CHAPTER 6

SUBSURFACE DRAINAGE PROCEDURES

6-1. Purpose. Subsurface drainage may be divided according to its purpose into base- and subbase-course drainage, subgrade drainage, and intercepting drainage. Base and subbase drainage consists of removing water from a base and/or subbase course beneath a pavement; subgrade drainage consists of removing water from the subgrade beneath a pavement; and intercepting drainage consists of collecting and removing water under artesian pressure found flowing in pervious foundation strata or water flowing from springs.

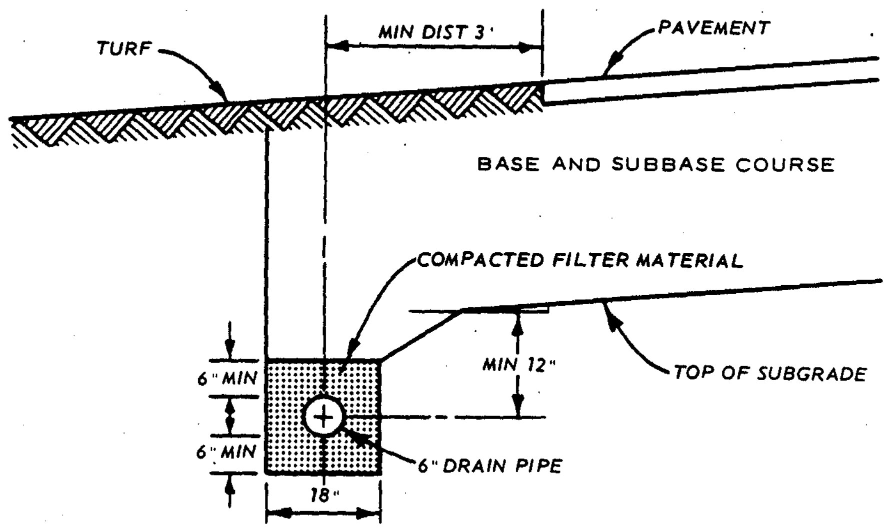
6-2. Methods. The drainage of subsurface water may be affected by a system of subsurface drainpipes placed in trenches or by circumferential or intercepting open ditches. The backfill filter for pipes in trenches should be designed to maintain progressively greater outflow capabilities in the direction of flow. The outlet for subsurface drains should be properly located or protected to prevent backwater from the surface drainage system from entering the subsurface system. In addition, there are special methods for subsurface drainage, such as dry wells that are designed to drain a perched-water table into a lower ground water reservoir.

6-3. Base- and subbase-course drainage. Base- and subbase-course drainage generally consists of subsurface drainpipes laid parallel and adjacent to pavement edges with pervious backfill material connecting the base and subbase course to the drain. The top of the subgrade beneath paved shoulder areas should be sloped to provide drainage to subsurface drainage pipelines. Additional lines of pipe may be required beneath large paved areas with relatively flat slopes to obtain adequate base- and subbase-course drainage. A sketch of a typical base and subbase drain is shown in figure 6-1.

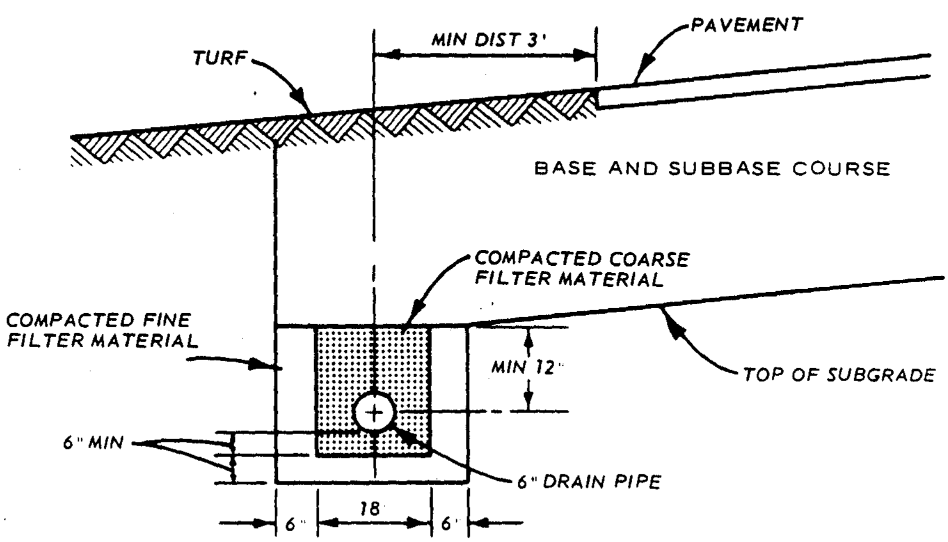
a. Ground water. Base and subbase drainage is also required where the ground water rises to the bottom of the base or subbase course as a result of either seasonal conditions, ponding of surface runoff, or consolidation of soil under the weight of the base and subbase course.

b. Design of base- and subbase-course drainage. To simplify the analysis of drainage, it is assumed that the base and subbase courses are fully saturated and no inflow occurs during drainage. It is assumed the subgrade constitutes an impervious boundary and the base and subbase courses have a free outflow into the drain trench.

(1) Maximum rate of discharge. The following equation may be used to determine the maximum rate of discharge for a saturated base and subbase course of dimensions shown in figure 4-3.



a. ONE GRADATION OF FILTER MATERIAL



b. TWO GRADATIONS OF FILTER MATERIAL

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FIGURE 6-1. TYPICAL DETAILS OF BASE- AND SUBBASE-COURSE DRAIN INSTALLATIONS

$$q = \frac{kHH_o}{60D}$$

where:

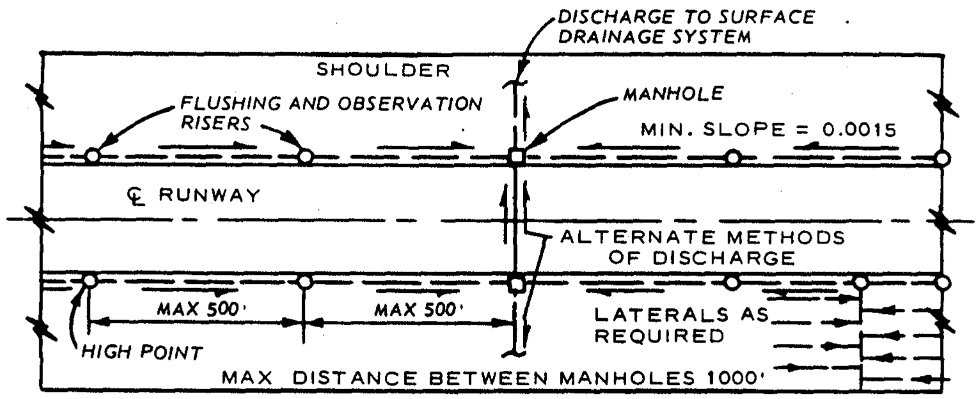
q = peak discharge quantity of drain, cfs/lin feet
k = coefficient of horizontal permeability, fpm
H, H_o, and D = dimensions as shown in figure 4-3, feet

(2) Spacing of drains. When the time in days determined using equation 4-2 is greater than 10 days, then the spacing between drains should be decreased until the time for drainage is 10 days or less, or a more pervious base and subbase material should be selected, or a greater thickness of base and subbase should be used in the design. For most runways and taxiways of widths from crown to edge of not more than 75 feet, a single line of base and subbase drains along the edges should meet the design criteria. It may be necessary on wider pavement widths, or where reasonably pervious base- and subbase-course materials are not locally available, to install intermediate lines of drains to provide satisfactory base and subbase drainage.

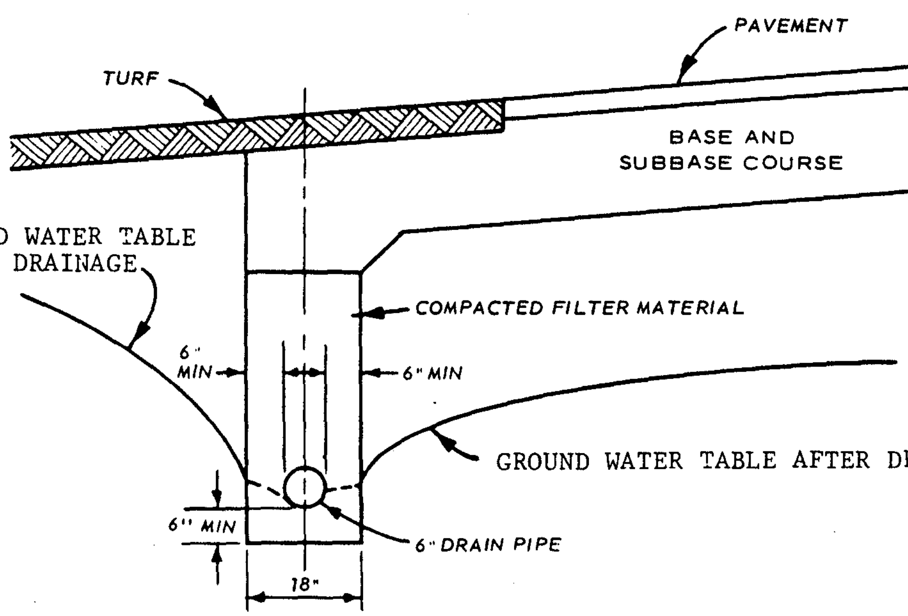
6-4. Subgrade drainage. Subgrade drainage is provided primarily to drain subsurface waters from a subgrade in which there exists a high ground water table. These drains generally consist of either a system of subsurface drainpipes or a system of open ditches. The type, location, depth, and spacing of drains depend upon the soil characteristics and depth to ground water table. Subgrade drains may also drain base and subbase courses. Sketches of a typical subgrade drainage installation and layout using pipes are shown in figure 6-2.

a. Depth and spacing of drains. Subgrade drains should be placed at a depth of not less than 1 foot below the bottom of the base and subbase course and at a depth of not less than 1 foot below the ground water table (fig 6-2). Frequently, depth of cover will be controlled by frost conditions or loading requirements in accordance with paragraph 6-10. Subgrade drains are generally required only at pavement edges. Intermediate subgrade drains on large areas are necessary only where unusual ground water conditions exist.

b. Design of subgrade drainage systems. At locations where subgrade drainage is required as indicated in the above paragraph, and to simplify the analysis of drainage of subgrade materials, the following assumptions are made: the subgrade is saturated below the ground water table, infiltration has raised the ground water table in the shoulder area adjacent to a subgrade drain as shown in figure 6-3, no appreciable quantity of flow develops from the subgrade beneath the paved area, and the drains must have a capacity sufficient to collect the peak flow from the shoulder. This peak flow occurs immediately



a. SUBSURFACE DRAINAGE SYSTEM



b. CROSS SECTION OF SUBGRADE DRAIN

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FIGURE 6-2. TYPICAL SUBGRADE DRAINAGE DETAILS

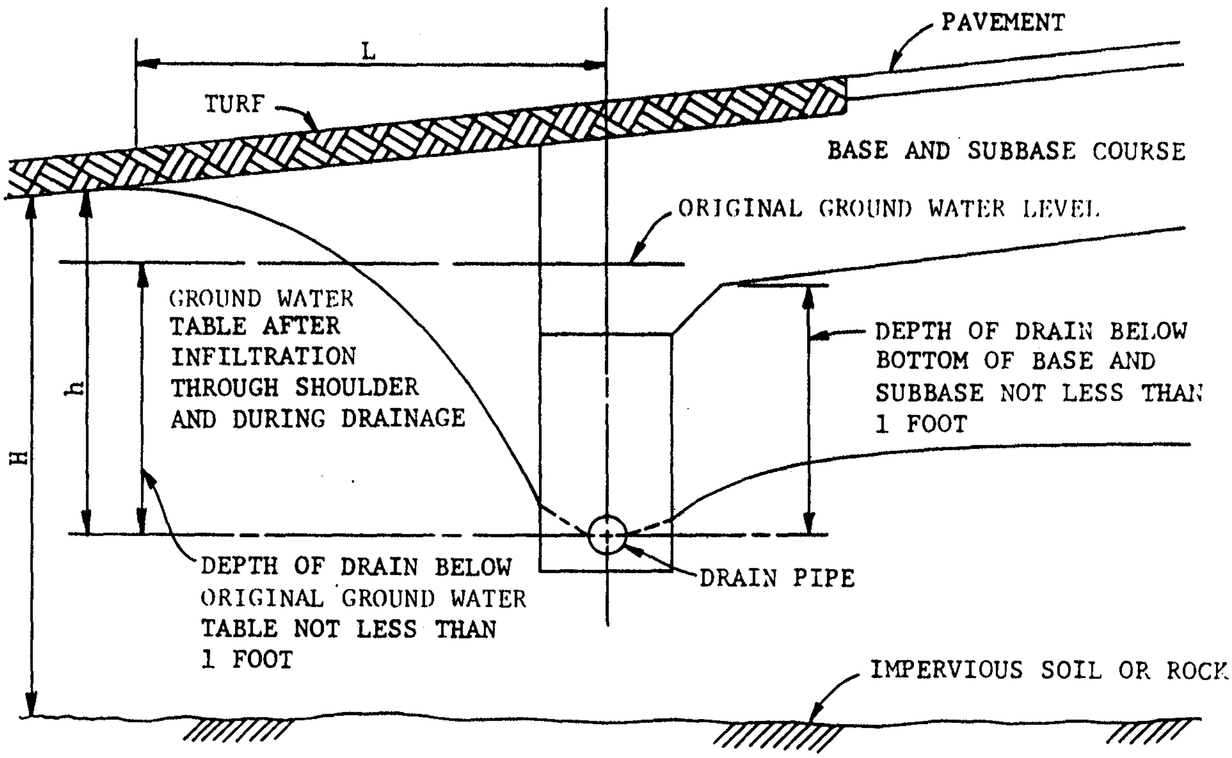

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FIGURE 6-3. GROUND WATER CONDITIONS AFTER INSTALLATION OF SUBGRADE DRAINAGE after the ground water table has risen to its maximum height, assumed to be as shown in figure 6-3.

The quantity of water discharged by the soil and collected by the drain may be determined using the following equation:

$$q = \frac{khc}{60}$$

where:

q = discharge quantity of drain, cfs/lin ft
k = coefficient of horizontal permeability of soil in the shoulder, fpm
h = difference in elevation between the midpoint of the pipe and the ground surface at L distance from drain as shown in figure 6-3, feet
c = shape factor dependent upon L and H, where H is the thickness in feet of the soil being drained as shown in figure 6-3. Determine c from figure 6-4 using L=50 for a k larger than 10^{-3}fpm

6-5. Intercepting drainage. Intercepting drainage is provided to intercept ground water flowing in a pervious shallow stratum toward a paved area or into the face of a cut. Intercepting drainage is also provided to collect water from springs in subgrade excavations. The type and depth of drains depend upon the soil and ground water conditions. These drains may consist of either subsurface drainpipe or ditches. A schematic of a typical pipe installation is shown in figure 6-5.

6-6. Type of pipe. Subsurface drainage systems may be constructed of various types of standard manufactured pipe. The type of pipe selected should satisfy local requirements such as the condition of the soil, the loading and amount of cover, the cost, and the availability of pipe. The following types of pipe are currently available: perforated, bell-and-spigot, cradle-invert (skip), porous concrete, bituminized fiber, farm tile, PVC, and corrugated polyethylene.

a. Perforated. Perforated pipes are usually laid with closed joints and with the holes down except where the holes are spaced all around the pipe. Perforated pipe is manufactured of vitrified clay, nonreinforced concrete, bituminous-coated or uncoated corrugated metal, bituminized fiber pipe, asbestos-cement, plastic, cast iron, PVC, and corrugated polyethylene.

b. Bell-and-spigot. Bell-and-spigot pipes are laid with open joints. Collars of burlap or roofing paper, or oakum in the joints are not required where the filter material is properly designed. The use

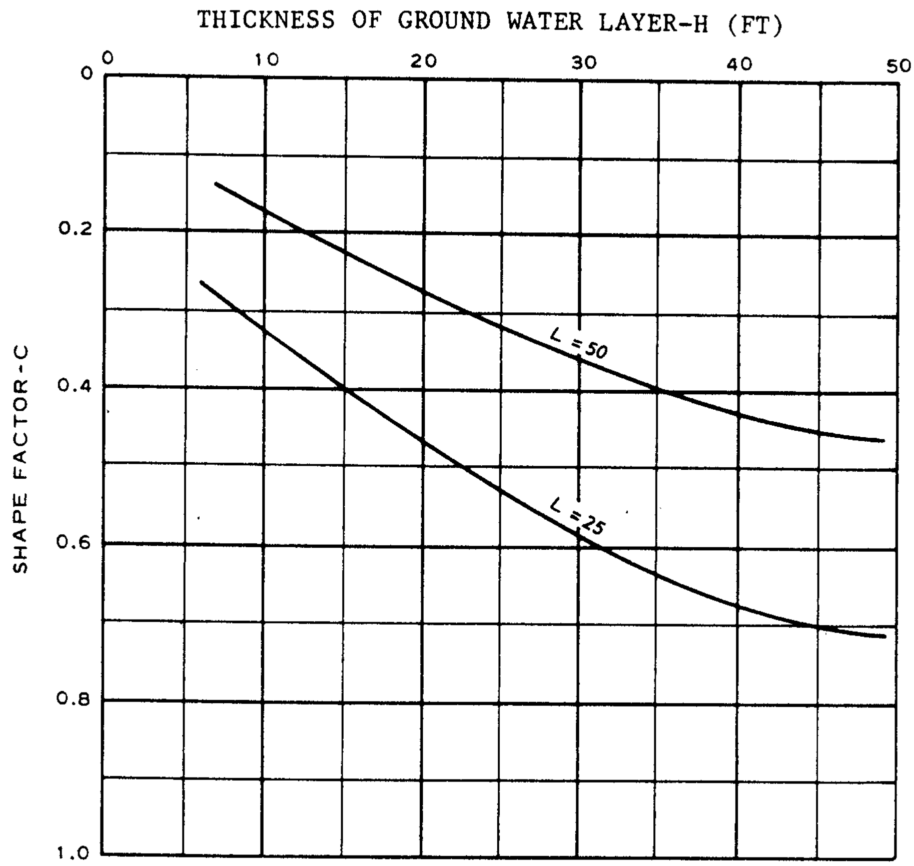

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FIGURE 6-4. THICKNESS OF GROUND WATER LAYER IN RELATION TO SHAPE FACTOR

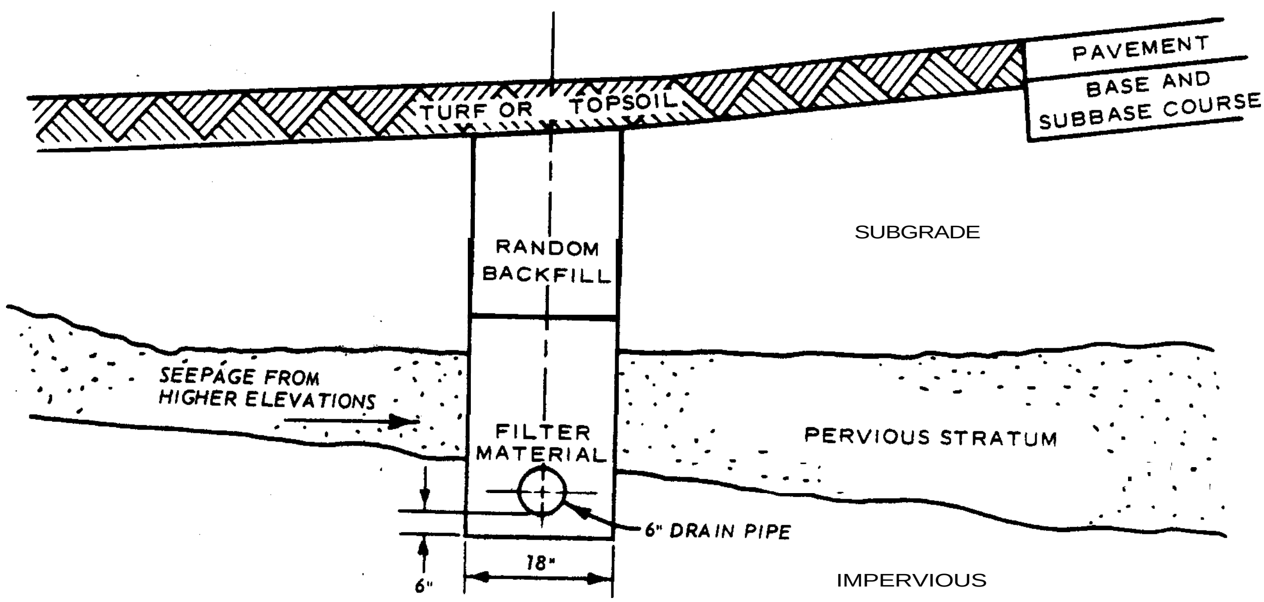

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FIGURE 6-5. TYPICAL INSTALLATION OF INTERCEPTING DRAINS of partially mortared joints is desirable to provide positive alinement and spacing of the pipe. Materials used in the manufacture of bell-and-spigot pipe are vitrified clay, nonreinforced concrete, and cast iron.

c. Cradle-invert. Cradle-invert (skip) pipe is manufactured of both vitrified clay and cast iron. The pipe is designed so that water enters the pipe at bell-and-spigot-type joints, which are designed to provide a gap around the bottom semicircumference, and through a slot across the flat top surface of the pipe. Cast-iron, cradle-invert (skip) pipe is provided with a device to hook adjoining sections together.

d. Porous concrete. Porous concrete pipe is laid with sealed joints. It collects water by seepage through the porous concrete wall of the pipe. Porous concrete pipe should not be used where chemically active waters may cause disintegration of concrete. When severe attack by chemically active ground water is anticipated, sulfate-resistant cement should be specified for other types of concrete pipe which might be considered. Criteria for granular filters and fabric filters used adjacent to porous concrete pipe are presented in paragraph 5-2e.

e. Farm tile. Farm tile pipe is manufactured of both clay and concrete. It is laid with butt joints slightly separated to permit collection of water through joints. This type of pipe is not recommended for use on airfields.

f. Plastic pipe. Criteria for the use and placement of PVC, corrugated polyethylene, and ABS pipe are to be as recommended by the manufacturer.

6-7. Manholes and observation basins. Manholes, observation basins, and risers are installed on subsurface drainage systems for points of access to the system to observe its operation and to flush or rod the pipe for cleaning. Manholes on base- and subbase-course or subgrade pipe drains should be at intervals of not over 1,000 feet with one flushing riser located between manholes and at dead ends. Manholes should be provided at principal junction points of several drains. Typical details of construction are given on Standard Mobilization Drawing No. XEC 001.

6-8. Pipe sizes and slopes. Except for long intercepting lines and extremely severe ground water conditions, 6-inch-diameter drains are satisfactory for all subsurface drainage installations. The rate of infiltration into the drains, computed as specified in paragraph 6-4b of this manual, is used to determine whether the expected total flow in the intercepting drains may require pipe larger than 6 inches.

a. Sizes. The nomograph shown in figure 6-6 may be used for the design of drainpipes for subsurface drains. The values to be used for the coefficient of roughnesss "n" are as follows:

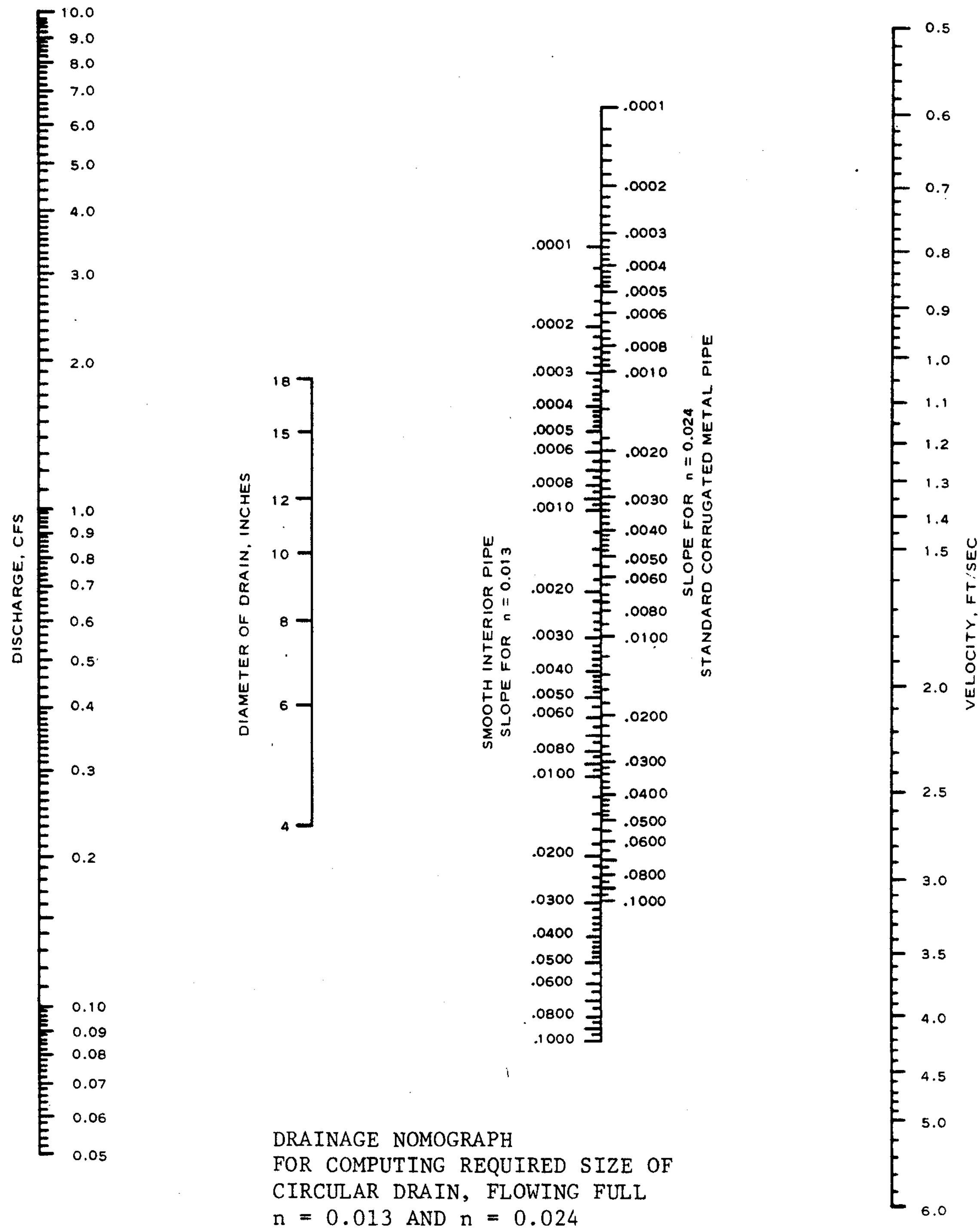
Type of pipe	Coefficient of roughness, n
Clay, concrete, bituminized fiber, plastic, and asbestos-cement pipe	0.013
Bituminous-coated or uncoated corrugated-metal pipe	0.024

The values of any two unknowns in the nomograph may be determined by connecting two known values with a straightedge.

b. Slopes. The recommended minimum slope for subdrains is 0.15 foot in 100 feet.

6-9. Filter material. A minimum thickness of 6 inches of granular filter material should be provided around all types of subsurface drains. Gradation of the granular filter material should be designed with respect to the soil being drained to conform with pertinent provisions of paragraph 5-2. When this gradation is such that it does not satisfy the provision pertaining to material adjacent to joint openings or pipe perforations, a single wrap of filter cloth around the pipe may be used in lieu of a second filter material. Fabric filters are manufactured of plastic materials in both woven and unwoven type. Size of openings vary widely from No. 30 sieve to No. 100 sieve or even finer. Normally fabric filters of sieve sizes between No. 80 and No. 100 are used. The fabric may be wrapped around open joints of unperforated pipe or around the entire length of perforated or unperforated pipe. Prefabricated fabric filter sleeves may also be used to encase the pipe. When the gradation of filter material is such that it satisfies provisions pertaining to material adjacent to joint openings or pipe perforations, but is too coarse to satisfy the filter criteria pertaining to the protected soil, a single layer fabric filter may be used adjacent to the protected soil in lieu of a second filter material. This use of fabric filters is restricted to situations where the soil to be protected is sand (SW, SP, SW-SM) with less than 85 percent passing a No. 200 sieve. When fabric filters are used, requirements stated in paragraph 5-2 pertaining to the adjacent granular material should be satisfied.

6-10. Depth of cover over drains. The cover over drains is dependent upon loading and frost requirements. Cover requirements for different design wheel loads are indicated in paragraph 8-5 of this manual. With respect to frost in areas of seasonal freezing, the depth of cover to the center line of pipe should be not less than the depth of frost penetration as determined from table 8-4 of this manual. The trench



DRAINAGE NOMOGRAPH
FOR COMPUTING REQUIRED SIZE OF
CIRCULAR DRAIN, FLOWING FULL
n = 0.013 AND n = 0.024

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FIGURE 6-6. DRAINAGE NOMOGRAPH

for subdrains should be backfilled with free draining, non-frost-susceptible material. Within the depth of frost penetration, gradual transitions should be provided between nonfrost-susceptible trench backfill and frost-susceptible subgrade materials around drains placed beneath pavements. This precaution will prevent detrimental differential heave, particularly for the case of frost condition pavement design based on reduced subgrade strength.