CHAPTER 18

DROP STRUCTURES AND CHECK DAMS

18-1. Description and purpose. Drop structures and check dams are designed to check channel erosion by controlling the effective gradient and to provide for abrupt changes in gradient by means of a vertical drop. They also provide satisfactory means for discharging accumulated surface runoff over fills with heights not exceeding about 5 feet and over embankments higher than 5 feet provided the end sill of the drop structure extends beyond the toe of the embankment. The check dam is a modification of the drop structure used for erosion control in small channels where a less elaborate structure is permissible.

18-2. Design.

a. Typical drop structure. Pertinent features of a typical drop structure are shown in figure 18-1a. The hydraulic design of these structures can be divided into two general phases: design of the notch weir and design of the stilling basin. It is emphasized that for a drop structure or check dam to be permanently and completely successful, the structure must be soundly designed to withstand soil and hydrostatic pressures and the effects of frost action, when necessary, and also the adjacent ditches or channels must be completely stable. A stable grade for the channel must first be ascertained before the height and spacing of the various drop structures can be determined. The following design rules are based on hydraulic considerations only. They are minimum standards subject to increase on the basis of other considerations such as structural requirements and special frost condition design.

b. Notch design. The design of the notch or weir can be determined by use of figure 18-1b. As illustrated in the example below, a trial-and-error procedure will be used to balance the design of the notch with the ditch cross section. To minimize erosion in the approach channel, the length of the notch will be adjusted to maintain a head on the notch (d_c) equivalent to the depth of flow (d_s) in the channel. The controlling features of the stilling basin are determined by the following criteria.

$$d_c = (Q/5.67\ b_n)^{2/3}$$
$$L = C_L(hd_c)^{1/2}$$
$$h_t = d_c/2$$
$$h_l = 3d_c/8$$
$$b_n/b_s$$

where:

d_c = Critical depth (depth of head on notch), feet
Q = Normal channel discharge to drop structure, cfs

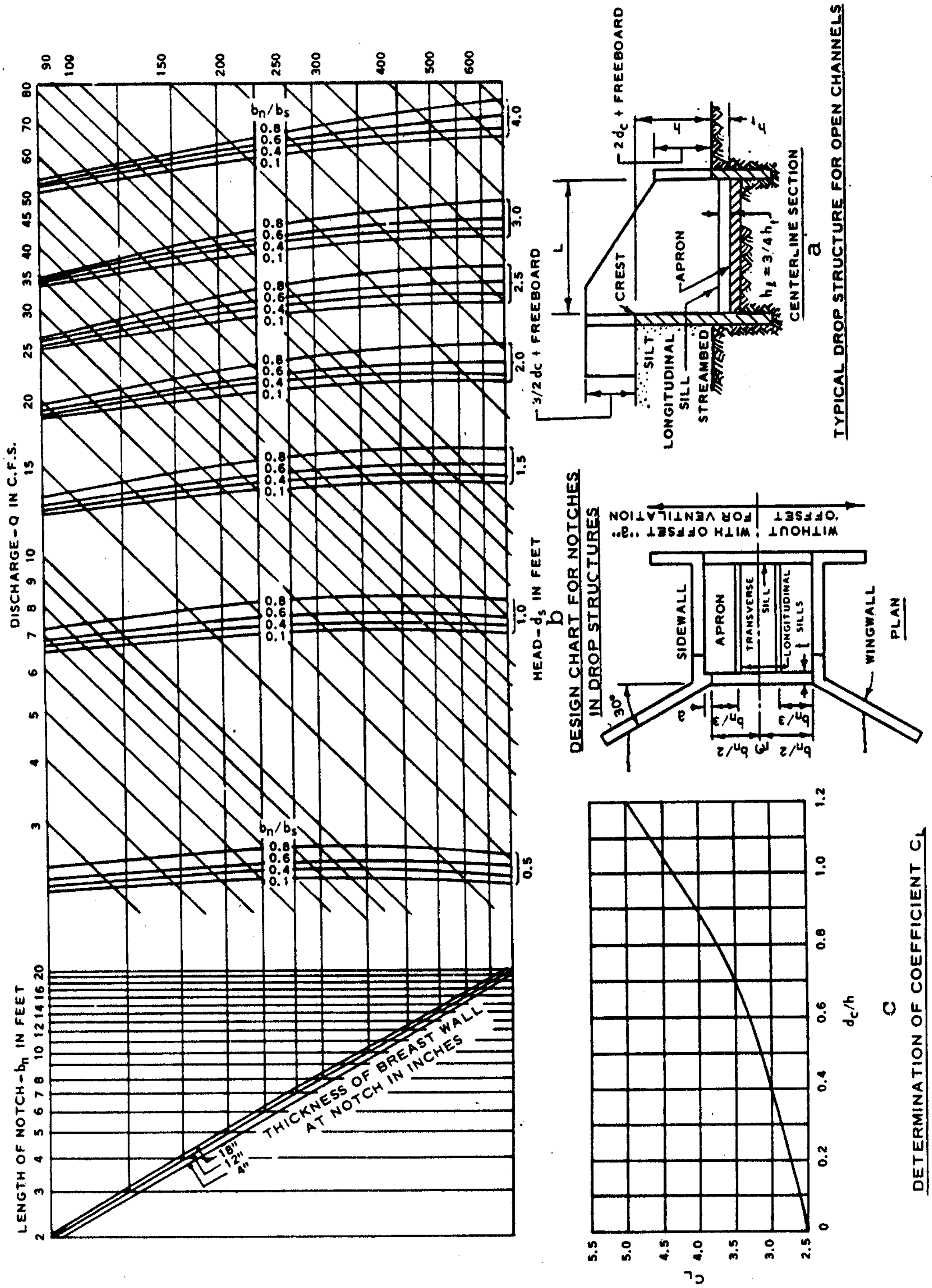

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FIGURE 18-1. DESIGN OF DROP STRUCTURES FOR OPEN CHANNELS

b_n = Width of notch (weir), feet
L = Length of drop structure apron, feet
h = height of fall or drop in structure, feet
C_L = Coefficient, obtained from figure 18-1c for condition of $d_c/h = 1$
h_t = height of transverse end sill, feet
h_l = height of longitudinal sill, feet
b_s = Bottom width of regular channel or bottom width of transition section if required, feet

18-3. Typical design problem. The use of the above-mentioned equations is illustrated in the following example. Design a drop structure for a discharge of 40 cfs and a drop of 4 feet. The channel in which the structure is to be built has a 2-foot bottom width, 1 foot on four side slopes, and a design depth of flow of 2 feet. Maximum permissible velocity due to soil conditions is 2 fps.

18-4. Solution - design of notch.

a. From figure 18-1b with a head of 2 feet and b_n/b_s of 0.8, it is evident that b_n must be approximately 4 feet, which is greater than the bottom width of the regular channel and requires that a transition from the regular channel be provided immediately upstream from the drop structure. The transition should be of sufficient length to provide a gradual change between the regular channel and the drop structure. In this problem the transition is made to a section with a 5 foot bottom width, 1 on 2 side slopes and a 2-foot depth. Using the above revised channel elements, enter figure 18-1b, with a head of 2 feet and an assumed $b_n/b_s = 0.8$ ($b_n = 4.0$). From the intersection of $b_n/b_s = 0.8$ and Q = 40 cfs follow the horizontal line to intersection with t = 12 inches, the assumed thickness of the breast wall and thence vertically to read b_n = 4 feet. This checks the assumed b_n and no further adjustment is necessary.

b. To design the stilling basin calculate the critical depth at notch, d_c:

$$d_c = (Q/5.67b_n)^{2/3} = (40/5.67 \times 4.0)^{2/3} = 1.46 \text{ feet}$$

Length of stilling basin: In figure 18-1c for a value of d_c/h = 1.46/4.0 = 0.37, C_L = 3.0

$$L = C_L \quad hd_c = 3.0 \quad 4.0 \times 1.46 = 7.25 \text{ feet}$$

(use 7 feet 3 inches)

Height of transverse end sill, h_t

$$h_t = d_c/2 = 1/2 \times 1.46 = 0.73 \text{ foot}$$

(use 0 foot 9 inches)

Height of longitudinal sills, h_l

$$h_l = 3\, d_c/8 = 3/8 \times 1.46 = 0.55 \text{ foot}$$

(use 0 foot 7 inches)

spacing of longitudinal sills: An average spacing of sills equal to $b_n/3$ is satisfactory.

18-5. Alternate design.

a. Alternate drop structure. Pertinent features of an alternate drop structure are shown in figure 18-2. Notations used in the design of the structure are defined in appendix B.

b. Weir calculations. Discharge over the weir should be computed from the equation:

$$Q = CWH^{3/2}$$

where:

Q = discharge, cfs
C = discharge coefficient (for alternate design use C = 3.0)
W = length of weir, feet
H = head (depth of flow), feet

The length of the weir should be such as to obtain maximum use of the available channel cross section upstream from the structure. A trial-and-error procedure should be used to balance the weir height and width with the channel cross section.

c. Stilling basin dimensions. Stilling basin length and end sill height should be determined from the design curves in figure 18-2.

d. Riprap. Riprap probably will be required on the side slopes and below the end sill immediately downstream from the structure.

e. Toe slopes. The toe of the side slopes of the channel downstream from the structure should be offset from the basin walls in order to prevent scouring of side slopes immediately downstream from the end sill.

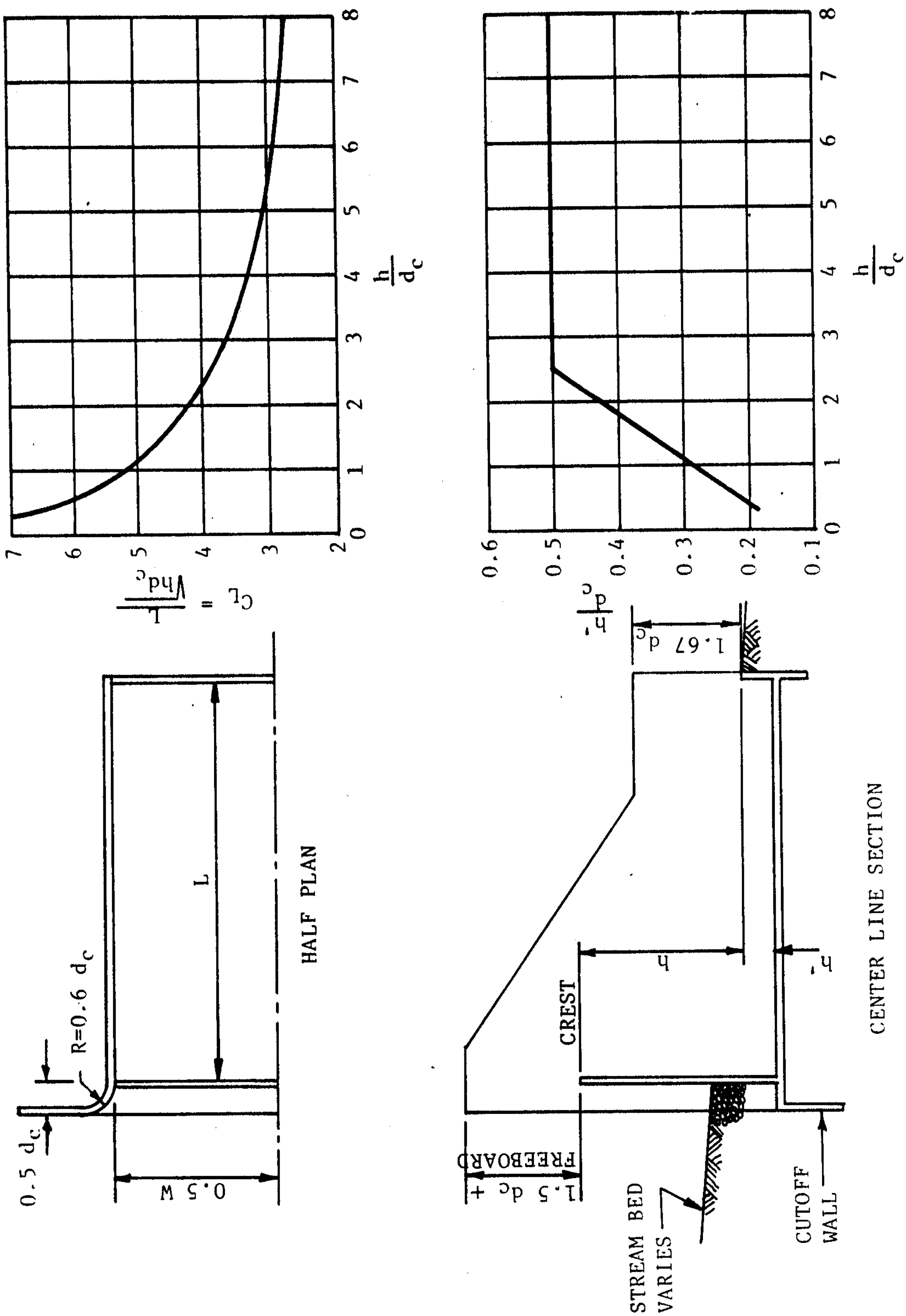

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FIGURE 18-2. DETAILS AND DESIGN CHART FOR TYPICAL DROP STRUCTURE