall be provided at intervals not to exceed 500 feet. Drain cleaning provisions should be installed in such a way that the drains can be cleaned in an upstream or rising grade direction. If possible, drains in ochre-prone areas should be installed during the dry season when the water table is low and the iron is in its insoluble form.

Where possible, in areas where the potential for ochre problems is high, protection against ochre development can be provided by designing an outlet facility to ensure permanent submergence of the drain line.

g) Safety

Trenching, particularly in saturated soils, can be hazardous. Failure of trench walls can occur suddenly and without warning. Because of this, the federal Occupational Safety and Health Administration (OSHA) has developed specific standards, practices, and procedures governing trench excavation. Contractors are familiar with these regulations and must adhere to the requirements.

No excavation should take place on a project site until a utility mark-out has been completed. Buried utilities, particularly gas lines, can be extremely dangerous. Landowners or contractors must call the State buried utility location service prior to construction. On-farm utility lines, such as irrigation mains, may not be identified by the service. In such cases, landowner knowledge, previous plans, and field evidence must be relied upon.

h) Maintenance

Maintenance of drainage systems, while not extensive, is very important for operation of the system. If the subsurface drains are working properly, water will stand in the field for only a short time after a heavy rainfall. If water stands for a few days, the drain may be partly or completely blocked. Regular inspection of the drainage system is essential. Flow rates in surface inlets, junction boxes, manholes, or at the outlet should be monitored after heavy rains or in the spring when ground water levels tend to be higher. Changes in flow can indicate blockages. Prompt repair will keep the system serviceable.

Many subsurface drainage systems fail due to sediment buildup and blockage of the outlet. Ditches should be cleaned and additional land treatment measures applied where excessive sedimentation occurs.

Holes or depressions may occur over drain lines indicating that soil has been displaced into the line. This can occur at joint separations or where the drain line has been crushed or damaged. Again, prompt repairs should be made.

Drainage systems in fine sands or silty soils should be checked frequently following installation for signs of sediment, as the newly disturbed soil lacks structure and can be easily displaced. In time as finer particles are removed, coarser ones may be retained at the perforation, eventually slowing the rate of displacement or piping.

Subsurface drainage systems have an estimated service life of 20 years. This can be achieved and prolonged through proper maintenance. Standardized operation and maintenance plans have been developed for subsurface drainage practices and can be found in the NRCS New Jersey electronic Field Office Technical Guide.

Figure 3-6 Typical bedding or envelope installations

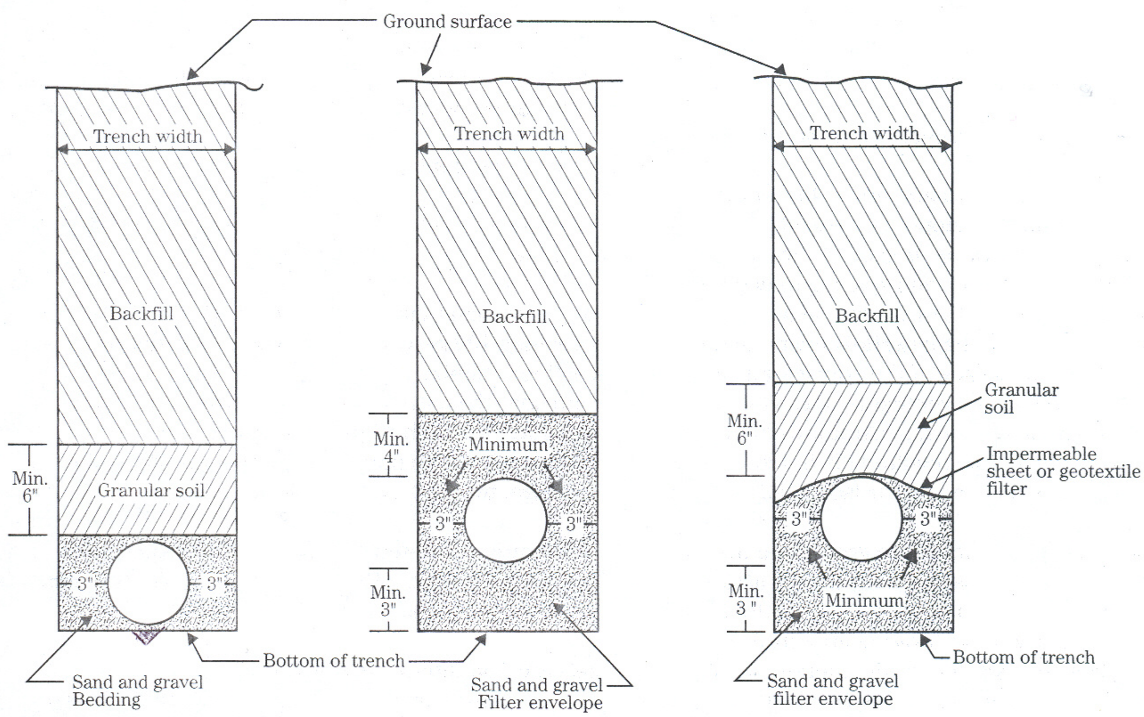


Figure 3-7 Typical junction box and silt trap

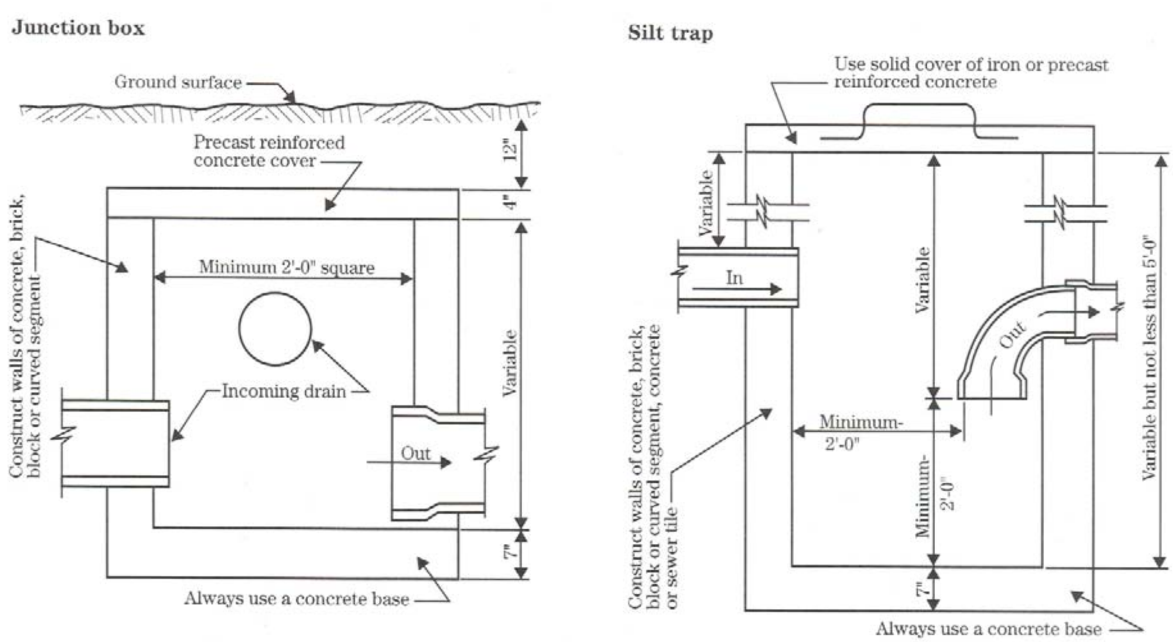


Figure 3-8 Blind surface inlet

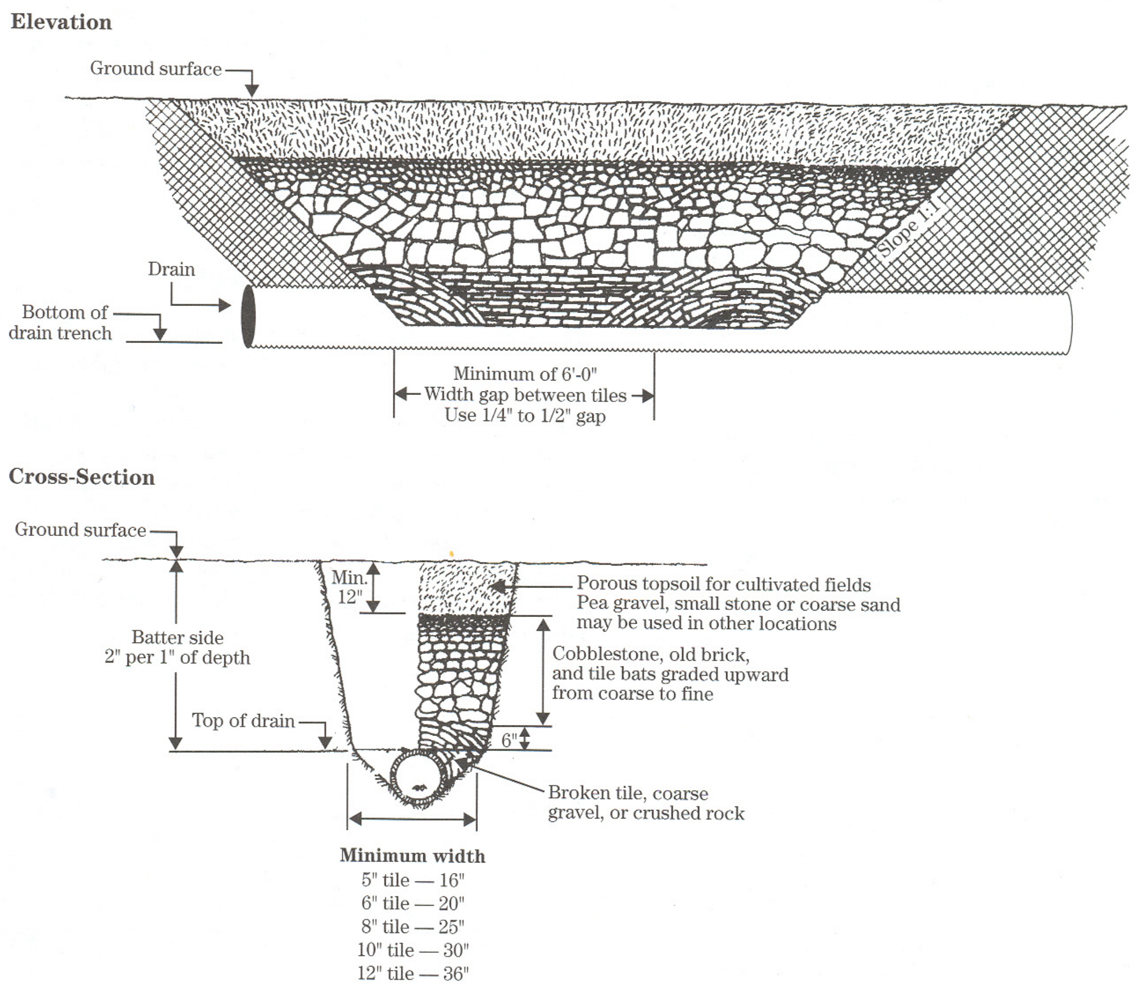


Figure 3-9 Vent or relief well

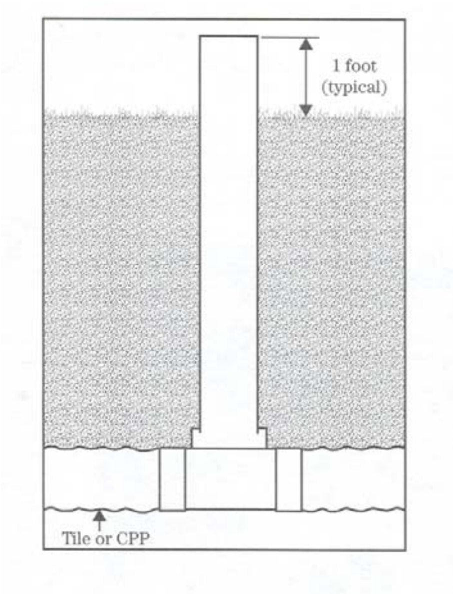


Figure 3-10 Typical animal guards

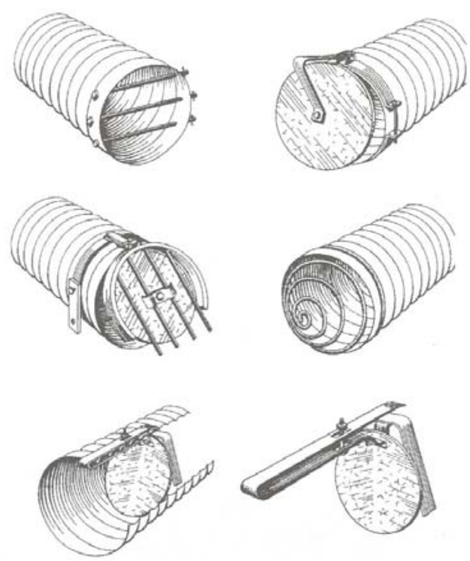


Figure 3-11 Drain crossings and outlets

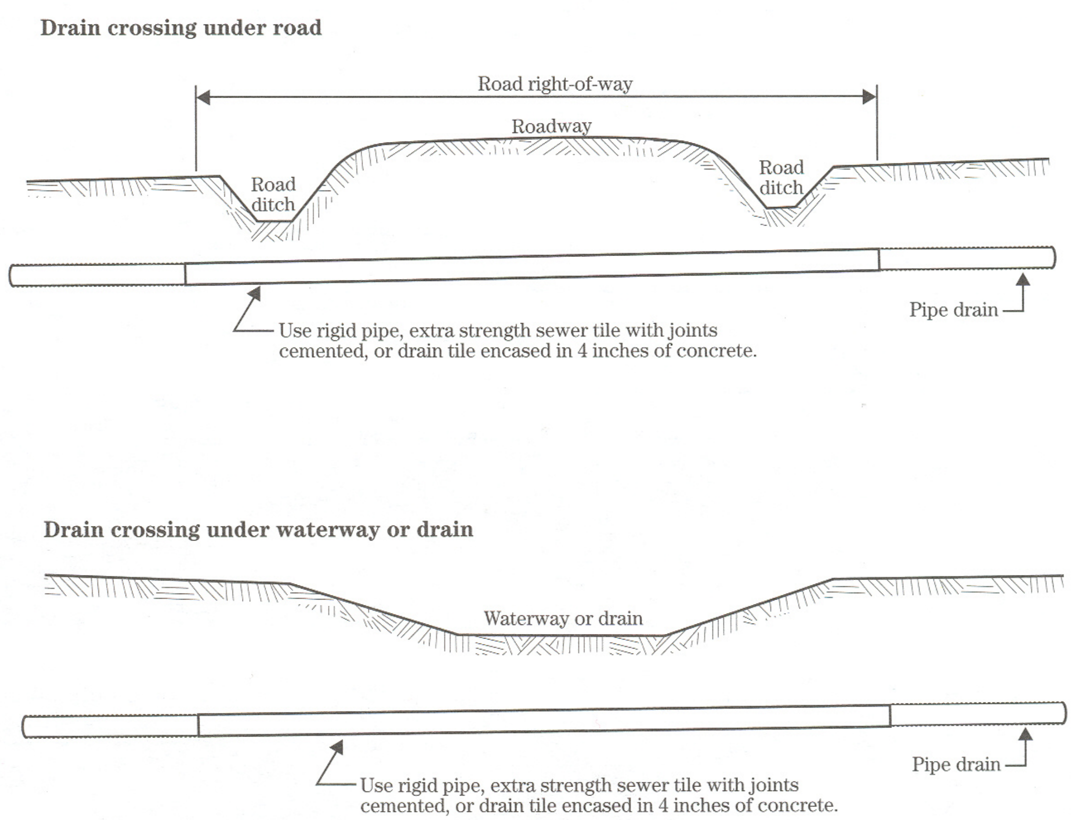
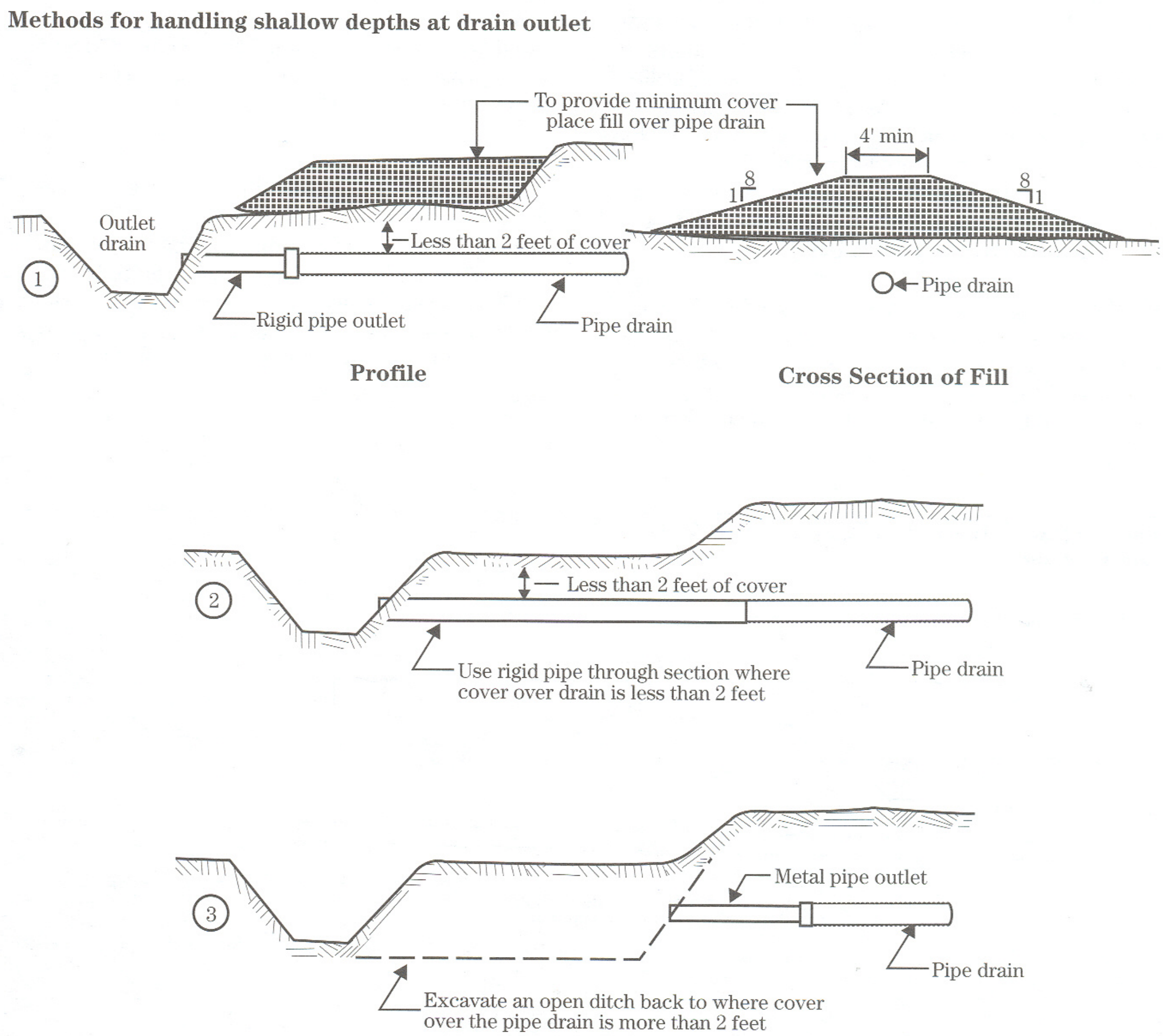


Figure 3-11 Drain crossings and outlets (continued)



Chapter 4 Interception Drainage

Contents

NJ650.1404 Interception Drainage

Interception drainage is used to intercept surface and subsurface water. The investigation, planning, and construction of surface interception drains follow the requirements and procedures given for surface drainage. Interception of subsurface water is discussed in part 624 (section 16) of the National Engineering Handbook.

a) Ground water movement

Ground water elevation and movement are needed for proper establishment of interceptor drains. Some of the more common conditions indicating the need for interception drainage are illustrated in figure 4–1, which is a sketch of a valley cross section extending beyond the ridge into the adjoining valley.

Most ground water for which drainage is required comes from recent rainfall that accumulates on the soil or within the upper part of the soil profile. After replenishing the soil to water-holding capacity, the excess water moves downward through the soil to the water table or builds up above restricting layers. Here it accumulates and moves laterally, often parallel with the land slope, toward an outlet. Its movement may reach the surface and return to the subsurface a number of times in its course to an outlet.

In a valley, barriers within 8 to 20 inches of the soil surface often cause a perched water table above the true water table. A true water table seldom is encountered until well down the valley side slopes or on the valley floor. For example, in figure 4–1, rainfall penetrating a permeable surface soil below the ridge at **A** may accumulate water over a less permeable subsoil during wet periods. Resistance to movement into the subsoil diverts most of the water over the less permeable layer to appear at the surface at location **B** as a wet weather seep. During the summer, such seep spots may completely dry out. Also, where soil is shallow over less permeable layers, a false water table close to the surface may accumulate sufficient water to pond at the surface in wet seasons and later completely disappear.

The same water movement also can develop seeps at point **C**. However, a larger collecting area and more complete interception by the impervious layer may accumulate sufficient water to produce a flowing spring, particularly if it is in a depression where the water converges and is confined in a small area. On the other hand, a rock ledge or compact layer may lie as a shelf with visible flow only at the depressions, even though this may be a small part of the total water coming to the surface along the same approximate contour.

Proceeding down into the valley trough, flow from adjoining watersheds can complicate the problem. Springs developed from these sources frequently have year-round discharge. When the flow is confined between impermeable layers, such as at **D**, it may build up a head of water a considerable distance above the point of issue. This can create an artesian supply that can discharge under pressure over an extended area. If the flow is not free but is covered by a mantle of moderately permeable to fine textured soil, artesian springs may saturate an extensive area at great depths by pressure and capillary action. Because of this, the location and treatment of these springs are difficult. Abrupt changes in grade of fine textured soils, shown in **E**, may slow water movement on the flatter slope enough to cause water accumulation and wetness at the surface.

On some sites, open observation wells or piezometers are necessary to locate the source and direction in which subsurface flow takes place.

b) Location of interceptor

In the planning and establishment of interceptor drains for both surface and subsurface water, the location of the outlet is of utmost importance. Insofar as possible, cross drains should be laid out to use the best natural outlet available. Because the interceptor may intercept other drainageways and add their discharge to the selected outlet, it is necessary to check the adequacy of the outlet to be used. Often, discharge can be spread over a well

Figure 4–1 Ground water movement

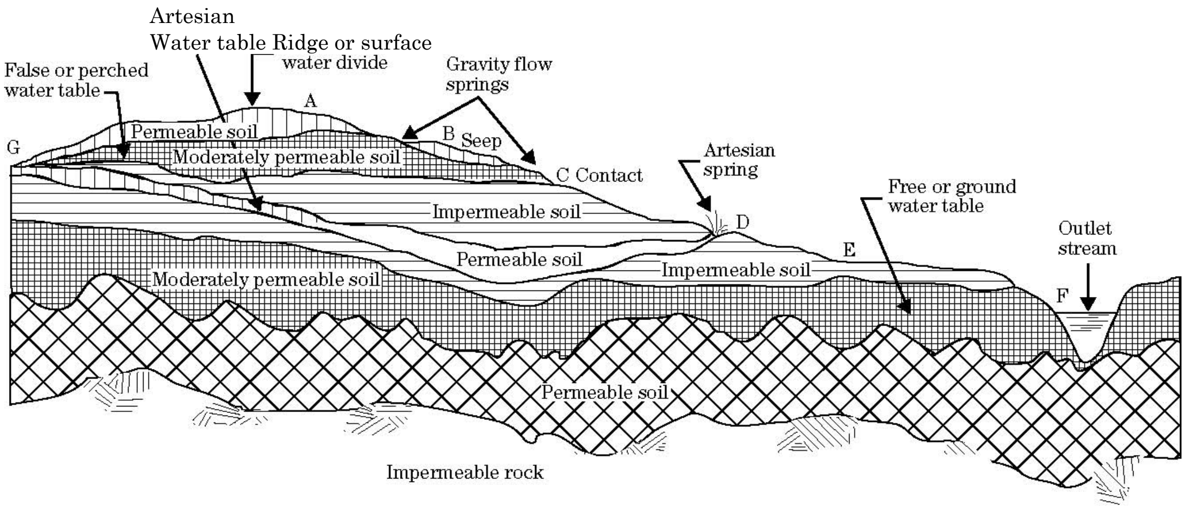
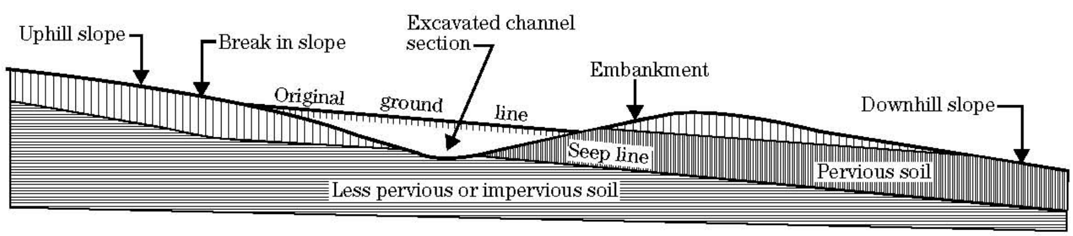
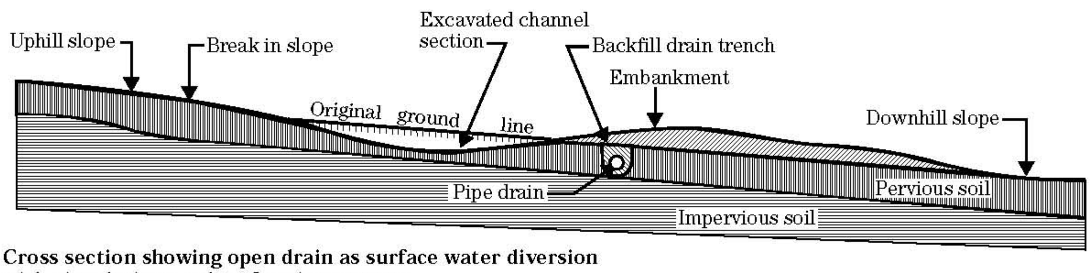


Figure 4-2 Typical interceptor installations

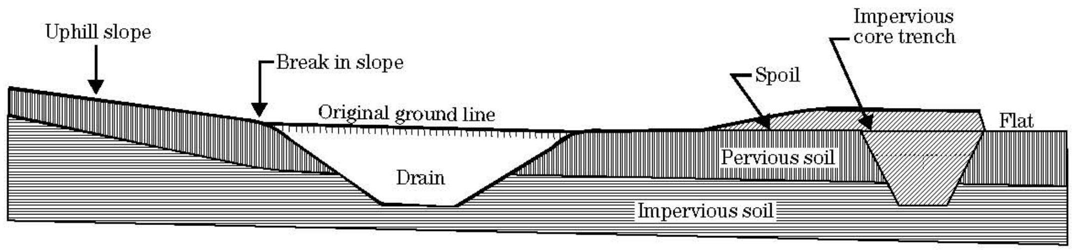


A. - **Cross section showing open drain as surface water diversion and interceptor of surface and subsurface water from sloping lands.**

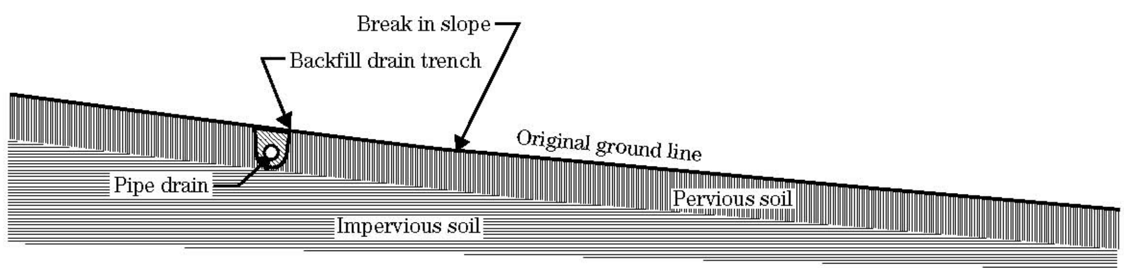


B. - **Cross section showing open drain as surface water diversion with pipe drain as subsurface interceptor.**

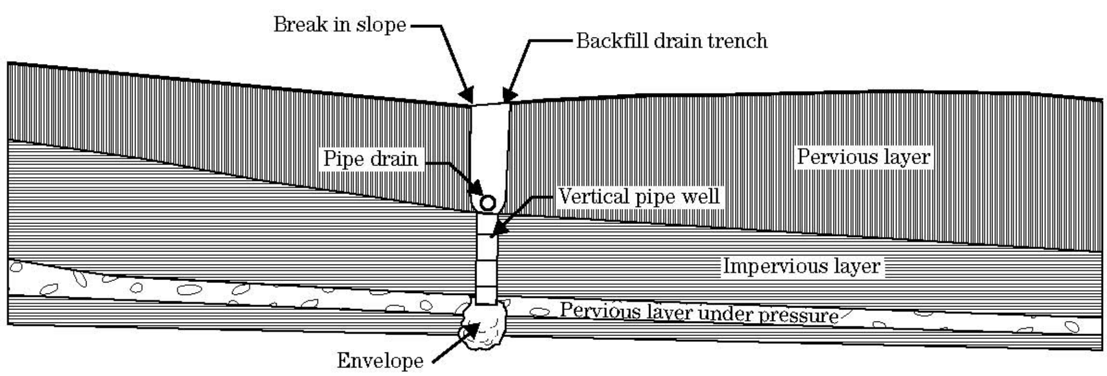
Figure 4-2 Typical interceptor installations (continued)



C. - **Cross section showing open drain as surface water diversion and subsurface water interceptor located at interface of sloping and flat lands.**



D. - Cross section showing drain as subsurface interceptor.



E. -Cross section showing relief well and interceptor drain.

Figure 4-3 Diversion system on moderate to steep slope

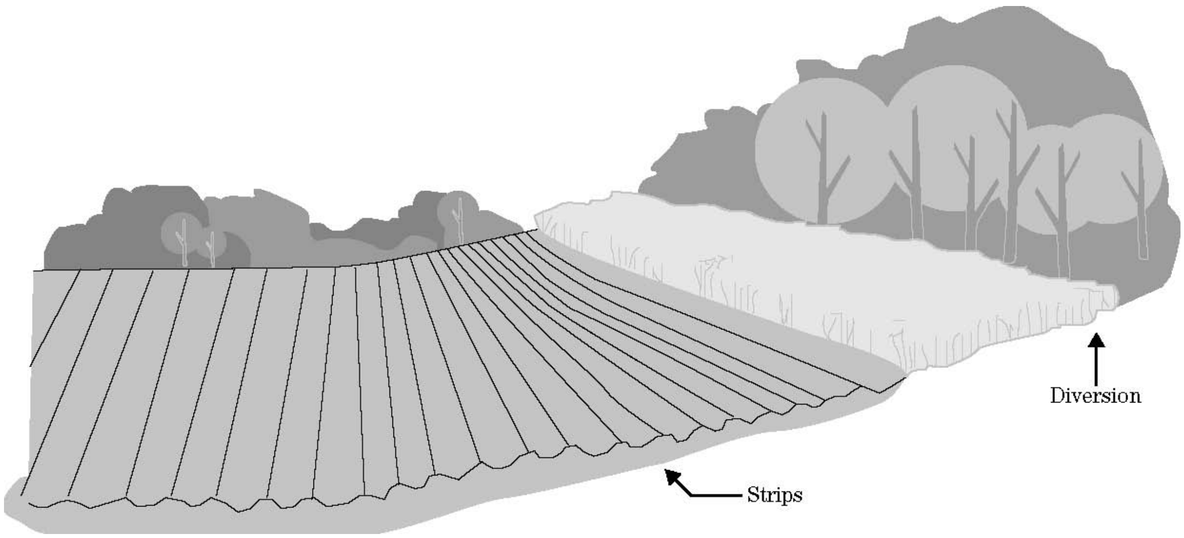
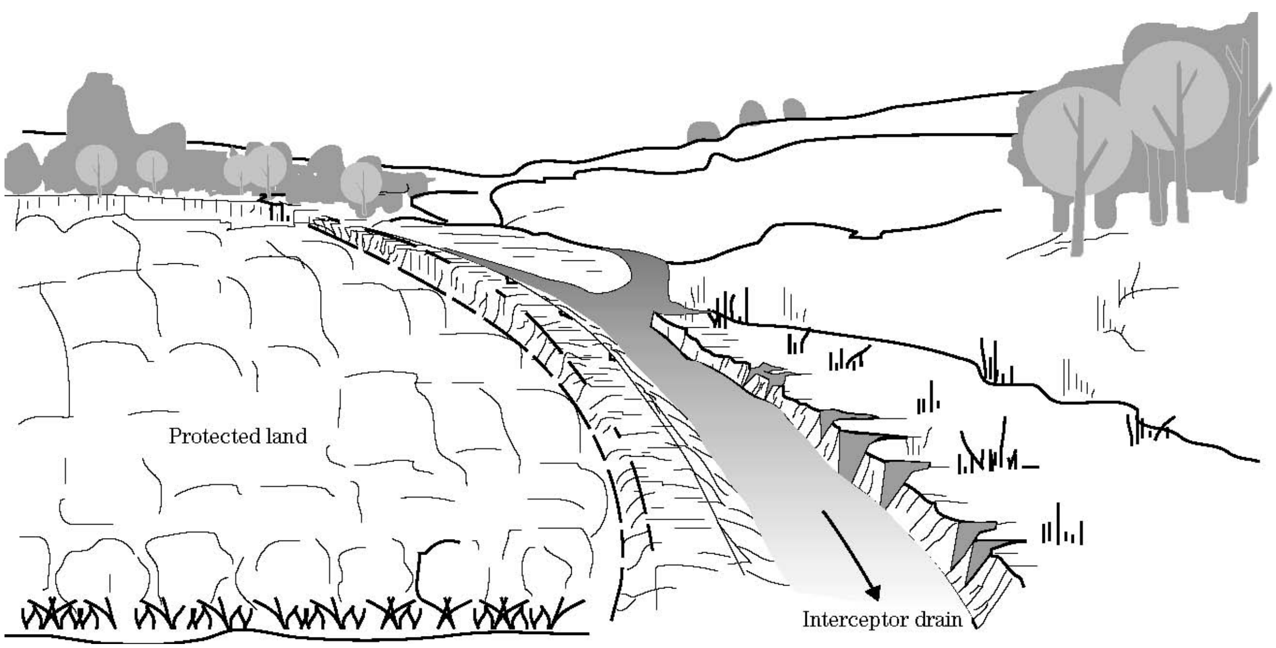


Figure 4-4 Interceptor drain on bottom land



sodded pasture, stony field, or into gently sloping woods.

If a satisfactory natural outlet is unavailable, special channels can be constructed. Vegetative outlets on slopes are preferred over masonry or similar channels because of their economy. They should be established well ahead of the interceptors so that the turf can safely handle the concentrated flow. If vegetative outlets must handle continuous flow, as supplied by springs, the center of the channel should be troughed to confine low flows.

If surface wetness is undesirable, subsurface drainage can be provided by a conduit placed along one side of the channel, well into the bank and away from possible surface wash. Subsurface drains should be vented at breaks in grade to reduce suction at the head of the slope and pressure at the base. In flats at the base of slopes, main or lateral ditches of trapezoidal or parabolic section can be used.

In planning and establishing an interceptor diversion, a few well placed lines at obvious seep planes and distinct changes in slope may be sufficient. In such cases, a detailed map may not be needed, and the line can be staked directly on the site. If subsurface interception must also be considered, the approximate location should be determined first from observations of surface conditions and preliminary borings.

After the line is staked, additional borings should be taken along and across the staked line and the alignment shifted until good interception is obtained. In irregular bowl-shaped areas, some changes in grade or shifting of the diversion lines upslope or downslope may be needed to obtain reasonably uniform farming strips, headlands, and access points for farming equipment.

If a uniform grade from one side to the other causes considerable divergence or location of the drain away from the approximate line of seepage and desirable pattern of farming strips, several parallel drains may be needed. If this is done, the least needed length of drain generally results from placing the shorter line at the higher elevation near the outlet. As an alternate, if an outlet is also available on the opposite side of the seep area, an alternate method is to break the grade along a single line so that the fall is in both directions. The most advantageous point of breaking grade may require several trials until grade and alignment provide the desired location, interception, and outlet points. Such sites often have so many irregularities and outlet location problems that a complete contour map may be needed as an aid to planning.

Interception drainage may be accomplished by open drains or subsurface pipe drains (figure 4–2). A channel used for controlling surface water (figure 4–3), commonly called a diversion, may be shallower than one required to intercept subsurface water movement. The open drain must have sufficient depth to intercept subsurface water movement. The drains are frequently V-shaped, with the bottom and top rounded by construction and cultivation so they nearly conform to parabolic sections.

Side slopes preferably should be 6:1 or flatter for ease of construction and farming. However, 4:1 or steeper side slopes may be necessary on land that has slopes of more than 12 percent.

Where a series of interceptor ditches is necessary to reduce the length of slope and contributing drainage area, spacing ordinarily should not exceed 200 feet for slowly permeable soils. More often, break in slope, location of spring or seep lines, and the necessary location of the top interceptor result in spacing of less than 200 feet. In more permeable soils, erosion control requirements may govern spacing.

If an interceptor open drain carries spring flow and elimination of continuous wetness in the open drain is desirable, a shallow diversion that has an auxiliary subsurface drain conduit can be used. The subsurface drain can be placed on either side of the surface drain; however, in most shallow soils, a location slightly downhill from the surface drain provides deeper interception and added cover from the embankment (figure 4-3).

The subsurface drain need not follow the course of the surface open drain throughout its length if topography warrants deviation.

An open drain that has a standard trapezoidal or parabolic cross section (figure 4–2C) can be used to intercept surface water at the base of a slope surrounding a depression or at the outer edge of a flood plain (figure 4–4). The depth of the open drain must be ample to provide:

- necessary subsurface interception,
- allowance for shrinkage where peat and muck are involved, and
- lateral movement of water if the drain is also used as an outlet for internal drainage of the protected area.

Spoil always should be placed on the downslope bank to permit free movement of upland water into the drain. It can also be used in diking to gain added channel capacity for overflow protection. If diking is not needed, spoil should be spread to blend into the surrounding landscape and to facilitate maintenance.

If drainage areas are small, subsurface drainage often can be used alone for interception of seeps and springs (figure 4–2D). The drainage lines are generally close to breaks in grades so that the drain has adequate cover and proper depth for intercepting the seepage. Added cover can be obtained on many sites by moving the lines slightly uphill above the break in slope where the impervious layer generally is at a greater depth. The bottom of the drain should be just within the impervious layer. If minimum cover is not available at this depth, the drain should be placed as far into the impervious layer as necessary to attain the needed cover. This may reduce the amount of flow into the pipe and its potential capacity, but deepening and widening the trench and installing 4 to 6 inches of envelope material around the pipe improve flow into the drain. In fine textured soils, permeable material should be used as backfill over the line to within plowed depth.

Isolated seeps at elevations above the drain can be tapped with stub relief drains to avoid additional long lines across the slope.

If pervious layers are considerably below normal drain depth or deep artesian flow is present, water under pressure may saturate an area well downslope. Vertical relief wells or pits can be installed at intervals along the cross drain down to an impervious layer or springhead, and the excess flow can rise through these vertical pipes and discharge into the cross drain (figure 4–2E). Open pits can be filled with bank run gravel or coarse sand, serving much as a French drain to permit water from deep-seated springs to rise into the cross drain. Construct by installing pipe and filling it with filter material; after which the pipe is withdrawn, leaving a vertical or chimney drain.

c) Use of surface or subsurface drains

Open drains can be used to lower or control the water table where subsurface drains are not feasible. They are used in shallow, hardpan soils where the depth of the soil does not permit satisfactory installation of subsurface drains. They are also used in deep soils in cultivated fields, either as temporary measures or permanent installations. Where the entrance of surface water can cause bank erosion, adequate devices, such as pipe inlets, should be considered.

Open drains may be used as temporary installations to intercept and monitor subsurface flow. Often an open drain is retained as a permanent installation if the flow is so great that a pipe drain installation would be too costly.

Drains must be deep enough to tap and provide an outlet for ground water that is in shallow, permeable strata or in water-bearing sand. The spacing of drains varies with soil permeability and drainage requirements. The capacity of the open drains generally is greater than required because of the required depth and the construction equipment used. Refer to Appendix II for spacing recommendations.

Advantages of using open drains:

- Nearly always have a smaller initial cost than subsurface drains.
- Are more easily inspected.
- Are applicable in many soils where subsurface drains are not recommended.
- Can be used on a very flat gradient where the permissible depth of the outlet is not adequate to permit the installation of

subsurface drains at the minimum required grade.
- Can be used in lieu of subsurface drains to avoid problems with iron ochre.
- Are generally more accessible by equipment for cleaning and maintenance purposes.

The disadvantages:
- Reduce the area of land available for farming, especially to unstable soils that require flat side slopes.
- Are more difficult and costly to maintain than subsurface drains.
- Limit access and interrupt farming patterns.
- Pose both social and environmental impacts.

d) Size of drains

Table 4–1 can be used to determine the required capacity of single random interception drains in some humid areas. If one line is insufficient, additional lines may be used.

Table 4–1 Interception drain inflow rates

Soil texture	Inflow rate per 1000 feet of line, cfs
Sand, gravel, muck (GP, GW, SP, SW, OH, OL, PT)	0.15 to 1.00
Sandy clay loam, sandy loam, loamy sand (SM, SC, GM, GC)	0.07 to 0.25
Silt loam, loam (CL, ML)	0.04 to 0.10
Clay, sandy clay, clay loam, silty clay loam (CL, CH, MH)	0.02 to 0.20

* Discharge of flowing springs or direct entry of surface flow through a surface inlet must be added. Such flow should be measured or estimated. Required inflow rates for interceptor drains on sloping land should be increased by 10 percent for 2 to 5 percent slopes, by 20 percent for 5 to 12 percent slopes, and by 30 percent for slopes over 12 percent.

e) Design and installation

Design considerations for grade and velocity, drain envelope, and appurtenances; and installation requirements for interceptor drains can be found in Chapter 3, Subsurface Drainage.

Chapter 5 Water Table Management

Contents

NJ650.1405 Water Table Management

a) General

This subchapter describes water table management, which includes controlled drainage and subirrigation. See chapter 10, NEH part 624 for additional details. Controlled drainage and subirrigation have many benefits. Controlled drainage, as the name implies, is a modification of a drainage system that restricts or allows for management of outflow. Subirrigation is typically an additional refinement of controlled drainage in which a water source is added to maintain a water table at the desired stage to provide capillary water for plant use. Refer to figure 5-1.

Water table management systems not only improve crop production and reduce erosion, but also protect water quality.

Most water table management systems include water-control structures that raise or lower the water table, as needed. Lowering the water table in a soil increases the infiltration of water by providing more room in the soil profile for water storage. The result is less surface runoff, less erosion, and less sedimentation of surface water.

Nitrates (mostly from nitrogen fertilizer) commonly move in solution with water and have been measured in subsurface drain flows. Some studies suggest that ground water can be denitrified and the nitrogen returned to the atmosphere as a gas if the water table is maintained close to the soil surface. This is especially true during the nongrowing, dormant periods. The use of water table management practices to reduce the loss of nitrates to public water is being studied for various soil, cropping, and climatic conditions. Management of the systems to accomplish denitrification is critical.

Interest in water table management systems has increased in the Atlantic Coastal Plain and other humid areas. The NRCS has helped landowners install water-control structures in open drains in for water quality protection and water conservation. The drainage water management facilities are closely monitored to avoid conflict with the objectives of protection and enhancement of wetlands and to guide management of the systems to achieve the intended purpose.

Controlled drainage

Controlled drainage is beneficial for water quality protection and water conservation. This form of water table management does not include adding an outside water source. Controlled drainage has been used historically in organic and muck soils, but is also applicable in mineral soils. Some drainage systems may remove water needed for crop production later in the season. Structures that retard drainage water losses can partly overcome this problem. The conserved water is used as needed during the growing season.

In organic and muck soils, oxidation is slowed when the soils are saturated. By raising the water table in the soil when crops are not being grown, the rate of subsidence can be reduced. Water control structures can be installed in surface drainage channels and in subsurface drain lines to allow management of the water table elevation in the adjacent fields.

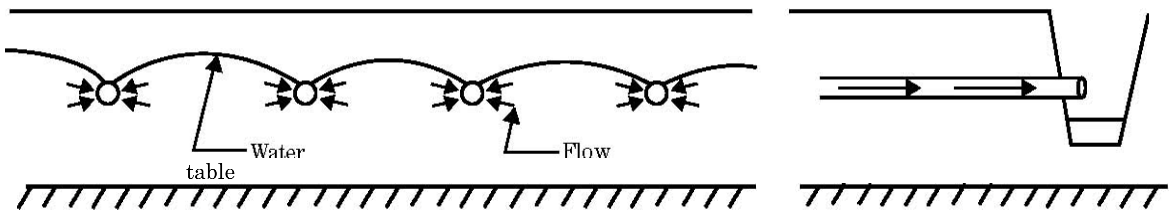
Structures for water control normally use spillways fitted with stoplogs or gates to control the water level. Control structures in conjunction with wells may be placed in the subsurface drain system. They generally are a type of manhole fitted with stoplogs or adjustable metal slides that control the flow of water in the subsurface drain system (fig. 5–2). Chapter 6 of the Engineering Field Handbook gives more information on using structures for water control.

Subirrigation

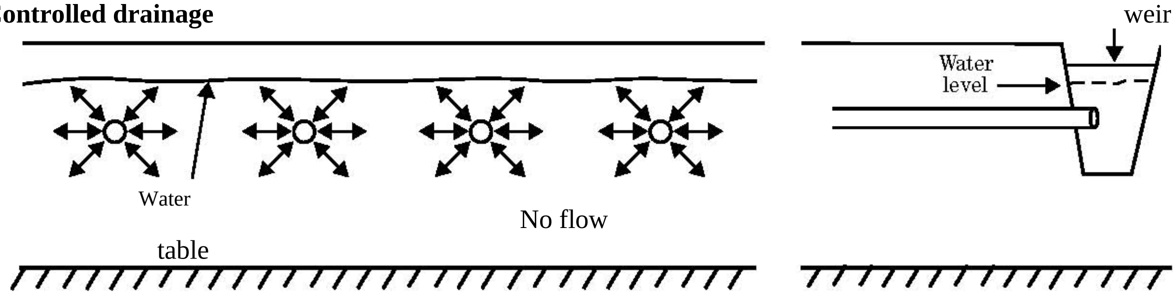
In subirrigation, the water table is artificially elevated by the input of irrigation water below the ground surface to a level where it is available to the crop roots. Although not a common practice in New Jersey, there are locations with suitable site conditions.

Figure 5-1 Water table management alternatives

(a) Subsurface drainage



(b) Controlled drainage



(c) Subirrigation

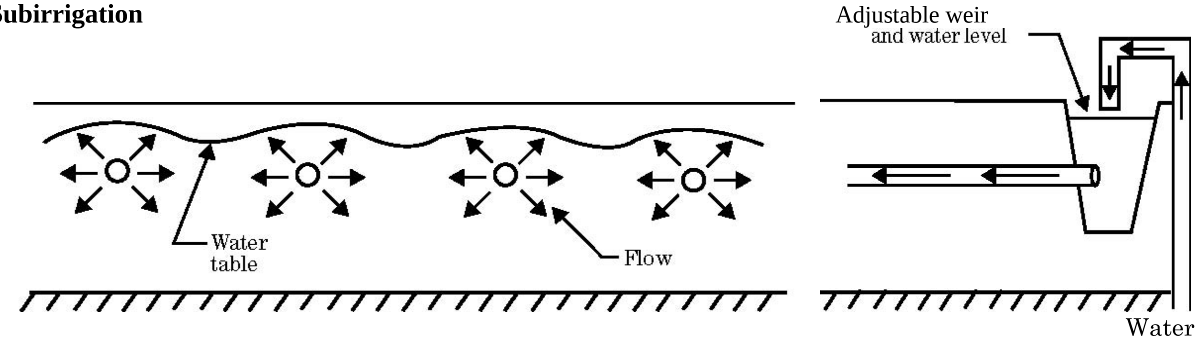
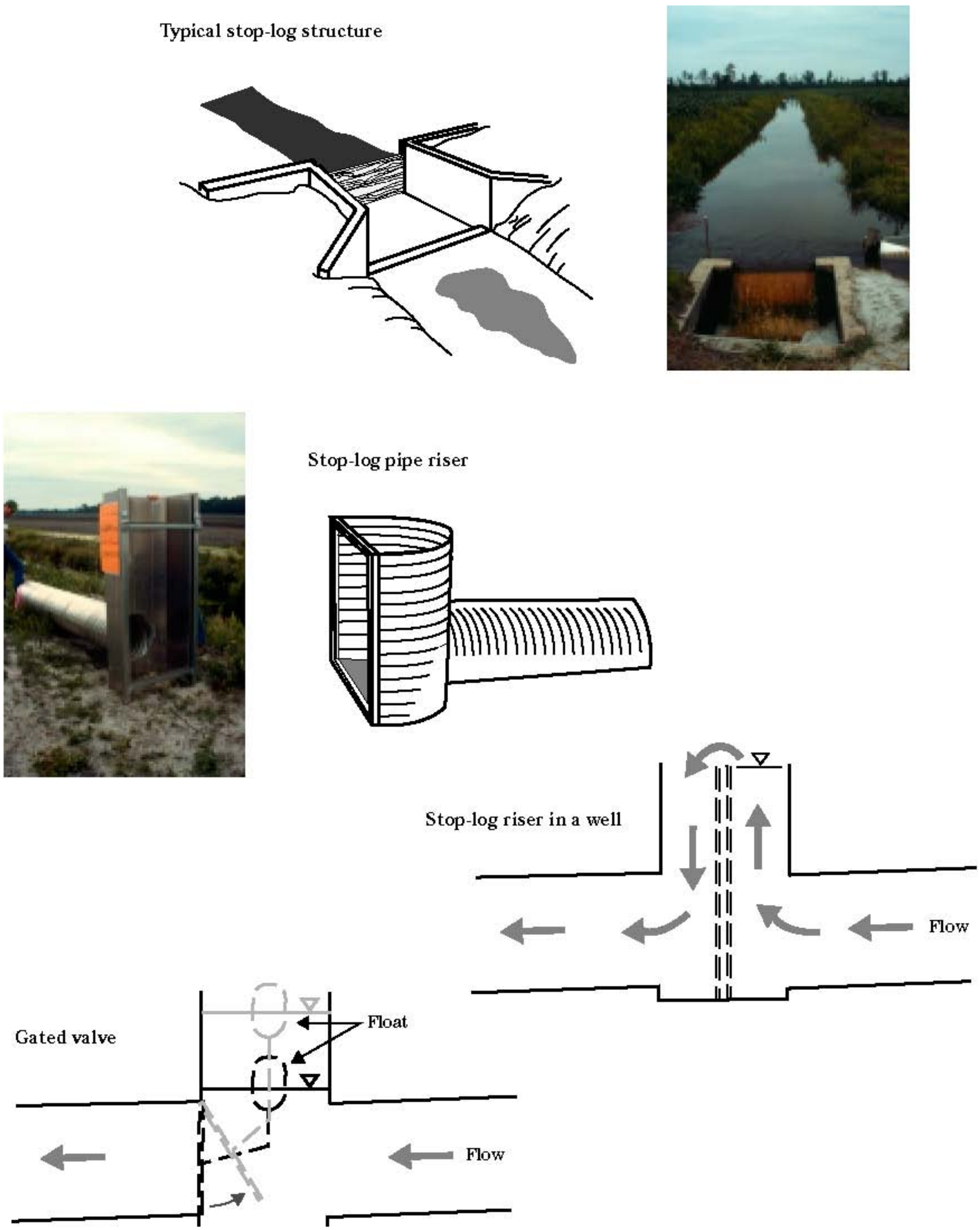


Figure 5-2 Water control structures



B) Water table management

Water table management (WTM) is the control of ground water level by regulating the flow of water in the drainage and subirrigation modes. It is accomplished by the use of structures that control the rate of flow or maintain a desired water surface elevation in natural or artificial channels. A source of water along with a pumping plant may be needed to satisfy the subirrigation objective. Figure 5-1 shows the effect of using these water management alternatives with a subsurface drainage system.

General requirements

For water table management to be successful, the following conditions generally must be met.

- The site has a relatively flat surface and the slope is no greater than 1 percent.
- The soils at the site have a moderate-to-high hydraulic conductivity.
- The soil has a natural high water table or a shallow, impermeable layer. Deep seepage losses should not be a problem where these conditions exist.
- The site has a satisfactory drainage outlet. This can be a pumped or natural gravity outlet.
- An adequate water supply is available.
- Saline or sodic soil conditions can be maintained at an acceptable level for efficient production of crops.
- Unacceptable degradation of offsite water will not result from operation of the system.
- Benefits of the proposed water table control will justify installation of the system.

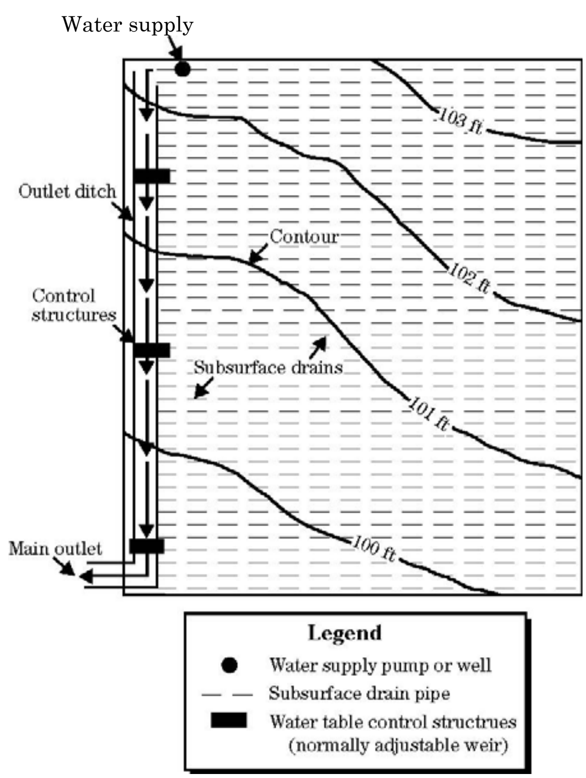
Planning considerations

The entire area impacted by the management of the WTM system must be evaluated. The control of the water table by an adjustable weir or gates may impact adjoining fields. Figure 5-2 shows typical water table management structures. A topographic survey of the field or fields is needed to plan the system, including avoiding an adverse impact on adjacent fields and drainage systems. Figure 5-3 depicts basic layout features of a WTM system.

The type of system that can be used must be determined. It should be consistent with the landowner's needs and management requirements. Planning considerations include:

- Type and layout of the surface and subsurface drainage system.
- Need for land smoothing or precision leveling.
- Alignment of system to best fit topography, spacing, and location of structures. Structures should be located to maintain the water table within an acceptable level below the root zone so that good drainage is provide when needed and water is furnished by capillary movement from the water table throughout the growing season.

Figure 5-3 Field layout of WTM system



The most critical factor is the feasibility of maintaining a water table, which is often dependent on the presence of a barrier. This is discussed later as well as hydraulic conductivity and determining spacing of subsurface drain laterals to provide for both drainage and subirrigation.

Water table location

The location of the natural seasonal high water table in the soil profile is critical. A seasonal high water table indicates that the soil can maintain the water table required for subirrigation during dry periods. If the seasonal high water table is more than 30 inches below the surface (with natural drainage), the soil is considered to be well drained, and a water table may be difficult to develop and maintain close enough to the root zone to supply the plant's water needs because of excessive seepage.

In most areas where water table control systems will be used, the natural seasonal water table has been altered by artificial drainage, and the depth of the drainage channels control the depth to the modified seasonal water table. Excessive lateral seepage can be a problem if the proposed system is surrounded by drainage channels that cannot be controlled or by fields that have excessively deep seasonal water tables. The depth to the seasonal water table during periods of a crop’s peak demand for water must be evaluated and potential seepage losses estimated.

Barrier

If water table management is successful, a barrier on which to build the artificial high water table during the growing season must occur at a reasonable depth. An impermeable layer or a permanent water table must be reasonably assured.

Hydraulic conductivity

Hydraulic conductivity is the most important soil property affecting the design of a water table management system. The final design must be based on actual field measured conductivity. A soil hydraulic conductivity of 0.75 inches per hour should be used as a benchmark for planning. If the flow rate is less than 0.75 inches per hour, the cost of installing the system may be the limiting factor. However, all costs should be evaluated before rejecting the site. If other system costs, especially that of water supply, are low, soils that have a hydraulic conductivity of less than 0.75 inches per hour may still be economical.

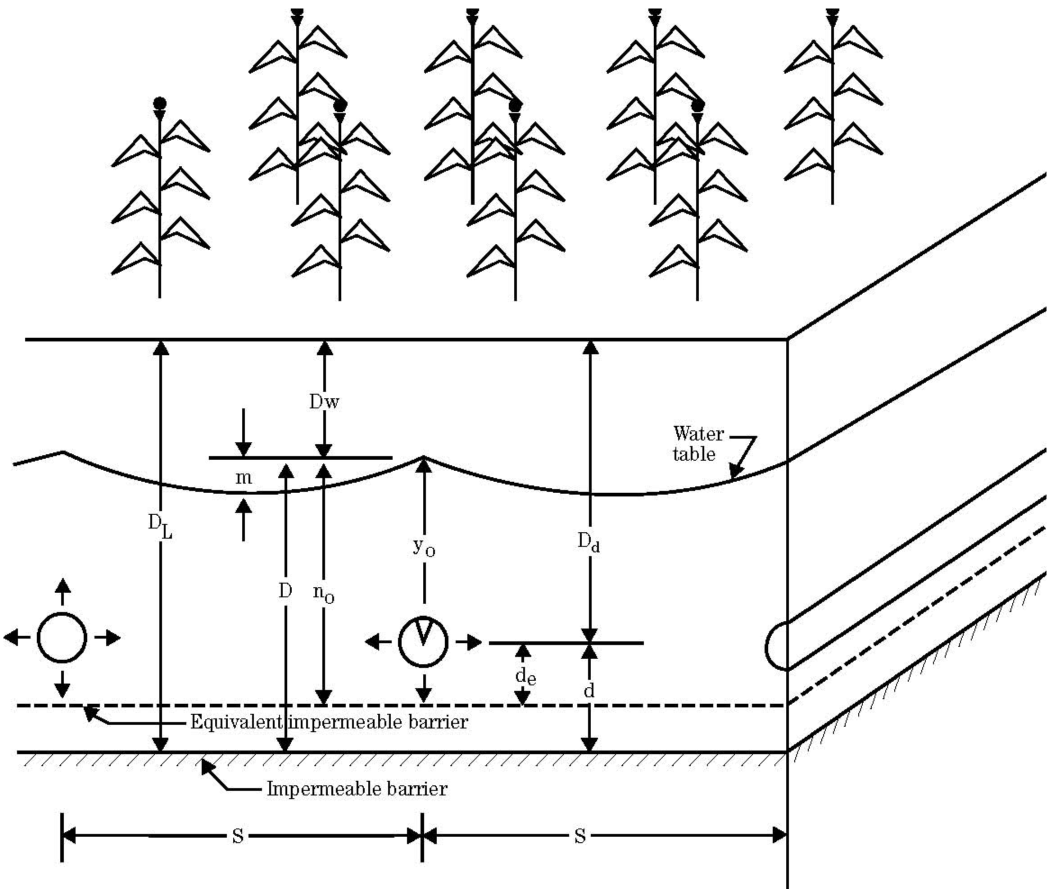
Engineering Field Handbook, Chapter 14, Appendix 14D provides detailed information on the auger-hole method of determining hydraulic conductivity.

Lateral spacing

If water is being added to the system, the water level over the drains must be maintained higher to create sufficient head to cause water to flow laterally outward from the drain. Figure 5-4 depicts the water table in the soil during subirrigation while water is being supplied to the laterals and at the same time is being withdrawn from the soil by evapotranspiration. It also details the notation to use in the design process and the terminology used to relate the position of the water table in relation to the ground surface, the laterals, and the barrier.

The spacing of subsurface drain laterals is less (placed closer together) for either controlled drainage or subirrigation than for drainage alone. This is basically because the restricted drainage effect of holding the water table above the drains causes the drains to be less efficient. Further the subirrigation mode of moving water horizontally to the midpoint between laterals requires less space than for drainage alone. For the numerous systems designed and installed, the average lateral spacing is about 70 percent of the recommended drainage spacing from local drainage guides. Because of the many variables, it is recommended that the DRAINMOD computer program be used for the spacing of laterals. For additional details refer to NEH Part 624, Chapter 10, Water Table Control.

Figure 5-4 Subirrigation lateral spacing and water table position



System operation

Operation of a water table management system can be automated. However, until experience has proven the timing and selected stages for the structure settings that give the desired results, frequent observations, manual structure setting, and pump operation should be used. To conserve water and minimize the amount of pumping necessary, the controlled drainage mode should be used to the greatest extent feasible. Monitoring wells in the field can provide for direct reading of water table levels that are correlated to stage settings of the control structures. As experience is gained, fewer well readings are needed to provide the information to operate the system. The water table should be maintained close enough to the root zone so that capillary upward flux provides all the water needed for evapotranspiration. If the water table is too far below the root zone, sufficient water may need to be provided at the source or moved through the soil profile rapidly enough to reestablish the desired water table level. Adequate drainage is needed at all crop stages.

Chapter 6 — Pump Drainage

Contents

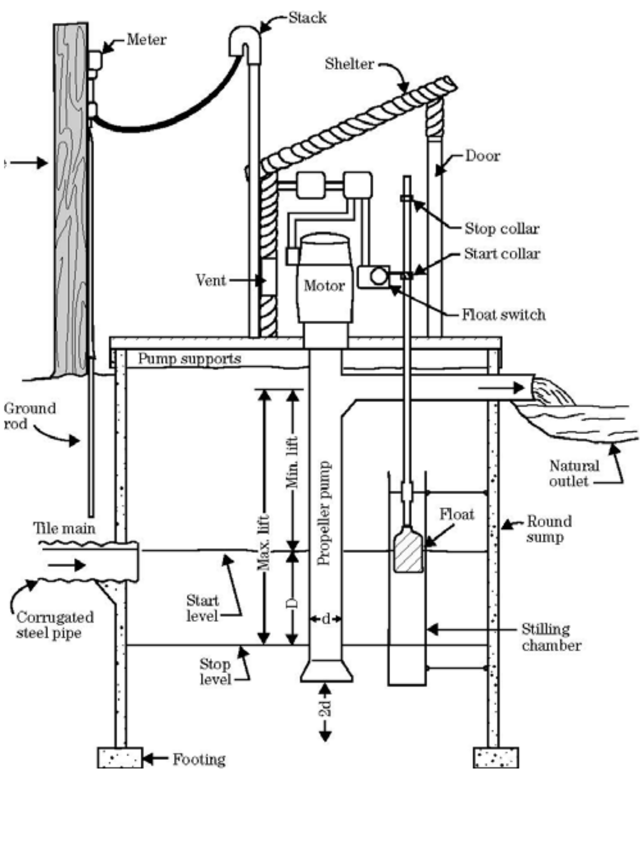
Figures

NJ650.1406 Pump Drainage

a) General

Drainage pumping plants remove excess surface or ground water where it is impossible or economically infeasible to obtain gravity outlets for drainage. They are also used on sites that have adequate outlets except during periods of prolonged high water. Figure 6-1 shows a typical installation of a pumping plant. A much more detailed description of drainage pumping is in NEH, Section 16, Drainage of Agricultural Lands.

Figure 6-1 Typical pumping plant



b) Surface drainage pumping conditions

Pumping for surface drainage may be feasible on the following landforms:

Bottom lands or flatlands protected from flooding by dikes, where gravity drainage is restricted because of periodic high stages in the outlet, or where the outlet has inadequate capacity. Floodgates are installed to permit the maximum gravity drainage possible while preventing the inflow of floodwater. The amount of pumping required can vary from a small percentage of the drainage flow to practically all of it.

Coastal plains that do not afford enough slope to the water surface for gravity drainage. Here, the land to be drained is diked, and pumping is done from a sump. The amount of the drainage water that must be pumped depends on the elevation of the land above tidewater. In some situations, the entire runoff must be pumped.

Areas in which the runoff water is to be used for irrigation. The area may or may not be diked, depending on the outlet situation for gravity drainage. Water control structures are necessary.

Areas in which the soil requires a high degree of water table control, such as in areas of organic soils. Pumping is sometimes required to lower water levels during wet periods and raise water levels during dry periods.

c) Subsurface drainage pumping conditions

Conditions under which pumping for subsurface drainage may be feasible:

- Where it is desired to add the drainage water to the irrigation water.
- Where the outlet is at an elevation that does not permit gravity flow from drains located at depths required for adequate drainage.
- Where the indicated method of drainage is to pump the water from an underlying aquifer, which may or may not be under artesian pressure.

d) Relation of pumping plant to drainage system

The pumping plant should be planned and designed as an integral part of the drainage system. The reconnaissance or preliminary survey determines the condition of the drainage outlet and whether pumping is required. A drainage system in which the pumping plant is designed into the system generally functions much more efficiently than one in which the pumping facilities are added after the system is installed because the outlet is inadequate.

Features that require coordination

The pumping plant must be designed to pump the amount of water necessary to give adequate drainage against the total head expected. In determining this, disposing of all the runoff possible by diversion around the area and providing for all possible gravity flow through floodgates should be considered.

The plant should be located where it best serves the intended purposes. Condition of the foundation, access for servicing, proximity to sources of power, and locations that might be susceptible to vandalism should be considered. Where significant sump storage is available, the pumping plant should be located to take maximum advantage of the storage provided. The location should permit safe discharge into the outlet with a minimum of construction outside the diked area.

If possible, the plant should be easily accessible. Ordinarily, the dike can be widened to accommodate vehicular traffic. An all-weather access road is desirable.
The requirements for a stable foundation often 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 often yields big dividends in reduced costs.

Sump storage

Careful consideration should be given to providing storage for runoff within the diked area. The effective storage is that capacity in sump areas and ditches between the lowest elevation at which drainage is by gravity, or the cutoff elevation for the pumps, and the elevation at which flooding of the land to be protected begins. This is determined largely by the topography of the project area and the type of drainage system. A sump for a subsurface drainage system may be only a circular well 8 feet or less in diameter that has 2 feet of effective storage.

A sizeable area near the surface drainage system outlet that is lower than the area to be drained can be used for storage without crop loss. Borrow pits of appreciable size for dike construction and drainage ditches that have sufficient storage capacity can also be used.

All of the storage capacity available should be used to reduce the required pumping capacity, considering the economics of the project. For high-value, highly developed cultivated land, the only storage capacity that may be available is that in open ditches. For watersheds used for low-value crops and that may contain appreciable areas of undeveloped land, a rather large area of low-lying land may be devoted to sump storage. This will result in a less expensive pumping plant. Where the area needs to be developed to more intensive use, the pumping capacity can be increased and some of the area otherwise devoted to sump storage can be developed.

The ditches supplying runoff to the pumps must be capable of delivering water at the maximum pumping rate. The highest roughness factor considered likely to occur should be used to determine the ditch size for this requirement.

Sumps designed to collect and store large volumes of water generally collect runoff as well as subsurface drainage discharge. These sumps can be used where a uniform rate of discharge is desirable in the drainage outlet or where the discharge is desirable only during specified times.

The following formula helps determine sump storage requirements for continuous pumping operations over a specified time period:

$$S = V\,[\,1 - I/P\,]$$

where:
V = Total volume of drain water to be stored over a specified time period
S = Sump storage (gallons)
I = Inflow rate (gallons per minute)
P = Pumping rate (gallons per minute)

The total time during which the pump will operate continuously is defined by:

$$T = V / 60P$$

where:
T = Pumping time (hr)

Example:
If a continuous flow of 600 gpm is desired and an inflow of 250 gpm occurs for 12 hours, then the storage volume needed in the sump will be:

$$S = 250 \times 12 \times 60 \times [\,1 - 250 / 600\,] = 104{,}994\ gal$$

To convert this to cubic feet, divide the 104,994 gallons by 7.48. S = 14,037 cubic feet.

The continuous flow of 600 gpm would occur for a time of:

$$t = \frac{250 \text{ x } 12 \text{ x } 60}{60 \text{ x } 600} = 5 \text{ hrs}$$

Thus sump and pumps can be selected for individual farm needs or desires.

Concrete sumps are most commonly used for subsurface drainage systems because they are easily equipped with automatic controls and require little space and minimum maintenance.

The sump capacity is based upon the inflow and pumping rate so that the pump cycle is sufficient to allow the pump to operate with an acceptable overall efficiency. A sump should be designed to allow about 10 cycles per hour in the pump system. If it exceeds 15 cycles per hour, pump efficiency and power costs may be undesirable.

The inflow rate, pumping rate, storage capacity, and cycle time for drainage outlets can be determined using the following formula.

$$[\,60 / N\,] = [\,S / I\,] + S / [\,P - \mathrm{I}\,]$$

P = Pumping rate (gpm)
I = Inflow rate (gpm)
S = Storage volume (gal) between the on and off stage of the sump
N = Number of complete cycles per hour where the length of the complete cycle equals the standing time plus the running time

The following formula can be used to rearrange and convert storage from gallons to cubic feet:

$$N = \frac{7.48 \text{ x } I \text{ x } [\,P - I\,]}{P} \text{ x } S$$

This formula can also be used to compute the frequency of cycling for given values of S and P and for various rates of inflow.

Sufficient storage capacity needs to be provided in the sump or collection ditch to avoid excessive cycling of the pump in a system using automatic pump controls. Starting an idle pump requires extra energy and also increases maintenance. A reduction in the sump storage capacity can be attained by increasing the cycling frequency of the pump, but the savings may be offset by the increase in operational costs. Similarly, the selection of a pump having a capacity greatly in excess of that required for a given sump should be avoided. This creates a problem with the movement of water being held in more distant storage areas. Often this water is not moved fast enough to maintain continuous pump operation. The maximum S occurs when $I = (1/2)P$. For design purposes the amount of storage required in cubic feet is determined by the following equation:

$$S = [2P] / N$$

where:
N = the maximum or permissible number of cycles per hour
S = the storage in cubic feet

The sump depth between the on and off positions of the pump control and the cross-sectional area of the sump are chosen so that their product is equal to or greater than S. Generally, the S value is used as a minimum sump requirement.

If the number of cycles per hour is set at 5, the last formula may be further simplified as

$$S = 04P$$

The pumping rate P should be equal to or greater than the peak discharge rate from the drain system. For sump depth of more than 15 feet between on and off positions, consideration should be given to a horizontal type sump, which may be more economical

e) Economic justification of pumping plant

Frequently, a decision must be made as to whether areas protected against flooding by dikes and floodgates should be provided with a pumping plant to remove interior drainage during periods when the floodgates are closed. Such a decision cannot be made without a frequency study of precipitation and flood stage records, a determination of the project area that will be flooded without a pumping plant, and an estimate of the resulting damages. The study required for the justification of a pumping plant should be based on a comparison of its cost against the damages expected without it.

f) Pumping from subsurface aquifers

In drainage systems that require pumping from an underlying aquifer, location of the wells and pumps must be based on an extensive subsurface investigation. This investigation must determine the practicability of lowering the water table by pumping the aquifer and also determine the most suitable location for the wells to accomplish the objectives. The drainage water may be discharged either into an irrigation system or through shallow surface ditches to a drainage outlet. In either case, location of the well would be based primarily on requirements for pumping the aquifer instead of conditions for discharge of the effluent.

g) Basic information required for plant design

The amount of data required varies according to specific arrangements. As a general rule, data on the following items are needed:

Location of plant—detailed topography and data on foundation investigations may or may not be provided.

Pump capacity—design removal rate less available storage. The pump capacity can be determined from the drainage coefficient applied to the area served, or by direct hydrologic analysis. The capacity selected should be able to pump the amount of water necessary to provide adequate drainage against the total head anticipated.

Pumping plant capacity for a surface drainage system is usually determined on a daily-rate basis, so that the required capacity can be determined as the runoff from a 24-hour rainfall of a selected frequency of occurrence, plus base flow, less allowances for available surface and groundwater storage.

Pumping plants designed to pump only subsurface water should have a pump capacity equal to the maximum drainage system discharge, plus a 20 percent safety factor.

Pumping plants for both surface and subsurface water should have the capacity to remove from one-half inch to one inch of water in a 24-hour period from the drainage area, for areas of 100 acres or less. For high value crops, the pump capacity should be increased to one and a half to two inches of water per 24 hours.

Maximum, minimum, and average static heads—
based on stage-frequency analysis of the outlet.

The maximum static head is the elevation of the maximum stage in the outlet minus the optimum elevation in the suction bay. Efficiency at this head may be lower than that required at the average head.

The minimum static head is the difference between the mean monthly minimum stage in the outlet and the optimum stage in the suction bay. Where multiple pumping units are required, at least one unit should have a high efficiency at this head.

The average static head is the difference between the average monthly stage in the outlet and the optimum stage in the suction bay, weighted according to the amounts of runoff to be expected for the respective months. The plant should operate at peak efficiency for this stage.

Type, number, and size of pumps—For low heads of up to 15 to 20 feet, the axial flow pump is recommended. For heads of up to 40 to 50 feet, the mixed flow pump is recommended. For large installations, at least two pumps should be recommended with the relative size based on operational requirements. For average conditions, one of the two pumps should have about twice the capacity of the other. A 3-unit plant gives good flexibility of operation. Sizes recommended should be based on holding velocities in the discharge pipe at 8 to 10 feet per second for the design capacity.

Recommended start and stop elevation for each unit.

Schematic layout of the proposed plant-should include suggestions for layout and appurtenant facilities. Such items as the installation of discharge pipes over dikes, trash racks, siphon breakers, equipment for automatic control of operation, and access roads should be indicated.

Pumping plants that pump surface water should be provided with trash racks to screen out trash and debris. Strainers or screens mounted on the pump intake should be avoided as these tend to clog and are difficult to clean. The trash rack should be located across the entrance of the sump and inclined toward the structure in such a manner that flows move evenly through the rack, so floating trash and debris tend to move upward toward the water surface where it can be easily removed with rakes. Bar screens should be used in which the total clear space between bars is in the range of one to three inches. The total clear flow area of the rack should be sufficient to keep flow velocity through the rack under two feet per second.

<u>h) Maintenance</u>

Pumping plants have an estimated service life of 15 years. This can be achieved and prolonged through proper maintenance. Standardized operation and maintenance plans have been developed for pumping plants and can be found in the NRCS New Jersey electronic Field Office Technical Guide.

Glossary

NJ650.14 Glossary

The glossary defines some of the specific terms used in this chapter. The listing is not intended to be complete, but should assist in providing a quick reference to many terms that may not be commonly understood.

Aquifer A geologic formation that holds and yields useable amounts of water. Aquifers can be classified as confined or unconfined.

Artesian aquifer Aquifer that contains water under pressure as a result of hydrostatic head. For artesian conditions to exist, an aquifer must be overlain by a confining material of aquiclude and receive a supply of water. The free water surface stands at a higher elevation than the top confining layer.

Bedding (1) A surface drainage method accomplished by plowing land to form a series of low narrow ridges separated by parallel dead furrows. The ridges are oriented in the direction of the greatest land slope (crowning or ridging). (2)Preparation of furrow-irrigated rowcropped field with wide, flattened ridges between furrows on which one or more crop rows are planted. (3) The process of laying a pipe or other conduit in a trench with the bottom shaped to the contour of the conduit or tamping earth around the conduit to form its bed. The manner of bedding may be specified to conform to the earth load and conduit strength. (4) Material placed under a pipe or other conduit for mechanical support.

Blind drain Type of drain consisting of an excavated trench, refilled with pervious materials (coarse sand, gravel, or crushed stones) through whose voids water percolates and flows toward an outlet (also called a trench drain).

Blind inlet Surface water inlet in which water enters by percolation rather than through open flow conduits.

Blinding Material placed on top of and around a drain tile or conduit to improve the flow of water to the drain and to prevent displacement during backfilling of the trench

Capillary fringe A zone in the soil just above the water table that remains saturated or almost saturated the extent of which depends on the size-distribution of pores.

Confined aquifer An aquifer whose upper, and perhaps lower, boundary is defined by a layer of natural material that does not readily transmit water

Controlled drainage Regulation of the water table by means of control dams, check drains, or a combination of these, for maintaining the water table at a desired depth.

Deep percolation Water that moves downward through the soil profile below the root zone and is unavailable for use by vegetation.

Diversion A channel with supporting berm constructed across a slope, generally uphill of the area to be protected, to intercept surface runoff and divert it to a safe or convenient discharge point.

Drain Any closed conduit (perforated tubing or tile) or open channel used for removal of surplus ground or surface water.

Drainage Process of removing surface or subsurface water from a soil or area.

Drainage coefficient Rate at which water is to be removed from a drainage area, expressed as depth per day or flow rate per unit of area.

Drainage curves Flow rate versus drainage area curves giving prescribed rates of runoff for different levels of crop protection.

Drainage pumping plant Pumps, power units, and appurtenances for lifting drainage water from a collection basin to an outlet

Drainage system Collection of surface or subsurface drains, or both, together with structures and pumps, used to remove surface or ground water

Drop structure Hydraulic structure for safely transferring water in a channel to a lower elevation without causing erosion.

Envelope, Drain Generic name for materials placed on or around a drainage conduit, irrespective of whether used for structural support, improvement in flow, or to stabilize surrounding soil material.

Envelope, Hydraulic Permeable material placed around a drainage conduit to improve flow conditions in the area immediately adjacent to the drain.

Envelope, Filter Permeable material placed around a drainage conduit to enhance water entry and to stabilize the structure of the surrounding soil material.

Field ditch A shallow channel, usually constructed with relatively flat side slopes, that collects surface water within a field.

Geotextile A woven or non-woven fabric of synthetic polymer fibers used to enhance soil properties or to improve structural performance.

Grade stabilization structure Hydraulic structure used to control the grade and head cutting in natural or artificial channels.

Ground water Water occurring in the zone of saturation in an aquifer or soil.

Hardpan (soil) A hardened soil layer, in the lower A or B horizon, caused by cementation of soil particles.

Hydraulic conductivity The ability of a porous medium to transmit a specific fluid under a unit hydraulic gradient; a function of both the characteristics of the medium and the properties of the fluid being transmitted (usually a laboratory measurement corrected to a standard temperature and expressed in units of length/time).

Hydraulic gradient Change in the hydraulic head per unit distance (water surface slope in an open channel).

Impermeable barrier layer A soil stratum with a permeability less than ten percent of the soil permeability between the layer and the ground surface.

Infiltration The downward entry of water through the soil surface into the soil.

Infiltration rate The quantity of water that enters the soil surface in a specified time interval (often expressed in volume of water per unit of soil surface area per unit of time).

Interceptor drain A channel or perforated conduit located across the flow of ground water; and sometimes surface water, to collect flow before reaching an area to be protected.

Iron ochre A reddish or yellowish brown gelatinous deposit formed by iron fixing bacteria

Land smoothing Shaping the land to remove irregular, uneven, mounded, broken, or jagged surfaces without the need for detailed survey information.

Land grading The operation of shaping the land surface to predetermined elevations for improved surface drainage or erosion control (also known as precision land forming).

Lateral Secondary or side channel, ditch, or conduit that conveys flow to a mainline.

Perched water table A localized condition of saturated soil held in a pervious soil stratum because of an underlying impervious layer that prevents percolation to a deeper aquifer.

Percolation rate The rate at which water moves through a porous media, such as soil.

Permeability (qualitative) The ease at which gases ,liquids, or plant roots penetrate or pass through a layer of soil or porous media.; (quantitative) The specific soil property designating the rate at which gases and liquids can flow through the soil or porous media.

Permittivity A measure of the ability of a geotextile to permit water flow perpendicular to its plane. (The volumetric flow rate of water per unit cross-sectional area per unit head.)

Quick condition Condition in which water flows through the soil material (upward or horizontally) with sufficient velocity to significantly reduce the bearing capacity of the material through a decrease in intergranular pressure.

Recharge Process by which water is added to the zone of saturation to replenish an aquifer.

Relief drainage system A system of subsurface drain lines, installed within an area having a high water table, to lower the water table or maintain it at a given level.

Root zone Depth of soil that roots readily penetrate and in which the predominant root activity occurs.

Seepage The movement of water into and through the soil from unlined canals. ditches, or water control facilities

Steady flow Open channel flow in which the rate and cross-sectional area remain constant with time at a given station.

Subirrigation Application of irrigation water below the ground surface by raising the water table to within or near the root zone.

Subsoiling Tillage operation to loosen the soil below the tillage zone without inversion and with a minimum of mixing within the tilled zone.

Subsurface drain Subsurface conduits used primarily to remove subsurface water from soil. Classifications of subsurface drains include pipe drains, tile drains, and blind drains.

Surface drainage 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 the land surface to such channels.

Surface inlet Structure for diverting surface water into an open ditch, subsurface drain, or pipeline.

Unconfined aquifer An aquifer whose upper boundary consists of relatively porous natural material that transmits water readily and does not confine water. The water level in the aqifer is the water table.

Vent An appurtenance to a pipeline that permits the passage of air to or from the pipeline.

Water table The upper limit of a free water surface in a saturated soil or underlying material.

Water table management The control of ground water levels by regulating the flow of water with a controlled drainage or subirrigation system.

References

NJ650.14 References

The New Jersey Water Management Guide is an update of the 1987 New Jersey Drainage Guide. Much of the text was adapted from National Engineering Handbook, Part 650, Engineering Field Handbook, Chapter 14. References cited below are the primary sources used for update of the NJ Water Management Guide. For the complete list of sources, refer to EFH Chapter 14.

United States Department of Agriculture, Soil Conservation Service, New Jersey Drainage Guide, July 1987.

United States Department of Agriculture, Natural Resources Conservation Service, National Engineering Handbook, Part 650, Engineering Field Handbook, Chapter 14, Water Management (Drainage).

United States Department of Agriculture, Natural Resources Conservation Service, National Engineering Handbook, Part 650, Engineering Field Handbook, Chapter 13, Wetland Restoration, Enhancement, or Creation.

United States Department of Agriculture, Natural Resources Conservation Service, National Engineering Handbook, Part 624 (Section 16), Drainage.

Appendix A

Drainage Runoff Curves

ACRES DRAINED PER QUANTITY OF FLOW

Quantity cfs	Acres A	Acres B	Acres C	Acres D	Quantity cfs	Acres A	Acres B	Acres C	Acres D
1	3	7	12	18	41	136	254	593	1182
2	6	13	21	31	42	140	260	621	1220
3	10	19	30	44	43	143	267	649	1260
4	13	25	39	57	44	147	274	677	1300
5	16	31	48	70	45	150	281	705	1340
6	20	37	57	85	46	154	288	733	1380
7	23	43	66	100	47	157	295	761	1420
8	26	50	75	126	48	161	302	789	1460
9	30	55	84	132	49	164	309	817	1500
10	33	60	93	148	50	168	316	845	1540
11	36	66	102	164	52	175	331	900	1610
12	40	73	111	180	54	182	347	955	1680
13	43	79	120	208	56	190	362	1010	1750
14	46	85	130	226	58	197	378	1065	1820
15	50	91	141	245	60	204	393	1130	1890
16	53	97	152	269	62	211	413	1176	1960
17	56	103	163	293	64	218	433	1232	2030
18	60	109	175	317	66	225	453	1288	2100
19	63	115	187	341	68	232	473	1337	2170
20	66	120	198	365	70	239	492	1386	2240
21	70	127	209	401	72	246	519	1435	2317
22	73	131	223	437	74	253	545	1484	2394
23	76	139	237	474	76	260	571	1533	2471
24	80	145	251	510	78	267	598	1581	2548
25	83	150	265	550	80	274	625	1630	2624
26	86	156	279	590	82	281	659	1679	2701
27	90	162	283	630	84	288	693	1728	2778
28	93	169	307	670	86	295	727	1780	2854
29	97	175	321	710	88	302	761	1831	2931
30	100	182	335	750	90	310	795	1883	3008
31	103	188	356	790	92	318	830	1934	3085
32	107	195	377	830	94	326	864	1986	3162
33	110	201	398	870	96	334	899	2037	3238
34	113	208	419	910	98	342	933	2089	3315
35	117	214	440	949	100	350	968	2140	3392
36	120	220	465	988	105	373	1052	2269	3597
37	123	227	490	1026	110	397	1137	2398	3802
38	127	234	515	1065	115	420	1223	2526	4006
39	129	240	540	1104	120	443	1307	2655	4211
40	133	247	565	1143	125	467	1390	2784	4416

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	RTSC-NE-ENG.
DRAINAGE RUNOFF CURVES NORTHERN HUMID AREAS	SOIL CONSERVATION SERVICE ENGINEERING & WATERSHED PLANNING UNIT UPPER DARBY, PENNSYLVANIA	1410 SHEET 1 OF 2

ACRES DRAINED PER QUANTITY OF FLOW

Quantity cfs	Acres A	Acres B	Acres C	Acres D
130	490	1473	2918	4621
135	518	1556	3053	4826
140	546	1639	3187	5030
145	573	1722	3322	5235
150	601	1805	3456	5440
155	629	1888	3592	5664
160	657	1980	3738	5888
165	701	2072	3878	6112
170	745	2165	4019	6336
175	788	2258	4160	6560
180	832	2350	4310	6784
185	875	2442	4442	7008
190	917	2535	4523	7232
195	960	2628	4724	7456
200	1004	2720	4864	7680
205	1048	2826	5019	7904
210	1092	2931	5172	8128
215	1136	3037	5326	8352
220	1180	3142	5479	8576
225	1224	3248	5633	8800
230	1268	3354	5787	9024
235	1312	3459	5940	9248
240	1364	3565	6094	9472
245	1416	3670	6247	9690
250	1468	3776	6400	9920
255	1520	3884	6560	10160
260	1572	3994	6720	10400
265	1624	4102	6880	10640
270	1676	4211	7040	10880
275	1728	4320	7200	11120
280	1786	4429	7360	11360
285	1844	4540	7520	11600
290	1903	4646	7680	11840
295	1961	4755	7840	12080
300	2019	4864	8000	12320
305	2077	4992	8160	12576
310	2135	5120	8320	12832
315	2193	5248	8480	13088
320	2252	5376	8640	13340
325	2310	5504	8800	13600
330	2368	5632	8960	13856
335	2432	5760	9120	14112
340	2496	5888	9280	14368
345	2560	6016	9440	14624
350	2624	6144	9600	14880
355	2688	6266	9766	15152
360	2752	6387	9933	15424
365	2816	6509	10097	15696
370	2880	6630	10266	15968
375	2955	6752	10432	16240
380	3029	6874	10598	16512
385	3104	6995	10765	16784
390	3179	7117	10931	17056
395	3253	7238	11098	17328
400	3328	7360	11264	17600

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	RTSC-NE-ENG.
DRAINAGE RUNOFF CURVES NORTHERN HUMID AREAS	SOIL CONSERVATION SERVICE ENGINEERING & WATERSHED PLANNING UNIT UPPER DARBY, PENNSYLVANIA	1410 SHEET 2 OF 2

Appendix B Drainage Recommendations by Soil Type

Soils with recommendations included in this guide:

ABBOTTSTOWN
ADELPHIA
ADRIAN
ATHERTON
ATSION
BERRYLAND
BERTIE
BIDDEFORD
BOWMANSVILLE
BRACEVILLE
CALIFON
CARLISLE
CATDEN
CHALFONT
CHICONE
COKESBURY
COLEMANTOWN
CROTON
DONLONTON
DOYLESTOWN
ELKTON
ELLINGTON
FALLSINGTON
FREDON
HALSEY
HAMMONTON
HIBERNIA
HOLMDEL
JADE RUN
KEANSBURG
KEYPORT
KLEJ
KRESSON
LAKEHURST
LAMINGTON
LAWRENCEVILLE
LEHIGH
LENNI
LENOIR
LIVINGSTON
LYONS
MANAHAWKIN
MARLTON
MATAWAN
MATTAPEX
MIDDLEBURY
MINOA
MOUNT LUCAS
MULLICA
NORWICH
OTHELLO
PARSIPPANY
PEMBERTON
PLUMMER
POMPTON
PORTSMOUTH
PREAKNESS
RARITAN
READINGTON
REAVILLE
RIDGEBURY
ROWLAND
SHREWSBURY
TIMAKWA
TURBOTVILLE
VENANGO
WALLKILL
WATCHUNG
WAYLAND
WEEKSVILLE
WHIPPANY
WHITMAN
WOODSTOWN
WURTSBORO

Headings and Abbreviations

Average Land Slope: The land slope has been divided into two categories: flat and sloping. The ranges are indicated in percent.
:
Crop or Landuse: The major agricultural uses that drainage could benefit are listed. For each use, different drainage practices and guideline recommendations are given for consideration in solving the drainage problem.

Drainage Coefficient: The letter (B, C, or D) represents the minimum drainage curve to be used to compute water removed by surface drainage. The fraction (3/8 or ¾) indicates the number of inches of water depth removed in a 24 hour period over the designated area for a subsurface drainage system.

Side Slope: The “Min” column gives the steepest slope recommendation. The “Rec” Column gives the recommended slope for most situations. The horizontal component of the slope ratio is listed.. For example, 10 represents a 10:1, or 10 feet horizontal to 1 foot vertical slope.

Depth: The recommended depths for surface drains are given in inches under minimum (Min) and maximum (Max) columns. The minimum depth represents the normal minimum depth that would be effective. The maximum depth applies to most site conditions except for short reaches necessary to cut through ridges or to reach an outlet.

Spacing: This is the recommended minimum (Min) and maximum (Max) distances for the spacing of surface drains and subsurface drains used in a parallel or herringbone system. A designation of “Random” indicates that parallel or patterned systems are not typical for the particular land use and slope.

Filter: A filter is a zone of material surrounding a subsurface drain designed to protect the soil material from piping into the drainage system. Filters include sand and gravel mixtures and geotextiles. Soils for which a filter MAY be needed are identified with “Check” in the “Filter” column. Soils for which a filter is needed are identified with “Req’d” in the “Filter” column.

Surface Treatment: Minor depressions and irregularities can inhibit the movement of surface water across a field. For those soils where this may be a problem, a recommendation of “Smooth” is given. Land smoothing is performed by grading the land surface with a land plane or land leveler to provide a more uniform plane for moving surface water to the drainage system.

Table of Contents

Series: ABBOTTSTOWN

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24		100		Smooth
3+	Cropland-Pasture	C	4	10	10	24	Random			
0-3	Turf	B	4	10	10	24		100		Smooth
3+	Turf	B	4	10	10	24	Random			

This soil formed in material weathered from red and brown shale and sandstone.
Drainage problems: perched water table, seeps.
Use shallow ditches to pick up seeps.

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	1	3	30	36		200		Smooth
3+	Cropland-Pasture	C	1	3	30	36	Random			
0-3	Turf	B	1	3	30	36		200		Smooth
3+	Turf	B	1	3	30	36	Random			

Land smoothing may be needed for surface drainage on flatter slopes.
Depth to fragipan ranges from 15 to 30 inches. Fragipan is about 20 inches in thickness.

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Subsurface Drain										
	Cropland-Pasture	3/8			30	36	Random			Smooth
	Turf	3/4			30	36	Random			Smooth

Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture.
Coefficient = 0.10 cfs per 1000 feet of drain for turf.
Pan restricts vertical drainage. Subsurface drains are generally too slow to be effective unless used to intercept seeps.

Series: ADELPHIA

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Blueberries	C	4	10	10	24	60	180		Smooth
0-3	Cropland-Pasture	C	4	10	10	24	60	180		Smooth
3+	Cropland-Pasture	C	4	10	10	24	Random			
0-3	Turf-Vegetables	B	4	10	10	24	50	150		Smooth
3+	Turf-Vegetables	B	4	10	10	24	Random			
This soil formed in unconsolidated marine deposits in which glauconite is common. Drainage problem: seasonal high water table. Use shallow ditches to pick up depressions.										
Surface Drainage – Main or Lateral										
0-3	Blueberries	C	2	3	18		135	270		Smooth
0-3	Cropland-Pasture	C	2	3	24		180	270		Smooth
3+	Cropland-Pasture	C	2	3	24		Random			
0-3	Turf-Vegetables	B	2	3	24		150	225		Smooth
3+	Turf-Vegetables	B	2	3	24		Random			
Surface drainage is important. Flatter slopes may need land smoothing..										
Subsurface Drain										
0-3	Blueberries	3/8			30	48	70	100	Check	Smooth
0-3	Cropland-Pasture	3/8			30	48	70	100	Check	Smooth
3+	CroplandPasture	3/8			30	48	Random		Check	
0-3	Turf-Vegetables	3/4			30	48	40	70	Check	Smooth
3+	Turf-Vegetables	3/4			30	48	Random		Check	
Coefficient = 0.10 cfs per 1000 feet of drain for blueberries, cropland and pasture. Coefficient = 0.15 cfs per 1000 feet of drain for turf and vegetables. Filters may be needed.										

Series: ADRIAN

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-2	Vegetables-Turf	B	4	10	10	24	100			
This soil was formed in material deposited in extinct lake basins found in outwash plains or lake plains. Typically, this soil is 16 to 50 inches of muck over gray sand. Drainage problems: high water table, subsidence, outlet.										
Surface Drainage – Main or Lateral										
0-2	Vegetables-Turf	B	0.25	3	24	36	150	200		
Precautions need to be taken when ditch bottom extends into the sand subsoil as the sand will flow into the ditch causing the sides to slough creating maintenance problems.										
Subsurface Drain										
0-2	Vegetables-Turf	3/4			36	48	100	200	Check	
Coefficient = 1.00 cfs per 1000 feet of drain for vegetables or turf. In deep muck, drain tubing should not be used until 3 years after initial drainage. Pumps may be needed where outlet is not available. When tubing is placed in the fine sand subsoil, a filter is needed.										

Series: ATHERTON

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24	75	100		Smooth
3+	Cropland-Pasture	C	4	10	10	24	Random			
0-3	Turf	B	4	10	10	24	65	90		Smooth
3+	Turf	B	4	10	10	24	Random			
This soil formed on glacial outwash terraces from water sorted material. Drainage problems: perched water table, seeps. Use shallow ditches to pick up seeps.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	2	3	24		150	200		Smooth
3+	Cropland-Pasture	C	2	3	24		Random			
0-3	Turf	B	2	3	24		140	190		Smooth
3+	Turf	B	2	3	24		Random			
Land smoothing may be needed for surface drainage on flatter slopes.										
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	48	60	140		Smooth
3+	Cropland-Pasture	3/8			30	48	Random			
0-3	Turf	3/4			30	48	30	80		Smooth
3+	Turf	3/4			30	48	Random			
Coefficient = 0.10 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.15 cfs per 1000 feet of drain for turf. Use subsurface drains to pick up seeps.										

Series: ATSION

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-1	Blueberries	C	4	10	10	24	60	140		
0-1	Cropland	C	4	10	10	24	80	200		
0-1	Pasture	D	4	10	10	24	120	300		
0-1	Turf-Vegetables	B	4	10	10	24	50	120		
This soil formed in coastal plain sediments. Drainage problem: high water table.										
Surface Drainage – Main or Lateral										
0-1	Blueberries	C	1	3	24		140			
0-1	Cropland	C	1	3	24		200			
0-1	Pasture	D	1	3	24		300			
0-1	Turf-Vegetables	B	1	3	24		120			
Water level control is needed for blueberries.										
Subsurface Drain										
0-1	Blueberries	3/8			30	48	150		Check	
0-1	Cropland	3/8			30	48	200		Check	
0-1	Pasture	3/8			30	48	250		Check	
0-1	Turf-Vegetables	3/4			30	48	100		Check	
Coefficient = 0.10 cfs per 1000 feet of drain for pasture. Coefficient = 0.15 cfs per 1000 feet of drain for blueberries, cropland, turf and vegetables. Filters may be needed.										

Series: BERRYLAND

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-1	Blueberries	C	4	10	10	24	60	140		
0-1	Cropland	C	4	10	10	24	80	200		
0-1	Pasture	D	4	10	10	24	120	300		
0-1	Turf-Vegetables	B	4	10	10	24	50	120		
This soil formed in sandy coastal plain sediments. Drainage problem: high water table.										
Surface Drainage – Main or Lateral										
0-1	Blueberries	C	1	3	24		140	230		
0-1	Cropland	C	1	3	24		200	250		
0-1	Pasture	D	1	3	24		300	400		
0-1	Turf-Vegetables	B	1	3	24		120	225		
Water level control is needed for blueberries.										
Subsurface Drain										
0-1	Blueberries	3/8			30	48	100	250	Check	
0-1	Cropland	3/8			30	48	150	200	Check	
0-1	Pasture	3/8			30	48	250	350	Check	
0-1	Turf-Vegetables	3/4			30	48	70	225	Check	
Coefficient = 0.10 cfs per 1000 feet of drain for pasture. Coefficient = 0.15 cfs per 1000 feet of drain for blueberries, cropland, turf and vegetables. Filters may be needed.										

Series: BERTIE

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-2	Cropland-Pasture	C	4	10	10	24	60	120		Smooth
2+	Cropland-Pasture	C	4	10	10	24	Random			
0-2	Turf-Vegetables	B	4	10	10	24	50	100		Smooth
2+	Turf-Vegetables	B	4	10	10	24	Random			
This soil developed from unconsolidated and somewhat stratified sediments in the coastal plain. Drainage problem: seasonal high water table. Use shallow field ditches to drain depressions.										
Surface Drainage – Main or Lateral										
0-2	Cropland-Pasture	C	1	3	24		90	200		Smooth
2+	Cropland-Pasture	C	1	3	18		Random			
0-2	Turf-Vegetables	B	1	3	24		60	150		Smooth
2+	Turf-Vegetables	B	1	3	18		Random			
Land smoothing may be needed for surface drainage on flatter slopes.										
Subsurface Drain										
0-2	Cropland-Pasture	3/8			30	48	50	175		Smooth
2+	Cropland-Pasture	3/8			30	48	Random			
0-2	Turf-Vegetables	3/4			30	48	50	100		Smooth
2+	Turf-Vegetables	3/4			30	48	Random			
Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.10 cfs per 1000 feet of drain for turf and vegetables.										

Series: BIDDEFORD

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-2	Cropland-Pasture	C	4	10	10	24	25			Smooth
0-2	Turf-Vegetables	B	4	10	10	24	20			Smooth
This soil formed in stratified glacial lucstrine deposits and have a thin mantle of silty and mucky sediment washed from surrounding soils. Drainage problems: ponding, slow percolation, outlet.										
Surface Drainage – Main or Lateral										
0-2	Cropland-Pasture	C	1.5	3	24		75			Smooth
0-2	Turf-Vegetables	B	1.5	3	24		50			Smooth
Land smoothing may be needed for surface drainage on flatter slopes										
Subsurface Drain										
0-2	Cropland-Pasture	3/8			30	48	Random			Smooth
0-2	Turf-Vegetables	3/4			30	48	Random			Smooth
Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.10 cfs per 1000 feet of drain for turf and vegetables. Subsurface drains are not recommended due to slow permeability of the soil.										

Series: BOWMANSVILLE

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-2	Cropland-Pasture	C	4	10	10	24	50			Smooth
0-2	Turf	B	4	10	10	24	30			Smooth
This soil formed in alluvium washed from nearby uplands which are underlain by red and Brown shale and sandstone, or by granite gneiss. Drainage problems: high water table, flooding. Use shallow ditches to drain depressions.										
Surface Drainage – Main or Lateral										
0-2	Cropland-Pasture	C	2	3	24		50			Smooth
0-2	Turf	B	2	3	24		40			Smooth
Land smoothing may be needed for surface drainage on flatter slopes.										
Subsurface Drain										
0-2	Cropland-Pasture	3/8			30	48	60	175		Smooth
0-2	Turf	3/4			30	48	30	100		Smooth
Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.10 cfs per 1000 feet of drain for turf.										

Series: BRACEVILLE

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24	30	75		Smooth
3+	Cropland-Pasture	C	4	10	10	24	Random			
0-3	Turf	B	4	10	10	24	25	50		Smooth
3+	Turf	B	4	10	10	24	Random			
This soil formed on glacial outwash terraces in material derived predominately from gray Sandstone and slate with smaller amounts of siltstone or sandstone. Drainage problems: perched water table, seeps. Use shallow ditches to drain depressions.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	1.5	3	24		60	150		Smooth
3+	Cropland-Pasture	C	1.5	3	24		Random			
0-3	Turf	B	1.5	3	24		50	120		Smooth
3+	Turf	B	1.5	3	24		Random			
Land smoothing may be needed for surface drainage on flatter slopes. Use ditches to pick up seeps. The depth to the fragipan varies from 15 to 30 inches. Fragipan is 8 to 30 inches in thickness.										
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	48	75	175		Smooth
3+	Cropland-Pasture	3/8			30	48	Random			
0-3	Turf	3/4			30	48	40	100		Smooth
3+	Turf	3/4			30	48	Random			
Coefficient = 0.10 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.15 cfs per 1000 feet of drain for turf. Dense pan restricts vertical drainage. Use cross slope drains to intercept seeps. Provide surface inlets to drain depressions.										

Series: CALIFON

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24	25	45		
3+	Cropland-Pasture	C	4	10	10	24	Random			
0-3	Turf-Vegetables	B	4	10	10	24	20	35		
3+	Turf-Vegetables	B	4	10	10	24	Random			
This soil formed in colluvium or in deeply weathered till derived mainly from granite gneiss. Drainage problems: perched water table, seeps. Use shallow surface ditches to drain depressions.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	1.5	3	24		30	50		
3+	Cropland-Pasture	C	1.5	3	24		Random			
0-3	Turf-Vegetables	B	1.5	3	24		25	40		
3+	Turf-Vegetables	B	1.5	3	24		Random			
Ditches are needed at toe of slopes to pick up seeps. The fragipan is at a depth of 20 to 30 inches and is about 25 inches in thickness.										
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30		25	45		
3+	Cropland-Pasture	3/8			30		Random			
0-3	Turf-Vegetables	3/4			30		20	35		
3+	Turf-Vegetables	3/4			30		Random			
Coefficient = 0.10 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.15 cfs per 1000 feet of drain for turf and vegetables. Dense pan restricts vertical drainage. Subsurface drains are generally too slow to be effective unless used to intercept seeps at fragipan depth.										

Series: CARLISLE

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-2	Vegetables-Turf	B	4	10	10	24	50	100		
This soil was formed in the organic residue of plant remains accumulated over a period of thousands of years. The organic layer is about 60 inches in thickness. Drainage problems: high water table, surface runoff is slow.										
Surface Drainage – Main or Lateral										
0-2	Vegetables-Turf	B	0.25	3	24		100	200		
On-site investigations of shrinkage and permeability should be made when extensive drainage is involved.										
Subsurface Drain										
0-2	Vegetables-Turf	3/4			30	48	100	200		
Coefficient = 1.00 cfs per 1000 feet of drain for all crops. Subsurface drain tubing should not be used until 3 years after initial drainage. Pumps may be needed where outlets are not available.										

Series: CATDEN

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-2	Vegetables-Turf	B	4	10	10	24	50	100		
This soil was formed in the organic residue of plant remains in depressions on lake plains, Moraines and flood plains. The organic layer is about 60 inches in thickness. Drainage problems: high water table, surface runoff is slow.										
Surface Drainage – Main or Lateral										
0-2	Vegetables-Turf	B	0.25	3	24		100	200		
On-site investigations of shrinkage and permeability should be made when extensive drainage is involved.										
Subsurface Drain										
0-2	Vegetables-Turf	3/4			30	48	100	200		
Coefficient = 1.00 cfs per 1000 feet of drain for all crops. Subsurface drain tubing should not be used until 3 years after initial drainage. Pumps may be needed where outlets are not available.										

Series: CHALFONT

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24				Smooth
3+	Cropland-Pasture	C	4	10	10	24	Random			
0-3	Turf	B	4	10	10	24				Smooth
3+	Turf	B	4	10	10	24	Random			
This soil formed in a loess mantle overlying residuum that is predominately free from shale and sandstone. Drainage problems: perched water table, seeps. Use shallow ditches to drain depressions.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	1	3	30					Smooth
3+	Cropland-Pasture	C	1	3	30		Random			
0-3	Turf	B	1	3	30					Smooth
3+	Turf	B	1	3	30		Random			
Use ditches to pick up seeps. The depth to the fragipan varies from 15 to 30 inches. Fragipan is between 20 to 30 inches in thickness.										
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	48				Smooth
3+	Cropland-Pasture	3/8			30	48	Random			
0-3	Turf	3/4			30	48				Smooth
3+	Turf	3/4			30	48	Random			
Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.10 cfs per 1000 feet of drain for turf. Dense pan restricts vertical drainage. Subsurface drains are generally too slow to be effective unless used to intercept seeps.										

Series: CHICONE

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-2	Cropland-Pasture	C	4	10	10	24	75	120		Smooth
0-2	Turf-Vegetables	B	4	10	10	24	50	100		Smooth
This soil formed in recent deposits of mineral soil eroded from adjoining locations.. Drainage problems: high water table, flooding. Use shallow ditches to drain depressions.										
Surface Drainage – Main or Lateral										
0-2	Cropland-Pasture	C	2	3	24		80	200		Smooth
0-2	Turf-Vegetables	B	2	3	24		60	150		Smooth
Land smoothing may be needed for surface drainage on flatter slopes Use ditches to divert seepage water..										
Subsurface Drain										
0-2	Cropland-Pasture	3/8			30	48	65	170	Check	Smooth
0-2	Turf-Vegetables	3/4			30	48	30	100	Check	Smooth
Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.10 cfs per 1000 feet of drain for turf and vegetables. Filter may be needed.										

Series: COKESBURY

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24				Smooth
3+	Cropland-Pasture	C	4	10	10	24	Random			
0-3	Turf	B	4	10	10	24				Smooth
3+	Turf	B	4	10	10	24	Random			
This soil formed in weathered glacial till and colluvium derived mainly from granitic gneiss And is underlain by weathered granitic gneiss. Drainage problems: perched water table, seeps. Use shallow ditches to drain depressions.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	1.5	3	24					Smooth
3+	Cropland-Pasture	C	1.5	3	18		Random			
0-3	Turf	B	1.5	3	24					Smooth
3+	Turf	B	1.5	3	18		Random			
Land smoothing may be needed for surface drainage on flatter slopes.										
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	36				Smooth
3+	Cropland-Pasture	3/8			30	36	Random			
0-3	Turf	3/4			30	36				Smooth
3+	Turf	3/4			30	36	Random			
Coefficient = 0.10 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.15 cfs per 1000 feet of drain for turf. Use subsurface drains placed across slope to pick up seeps.										

Series: COLEMANTOWN

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24		120		Smooth
0-3	Turf	B	4	10	10	24		100		Smooth
This soil formed in highly glauconitic clay marine sediments. Drainage problems: perched water table, outlet. Use smoothing and shallow ditches for surface drainage..										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	1.5	3	12			150		Smooth
0-3	Turf	B	1.5	3	12			120		Smooth
Water may be present below the subsoil under pressure.										
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30		Random			Smooth
0-3	Turf	3/4			30		Random			Smooth
Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.10 cfs per 1000 feet of drain for turf. Subsurface drains generally work too slowly to benefit the surface, but can be used to drain the substratum.										

Series: CROTON

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24				Smooth
3+	Cropland-Pasture	C	4	10	10	24	Random			
0-3	Turf	B	4	10	10	24				Smooth
3+	Turf	B	4	10	10	24	Random			
This soil formed in residuum weathered from fine-grained silty sandstone, argillite, or red shale. Drainage problems: perched water table, seeps, outlets. Use land smoothing and shallow ditches where soil is shallow over pan.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	1	3	24					Smooth
3+	Cropland-Pasture	C	1	3	24		Random			
0-3	Turf	B	1	3	24					Smooth
3+	Turf	B	1	3	24		Random			
Land smoothing may be needed for surface drainage on flatter slopes. Depth to fragipan ranges from 18 to 36 inches. Fragipan is about 18 inches in thickness.										
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30					Smooth
3+	Cropland-Pasture	3/8			30		Random			
0-3	Turf	3/4			30					Smooth
3+	Turf	3/4			30		Random			
Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.10 cfs per 1000 feet of drain for turf. Dense pan restricts vertical drainage. Subsurface drains are generally too slow to be effective unless used to intercept seeps.										

Series: DONLONTON

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24	45			Smooth
3+	Cropland-Pasture	C	4	10	10	24		200		
0-3	Turf-Vegetables	B	4	10	10	24	30			Smooth
3+	Turf-Vegetables	B	4	10	10	24		180		

This soil formed in old marine sediments containing moderate amounts of glauconite.
Drainage problems: perched water table, seeps.
Use land smoothing and shallow ditches where soil is shallow over pan..

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	1.5	3	24		45			Smooth
3+	Cropland-Pasture	C	1.5	3	24			200		
0-3	Turf-Vegetables	B	1.5	3	24		30			Smooth
3+	Turf-Vegetables	B	1.5	3	24			200		

Land smoothing may be needed for surface drainage on flatter slopes.
Ditches can be used to pick up seeps.

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	48	35	65		Smooth
3+	Cropland-Pasture	3/8			30	48	Random			
0-3	Turf-Vegetables	3/4			30	48	20	40		Smooth
3+	Turf-Vegetables	3/4			30	48	Random			

Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture.
Coefficient = 0.10 cfs per 1000 feet of drain for turf and vegetables.
Use subsurface drains placed across slope to pick up seeps.

Series: DOYLESTOWN

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24		150		Smooth
3+	Cropland-Pasture	C	4	10	10	24	Random			
0-3	Turf	B	4	10	10	24		100		Smooth
3+	Turf	B	4	10	10	24	Random			

This soil formed in a mantle of silty material that was weathered from red shale or, possibly deposited by wind.
Drainage problems: perched water table, seeps.
Use land smoothing and shallow for surface drainage..

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	1	3	24			175		Smooth
3+	Cropland-Pasture	C	1	3	24		Random			
0-3	Turf	B	1	3	24			150		Smooth
3+	Turf	B	1	3	24		Random			

Land smoothing may be needed for surface drainage on flatter slopes.
The depth to the fragipan varies from 18 to 30 inches and it extends to bedrock.

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	48		150		Smooth
3+	Cropland-Pasture	3/8			30	48	Random			
0-3	Turf	3/4			30	48		125		Smooth
3+	Turf	3/4			30	48	Random			

Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture.
Coefficient = 0.10 cfs per 1000 feet of drain for turf.
Use subsurface drains to pick up seeps over the pan.

Series: ELKTON

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24	75	150		Smooth
3+	Cropland-Pasture	C	4	10	10	24	Random			
0-3	Turf	B	4	10	10	24	50	100		Smooth
3+	Turf	B	4	10	10	24	Random			
This soil formed in clayey coastal plain sediments. Drainage problems: perched water table, seeps. Use shallow ditches and land smoothing where soil is shallow over clay subsoil.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	1.5	3	24			150		Smooth
3+	Cropland-Pasture	C	1.5	3	24		Random			
0-3	Turf	B	1.5	3	24		75	100		Smooth
3+	Turf	B	1.5	3	24		Random			
Land smoothing may be needed for surface drainage on flatter slopes. Use ditches to pick up seeps.										
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	48		125		Smooth
3+	Cropland-Pasture	3/8			30	48	Random			
0-3	Turf	3/4			30	48		100		Smooth
3+	Turf	3/4			30	48	Random			
Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.10 cfs per 1000 feet of drain for turf. Use subsurface drains to intercept seeps.										

Series: ELLINGTON

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24	50	100		Smooth
3+	Cropland-Pasture	C	4	10	10	24	Random			
0-3	Turf	B	4	10	10	24	40	75		Smooth
3+	Turf	B	4	10	10	24	Random			
This soil formed in somewhat gravelly material derived from shale, siltstone and sandstone underlain by finer textured residual material. Drainage problems: depressions, seeps.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	1.5	3	24		100	150		Smooth
3+	Cropland-Pasture	C	1.5	3	18		Random			
0-3	Turf	B	1.5	3	24		75	100		Smooth
3+	Turf	B	1.5	3	18		Random			
Land smoothing may be needed for surface drainage on flatter slopes.										
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	36	60	100		Smooth
3+	Cropland-Pasture	3/8			30	36	Random			
0-3	Turf	3/4			30	36	50	75		Smooth
3+	Turf	3/4			30	36	Random			
Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.10 cfs per 1000 feet of drain for turf.										

Series: FALLSINGTON

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope		Depth Inches		Spacing Feet		Filter	Surface Treatment
			Min	Rec	Min	Max	Min	Max		
Surface Drainage – Field Ditch										
0-2	Blueberries	C	4	10	10	24	50	100		Smooth
0-2	Cropland	C	4	10	10	24	60	80		Smooth
0-2	Turf-Vegetables	B	4	10	10	24	50	75		Smooth
This soil formed in marine and old alluvial sediments that are predominantly sandy and characteristically low in silt. Drainage problem: high water table. Surface drainage is important.										
Surface Drainage – Main or Lateral										
0-2	Blueberries	C	1.5	3	18		75	100		Smooth
0-2	Cropland	C	1.5	3	24		90	100		Smooth
0-2	Turf-Vegetables	B	1.5	3	24		50	60		Smooth
Land smoothing may be needed for surface drainage on flatter slopes.										
Subsurface Drain										
0-2	Blueberries	3/8			30	48	60	80	Check	Smooth
0-2	Cropland	3/8			30	48	60	90	Check	Smooth
0-2	Turf-Vegetables	3/4			30	48	50	75	Check	Smooth
Coefficient = 0.10 cfs per 1000 feet of drain for blueberries and cropland.. Coefficient = 0.15 cfs per 1000 feet of drain for turf and vegetables. Filter may be needed.										

Series: FREDON

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24	50	100		
3+	Cropland-Pasture	C	4	10	10	24	Random			
0-3	Turf	B	4	10	10	24	45	75		
3+	Turf	B	4	10	10	24	Random			
This soil formed in glacial outwash material derived predominately from gray sandstone, shale and siltstone. Drainage problems: high water table, seeps.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	1.5	3	24		70	150		
3+	Cropland-Pasture	C	1.5	3	18		Random			
0-3	Turf	B	1.5	3	24		50	100		
3+	Turf	B	1.5	3	24		Random			
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	48	75	150	Check	
3+	Cropland-Pasture	3/8			30	48	Random		Check	
0-3	Turf	3/4			30	48	50	100	Check	
3+	Turf	3/4			30	48	Random		Check	
Coefficient = 0.10 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.15 cfs per 1000 feet of drain for turf. Filter may be needed. Use random subsurface drains to pick up seeps.										

Series: HALSEY

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24	70	120		
3+	Cropland-Pasture	C	4	10	10	24	Random			
0-3	Turf	B	4	10	10	24	50	100		
3+	Turf	B	4	10	10	24	Random			
This soil formed in glacial outwash material derived predominately from gray sandstone, shale, and siltstone. Drainage problems: high water table, seeps.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	1.5	3	24		50	175		
3+	Cropland-Pasture	C	1.5	3	24		Random			
0-3	Turf	B	1.5	3	24		40	100		
3+	Turf	B	1.5	3	24		Random			
Deep ditches can be used effectively.										
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	48	30	150	Check	
3+	Cropland-Pasture	3/8			30	48	Random		Check	
0-3	Turf	3/4			30	48	25	120	Check	
3+	Turf	3/4			30	48	Random		Check	
Coefficient = 0.10 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.15 cfs per 1000 feet of drain for turf. Filter may be needed. Use random subsurface drains to pick up seeps.										

Series: HAMMONTON

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-2	Cropland	C	4	10	10	24	60			Smooth
0-2	Turf-Vegetables	B	4	10	10	24	50			Smooth
This soil formed in sandy coastal plain sediments. Drainage problem: high water table. Use shallow field ditches and land smoothing for surface drainage. Surface drainage is important.										
Surface Drainage – Main or Lateral										
0-2	Cropland	C	1	3	24		90			Smooth
0-2	Turf-Vegetables	B	1	3	24		75			Smooth
Subsurface Drain										
0-2	Cropland	3/8			30	48	60		Check	
0-2	Turf-Vegetables	3/4			30	48	50		Check	
Coefficient = 0.10 cfs per 1000 feet of drain for cropland.. Coefficient = 0.15 cfs per 1000 feet of drain for turf and vegetables. Filter may be needed.										

Series: HIBERNIA

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24	50	70		Smooth
3+	Cropland-Pasture	C	4	10	10	24	Random			
0-3	Turf-Vegetables	B	4	10	10	24	50	100		Smooth
3+	Turf-Vegetables	B	4	10	10	24	Random			
This soil formed in glacial till primarily of granite gneiss and small amounts of quartzite. Drainage problems: seasonal high water table, perched water table, seeps. Use land smoothing and shallow ditches to drain depressions.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	1.5	3	24		50	75		Smooth
3+	Cropland-Pasture	C	1.5	3	24		Random			
0-3	Turf-Vegetables	B	1.5	3	24		40	60		Smooth
3+	Turf-Vegetables	B	1.5	3	24		Random			
Land smoothing may be needed for surface drainage on flatter slopes. Use ditches to drain depressions.										
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	48	25	45		
3+	Cropland-Pasture	3/8			30	48	Random			
0-3	Turf-Vegetables	3/4			30	48	20	35		
3+	Turf-Vegetables	3/4			30	48	Random			
Coefficient = 0.10 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.15 cfs per 1000 feet of drain for turf and vegetables.										

Series: HOLMDEL

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Blueberries	C	4	10	10	24	50	150		Smooth
0-3	Cropland-Pasture	C	4	10	10	24	50	150		Smooth
3+	Cropland-Pasture	C	4	10	10	18	Random			
0-3	Turf-Vegetables	B	4	10	10	24	40	120		Smooth
3+	Turf-Vegetables	B	4	10	10	18	Random			
This soil formed in marine deposits containing glauconite. Drainage problem: high water table. Grade for surface drainage.										
Surface Drainage – Main or Lateral										
0-3	Blueberries	C	1.5	3	18		160	180		Smooth
0-3	Cropland-Pasture	C	1.5	3	24		150	175		Smooth
3+	Cropland-Pasture	C	1.5	3	18		Random			
0-3	Turf-Vegetables	B	1.5	3	24		150	220		Smooth
3+	Turf-Vegetables	B	1.5	3	18		Random			
Water level control is needed for blueberries. Land smoothing may be needed for surface drainage on flatter slopes.										
Subsurface Drain										
0-3	Blueberries	3/8			30	48	50	150	Check	Smooth
0-3	Cropland-Pasture	3/8			30	48	50	120	Check	Smooth
3+	Cropland-Pasture	3/8			30	48	Random		Check	
0-3	Turf-Vegetables	3/4			30	48	40	90	Check	Smooth
3+	Turf-Vegetables	3/4			30	48	Random		Check	
Coefficient = 0.10 cfs per 1000 feet of drain for blueberries, cropland and pasture. Coefficient = 0.15 cfs per 1000 feet of drain for turf and vegetables. Filters may be needed.										

Series: JADE RUN

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-2	Cropland-Pasture	C	4	10	10	24	45			Smooth
0-2	Turf-Vegetables	B	4	10	10	24	30			Smooth
This soil formed from unconsolidated silts and very fine sands of marine origin. Drainage problem: high water table.										
Surface Drainage – Main or Lateral										
0-2	Cropland-Pasture	C	2	3	24		75	120		Smooth
0-2	Turf-Vegetables	B	2	3	24		50	100		Smooth
Land smoothing may be needed for surface drainage.										
Subsurface Drain										
0-2	Cropland-Pasture	3/8			30	48	60	100	Check	Smooth
0-2	Turf-Vegetables	3/4			30	48	30	60	Check	Smooth
Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.10 cfs per 1000 feet of drain for turf and vegetables. Filter may be needed.										

Series: KEANSBURG

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-2	Blueberries	C	4	10	10	24	50	150		Smooth
0-2	Cropland	C	4	10	10	24	60	125		Smooth
0-2	Turf-Vegetables	B	4	10	10	24	50	100		Smooth
This soil formed in sandy sediments containing low or moderate amounts of glauconite. The sediments were eroded and redeposited with a mixture of other materials. Drainage problem: high water table.										
Surface Drainage – Main or Lateral										
0-2	Blueberries	C	1.5	3	18		75	225		Smooth
0-2	Cropland	C	1.5	3	24		90	200		Smooth
0-2	Turf-Vegetables	B	1.5	3	24		75	125		Smooth
Land smoothing may be needed for surface drainage on flatter slopes.										
Subsurface Drain										
0-2	Blueberries	3/8			30	48	60	200	Check	Smooth
0-2	Cropland	3/8			30	48	60	175	Check	Smooth
0-2	Turf-Vegetables	3/4			30	48	50	125	Check	Smooth
Coefficient = 0.10 cfs per 1000 feet of drain for blueberries and cropland.. Coefficient = 0.15 cfs per 1000 feet of drain for turf and vegetables. Filter may be needed. An iron cemented layer just below the plow layer may interfere with construction.										

Series: KEYPORT

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24	45			Smooth
3+	Cropland-Pasture	C	4	10	10	24		200		
0-3	Turf-Vegetables	B	4	10	10	24	30			Smooth
3+	Turf-Vegetables	B	4	10	10	24		200		
This soil formed on clay beds which are thick marine deposits containing variable amounts of glauconite. Drainage problems: perched water table, seeps. Use land smoothing and shallow ditches to drain depressions.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	1.5	3	24		45			Smooth
3+	Cropland-Pasture	C	1.5	3	24			200		
0-3	Turf-Vegetables	B	1.5	3	24		30			Smooth
3+	Turf-Vegetables	B	1.5	3	24			200		
Land smoothing may be needed for surface drainage on flatter slopes.										
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	48	35			Smooth
3+	Cropland-Pasture	3/8			30	48	Random			
0-3	Turf-Vegetables	3/4			30	48	20			Smooth
3+	Turf-Vegetables	3/4			30	48	Random			
Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.10 cfs per 1000 feet of drain for turf and vegetables. Subsurface drains can be used to intercept seeps.										

Series: KLEJ

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24	75			
0-3	Turf-Vegetables	B	4	10	10	24	50			
This soil formed in old, coarse textured highly siliceous sediments. Drainage problems: seasonal high water table.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	1	3	24		150			
0-3	Turf-Vegetables	B	1	3	24		100			
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	48	120		Check	
0-3	Turf-Vegetables	3/4			30	48	100		Check	
Coefficient = 0.10 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.15 cfs per 1000 feet of drain for turf and vegetables. Filters may be needed. Water level control should be considered.										

Series: KRESSON

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24	45			Smooth
3+	Cropland-Pasture	C	4	10	10	24		200		
0-3	Turf-Vegetables	B	4	10	10	24	30			Smooth
3+	Turf-Vegetables	B	4	10	10	24		200		
This soil formed in marine deposits containing large amounts of glauconite. Drainage problems: perched water table, seeps.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	1.5	3	24		45			Smooth
3+	Cropland-Pasture	C	1.5	3	24			200		
0-3	Turf-Vegetables	B	1.5	3	24		30			Smooth
3+	Turf-Vegetables	B	1.5	3	24			200		
Land smoothing may be needed for surface drainage on flatter slopes.										
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	48	35			Smooth
3+	Cropland-Pasture	3/8			30	48	Random			
0-3	Turf-Vegetables	3/4			30	48	20			Smooth
3+	Turf-Vegetables	3/4			30	48	Random			
Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.10 cfs per 1000 feet of drain for turf and vegetables. Use subsurface drains to intercept seeps.										

Series: LAKEHURST

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland	C	4	10	10	24	50			
0-3	Turf-Vegetables	B	4	10	10	24	35			
This soil formed in unconsolidated, very sandy, quartzose coastal plain sediments. Drainage problem: seasonal high water table.										
Surface Drainage – Main or Lateral										
0-3	Cropland	C	1	3	24		150			
0-3	Turf-Vegetables	B	1	3	24		125			
Subsurface Drain										
0-3	Cropland	3/8			30	48	120		Check	
0-3	Turf-Vegetables	3/4			30	48	100		Check	
Coefficient = 0.10 cfs per 1000 feet of drain for cropland.. Coefficient = 0.15 cfs per 1000 feet of drain for turf and vegetables. Filter may be needed. Water level control should be considered.										

Series: LAMINGTON

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-2	Cropland	C	4	10	10	24		75		
0-2	Turf-Vegetables	B	4	10	10	24		75		
This soil formed in old sediments derived from red and gray sandstone and shale. Drainage problems: perched water table, outlet. Use land smoothing and shallow ditches to provide surface drainage..										
Surface Drainage – Main or Lateral										
0-2	Cropland	C	1.5	3	12			150		
0-2	Turf-Vegetables	B	1.5	3	12			150		
Land smoothing may be needed for surface drainage on flatter slopes.										
Subsurface Drain										
0-2	Cropland	3/8			30	48	Random			
0-2	Turf-Vegetables	3/4			30	48	Random			
Coefficient = 0.08 cfs per 1000 feet of drain for cropland.. Coefficient = 0.10 cfs per 1000 feet of drain for turf and vegetables. Subsurface drains are not recommended due to the slow permeability of the soil.										

Series: LAWRENCEVILLE

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24	45			
3+	Cropland-Pasture	C	4	10	10	24		200		
0-3	Turf-Vegetables	B	4	10	10	24	30			
3+	Turf-Vegetables	B	4	10	10	24		200		
This soil formed in weathered shale. Drainage problems: perched water table, seeps. Use shallow surface ditches to drain depressions.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	2	3	30	48	45			
3+	Cropland-Pasture	C	2	3	30	48		200		
0-3	Turf-Vegetables	B	2	3	30	48	30			
3+	Turf-Vegetables	B	2	3	30	48		200		
Ditches may be needed at the toe of slopes.										
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	48	35			Smooth
3+	Cropland-Pasture	3/8			30	48	Random			
0-3	Turf-Vegetables	3/4			30	48	20			Smooth
3+	Turf-Vegetables	3/4			30	48	Random			
Coefficient = 0.10 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.15 cfs per 1000 feet of drain for turf and vegetables. Depth to fragipan ranges from 24 to 38 inches and is about 12 inches in thickness.										

Series: LEHIGH

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24		100		Smooth
3+	Cropland-Pasture	C	4	10	10	24	Random			
0-3	Turf-Vegetables	B	4	10	10	24		100		Smooth
3+	Turf-Vegetables	B	4	10	10	24	Random			
This soil formed in material weathered from shale and siltstone. Drainage problems: perched water table, seeps. Use shallow surface ditches to drain depressions.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	1.5	3	30	36		200		Smooth
3+	Cropland-Pasture	C	1.5	3	30	36	Random			
0-3	Turf-Vegetables	B	1.5	3	30	36		200		Smooth
3+	Turf-Vegetables	B	1.5	3	30	36	Random			
Land smoothing may be needed for surface drainage on flatter slopes.										
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	36		100		Smooth
3+	Cropland-Pasture	3/8			30	36	Random			
0-3	Turf-Vegetables	3/4			30	36		100		Smooth
3+	Turf-Vegetables	3/4			30	36	Random			
Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.10 cfs per 1000 feet of drain for turf and vegetables. Use subsurface drains to intercept seeps. In places, bedrock may interfere with installation of drain lines.										

Series: LENNI

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24	75	150		Smooth
3+	Cropland-Pasture	C	4	10	10	24	Random			
0-3	Turf	B	4	10	10	24	50	100		Smooth
3+	Turf	B	4	10	10	24	Random			
This soil formed in clayey coastal plain sediments. Drainage problem: seasonal high water table. Use shallow ditches and land smoothing for surface drainage.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	1.5	3	24			150		Smooth
3+	Cropland-Pasture	C	1.5	3	24		Random			
0-3	Turf	B	1.5	3	24		75	100		Smooth
3+	Turf	B	1.5	3	24		Random			
Land smoothing may be needed for surface drainage on flatter slopes.										
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	48		125		Smooth
3+	Cropland-Pasture	3/8			30	48	Random			
0-3	Turf	3/4			30	48		100		Smooth
3+	Turf	3/4			30	48	Random			
Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.10 cfs per 1000 feet of drain for turf.										

Series: LENOIR

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24	45			Smooth
3+	Cropland-Pasture	C	4	10	10	24		200		
0-3	Turf-Vegetables	B	4	10	10	24	30			Smooth
3+	Turf-Vegetables	B	4	10	10	24		200		

This soil formed in stratified marine sediments of clayey texture.
Drainage problems: seasonal high water table, seeps.
Use shallow ditches and land smoothing to provide surface drainage.

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	1.5	3	24		50			Smooth
3+	Cropland-Pasture	C	1.5	3	24			200		
0-3	Turf-Vegetables	B	1.5	3	24		40			Smooth
3+	Turf-Vegetables	B	1.5	3	24			200		

Land smoothing may be needed for surface drainage on flatter slopes.

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	48	35			Smooth
3+	Cropland-Pasture	3/8			30	48	Random			
0-3	Turf-Vegetables	3/4			30	48	20	100		Smooth
3+	Turf-Vegetables	3/4			30	48	Random			

Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture.
Coefficient = 0.10 cfs per 1000 feet of drain for turf and vegetables.
Subsurface drainage is generally not recommended due to slow soil permeability.

Series: LIVINGSTON

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24		75		Smooth
0-3	Turf	B	4	10	10	24		50		Smooth
This soil formed in calcareous estuarine or lacustrine clay deposits. Drainage problems: perched water table, outlet. Use smoothing and shallow ditches for surface drainage..										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	2	3	12			150		Smooth
0-3	Turf	B	2	3	12			120		Smooth
Land smoothing may be needed for surface drainage on flatter slopes. Use ditches to drain depressions.										
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	48	Random			Smooth
0-3	Turf	3/4			30	48	Random			Smooth
Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.10 cfs per 1000 feet of drain for turf. Subsurface drains are not recommended due to slow permeability of the soil.										

Series: LYONS

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24	Random			Smooth
3+	Cropland-Pasture	C	4	10	10	24	Random			
0-3	Turf	B	4	10	10	24	Random			Smooth
3+	Turf	B	4	10	10	24	Random			
This soil formed in calcarious glacial till derived from limestone, calcarious shale, and calcarious sandstone. Drainage problems: perched water table, seeps. Use shallow ditches to pick up seeps and depressions.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	1.5	3	24		Random			Smooth
3+	Cropland-Pasture	C	1.5	3	18		Random			
0-3	Turf	B	1.5	3	24		Random			Smooth
3+	Turf	B	1.5	3	18		Random			
Land smoothing may be needed for surface drainage on flatter slopes.										
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30		Random			Smooth
3+	Cropland-Pasture	3/8			30		Random			
0-3	Turf	3/4			30		Random			Smooth
3+	Turf	3/4			30		Random			
Coefficient = 0.10 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.15 cfs per 1000 feet of drain for turf. Sinkholes are likely to form. Surface grading is important on fields with subsurface drains.										

Series: MANAHAWKIN

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-2	Blueberries	C	4	10	10	24	50	100		
0-2	Vegetables-Turf	B	4	10	10	24	35	75		
This soil was formed in the organic remains of vegetation in submerged valleys of the coastal Plain and basins once occupied by ponds and lakes. Drainage problems: high water table, outlet.										
Surface Drainage – Main or Lateral										
0-2	Blueberries	C	0.25	1	24		75	150		
0-2	Vegetables-Turf	B	0.25	1	24		50	100		
On-site investigations of shrinkage and permeability should be made when extensive drainage is involved.										
Subsurface Drain										
0-2	Blueberries	3/8			30	48	50	300		
0-2	Vegetables-Turf	3/4			30	48	35	200		
Coefficient = 1.00 cfs per 1000 feet of drain for all crops. Pumps may be needed where outlets are not available.										

Series: MARLTON

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24	25			Smooth
3+	Cropland-Pasture	C	4	10	10	24		100		
0-3	Turf-Vegetables	B	4	10	10	24	20			Smooth
3+	Turf-Vegetables	B	4	10	10	24		100		
This soil formed in marine deposits that contain large amounts of glauconite. Drainage problems: seasonal high water table, perched water table, seeps. Use shallow ditches and land smoothing to provide surface drainage.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	1.5	3	24		45			Smooth
3+	Cropland-Pasture	C	1.5	3	24			200		
0-3	Turf-Vegetables	B	1.5	3	24		30			Smooth
3+	Turf-Vegetables	B	1.5	3	24			200		
Land smoothing may be needed for surface drainage on flatter slopes.										
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	48	35			Smooth
3+	Cropland-Pasture	3/8			30	48	Random			
0-3	Turf-Vegetables	3/4			30	48	30			Smooth
3+	Turf-Vegetables	3/4			30	48	Random			
Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.10 cfs per 1000 feet of drain for turf and vegetables.										

Series: MATAWAN

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland	C	4	10	10	24	25			Smooth
3+	Cropland	C	4	10	10	24		100		
0-3	Turf-Vegetables	B	4	10	10	24	20			Smooth
3+	Turf-Vegetables	B	4	10	10	24		100		
This soil formed in a mantle of sandy marine sediments over older, finer textured marine sediments. Drainage problem: seasonal and perched water table. Use shallow ditches and land smoothing for surface drainage.										
Surface Drainage – Main or Lateral										
0-3	Cropland	C	1.5	3	24		45			Smooth
3+	Cropland	C	1.5	3	18			200		
0-3	Turf-Vegetables	B	1.5	3	24		30			Smooth
3+	Turf-Vegetables	B	1.5	3	18			200		
Land smoothing may be needed for surface drainage on flatter slopes.										
Subsurface Drain										
0-3	Cropland	3/8			30	48	35			Smooth
3+	Cropland	3/8			30	48	Random			
0-3	Turf-Vegetables	3/4			30	48	20			Smooth
3+	Turf-Vegetables	3/4			30	48	Random			
Coefficient = 0.08 cfs per 1000 feet of drain for cropland. Coefficient = 0.10 cfs per 1000 feet of drain for turf and vegetables. Use subsurface drains to intercept seeps.										

Series: MATTAPEX

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-2	Cropland-Pasture	C	4	10	10	24	35	90		Smooth
2+	Cropland-Pasture	C	4	10	10	24	Random			
0-2	Turf-Vegetables	B	4	10	10	24	25	60		Smooth
2+	Turf-Vegetables	B	4	10	10	24	Random			
This soil formed in a mantle of highly silty sediments over older coarser sediments of marine or alluvial origin. Drainage problem: seasonal high water table. Use land smoothing and shallow ditches for surface drainage.										
Surface Drainage – Main or Lateral										
0-2	Cropland-Pasture	C	2	3	24		90			Smooth
2+	Cropland-Pasture	C	2	3	24		Random			
0-2	Turf-Vegetables	B	2	3	24		60			Smooth
2+	Turf-Vegetables	B	2	3	24		Random			
Land smoothing may be needed for surface drainage on flatter slopes. Use ditches along toe of slopes to pick up seeps..										
Subsurface Drain										
0-2	Cropland-Pasture	3/8			30	48	35	50		Smooth
2+	Cropland-Pasture	3/8			30	48	Random			
0-2	Turf-Vegetables	3/4			30	48				Smooth
2+	Turf-Vegetables	3/4			30	48	Random			
Coefficient = 0.10 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.15 cfs per 1000 feet of drain for turf and vegetables. Use subsurface drains at toe of slopes to pick up seeps.										

Series: MIDDLEBURY

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-2	Cropland-Pasture	C	4	10	10	24	75	150		
0-2	Turf	B	4	10	10	24	50	100		
This soil formed in post glacial alluvium predominately from areas of shale and sandstone. Drainage problems: high water table, flooding. Use shallow ditches to drain depressions.										
Surface Drainage – Main or Lateral										
0-2	Cropland-Pasture	C	2	3	24		100	200		
0-2	Turf	B	2	3	24		75	150		
Land smoothing may be needed for surface drainage on flatter slopes.										
Subsurface Drain										
0-2	Cropland-Pasture	3/8			30	48	60	175		
0-2	Turf	3/4			30	48	30	100		
Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.10 cfs per 1000 feet of drain for turf.										

Series: MINOA

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24		120		Smooth
3+	Cropland-Pasture	C	4	10	10	24	Random			
0-3	Turf-Vegetables	B	4	10	10	24		100		Smooth
3+	Turf-Vegetables	B	4	10	10	24	Random			
This soil formed in lacustrine sediment along the edge of former glacial lakes. Drainage problems: seasonal high water table. Use shallow surface ditches to drain depressions.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	2	3	24			140		Smooth
3+	Cropland-Pasture	C	2	3	24		Random			
0-3	Turf-Vegetables	B	2	3	24			120		Smooth
3+	Turf-Vegetables	B	2	3	24		Random			
Land smoothing may be needed for surface drainage on flatter slopes.										
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	48		175	Check	Smooth
3+	Cropland-Pasture	3/8			30	48	Random		Check	
0-3	Turf-Vegetables	3/4			30	48		100	Check	Smooth
3+	Turf-Vegetables	3/4			30	48	Random		Check	
Coefficient = 0.10 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.15 cfs per 1000 feet of drain for turf and vegetables.										

Series: MOUNT LUCAS

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24				
3+	Cropland-Pasture	C	4	10	10	24	Random			
0-3	Turf-Vegetables	B	4	10	10	24				
3+	Turf-Vegetables	B	4	10	10	24	Random			
This soil formed in material weathered from dark igneous diabase and basalt bedrock. Drainage problems: high water table, seeps, very slow permeability. Use shallow surface ditches to drain depressions.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	2	3	24					
3+	Cropland-Pasture	C	2	3	24		Random			
0-3	Turf-Vegetables	B	2	3	24					
3+	Turf-Vegetables	B	2	3	24		Random			
Use ditches at toe of slopes to pick up seeps.										
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	48				Smooth
3+	Cropland-Pasture	3/8			30	48	Random			
0-3	Turf-Vegetables	3/4			30	48				Smooth
3+	Turf-Vegetables	3/4			30	48	Random			
Coefficient = 0.10 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.15 cfs per 1000 feet of drain for turf and vegetables. Use subsurface drains to pick up seeps.										

Series: MULLICA

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-1	Blueberries	C	4	10	10	24	35	150		
0-1	Pasture	D	4	10	10	24	35	175		
0-1	Turf-Vegetables	B	4	10	10	24	35	150		
This soil formed in stratified coarse to medium textured marine or fluvial sediments. Drainage problems: high water table, outlet.										
Surface Drainage – Main or Lateral										
0-1	Blueberries	C	1.5	3	24		55	150		
0-1	Pasture	D	1.5	3	24		75	175		
0-1	Turf-Vegetables	B	1.5	3	24		45	100		
Land smoothing may be needed for surface drainage.										
Subsurface Drain										
0-1	Blueberries	3/8			30	48	75	175		
0-1	Pasture	3/8			30	48	100	225		
0-1	Turf-Vegetables	3/4			30	48	40	100		
Coefficient = 0.10 cfs per 1000 feet of drain for blueberries and pasture. Coefficient = 0.15 cfs per 1000 feet of drain for turf and vegetables. Pumps may be needed if an outlet is not available.										

Series: NORWICH

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-2	Cropland-Pasture	C	4	10	10	24		150		Smooth
0-2	Turf	B	4	10	10	24		150		Smooth
This soil formed in glacial till deposits high in reddish sandstone, siltstone and shale. Drainage problems: seasonal high water table, seeps, outlet.										
Surface Drainage – Main or Lateral										
0-2	Cropland-Pasture	C	1	3	12			150		Smooth
0-2	Turf	B	1	3	12			150		Smooth
Subsurface Drain										
0-2	Cropland-Pasture	3/8			30	48	Random			
0-2	Turf	3/4			30	48	Random			
Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.10 cfs per 1000 feet of drain for turf. Outlet for drainage tubing is difficult to obtain.										

Series: OTHELLO

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24	45			
0-3	Turf-Vegetables	B	4	10	10	24	30			
This soil formed in a mantle of highly silty sediments over older, coarser sediments of marine or alluvial origin. Drainage problem: high water table.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	2	3	24		45			
0-3	Turf-Vegetables	B	2	3	24		30			
Land smoothing may be needed for surface drainage.										
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	48	35			
0-3	Turf-Vegetables	3/4			30	48	20			
Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.10 cfs per 1000 feet of drain for turf and vegetables.										

Series: PARSIPPANY

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24	150			Smooth
0-3	Turf	B	4	10	10	24	150			Smooth
This soil formed in stratified sediment on the nearly level bottom of former glacial lakes. Drainage problems: seasonal perched water table, seeps. Use shallow ditches and land smoothing to drain depressions.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	1.5	3	12		150			Smooth
0-3	Turf	B	1.5	3	12		150			Smooth
Land smoothing may be needed for surface drainage.										
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	48	Random			
0-3	Turf	3/4			30	48	Random			
Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.10 cfs per 1000 feet of drain for turf. Outlet for drainage tubing is difficult to obtain. Subsurface drainage not recommended due to slow soil permeability.										

Series: PEMBERTON

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Blueberries	C	4	10	10	24	60	180		Smooth
0-3	Cropland-Pasture	C	4	10	10	24	60	180		Smooth
3+	Cropland-Pasture	C	4	10	10	24	Random			
0-3	Turf-Vegetables	B	4	10	10	24	50	150		Smooth
3+	Turf-Vegetables	B	4	10	10	24	Random			
This soil formed in old alluvium from marine sediments that contained glauconite. Drainage problem: seasonal high water table. Use shallow field ditches to drain depressions.										
Surface Drainage – Main or Lateral										
0-3	Blueberries	C	1	3	24		135			Smooth
0-3	Cropland-Pasture	C	1	3	24		180	220		Smooth
3+	Cropland-Pasture	C	1	3	18		Random			
0-3	Turf-Vegetables	B	1	3	24		135	150		Smooth
3+	Turf-Vegetables	B	1	3	18		Random			
Land smoothing may be needed for surface drainage on flatter slopes.										
Subsurface Drain										
0-3	Blueberries	3/8			30		135		Check	Smooth
0-3	Cropland-Pasture	3/8			30		130	200	Check	Smooth
3+	Cropland-Pasture	3/8			30		Random		Check	
0-3	Turf-Vegetables	3/4			30		75	140	Check	Smooth
3+	Turf-Vegetables	3/4			30		Random		Check	
Coefficient = 0.10 cfs per 1000 feet of drain for blueberries, cropland and pasture. Coefficient = 0.15 cfs per 1000 feet of drain for turf and vegetables. Filters may be needed.										

Series: PLUMMER

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-1	Blueberries	C	4	10	10	24	80	200		
0-1	Cropland	C	4	10	10	24	120	300		
0-1	Pasture	D	4	10	10	24	60	140		
0-1	Turf-Vegetables	B	4	10	10	24	50	120		
This soil formed in sandy and loamy sediments of marine terraces. Drainage problem: high water table.										
Surface Drainage – Main or Lateral										
0-1	Blueberries	C	1	3	24		200			
0-1	Cropland	C	1	3	24		300			
0-1	Pasture	D	1	3	24		140			
0-1	Turf-Vegetables	B	1	3	24		120			
Water level control is desirable for blueberries.										
Subsurface Drain										
0-1	Blueberries	3/8			30	48	190		Check	
0-1	Cropland	3/8			30	48	250	300	Check	
0-1	Pasture	3/8			30	48	125		Check	
0-1	Turf-Vegetables	3/4			30	48	70		Check	
Coefficient = 0.10 cfs per 1000 feet of drain for blueberries, cropland and pasture. Coefficient = 0.15 cfs per 1000 feet of drain for turf and vegetables. Filters may be needed.										

Series: POMPTON

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24	75			
3+	Cropland-Pasture	C	4	10	10	24	Random			
0-3	Turf	B	4	10	10	24	50			
3+	Turf	B	4	10	10	24	Random			
This soil formed in glacial water sorted, sandy and gravelly materials dominated by granitic gneiss. Drainage problems: depressions, seeps.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	1	3	24		100			
3+	Cropland-Pasture	C	1	3	24		Random			
0-3	Turf	B	1	3	24		75			
3+	Turf	B	1	3	24		Random			
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	48	75	300		
3+	Cropland-Pasture	3/8			30	48	Random			
0-3	Turf	3/4			30	48	40	250		
3+	Turf	3/4			30	48	Random			
Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.10 cfs per 1000 feet of drain for turf.										

Series: PORTSMOUTH

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-2	Cropland-Pasture	C	4	10	10	24	45			Smooth
0-2	Turf-Vegetables	B	4	10	10	24	30			Smooth
This soil formed in a mantle of highly silty sediments over older, coarser sediments of marine or alluvial origin. Drainage problem: high water table.										
Surface Drainage – Main or Lateral										
0-2	Cropland-Pasture	C	1.5	3	24		75	120		Smooth
0-2	Turf-Vegetables	B	1.5	3	24		50	75		Smooth
Land smoothing may be needed for surface drainage.										
Subsurface Drain										
0-2	Cropland-Pasture	3/8			30	48	60	100		
0-2	Turf-Vegetables	3/4			30	48	30	60		
Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.10 cfs per 1000 feet of drain for turf and vegetables.										

Series: PREAKNESS

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-2	Cropland-Pasture	C	4	10	10	24	60			Smooth
0-2	Turf-Vegetables	B	4	10	10	24	50			Smooth
This soil formed in stratified coarse textured material. Drainage problem: high water table, outlet.										
Surface Drainage – Main or Lateral										
0-2	Cropland-Pasture	C	1	3	24		90	200		Smooth
0-2	Turf-Vegetables	B	1	3	24		75	150		Smooth
Land smoothing may be needed for surface drainage.										
Subsurface Drain										
0-2	Cropland-Pasture	3/8			30	48	60	170	Check	
0-2	Turf-Vegetables	3/4			30	48	30	100	Check	
Coefficient = 0.10 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.15 cfs per 1000 feet of drain for turf and vegetables. Filter may be needed.										

Series: RARITAN

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-2	Cropland-Pasture	C	4	10	10	24	75			Smooth
2+	Cropland-Pasture	C	4	10	10	24	Random			
0-2	Turf-Vegetables	B	4	10	10	24	50			Smooth
2+	Turf-Vegetables	B	4	10	10	24	Random			
This soil formed in sediments washed from red shale, siltstone, and sandstone uplands. Drainage problem: seasonal high water table. Use shallow field ditches to drain depressions.										
Surface Drainage – Main or Lateral										
0-2	Cropland-Pasture	C	2	3	24		90			Smooth
2+	Cropland-Pasture	C	2	3	18		Random			
0-2	Turf-Vegetables	B	2	3	24		60			Smooth
2+	Turf-Vegetables	B	2	3	18		Random			
Land smoothing may be needed for surface drainage on flatter slopes. Use ditches along toe of slopes to pick up seeps..										
Subsurface Drain										
0-2	Cropland-Pasture	3/8			30	48	40	165		Smooth
2+	Cropland-Pasture	3/8			30	48	Random			
0-2	Turf-Vegetables	3/4			30	48	40			Smooth
2+	Turf-Vegetables	3/4			30	48	Random			
Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.10 cfs per 1000 feet of drain for turf and vegetables.										

Series: READINGTON

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24		200		Smooth
3+	Cropland-Pasture	C	4	10	10	24	Random			
0-3	Turf	B	4	10	10	24		200		Smooth
3+	Turf	B	4	10	10	24	Random			
This soil formed in medium textured residuum largely from red shale, siltstone, and fine grained sandstone. Drainage problems: perched water table, seeps. Use shallow field ditches and land smoothing for surface drainage.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	2	3	18			200		Smooth
3+	Cropland-Pasture	C	2	3	18		Random			
0-3	Turf	B	2	3	18			200		Smooth
3+	Turf	B	2	3	18		Random			
Land smoothing may be needed for surface drainage on flatter slopes. Depth to fragipan ranges from 24 to 36 inches. Fragipan is about 20 inches in thickness.										
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	48		200		
3+	Cropland-Pasture	3/8			30	48	Random			
0-3	Turf	3/4			30	48		200		
3+	Turf	3/4			30	48	Random			
Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.10 cfs per 1000 feet of drain for turf. Pan restricts vertical drainage.										

Series: REAVILLE

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24		200		Smooth
3+	Cropland-Pasture	C	4	10	10	24	Random			
0-3	Turf	B	4	10	10	24		200		Smooth
3+	Turf	B	4	10	10	24	Random			
This soil formed in residuum weathered from red shale and siltstone. Drainage problems: perched water table, seeps, shallow to bedrock. Use shallow ditches and land smoothing for surface drainage.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	1	3	18			200		Smooth
3+	Cropland-Pasture	C	1	3	18		Random			
0-3	Turf	B	1	3	18			200		Smooth
3+	Turf	B	1	3	18		Random			
Land smoothing may be needed for surface drainage on flatter slopes.										
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	48		200		
3+	Cropland-Pasture	3/8			30	48	Random			
0-3	Turf	3/4			30	48		200		
3+	Turf	3/4			30	48	Random			
Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.10 cfs per 1000 feet of drain for turf.										

Series: RIDGEBURY

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24	30	60		Smooth
3+	Cropland-Pasture	C	4	10	10	24	Random			
0-3	Turf	B	4	10	10	24	25	50		Smooth
3+	Turf	B	4	10	10	24	Random			
This soil formed in glacial till derived mainly from granite. Drainage problem: perched water table. Use shallow ditches to pick up seeps.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	2	3	24		75	150		Smooth
3+	Cropland-Pasture	C	2	3	24		Random			
0-3	Turf	B	2	3	24		50	100		Smooth
3+	Turf	B	2	3	24		Random			
Land smoothing may be needed for surface drainage on flatter slopes. The depth to the fragipan is about 16 inches. Fragipan is about 10 inches in thickness.										
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	48	30	60		
3+	Cropland-Pasture	3/8			30	48	Random			
0-3	Turf	3/4			30	48	20	40		
3+	Turf	3/4			30	48	Random			
Coefficient = 0.10 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.15 cfs per 1000 feet of drain for turf. Dense pan restricts vertical drainage. Subsurface drains are generally too slow to be effective unless used to intercept seeps.										

Series: ROWLAND

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-2	Cropland-Pasture	C	4	10	10	24	30	100		Smooth
0-2	Turf	B	4	10	10	24	25	75		Smooth
This soil formed in mixed alluvium derived from red shales and sandstone washed from uplands. Drainage problems: high water table, flooding. Use land smoothing and shallow ditches to drain depressions.										
Surface Drainage – Main or Lateral										
0-2	Cropland-Pasture	C	2	3	18		75	150		Smooth
0-2	Turf	B	2	3	18		50	100		Smooth
Land smoothing may be needed for surface drainage.										
Subsurface Drain										
0-2	Cropland-Pasture	3/8			30	48	50	100		Smooth
0-2	Turf	3/4			30	48	40	60		Smooth
Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.10 cfs per 1000 feet of drain for turf. Outlet for drainage tubing is difficult to obtain.										

Series: SHREWSBURY

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-2	Blueberries	C	4	10	10	24	50	150		Smooth
0-2	Cropland-Pasture	C	4	10	10	24	60	120		Smooth
0-2	Turf-Vegetables	B	4	10	10	24	50	100		Smooth
This soil formed in redeposited sediments containing glauconite. Drainage problem: high water table. Surface drainage is important.										
Surface Drainage – Main or Lateral										
0-2	Blueberries	C	1.5	3	18		75	200		Smooth
0-2	Cropland-Pasture	C	1.5	3	24		90	175		Smooth
0-2	Turf-Vegetables	B	1.5	3	24		75	120		Smooth
Land smoothing may be needed for surface drainage. Water table varies between 1 and 4 feet.										
Subsurface Drain										
0-2	Blueberries	3/8			30	48	60	175	Check	
0-2	Cropland-Pasture	3/8			30	48	60	150	Check	
0-2	Turf-Vegetables	3/4			30	48	50	100	Check	
Coefficient = 0.10 cfs per 1000 feet of drain for blueberries, cropland and pasture. Coefficient = 0.15 cfs per 1000 feet of drain for turf and vegetables. Filter may be needed.										

Series: TIMAKWA

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-2	Vegetables-Turf	B	4	10	10	24	100			
This soil was formed in material deposited in extinct lake basins found in outwash plains or lake plains. Typically, this soil is 16 to 50 inches of muck over gray sand. Drainage problems: high water table, subsidence, outlet.										
Surface Drainage – Main or Lateral										
0-2	Vegetables-Turf	B	0.25	3	24	36	150	200		
Precautions need to be taken when ditch bottom extends into the sand subsoil as the sand will flow into the ditch causing the sides to slough creating maintenance problems.										
Subsurface Drain										
0-2	Vegetables-Turf	3/4			36	48	100	200	Check	
Coefficient = 1.00 cfs per 1000 feet of drain for vegetables or turf. In deep muck, drain tubing should not be used until 3 years after initial drainage. Pumps may be needed where outlet is not available. When tubing is placed in the fine sand subsoil, a filter is needed.										

Series: TURBOTVILLE

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24				
3+	Cropland-Pasture	C	4	10	10	24	Random			
0-3	Turf-Vegetables	B	4	10	10	24				
3+	Turf-Vegetables	B	4	10	10	24	Random			
This soil formed in glacial till or marine deposits derived mainly from granitic material. Drainage problems: perched water table, seeps. Shallow field ditches may be needed..										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	2	3	24					
3+	Cropland-Pasture	C	2	3	24		Random			
0-3	Turf-Vegetables	B	2	3	24					
3+	Turf-Vegetables	B	2	3	24		Random			
Depth to fragipan ranges from 20 to 30 inches which is about 18 inches in thickness.										
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	48				
3+	Cropland-Pasture	3/8			30	48	Random			
0-3	Turf-Vegetables	3/4			30	48				
3+	Turf-Vegetables	3/4			30	48	Random			
Coefficient = 0.10 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.15 cfs per 1000 feet of drain for turf and vegetables. Dense pan restricts vertical drainage. Subsurface drains are generally too slow to be effective, unless used to intercept seeps.										

Series: VENANGO

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24	100			Smooth
3+	Cropland-Pasture	C	4	10	10	24	Random			
0-3	Turf	B	4	10	10	24	80			Smooth
3+	Turf	B	4	10	10	24	Random			
This soil formed in glacial till material weathered from shale, sandstone and slate. Drainage problems: perched water table, seeps. Use shallow field ditches to pick up seeps.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	1	3	20		200			Smooth
3+	Cropland-Pasture	C	1	3	20		Random			
0-3	Turf	B	1	3	20		180			Smooth
3+	Turf	B	1	3	20		Random			
Land smoothing may be needed for surface drainage on flatter slopes. Depth to fragipan ranges from 12 to 25 inches. Fragipan is about 25 inches in thickness.										
Subsurface Drain										
	Cropland-Pasture	3/8			30	48	Random			Smooth
	Turf	3/4			30	48	Random			Smooth
Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.10 cfs per 1000 feet of drain for turf. Pan restricts vertical drainage. Subsurface drains are generally too slow to be effective unless used to intercept seeps.										

Series: WALLKILL

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-2	Cropland-Pasture	C	4	10	10	24				Smooth
0-2	Turf-Vegetables	B	4	10	10	24				Smooth
This soil formed in alluvium overlaying organic soil material. Drainage problem: high water table.										
Surface Drainage – Main or Lateral										
0-2	Cropland-Pasture	C	2	3	18	48				Smooth
0-2	Turf-Vegetables	B	2	3	18	48				Smooth
Subsurface Drain										
0-2	Cropland-Pasture	3/8			30	48				Smooth
0-2	Turf-Vegetables	3/4			30	48				Smooth
Coefficient = 0.10 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.15 cfs per 1000 feet of drain for turf and vegetables.										

Series: WATCHUNG

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope		Depth Inches		Spacing Feet		Filter	Surface Treatment
			Min	Rec	Min	Max	Min	Max		
Surface Drainage – Field Ditch										
0-2	Cropland-Pasture	C	4	10	10	24		150		Smooth
0-2	Turf	B	4	10	10	24		100		Smooth
This soil formed in material weathered from dark gray or black igneous rock. Drainage problems: seasonal high water table, flooding. Use shallow field ditches and land smoothing for surface drainage.										
Surface Drainage – Main or Lateral										
0-2	Cropland-Pasture	C	1.5	3	12			150		Smooth
0-2	Turf	B	1.5	3	12			100		Smooth
Subsurface Drain										
0-2	Cropland-Pasture	3/8			30	48	Random			
0-2	Turf	3/4			30	48	Random			
Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.10 cfs per 1000 feet of drain for turf. Outlet for drainage tubing is difficult to obtain. Use subsurface drain to pick up seeps.										

Series: WAYLAND

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-2	Cropland-Pasture	C	4	10	10	24	Random			Smooth
0-2	Turf	B	4	10	10	24	Random			Smooth
This soil formed in recent alluvium that was derived mostly from limestone. Drainage problems: perched water table, flooding. Use shallow field ditches and land smoothing for surface drainage.										
Surface Drainage – Main or Lateral										
0-2	Cropland-Pasture	C	1.5	3	24		Random			Smooth
0-2	Turf	B	1.5	3	24		Random			Smooth
Land smoothing may be needed for surface drainage.										
Subsurface Drain										
0-2	Cropland-Pasture	3/8			30	48	Random			Smooth
0-2	Turf	3/4			30	48	Random			Smooth
Coefficient = 0.10 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.15 cfs per 1000 feet of drain for turf.										

Series: WEEKSVILLE

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-2	Blueberries	C	4	10	10	24	45			Smooth
0-2	Cropland-Pasture	C	4	10	10	24	45			Smooth
0-2	Turf-Vegetables	B	4	10	10	24	30			Smooth
This soil formed in very fine sediments of marine origin. Drainage problem: high water table.										
Surface Drainage – Main or Lateral										
0-2	Blueberries	C	1	3	18		50			Smooth
0-2	Cropland-Pasture	C	1	3	18		50			Smooth
0-2	Turf-Vegetables	B	1	3	18		45			Smooth
Land smoothing may be needed for surface drainage.										
Subsurface Drain										
0-2	Blueberries	3/8			30	48	55	200	Req’d	Smooth
0-2	Cropland-Pasture	3/8			30	48	50	175	Req’d	Smooth
0-2	Turf-Vegetables	3/4			30	48	30	100	Req’d	Smooth
Coefficient = 0.08 cfs per 1000 feet of drain for blueberries, cropland and pasture. Coefficient = 0.10 cfs per 1000 feet of drain for turf and vegetables.										

Series: WHIPPANY

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24		200		Smooth
3+	Cropland-Pasture	C	4	10	10	24	Random			
0-3	Turf	B	4	10	10	24		200		Smooth
3+	Turf	B	4	10	10	24	Random			
This soil formed in thick deposits of lacustrine sediment derived from red and brown shale and sandstone, basalt and granite. Drainage problems: perched water table, seeps, shallow to bedrock. Use shallow ditches and land smoothing for surface drainage.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	1.5	3	24			200		Smooth
3+	Cropland-Pasture	C	1.5	3	24		Random			
0-3	Turf	B	1.5	3	24			200		Smooth
3+	Turf	B	1.5	3	24		Random			
Land smoothing may be needed for surface drainage on flatter slopes.										
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	48	Random			
3+	Cropland-Pasture	3/8			30	48	Random			
0-3	Turf	3/4			30	48	Random			
3+	Turf	3/4			30	48	Random			
Coefficient = 0.08 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.10 cfs per 1000 feet of drain for turf.										

Series: WHITMAN

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24	25	50		Smooth
3+	Cropland-Pasture	C	4	10	10	24	Random			
0-3	Turf	B	4	10	10	24	20	45		Smooth
3+	Turf	B	4	10	10	24	Random			
This soil formed in glacial till derived mostly from granite, gneiss, and schist. Drainage problems: seasonal perched water table, seeps. Use shallow ditches to pick up seeps and drain depressions.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	1.5	3	24		25	75		Smooth
3+	Cropland-Pasture	C	1.5	3	18		Random			
0-3	Turf	B	1.5	3	24		20	60		Smooth
3+	Turf	B	1.5	3	18		Random			
Land smoothing may be needed for surface drainage on flatter slopes.										
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	48	20	60		
3+	Cropland-Pasture	3/8			30	48	Random			
0-3	Turf	3/4			30	48	15	40		
3+	Turf	3/4			30	48	Random			
Coefficient = 0.10 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.15 cfs per 1000 feet of drain for turf. Use subsurface drains to intercept seeps.										

Series: WOODSTOWN

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24	60	180		Smooth
3+	Cropland-Pasture	C	4	10	10	24	Random			
0-3	Turf-Vegetables	B	4	10	10	24	50	150		Smooth
3+	Turf-Vegetables	B	4	10	10	24	Random			
This soil formed in sandy marine and older alluvial sediments. Drainage problem: seasonal high water table. Use shallow field ditches and land smoothing for surface drainage.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	1.5	3	24		150	300		Smooth
3+	Cropland-Pasture	C	1.5	3	24		Random			
0-3	Turf-Vegetables	B	1.5	3	24		100	200		Smooth
3+	Turf-Vegetables	B	1.5	3	24		Random			
Surface drainage is important.										
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	48	75	175	Check	Smooth
3+	Cropland-Pasture	3/8			30	48	Random		Check	
0-3	Turf-Vegetables	3/4			30	48	50	100	Check	Smooth
3+	Turf-Vegetables	3/4			30	48	Random		Check	
Coefficient = 0.10 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.15 cfs per 1000 feet of drain for turf and vegetables. Filter may be needed.										

Series: WURTSBORO

Average Land Slope	Crop or Landuse	Drain Coef.	Side Slope Min	Side Slope Rec	Depth Inches Min	Depth Inches Max	Spacing Feet Min	Spacing Feet Max	Filter	Surface Treatment
Surface Drainage – Field Ditch										
0-3	Cropland-Pasture	C	4	10	10	24	25	50		Smooth
3+	Cropland-Pasture	C	4	10	10	24	Random			
0-3	Turf	B	4	10	10	24	25	40		Smooth
3+	Turf	B	4	10	10	24	Random			
This soil formed in a medium of coarse textured glacial till derived from quartzite, conglomerate, and sandstone. Drainage problems: perched water table, seeps. Use shallow ditches to drain depressions.										
Surface Drainage – Main or Lateral										
0-3	Cropland-Pasture	C	1.5	3	24		30	50		Smooth
3+	Cropland-Pasture	C	1.5	3	18		Random			
0-3	Turf	B	1.5	3	24		20	35		Smooth
3+	Turf	B	1.5	3	18		Random			
Land smoothing may be needed for surface drainage on flatter slopes. The depth to the fragipan varied from 17 to 28 inches. Fragipan varies from 12 to 30 inches in thickness.										
Subsurface Drain										
0-3	Cropland-Pasture	3/8			30	48	25	45		
3+	Cropland-Pasture	3/8			30	48	Random			
0-3	Turf	3/4			30	48	20	35		
3+	Turf	3/4			30	48	Random			
Coefficient = 0.10 cfs per 1000 feet of drain for cropland and pasture. Coefficient = 0.15 cfs per 1000 feet of drain for turf. Dense pan restricts vertical drainage. Subsurface drains are generally too slow to be effective unless used to intercept seeps.										

Appendix C Drainage for Agricultural Structures

Contents **NJ650.14C**

Figures

NJ650.14C Drainage for Agricultural Structures

a) Introduction

NRCS in New Jersey provides assistance on agricultural structures including agrichemical handling facilities, heavy use areas, and waste storage facilities. These structures may be roofed or unroofed. Proper drainage or management of surface and subsurface water around agricultural structures helps to ensure that these facilities can be operated and maintained as intended. Depending on the site, this will generally include diversion of surface water, disposal of roof runoff, and the lowering or interception of ground water. Conditions that commonly cause problems include:

- The land is flat or slopes toward the facility, permitting surface water (rain and melting snow) to drain in or around the structure.
- Lack of gutters and downspouts to handle roof water from rain and snow. The free-falling water may blow into the facility or form puddles, or wet soil conditions around the structure.
- The ground water level is close to the underside of the floor slab. Water rises through the slab by capillarity, producing dampness.
- For below grade structures, high ground water levels may increase loads on walls and slabs, reduce available storage due to inflow, or be susceptible to contamination due to leakage of stored wastes or pollutants.

b) Site Selection

With proper site selection and planning, many adverse conditions due to poor drainage can be avoided. General information on soil conditions, seasonal high water tables and so forth may be found in the local soil survey report. This information must be verified with an on-site investigation to confirm conditions critical to the site plan and structural design.

An important consideration in selecting the site for a new agricultural structure is proper drainage. This includes not only drainage of surface, but also drainage of any subsurface or ground water that may be present or that may accumulate over a period of time and be blocked from its normal course of flow by the new construction.

High points on the landscape often provide the best building sites and the best surface conditions for drainage. An elevated site provides good surface drainage away from the structure in all directions.

On sloping ground, level foundation areas may be created by cutting into the slope, filling out from the slope, or by a combination of cutting and filling. Surface water should be intercepted upslope of the facility and safely conveyed and released in a down slope location. Deep cuts may expose perched or seasonal high ground water tables that will result in seepage. Surface or subsurface drains may be needed to intercept and divert the seepage flow from the facility.

If the site is flat, the ground must be built up or graded to drain surface water away from the foundation.

Ideal sites are those with well drained soils where the seasonal high ground water level will be several feet below the deepest structural footing or foundation; are outside of flood plains or paths of concentrated flows; and are readily accessible in terms of farm operation and management needs.

c) Surface drainage

Surface drainage around an agricultural structure generally consists of a diversion constructed upslope of the facility to intercept sheet or shallow concentrated flows. Diversions are sized to handle a specified 24-hour design storm frequency based on the type of structure being protected. All structures should be located outside of floodplains or areas of concentrated flow.

d) Subsurface drainage

When areas having a high water table cannot be avoided, subsurface drainage may be required. It may be necessary to install a drain line or systematic pattern of drain lines in order to lower the ground water level and provide an adequate separation distance between the water table and the structure slab or foundation. Typically, the subsurface drain lines are installed with sand and gravel envelopes to improve interception and inflow into the drainage conduits. The systems should be conservatively designed with an adequate safety factor based on the knowledge and certainty of site conditions and the type or purpose of the structure.

Structural drains are often required around below grade structures such as storage tanks. On-site investigations and sampling will be necessary to properly design the structural drains and filter necessary to insure loading assumptions are met for pre-designed structures or to provide the geotechnical parameters needed for unique structural designs. Refer to the appropriate NRCS structural design and soil mechanics references when designing structural drainage systems.

e) Grading

Agricultural buildings typically include slabs constructed at or close to grade for ease of access by farm equipment or livestock. To maintain positive drainage away from buildings, floor slabs should be elevated a minimum of eight to twelve inches above the surrounding grade. Fill at access locations should be sloped away from the slab at a grade no steeper than fifteen percent. Other areas should be graded at 3H:1V or flatter depending on use and maintenance needs. The land slope in the vicinity of the structure should be a minimum of one percent, and preferable two percent, to avoid ponding during storm events or snow melt. Diversions or grassed waterways may be needed to intercept and convey runoff safety away from the facility.

Below grade structures such as standard waste storage tanks may have specific fill and grading requirements based on structural loading assumptions. These requirements must be met in the site grading plan.

f) Roof runoff

When roofs are installed as a component of an agrichemical handling facility, heavy use area, or waste storage structure, consideration needs to be given to management of roof runoff. Gutters and downspouts are recommended when blow-in of precipitation from the roof eaves is undesirable, or when roof runoff needs to be collected to avoid contamination, control erosion, improve site drainage, supplement water supplies, or to supplement infiltration. Collection systems may also consist of swales, troughs, or gravel filled trenches located along the drip line of the roof, especially where gutters may collect leaves or debris, or may not be easily adapted to the building eave. Gravel filled trenches may include perforated pipe, and non-perforated pipe to convey infiltrated runoff to an area of use or safe disposal. Likewise, downspouts may be connected to underground conduits for conveyance away from the structure. Surface disposal via a splash pad at the downspout may be acceptable where there are not water quality, storm water management, or erosion concerns. See figures C-1 and C-2 for typical installations.

Gutters, downspouts, and underground conduits are sized based on the peak discharge from a 10 year, 5 minute precipitation event except in manure management of concentrated livestock systems where the design storm is the 25 year, 5 minute event. Where collection tanks or infiltration structures are a part of the runoff management system, longer duration storms may need to be considered. Infiltration structures should be located at least 10 feet from building foundations, be accessible for monitoring, and be equipped with an overflow or by-pass pipe located at the structure or the downspout.

g) Dewatering

Dewatering is the temporary collection and disposal of ground water from an excavated area. The type of dewatering system needed depends on the site specific ground water and soil conditions; the depth and duration of excavation; and the soil moisture conditions required for construction. A typical dewatering system consists of a section of perforated pipe installed vertically in a low area of the excavation, backfilled with gravel, and into which a small sump pump or suction line is placed. Although for most NRCS-assisted projects, the contractor is responsible for submitting a dewatering plan, a site investigation is needed for design so that ground water conditions and dewatering needs pertinent to the structure can be identified. Also, quality assurance personnel should be knowledgeable of ground water conditions for evaluation of the contractor's dewatering plan.

Figure C-1 Typical downspout-splash pad installation

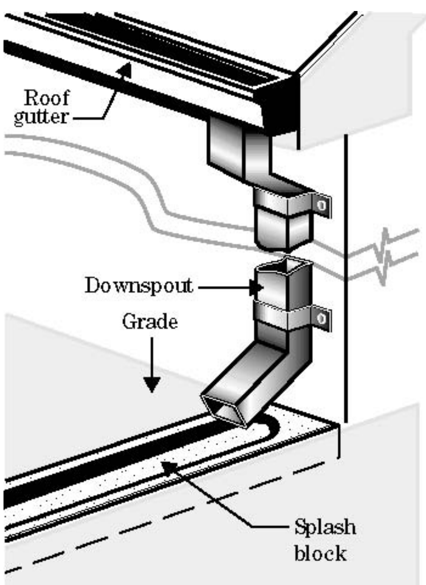
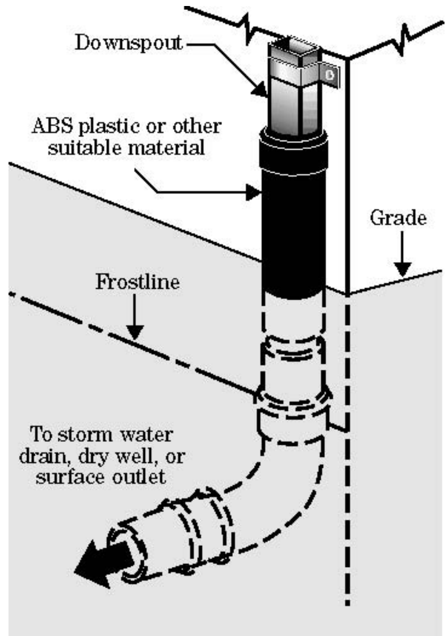


Figure C-2 Typical downspout-underground outlet pipe installation



h) Maintenance

Roof runoff structures and runoff management systems have estimated service lives of 15 years. Service life can be achieved and prolonged through proper maintenance. Standardized operation and maintenance plans have been developed for roof runoff structures and runoff management systems. These can be found in the NRCS New Jersey electronic Field Office Technical Guide.

Appendix D Restoration of Drained Areas

Contents NJ650.14D

NJ650.14D Restoration of Drained Areas

a) Introduction

For centuries, drainage has been a common practice in New Jersey. Agricultural land has been created and enhanced, often at the expense of wetland ecosystems. Today there are opportunities to restore wetlands by modifying, interrupting, or removing the drainage systems installed to convert these areas to agricultural production.

This Appendix provides an overview of the evaluation process that can be used to help select what will be a successful restoration site and presents some general guidance on techniques for reestablishing wetland soil and hydrologic conditions. More detailed information on wetland restoration including biological, vegetation, and wildlife aspects can be found in Engineering Field Handbook Chapter 13, Wetland Restoration, Enhancement, or Creation.

b) Goals and objectives

The goal of restoration is to return an area as close as practical to the pre-drained ecological condition in terms of wetland function, value, habitat, diversity, and capacity. Frequently, it will not be possible to fully restore an area simply by removing or impairing the drainage system. Other local, regional, or physical changes may have occurred that will limit the recreation of pre-drained conditions such as the oxidation and subsidence of drained organic soils; downgrading of stream channels limiting overflow frequency into flood plains; upstream migration of saline conditions in tidal rivers; or land use changes in the contributing watershed.

Objectives may include the enhancement of certain functions beyond what existed historically. For example, there may be the desire to diversify habitat by the creation of shallow or open water pools within the restoration area.

Only with goals and objectives established can planners begin to evaluate a proposed restoration site and determine what can be accomplished through removal of the existing drainage features and what additional measures or management features may be necessary to achieve the desired conditions.

c) Site evaluation

Data collection is the first phase of site evaluation in planning a wetland restoration project. The information obtained is often used to determine feasibility. The level of data collection will depend on the complexity of the proposed project. For restoring drained areas, the following may be needed:

- Extent and type of existing drainage system
- Existing and converted wetland area boundaries
- Watershed information such as drainage area, land use, stream parameters, etc
- Soils investigation to determine texture, permeability, depth to water, presence of restrictive layers, etc
- Soil testing for nutrients, pH, organic matter content, etc for plant establishment
- Topographic data
- Environmental assessment including native vegetation, fish and wildlife habitat, cultural resources, etc
- Water inputs including quantity and quality

Site evaluation involves looking beyond the limits of the drained area considered for restoration. Impacts to adjacent land uses caused by a loss or reduction in drainage efficiency need to be determined. This can include impacts to roadways, structures, septic systems, cropland, woodland and other land uses from the alteration of both surface and ground water conditions. In tidal areas, changes in water quality due to an increase in salinity levels may occur. Impacts on irrigation water supplies, vegetation and shallow wells should be investigated.

Hydrologic systems

Wetlands form in three basic hydrologic systems: depressional, riparian, and tidal. All occur in New Jersey and areas of each have been drained for agricultural production. In considering a site for restoration, identify what drainage practices have been installed. Also take note of any physical changes that may have taken place since the area was drained that could complicate restoration.

(1) Depressional wetlands

Depressional wetlands include areas where water collects or pools due to lack of a positive surface outlet and poor infiltration caused by a restrictive soil layer, or high ground water level. Drainage measures for these areas have included surface ditches, subsurface drain conduits or a combination of both. Depressions, especially shallow areas, may have been removed through land grading. Also, diversions may have been installed to intercept and remove surface water from contributing upland areas. Subsidence has occurred in areas where highly organic soils have been drained.

(2)Riparian wetlands

Riparian wetlands occur along rivers and streams. They also include areas of seeps and springs that contribute to surface flow. Most of these wetland areas in New Jersey include a ground water component in addition to surface water from out of bank flooding. Drainage of riparian wetlands has typically been accomplished with surface ditches that are often supplemented with subsurface conduits. Land grading has been used to elevate low areas and reduce the frequency of flooding. Diking along the bank of a stream or non-tidal river has not been a common practice, although it has been used to create bogs or reservoirs in areas of cranberry production. Streams and rivers have been modified to reduce flooding and improve drainage both for agriculture and mosquito control. In some areas, streams have become incised which has reduced the frequency of out of bank flooding.

(3)Tidal wetlands

Historically, tidal wetlands have been drained for agricultural production, primarily salt hay. Beginning in the late 1700's, meadow companies were chartered for the purpose of constructing and maintaining dikes and channels. Dikes constructed along river banks and estuary edges prevent tidal inundation of adjacent uplands, while networks of channels and ditches convey drainage and runoff to water control structures that provide outlets through the dikes. These dikes and tidegate structures often separate brackish tidal water from upland freshwater. Where organic soils have been drained, subsidence has occurred.

Soils

An investigation to assess the soils at the site of a proposed restoration must be conducted. The soil survey provides an overview of expected conditions which need to be field verified. The intensity of the investigation will depend on the extent and complexity of the site. Test pits or borings should be used to fully describe the soil profile including texture, structure, moisture condition, evidence of perched, seasonal, or permanent ground water levels, etc. On-site testing or the taking of samples for laboratory testing may be necessary. Factors important to the establishment of vegetation such as soil pH, organic matter content, and nutrient levels should be determined.

Water Budget

In evaluating the suitability of a site for restoration, the source of water that will supply the wetland must be carefully evaluated. A water budget for a wetland is an account of inflow, storage, and outflow of water. Water inflow includes precipitation, storm water runoff from a contributing drainage area, base flow from streams and surface sources, seepage and springs from ground water sources, tidal inflow, and water artificially added to a wetland. Water storage includes the water on the surface and in the pore space of the substrate. The wetland substrate is the accumulated organic matter and the soils from the surface of the wetland to the bottom of the potential rooting zone. Water outflow includes evaporation from the surface, transpiration from the plants, deep percolation below the substrate, surface base flow, tidal outflow, storm water outflow, and water artificially removed from the wetland. Where existing drainage systems will be impaired or removed, evaluate the quantity and efficiency of water removal. Consider upstream, on-site, and downstream impacts of drainage system changes.

Vegetation

The selection of vegetation for a restoration site will be based primarily on objectives, site conditions, and availability. Consideration should be given to plant species value for wildlife food and cover, and erosion control. Preference should be given to native species typical of adjacent wetland areas. Planting to establish vegetation may not always be necessary. Natural colonization may be considered where adequate seed stock exists in the wetland substrate and there is a reasonable expectation of success.

d) Drainage alteration measures

Restoration of a previously drained wetland area can be accomplished, at least in part, by modifying, interrupting, or removing the drainage system. In some situation, additional measures may be required to mitigate for other physical changes that have occurred since the area was drained, or to enhance the wetland beyond what can be accomplished through alteration of the existing drainage system.

Subsurface drain plugs

Over the years, subsurface drainage has been accomplished with the installation of clay drainage tile and, more recently, perforated plastic drainage tubing. Drainage effects can be reversed by plugging or removing portions of the drainage tile or conduit.

The minimum length of the drain to be removed or plugged is based on the average hydraulic conductivity of the soil. For rates over 2.0 inches per hour (sands and organic soils), the length is 150 feet; where the rate is between 0.6 and 2.0 inches per hour (loams), remove or plug 100 feet; and use 50 feet where the rate is under 0.6 inches per hour (clayey soils). Both the drain line and any envelope material should be removed for the specified length. The trench opened for disruption of the drain line should be filled and the soil compacted.

When upland portions of the drainage system are to remain functional, the drain lines through the proposed wetland area can be replaced with non-perforated pipe or re-routed around the area. Consider ground water availability, soil conditions, and lateral drainage effects in evaluating if restoration will be successful.

When the ability to manage ground water levels is desired, water control structures may be added to subsurface drain lines as described for controlled drainage in Chapter 5, Water Table Management.

Surface drain plugs

Wetland areas drained with ditches can be restored by constructing plugs or water control structures in the open drain system.

For field ditches and laterals with little contributing drainage area, plugging can be accomplished by filling a 50 foot length of the open drain with compacted soil. The soil should be crowned a minimum of one foot above the lower bank.

When runoff from the contributing drainage area could result in overtopping of the plug, provisions must be made to store, pass through, or divert excess runoff. Options may include

- armoring the ditch plug for overtopping,
- extending the overfill for the ditch plug 50 feet laterally into the flood plain to disperse flow around the plug,
- grading broad, shallow auxiliary spillways around the plug to return flow to the ditch downstream of the plug, or
- installing a drop structure.

Old spoil piles from construction or maintenance activity may exist adjacent to the ditch. Openings may need to be created through the piles to avoid concentrating flow over the ditch plug and to allow flow into the flood plain.

Drop structures may be equipped with stop logs to allow management of water levels where desired as a part of the restoration plan.

Dikes

Restoration plans can include breaching existing dikes to restore tidal or storm flows into drained areas. Breach width may depend on soil conditions, depth and duration of flow, and the level of inundation to be achieved in the previously drained area. Where erosion or continued widening of the breach is a concern, consideration can be given to armoring or gently grading the ends of the dike fill. Channels may be constructed through a breach to improve flow into the restoration area.

Restoration plans may also include construction of low dikes designed to retain surface water in the restored area. Outlet structures and auxiliary spillways may be necessary depending on the contributing drainage area and depth of impoundment. Dikes should not be constructed in flood plain areas where they will restrict out of bank flow during storm events.

Land forming

Land forming includes altering the topography and can include:

- Removal of sediment or fill to recreate original grades,
- Creation of micro-topographic features such as small isolated shallow pools and hummocks,
- Excavation of shallow impoundments to intercept surface runoff or ground water.

Soil sealing

Where soils are too permeable to retain water to the degree desired in the restoration plan, sealing or lining may be necessary. Generally, sealing will be feasible only for small areas.

Sealing may be accomplished through compaction of on-site soils that have a sufficient content of clayey fines. (See National Engineering Handbook, Part 651, Agricultural Waste Management Field Handbook, Chapter 10.) Where on-site soils are not suitable, the addition of bentonite may be required. Synthetic liners may be used, but can be costly. The sealed soil layer or liner should be covered with at least a one foot thickness of soil or wetland substrate material.

e) Maintenance

Plans for the restoration of previously drained area should strive to return the area to as natural a condition as possible. Long term maintenance requirements should be minimized by limiting structural components. Likewise, limiting structural components that have a relatively short service life, will help to ensure the longevity and value of the restored ecosystem.

Frequent inspections and maintenance during an initial establishment period is expected. Where structures or devices for manipulation of ground or surface water levels are included in the project, an operation plan including management objectives is to be developed.

Appendix E Tools and Worksheets

This appendix is available to the user for supplementing the New Jersey Water Management Guide with useful tools, worksheets, design examples, and other information relating to water management.