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Subsurface Drain

Description

A subsurface drain is a perforated conduit, such as tile, pipe or tubing, installed below the ground surface to intercept, collect, and/or convey drainage water. Subsurface drains are designed to remove excess water from soil. Uses include:

- improving the soil environment for vegetative growth by regulating the water table and ground water flow
- intercepting and preventing water movement into a wet area
- serving as an outlet for other subsurface drains
- regulating and controlling ground water for subirrigated areas or waste disposal areas
- removing surface runoff and ponded water around buildings, roads, airports, recreational fields and physical improvements

Subsurface drains are most beneficial in providing internal drainage of slopes to improve their stability and reduce erosion.

Other Terms Used to Describe

Drainage Tile
Interceptor Drain
Relief Drain
Tile
Underground Drain

Pollutants Controlled and Impacts

Subsurface drains are effective, although expensive, means of controlling stormwater or lowering a water table.

It is important to note that soluble phosphorus may be transported to surface water through subsurface drainage tiles. In addition, the ground water table may be depleted due to the installation of subsurface drains. This may jeopardize water supply needs, and may cause serious damage to wetlands.

Application

Land Use
Applicable to all land uses.

Soil/Topography/Climate
The soil should have enough depth and permeability to permit installation of an effective and economically feasible system.

When to Apply
Subsurface drains are used when it is necessary to remove excess water form soil, or to improve infiltration or percolation characteristics of soil in stormwater management facilities. Sometimes it is also necessary to use subsurface drains because the topography is not suitable to direct water to design locations. Subsurface drains will also be used when the topography would require a very deep "cut" through a hill or ridge in order to direct stormwater to a desirable outlet.

Where to Apply
Apply in areas: where it is necessary to intercept groundwater so slopes can be stabilized; where it is necessary to relieve hydrostatic pressure behind retaining walls and other similar structures; to provide a stable base for construction; or where lowering the water table justifies the installation of such a system.

Relationship With Other BMPs

Subsurface drains provide internal drainage behind bulkheads, seawalls, retaining walls and other Slope/Shoreline stabilization Structures.

They also provide drainage for dry storm water management structures and infiltration BMPs.

Specifications

Planning Considerations:

1. Conduct a site inspection to ensure that the site is suited for the proposed use(s). All potential impacts should be assessed prior to the onset of construction, with particular attention given to the potential impact of altering the water table.

   Where possible, do not install drain lines within 50 feet of trees to avoid tree roots that may clog the line. Use solid pipe with water-tight connections where tree roots cannot be avoided.

2. Evaluate soils to determine the appropriate method of installation. Certain soils necessitate using an envelope of granular drain material to maximize effectiveness.

3. Determine the appropriate **type** of subsurface drain needed. There are three types of drains:

   A. **Relief drains** (tile systems). These are used to lower the water table in large, relatively flat areas that frequently become too wet to support desirable vegetation. Although surface water may also be carried through relief drains, it is generally better to install a separate drain for this purpose.

   Relief drains may be installed in one of three patterns, as shown in Exhibit 1. Relief drains drain in the same direction as the slope.

   B. **Under drains.** These are type of relief drain used to improve infiltration characteristics in stormwater management facilities when permeability is restricted to soil texture or high water table conditions, or to specifically filter a portion of stormwater runoff contained in detention facilities prior to discharge.

C. **Interceptor drains.** These are used to remove excess groundwater from a slope, stabilize slopes, and lower the water table immediately below a slope. They also may be used to stabilize shallow foundations such as paved channels or construction Access Roads. They usually consist of a single pipe or a series of single pipes buried perpendicular to the slope on the upstream side of wet areas.

Design Considerations:
Subsurface drains should be designed by registered professional engineers.

All materials (i.e. perforated, continuous closed-joint conduits of concrete, corrugated plastic, corrugated metal) used in the construction of subsurface drains should be strong and durable enough to meet the requirements of the site.

Capacity:

A. **Relief drains** must be designed to remove at least 1 inch of groundwater per hour over the area served, or 0.042 ft^3/sec/acre. However, when the relief drain empties into an existing stormwater system, local design standards must also be met. The design capacity must be increased accordingly to accommodate any surface water which enters the system directly.

B. **Under drains.** The capacity of underdrains should be determined in conjunction with the corresponding stormwater treatment system to achieve treatment of a minimum 0.5 inches of runoff over the entire drainage area, and insure proper operations of the facility.

C. **Interceptor drains** should be designed to remove a minimum of 1.5 cfs/1000 ft. of length. As land slope increases, capacity should be increased according to the following table:

Land Slope	Capacity
2-5%	1.65 cfs/1000 ft.
6-12%	1.80 cfs/1000 ft.
> 12%	1.95 cfs/1000 ft.

As with relief drains, additional capacity must be included in the drain if surface or flowing spring water enters the drain.

Velocity:
The minimum velocity that should be used in all subsurface drains is 2.0 feet per second. Lower velocities will allow sediment to accumulate in the drain. Maximum allowable velocities are listed in Table 1, below, based on soil texture.

Table 1

Maximum Allowable Velocities for Various Soils

Soil Texture	Maximum Allowable Velocity (fps)
Sand and sandy loam (non-colloidal)	2.5
Silt loam (also high lime clay)	3.0
Sandy clay loam	3.5
Clay loam	4.0
Stiff clay, fine gravel, graded loam to gravel	5.0
Graded silt to cobbles (colloidal)	5.5
Shale, hardpan and coarse gravel	6.0

Size:
Subsurface drains should be designed to carry the required capacity without pressure flow. It is important to consider changes in upland land uses, particularly in urbanizing areas. Changes in land uses could result in increased flows, which may significantly alter the design of the drain. The minimum diameter for a subsurface drain is 4 inches.

Depth and Spacing:

1. **Relief drains.** Relief drains should be installed in a uniform pattern, with equal spacing between the drains. All drains should be the same depth. Spacing between drains depends on soil hydraulic conductivity (i.e. permeability) and the depth of the drain. A spacing of 50 feet is adequate.

   The maximum depth is limited by the allowable load for the type of pipe, depth to an impervious layer, and outlet conditions. (The depth to an impervious layer can be determined by soil borings). In no case should the relief drain be less than 24 inches deep, and in most cases a depth of 4 feet will be adequate.

   Design equations are available which may permit a more economic design.

2. **Interceptor drains.** The depth of an interceptor drain is determined primarily by the depth to which the water table is to be lowered or the depth to a permeability-restricting layer. The maximum depth is limited by the allowable load for the type of pipe used and the depth to an impermeable layer. For practical reasons, the maximum depth is usually limited to 6 feet, with a minimum cover of 2 feet to protect the conduit. Install close to the impermeable layer to ensure stability.

Outlet:
The outlet should be designed in conjunction with the conveyance system and should be in place before water is released from the conveyance system. The outlet should empty into a channel or other watercourse such that there is no overfall from the end of the apron to the receiving channel streambed.

Outlet protection using Riprap or other approved materials should be provided if the outlet velocity exceeds the permissible velocity of the stream. Specifications for riprap as outlet protection is given in the Riprap BMP.

The soils above and around the outlet should be compacted and stabilized to prevent piping around the structure. Riprap placed 3 feet above the ordinary high water mark is recommended for all outlets.

The outlet should be constructed of corrugated metal, cast iron, steel, concrete, or heavy-duty plastic without perforations.

Bedding Conditions:
The recommended method of bedding a rigid ditch conduit is to construct an earth foundation shaped to fit the lower part of the conduit for a width of at least 50% of the conduit breadth, and in which the remainder of the conduit is surrounded to a height of at least 1 foot above its top by clean, granular materials that are shovel-placed and shove-tamped to completely fill all spaces under and adjacent to the conduit.

When sand and gravel filter or envelopes are used, the foundation need not be shaped since the filter and envelope material are placed entirely around the conduit and provide for lateral pressures on the conduit. See "Envelopes and Envelope Materials", below.

Bedding Conditions for Flexible Drainage Tubing:
A flexible conduit has relatively little inherent load-bearing strength, and its ability to support soil loadings in a trench must be derived form pressures induced as the sides of the conduit deflect and move against the soil. This inability of a flexible conduit to deform and use the soil pressure to support it is the main reason that light-weight plastic drainage tubing can support soil loadings in drainage trenches.

A flexible tubing must be installed in a trench in a way which insures good soil support from all sides. There must be no voids remaining which would permit the soil pressure from backfill to cause deflection of the tubing to the point of buckling. Most installations will be made with machinery, without requiring a person in the trench to position the tubing or place the bedding. Some modification of machinery designed for installation of rigid conduit usually is necessary to install flexible conduits efficiently.

Envelopes and Envelope Material:
Envelopes should be used around drains where proper bedding of the conduit is required, or as necessary to improve the characteristics of ground water flow into the conduit. They are most often used with flexible drain tubing.

Materials used for envelopes should not contain materials which will cause an accumulation of sediment in the conduit, or render the envelope unsuitable for bedding of the conduit. Envelopes should be a minimum of 4 inches thick, and be comprised of gravel no larger than ¾ inches in diameter.

Filter fabric can be used to encase the gravel envelope. If soil is used for the backfill, place filter cloth over the top of the gravel before backfilling to prevent soil from moving into the gravel.

Materials For The Drain:
The conduit should meet strength and durability requirements of the site. Do not use crushed or otherwise damaged materials.

Pipe Size:
Pipe size is determined based on the volume of water to be removed (Q, in cfs), slope of the pipe (s) and the velocity when flowing full (v, in ft/sec). The volume of water to be removed is the drainage coefficient (inches of water removed/day) times the entire drainage area served by the subsurface drain (square feet).

The drainage charts in the attached exhibits can be used to determine the appropriate pipe size, or the expected flow may be determined and used in the Mannings equation to determine the correct pipe size. The design example below demonstrates how the exhibits can be used.

Design Example:
Situation:
An athletic field constructed on a silt loam is experiencing wet conditions that are unsatisfactory to the athletic club. The field has a 0.4% grade and is 1,000 feet long and 750 feet wide. The subsurface drain should extend the length of the field, plus an additional 50 feet to a suitable outlet. The surrounding area is adequately drained. Determine the appropriate tubing diameter assuming plastic tubing will be used. Assume a drainage coefficient of ½" (1/2 inch of water drained in 24 hours).

1. Refer to the Maximum Allowable Velocity (MAV) table (Table 1 of this BMP) to determine the MAV for silt loam. That value is 3.0 ft/sec. Choose a pipe size that will be adequate for this velocity.

2. Determine the number of acres drained. We know that the total length equals 1,050 feet and the width of the field is 750 feet, so the area 750,000 ft^2. One acre equals 43,560 ft^2, so 750,000 ft^2 is 17.2 acres.

3. Determine the pipe size using Exhibit 3, the Plastic Drainage Chart. Align a ruler with one end on the 0.4% grade (on the bottom of the chart) and the other end on 17 acres (with a ½" coefficient). The line created by connecting these two points crosses the V = 3.0 ft/sec. line within the 4" pipe size.

Construction Considerations:
1. Install Construction Barriers to prevent unwanted access to the construction site.

2. For work which must be done in the dry, use cofferdams to divert the waterbody temporarily. Use proper Dewatering techniques.

3. Overfill the trench a few inches allow for settlement.

4. Consider installing trash racks, rodent guards, and other protective outlet devices to gather debris and keep children and animals from accessing the drain.

5. Cap the upper end of each drain with a standard cap made for this purpose, or with concrete or other suitable material to prevent soil from entering the open end.

After Construction:
Stabilize all adjacent areas following specifications for Seeding and Mulching or Sodding.

Remove Construction Barriers.

Maintenance

Properly installed drains usually require very little maintenance unless trees such as willow are permitted to grow above a subsurface drain. In this case, it may be necessary to remove root obstructions.

Maintenance may also be necessary under the following conditions:

1. If piping occurs. This may result if the drain was not constructed with a good bond with the soil. Piping can cause a complete washout of the drain.

2. On outlets which begin to capture sediment, trash or other debris. These should be cleaned and the trash racks re-installed.

3. In wet areas where the soil has caved in due to vehicle traffic, blockage by roots, or other problems. Repair the site immediately.

Note: In some cases (especially in large urban areas) maintenance may require entering the enclosed drain. All staff which enter such drains should be trained in safety techniques for entering enclosed spaces.

Exhibits

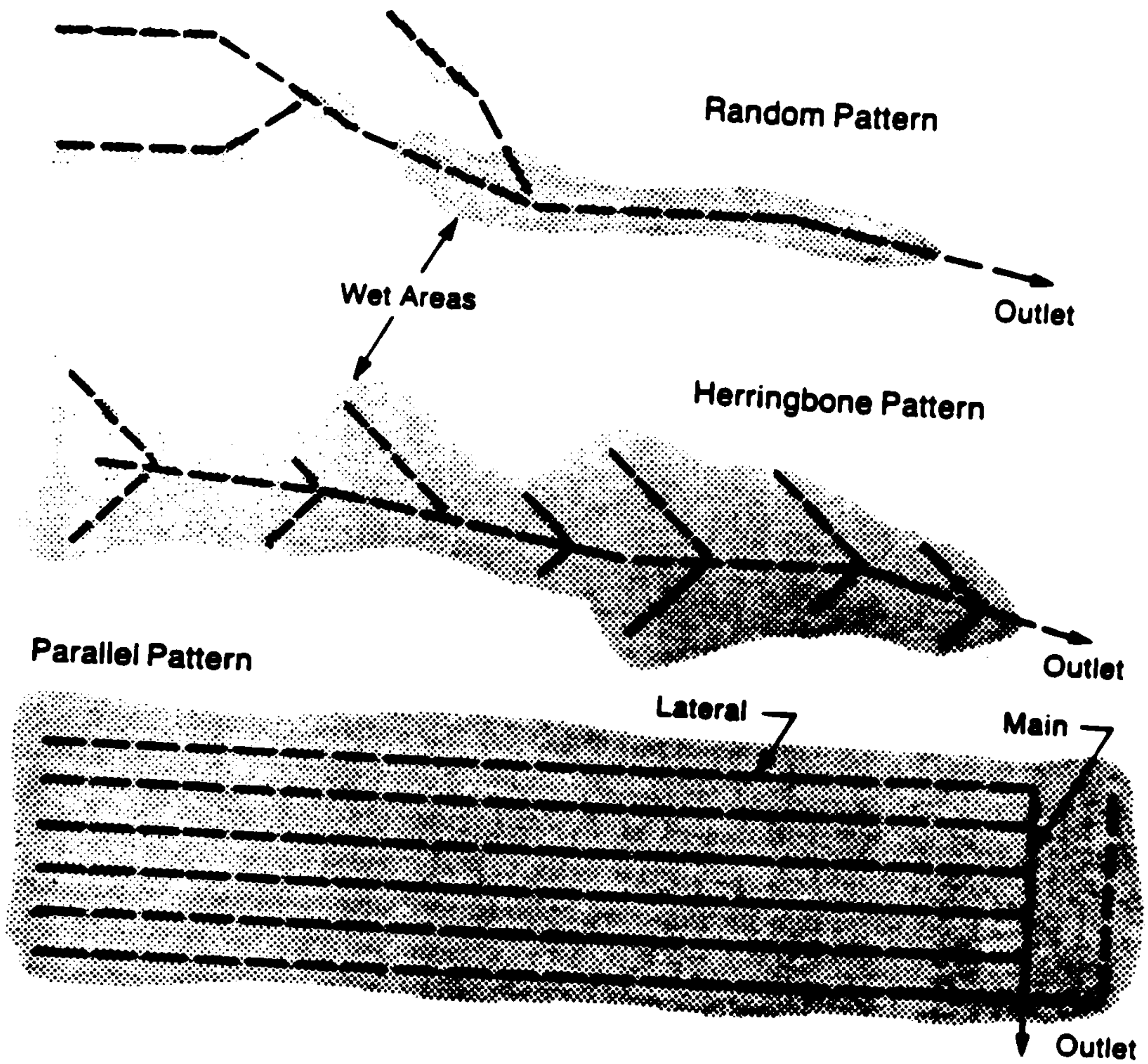
Exhibit 1: Subsurface Relief Drain Layouts. USDA, Soil Conservation Service.

Exhibit 2: Drainage Chart for Concrete Tile. USDA, Soil Conservation Service.

Exhibit 3: Drainage Chart for Plastic Pipe. USDA, Soil Conservation Service.

Exhibit 1

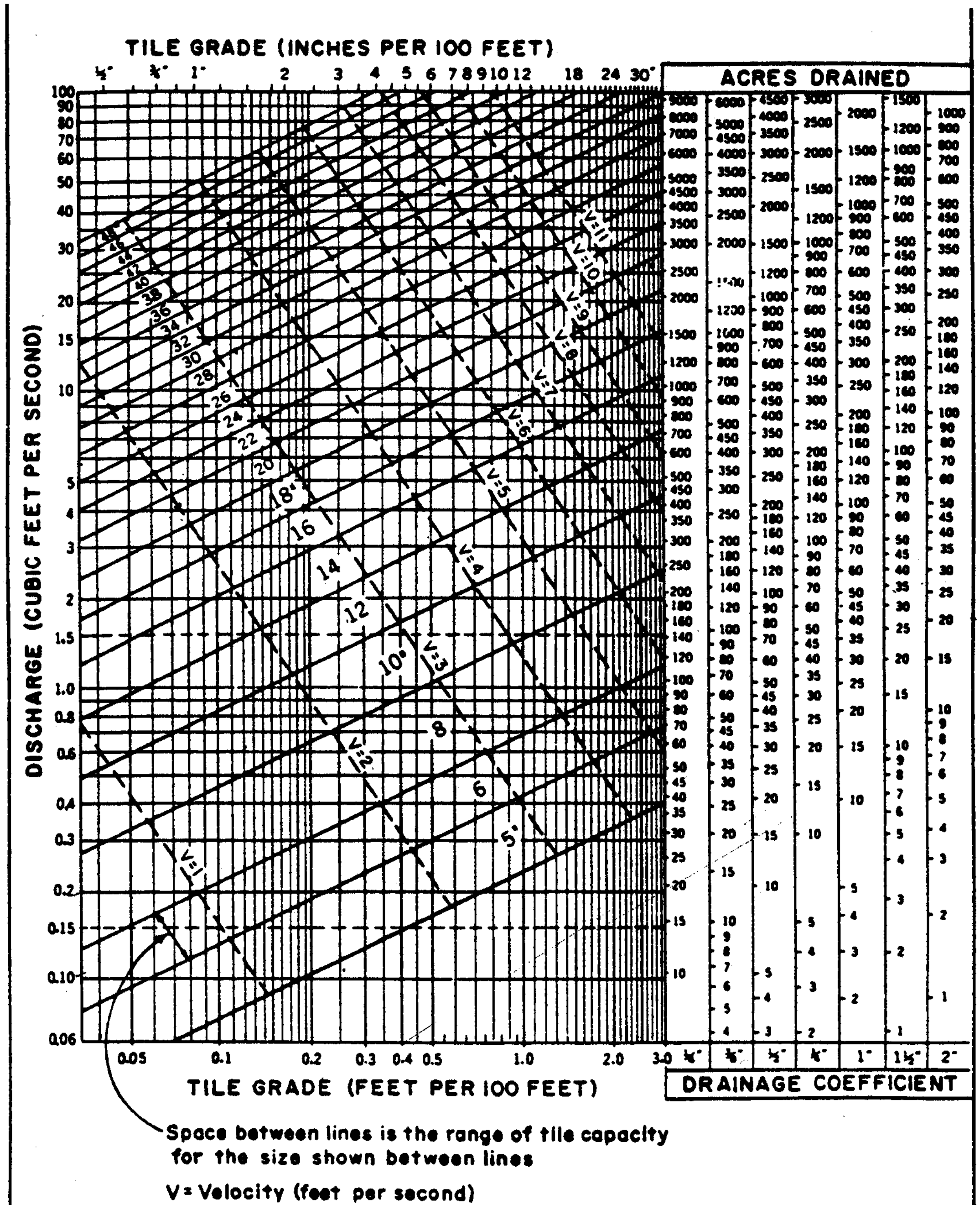
Subsurface Relief Drain Layouts



Source: USDA Soil Conservation Service.

Exhibit 2

Concrete Tile Drainage Chart
Acres Drained by Various Sizes of Tile



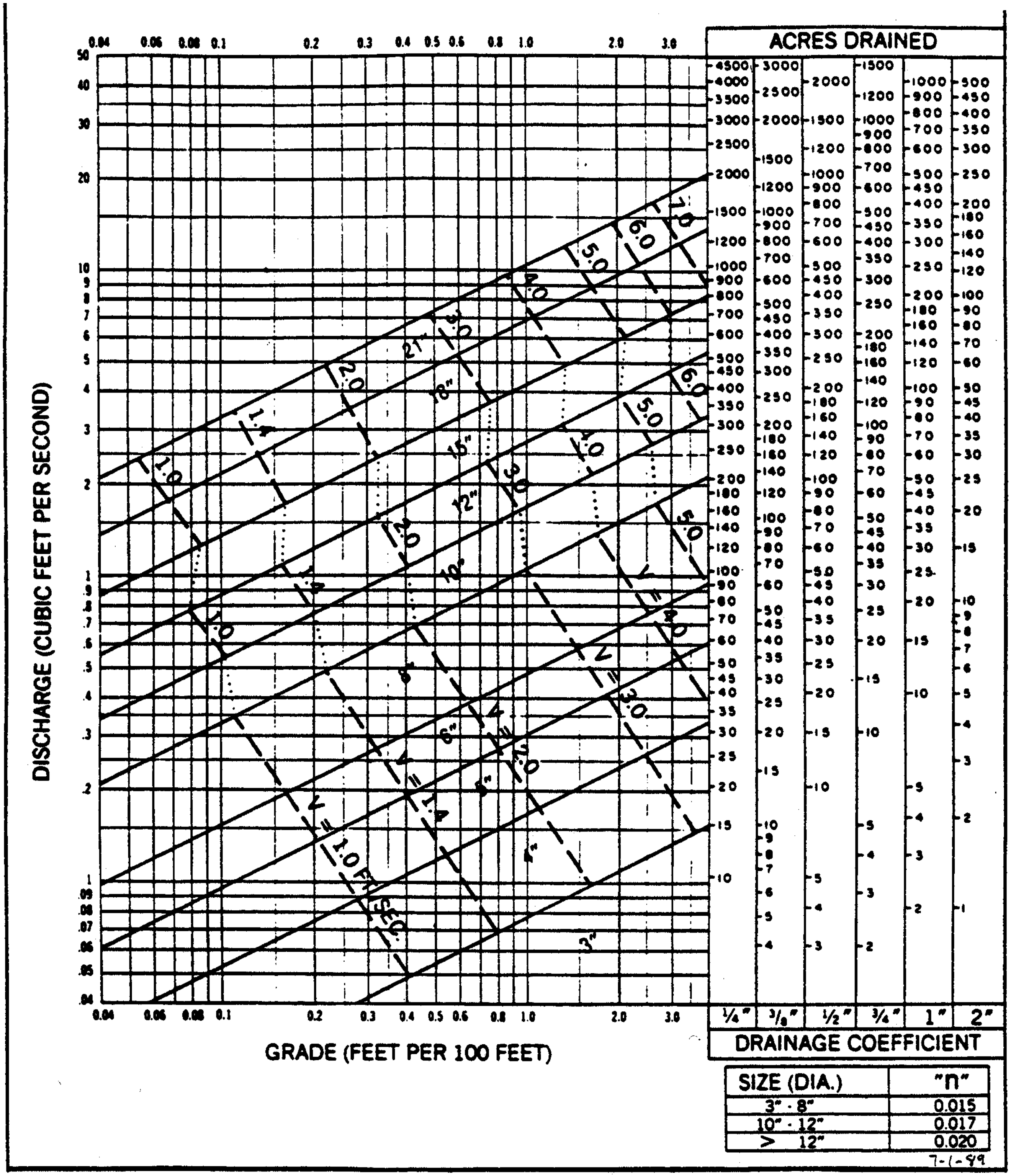
REFERENCE
Tile drainage chart based on Yarnell formula.

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

STANDARD DWG. NO.
ES-714
SHEET ___ OF ___
REVISED 2-2-59

Exhibit 3

Plastic Tubing Drainage Chart



Source: USDA Soil Conservation Service