CHUTES AND DROP SPILLWAYS (ENTRANCES-WEIRS)

Weirs (e.g., Fig. 1) are the inlet sections of chutes and drop spillways, which are often required to drop water over steep sections of the landscape where flow velocities would be too erosive for an earth or vegetated channel. The flow through a weir, q, is described by the weir equation:

$$q = CLH^{3/2} \quad \text{English Units} \quad (1a)$$

$$q = 0.55CLH^{3/2} \quad \text{SI Units} \quad (1a)$$

where L is the length of the "lip" over which the water flows, H is the head above the weir, and C is the weir coefficient, tabulated almost always in English units, which leads to the 0.55 coefficient fo the SI form of the weir equation (Eq. 1b).

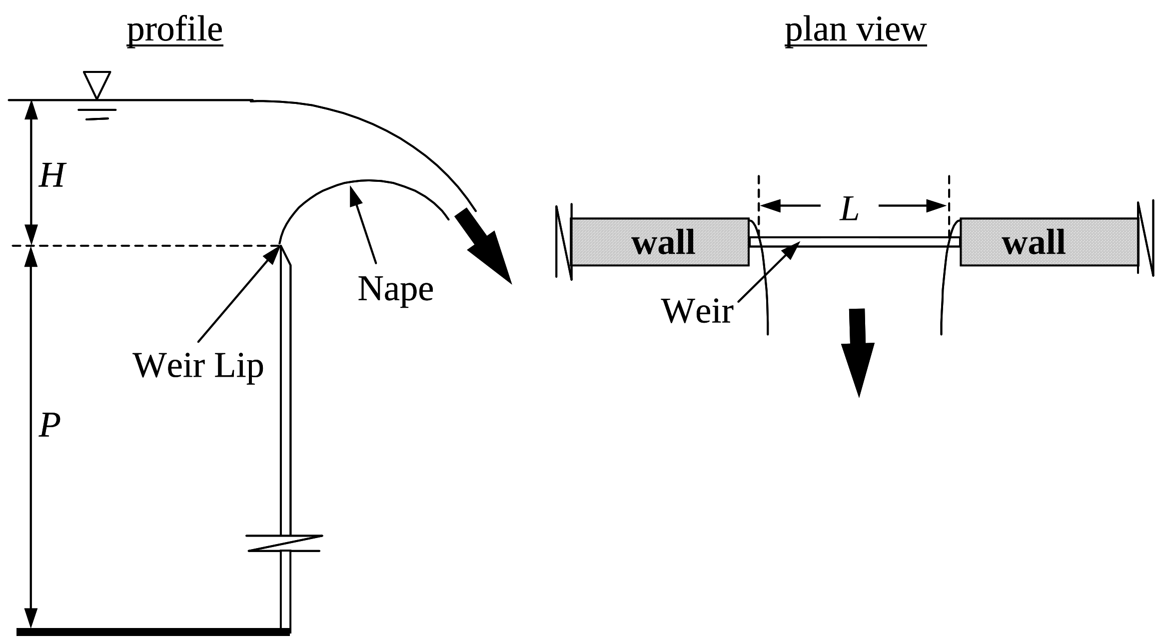


Figure 1: Schematic of a sharp crested weir profile and plan view; note that free outfall is shown.

The following provide brief discussions a appropriate tables and nomographs for the following:

A. Weir Types and Coefficients

B. Determining L

C. Ogee Spillways and Chutes

D. "Catchbasins" and Other Unweir Configurations

A. Weir Types and Coefficients

Important: *C* has dimensions and they are almost always in English units. Also, be cautious when determining *C* and *H* because some tables of *C* have been determined by including the velocity head, $v^2/2g$, in *H* and other consider *H* to be the depth of water above the weir (Fig. 1), thus, look closely at how weir coefficient have been developed. For those of you who like to relate engineering hydraulic equation back to fluid mechanics, note that embedded in *C* are physical constants, like $g = 32.2$ ft/s^2. There are literally an infinite variety of weir forms but two common, simple forms are the sharp and broad crested weirs (Fig. A.1)

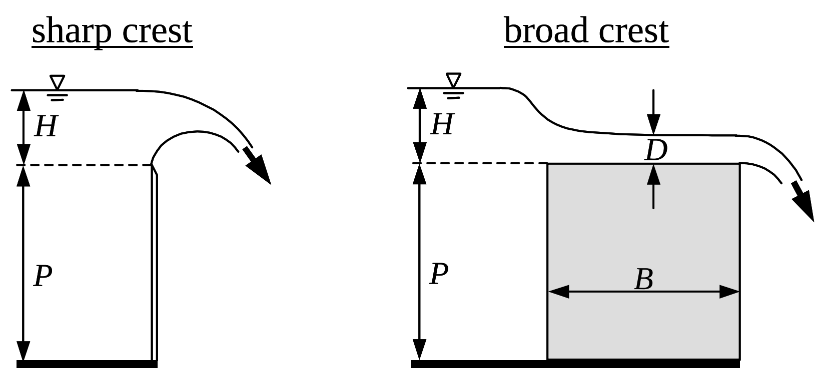


Figure A.1: Schematic of a sharp and broad crested weir profiles.

Table A.1: Coefficients for sharp crested weirs:

C	comments
3.2	generic satisfactory value as long as the upstream channel width is >1.5*L* *H* = depth above the weir
$3.21 + 0.4\frac{H}{P}$	commonly used equation for *H*/*P*<10 *H* = depth above the weir
$5.70\left(1+\frac{P}{H}\right)^{1.5}$	commonly used equation for *H*/*P*>15; the weir acts as a sill. *H* = depth above the weir

Tables are attached for broad crested weirs and references are provided at the end for good references related to weirs.

Special Notes:

- Drop spillways consisting of a sharp crested and downstream vertical drop are not advised for drops > 3 m.
- For large drops (>1 m), consider aerating the nappe to keep the flow from "sucking" onto the downstream spillway face and potentially compromising its structural integrity.

TABLE 51.—VALUES OF C IN THE FORMULA, $Q = CLH^{3/2}$ FOR BROAD-CRESTED WEIRS

Measured head in feet, H	Breadth of crest of weir in feet										
	0.50	0.75	1.00	1.50	2.00	2.50	3.00	4.00	5.00	10.00	15.00
0.2	2.80	2.75	2.69	2.62	2.54	2.48	2.44	2.38	2.34	2.49	2.68
0.4	2.92	2.80	2.72	2.64	2.61	2.60	2.58	2.54	2.50	2.56	2.70
0.6	3.08	2.89	2.75	2.64	2.61	2.60	2.68	2.69	2.70	2.70	2.70
0.8	3.30	3.04	2.85	2.68	2.60	2.60	2.67	2.68	2.68	2.69	2.64
1.0	3.32	3.14	2.98	2.75	2.66	2.64	2.65	2.67	2.68	2.68	2.63
1.2	3.32	3.20	3.08	2.86	2.70	2.65	2.64	2.67	2.66	2.69	2.64
1.4	3.32	3.26	3.20	2.92	2.77	2.68	2.64	2.65	2.65	2.67	2.64
1.6	3.32	3.29	3.28	3.07	2.89	2.75	2.68	2.66	2.65	2.64	2.63
1.8	3.32	3.32	3.31	3.07	2.88	2.74	2.68	2.66	2.65	2.64	2.63
2.0	3.32	3.31	3.30	3.03	2.85	2.76	2.72	2.68	2.65	2.64	2.63
2.5	3.32	3.32	3.31	3.28	3.07	2.89	2.81	2.72	2.67	2.64	2.63
3.0	3.32	3.32	3.32	3.32	3.20	3.05	2.92	2.73	2.66	2.64	2.63
3.5	3.32	3.32	3.32	3.32	3.32	3.19	2.97	2.76	2.68	2.64	2.63
4.0	3.32	3.32	3.32	3.32	3.32	3.32	3.07	2.79	2.70	2.64	2.63
4.5	3.32	3.32	3.32	3.32	3.32	3.32	3.32	2.88	2.74	2.64	2.63
5.0	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.07	2.79	2.64	2.63
5.5	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	2.88	2.64	2.63

TABLE 62.—VALUES OF C IN THE FORMULA $Q = CLH^{3/2}$ FROM EXPERIMENTS AT CORNELL UNIVERSITY ON MODELS RESEMBLING EXISTING DAMS (EXCEPT THAT THE LAST TWO EXPERIMENTS WERE MADE ON ACTUAL DAMS)

No. of figure	Length of model in feet	Head in feet, H									
		0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
64	7.94	....	3.30	3.32	3.36	3.40	3.43	3.48	3.53	3.62	3.72
64	15.97	3.32	3.44	3.46	3.42	3.41	3.46	3.50			
65	7.98	....	3.38	3.46	3.51	3.55	3.58	3.62	3.68	3.74	3.83
65	15.97	3.22	3.48	3.61	3.67	3.70	3.72				
66	15.97	3.15	3.45	3.64	3.75	3.82	3.87	3.88			
67	15.97	3.23	3.34	3.43	3.52	3.59	3.64				
68	15.97	3.18	3.30	3.37	3.42	3.46	3.49	3.52	3.54		
69	15.97	3.28	3.50	3.54	3.52	3.36	3.31	3.30			
70	15.97	3.53	3.54	3.55	3.50	3.35	3.27	3.25	3.25		
71	15.93	3.13	3.14	3.10	3.14	3.20	3.26	3.31	3.37		
72	....	3.09	3.11	3.33							
73	....	....	3.80								

Handbook of Hydraulics, 1939.
H. W. King. McGraw-Hill, NY.

B. Determining *L*

Straight Lips
If the weir is straight and especially wide or the upstream channel is about the same width as the weir lip, then L is just the physical length of the lip.

Non-Straight Lips
Sometimes it is advantageous to use a non-straight weir lip, as in the case of stormwater catchbasins and *L* is the physical length of the lip as shown in Fig. B.1. Of course, one must make sure that converging flows in a non-straight lipped weir do not substantially interfere with one another.

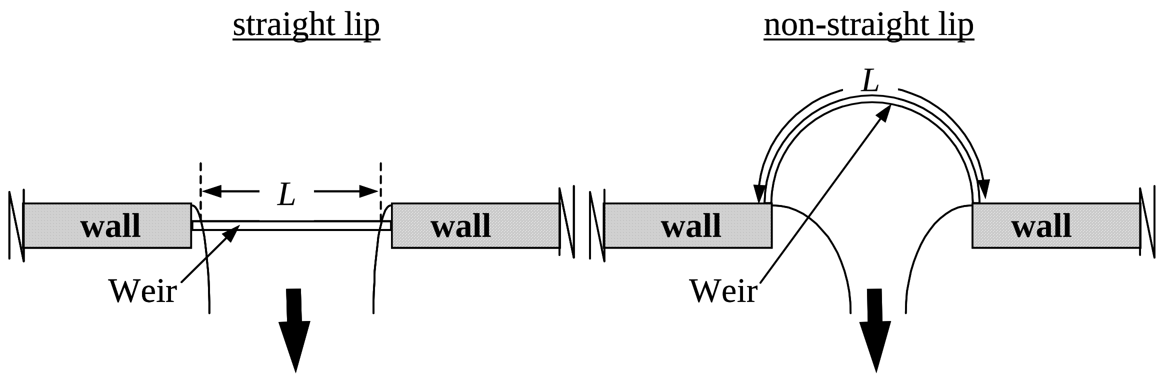


Figure B.1: Schematic of a straight and non-straight weir lips inn plan view.

Contractions
Notice the length of *L* is the straight-lip diagram in Fig. B.1 is slightly less than the physical length of the lip due to flow contraction. The general guideline is that each contraction reduces the *L* by 0.1*H* from the physical length of the lip; fig B.1 shows 2 contractions, one on each end, so *L* is the physical length of the weir lip minus 0.2*H*.

C. Ogee Spillways and Chutes

Chutes are weirs with a ramp on the downstream face. Depending on the steepness of the chute, these entrances to these control structures may perform more like a sharp crested weir or a broad crested weir. There are innumerable tables and nomographs for chute design, but for steep chutes it often sufficient to design the inlet using sharp-crested weir assumptions.

To reduce head losses that arise from a nappe forming at the entrance of a chute, the profile of the sharp crest is curved (Fig. C.1). Interestingly, ogee spillways can be designed to take advantage of "suction" of the nappe to the surface of the weir to get higher capacity than with a sharp crested weir, i.e., an ogee spillway often has a higher *C* than 3.2 (see the following tables).

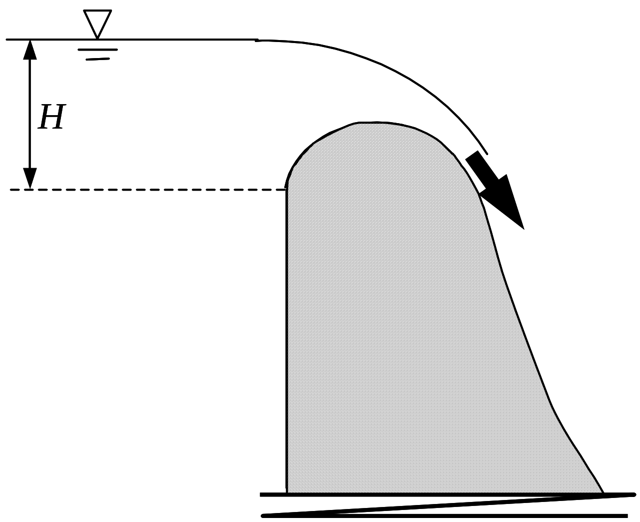


Figure C.1: Schematic of the lip of an ogee spillway

Design relationships for an ogee spillway are attached.

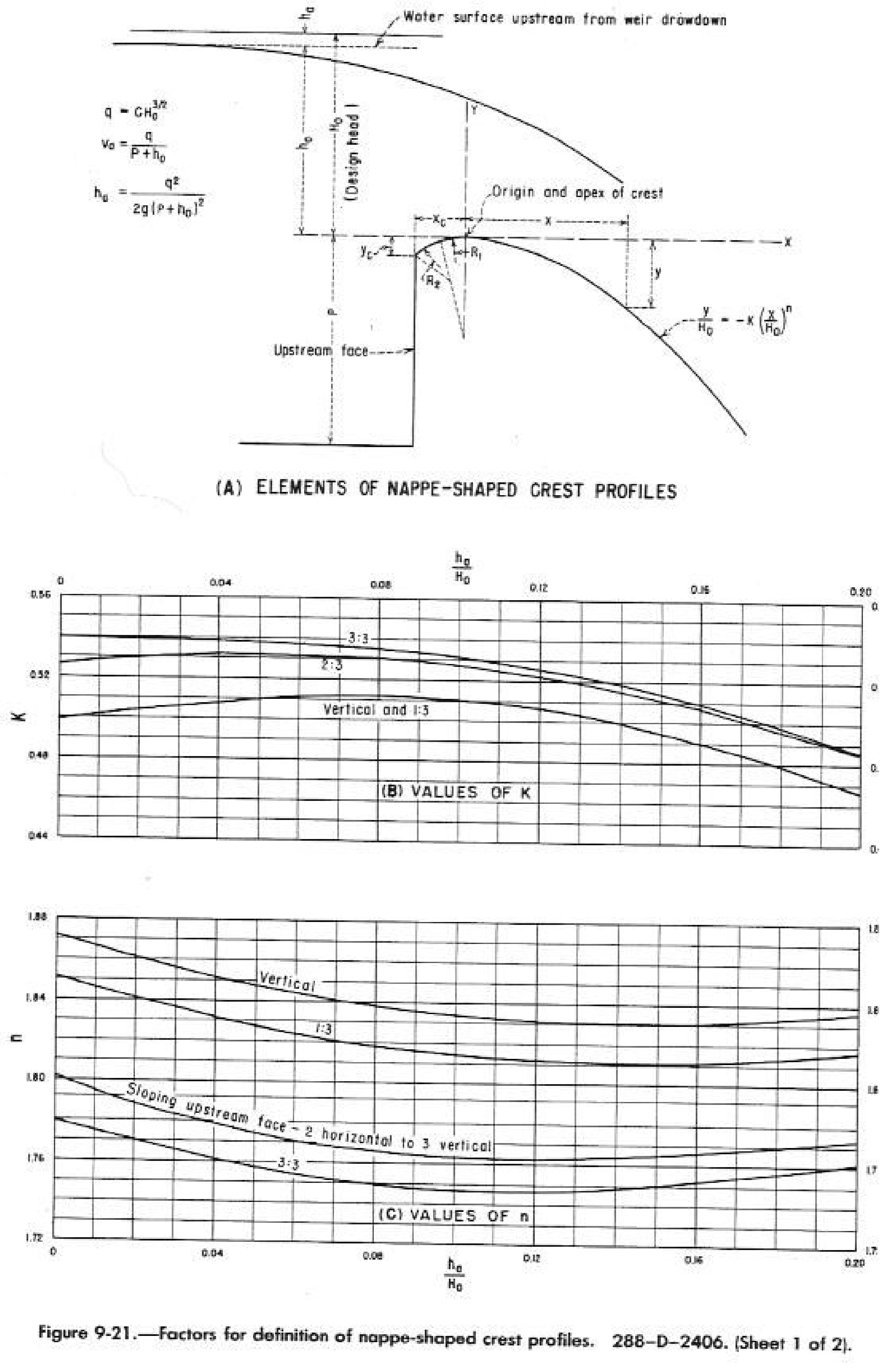


Figure 9-21.—Factors for definition of nappe-shaped crest profiles. 288-D-2406. (Sheet 1 of 2).

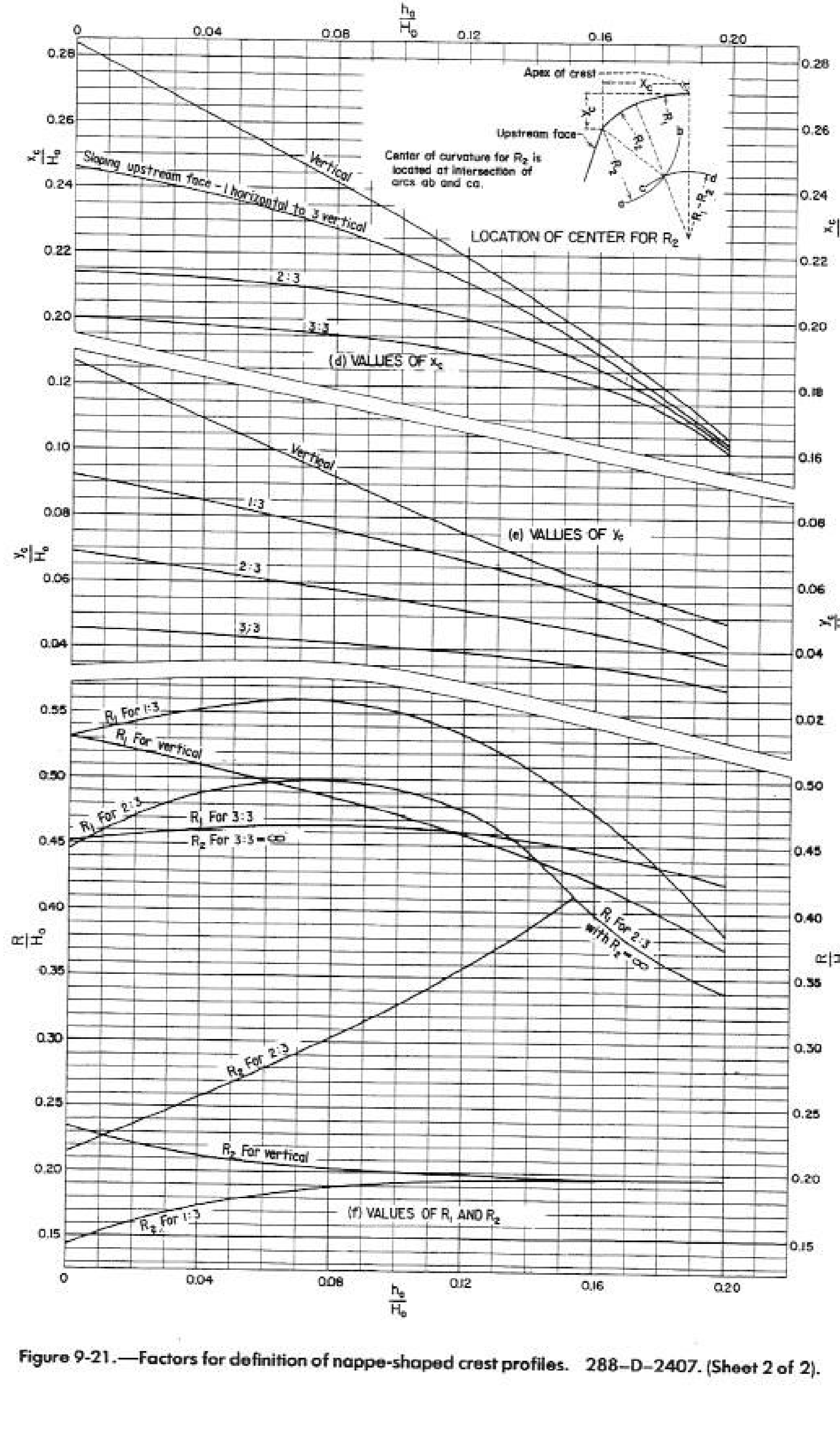


Figure 9-21.—Factors for definition of nappe-shaped crest profiles. 288–D–2407. (Sheet 2 of 2).

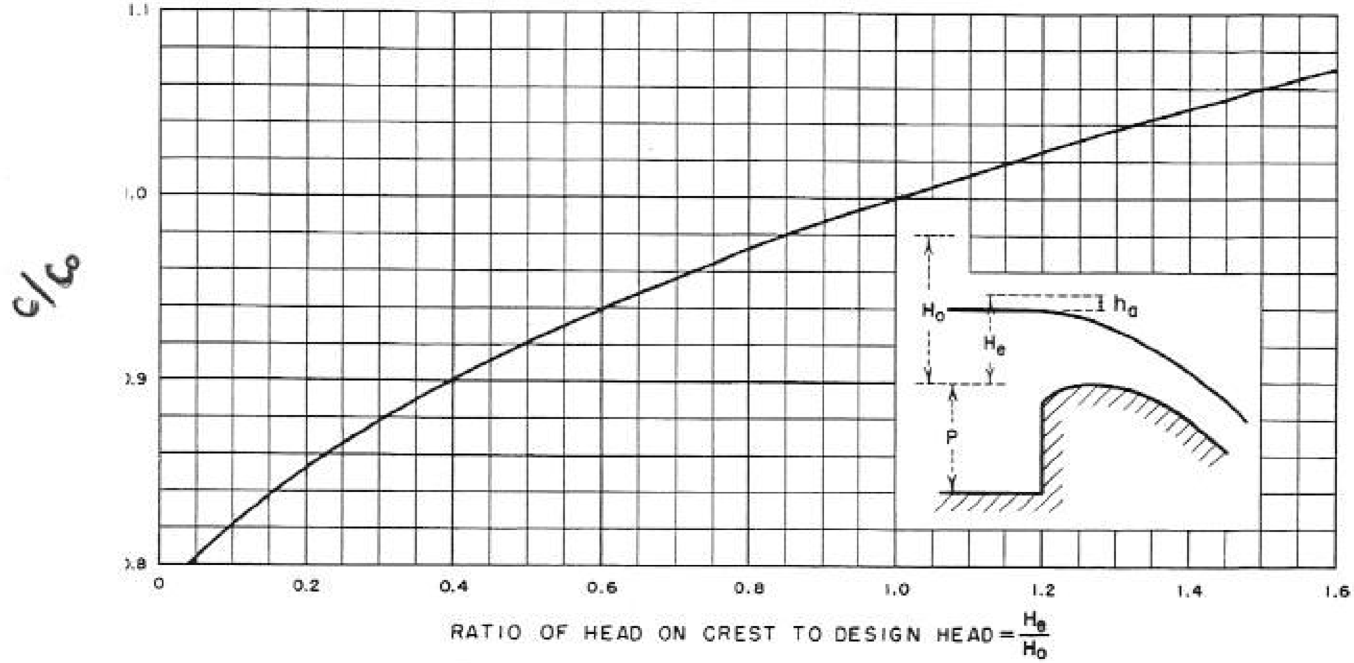


Figure 9-24.—Discharge coefficients for other than the design head. 288–D–2410.

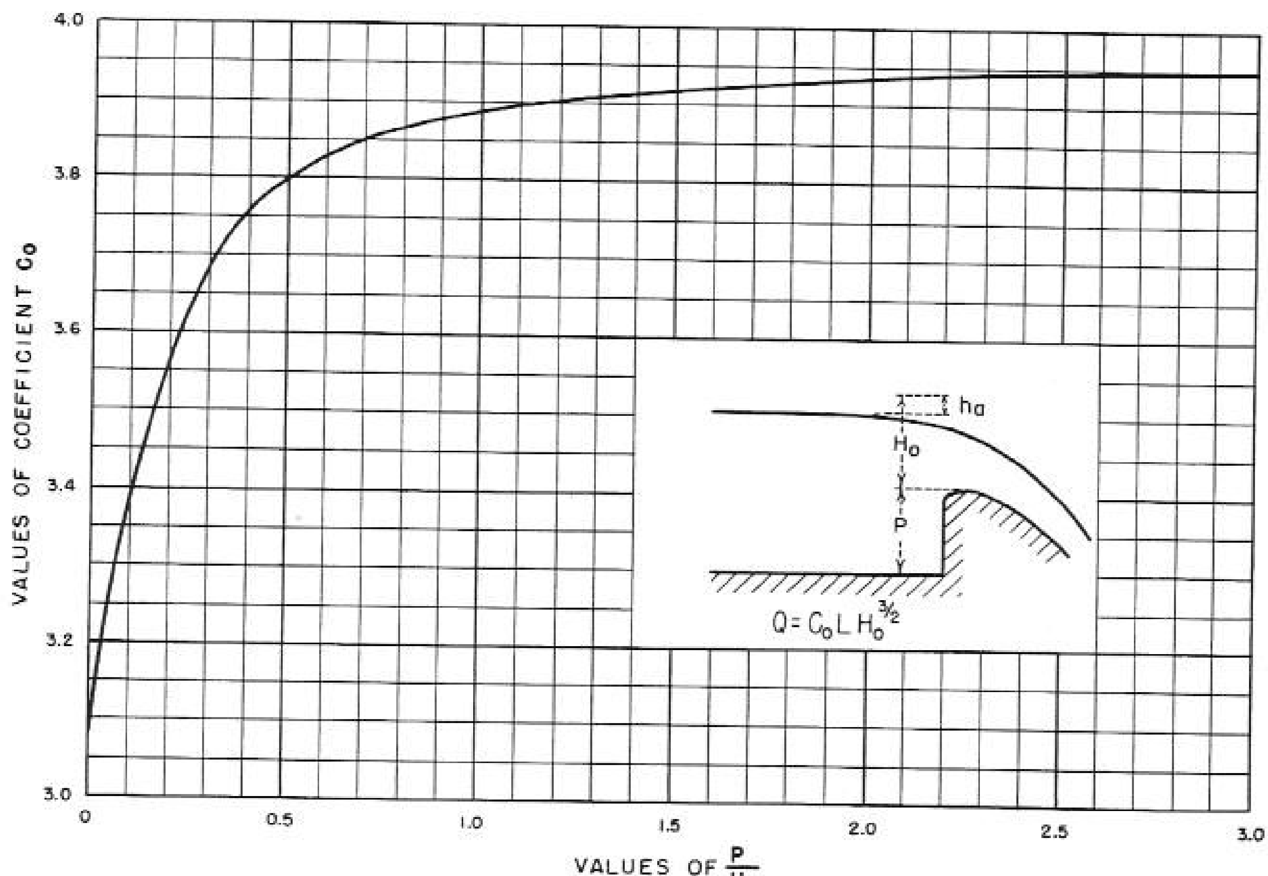


Figure 9-23.—Discharge coefficients for vertical-faced ogee crest. 288–D–2409.

D. "Catchbasins" and Other Unweir Configurations

Often structures transition among different types idealized hydraulic controls. For example, culverts running partially full behave like open channels and as flow increases they eventually behave like pipes or orifices. Weirs are subject to similar transitions as in the case shown if Fig. D.1, in which weir flows converge and could potentially begin to interfere with each other. This occurs in a variety of structures such as storm water catchbasins and morning-glory spillways. A general design guideline is that such structures will behave as weirs as long as $H/R < 0.45$ and will behave as orifices for $H/R > 1$ or 2. In some many instance catchbasins empty into pipe-drain systems and often pipe flow will control the entire system, thus care must be taken to explicitly calculate the height of water above the structure at a variety of flow conditions to understand how the different hydraulic elements work in series.

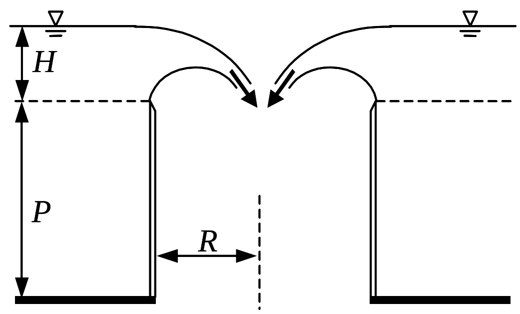


Figure D.1: schematic of converging weir flows.

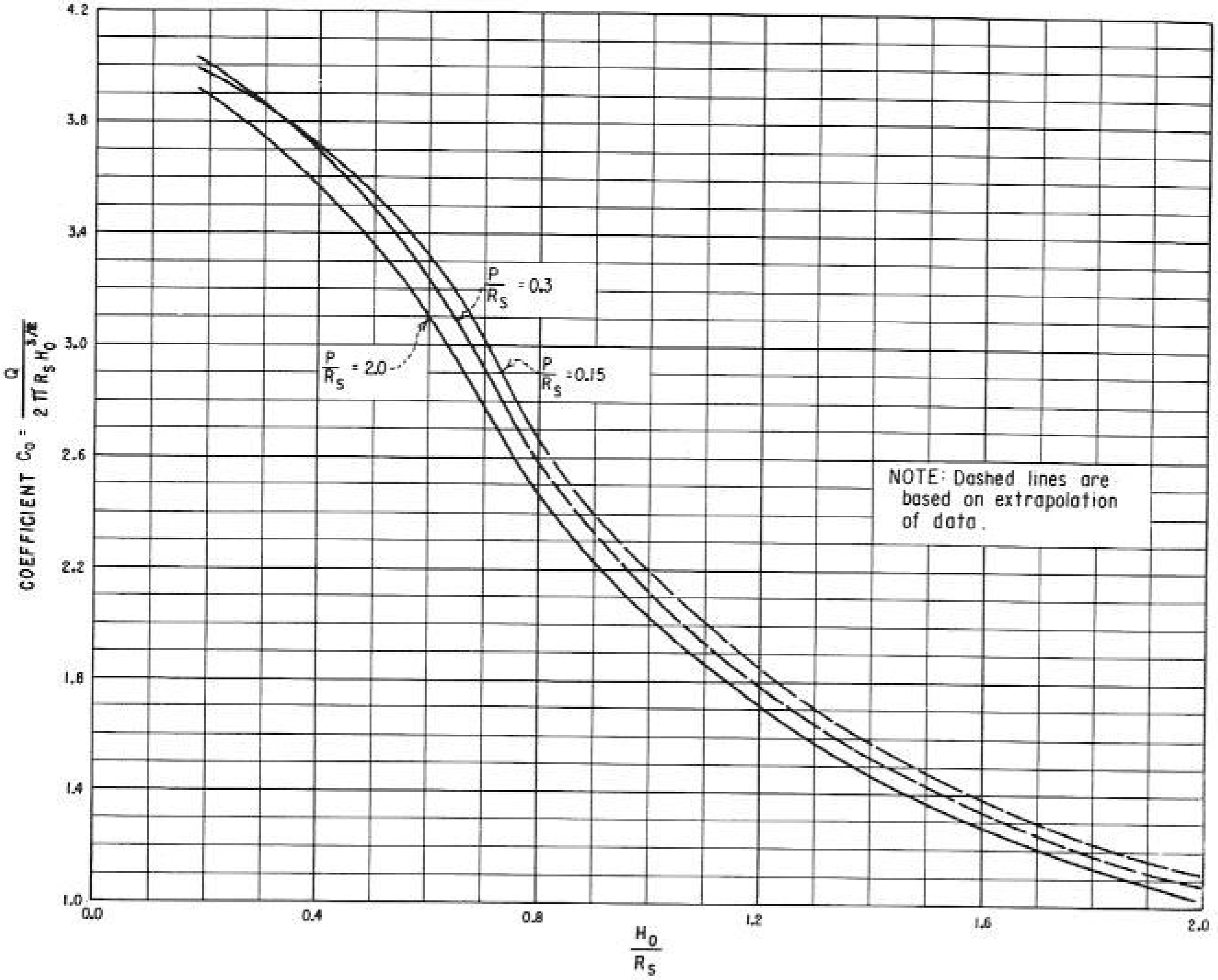


Figure 9-57.—Relationship of circular crest coefficient C_o to H_o/R_s for different approach depths (aerated nappe). 288-D-2441.

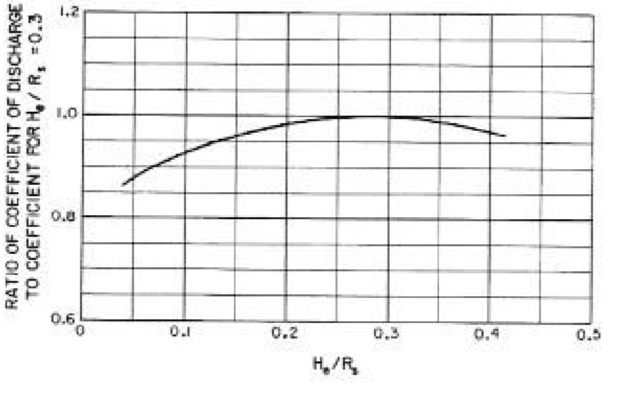


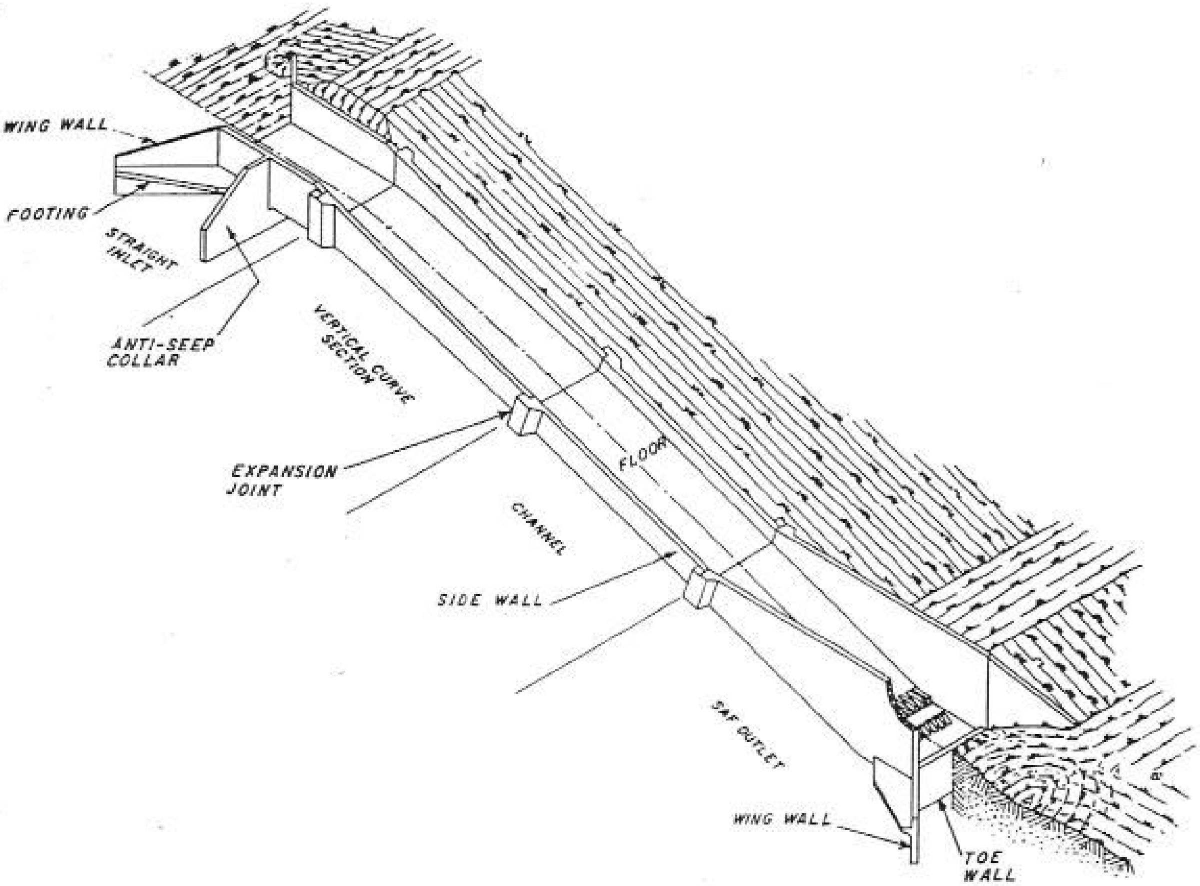
Figure 9-58.—Circular crest discharge coefficient for other than design head. 288-D-2442.

$R = Q_a^{1/2}/5H_a^{1/4}$; where H_a is equal to the distance between the water surface and the elevation under consideration. The diameter of the jet thus decreases with the distance of the free vertical fall for normal design applications.

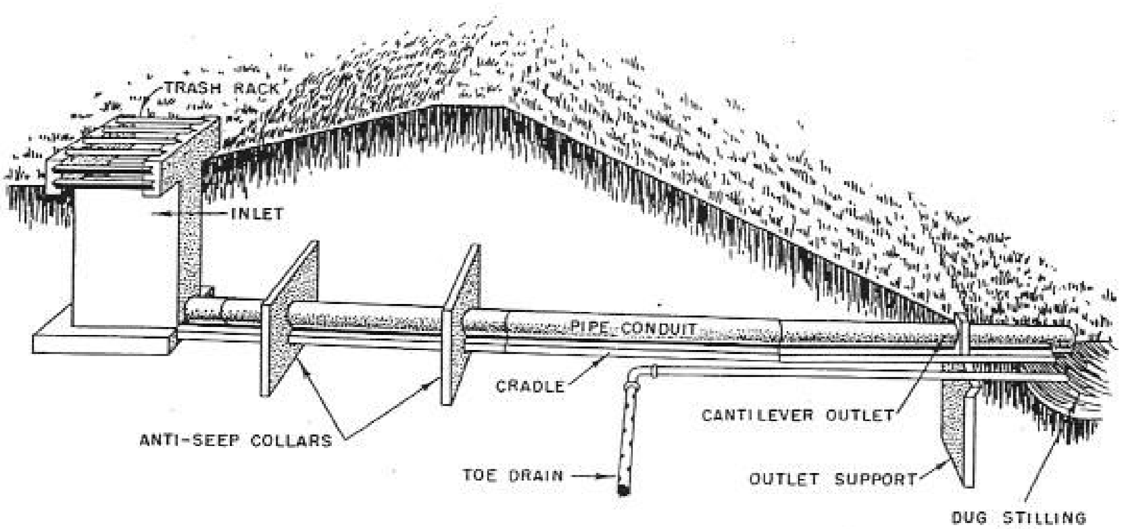
If an assumed total loss (including jet contraction losses, friction losses, velocity losses from direction changes, etc.) is taken as 0.1 H_a, the equation for determining the approximate required shaft radius may be written:

$$R = 0.204 \frac{Q_a^{1/2}}{H_a^{1/4}} \qquad (29)$$

Because this equation is for the shape of the jet,



CHUTE SPILLWAY



DROP INLET SPILLWAY

Figure 6-2 Nomenclature for various parts of chute and drop inlet spillways

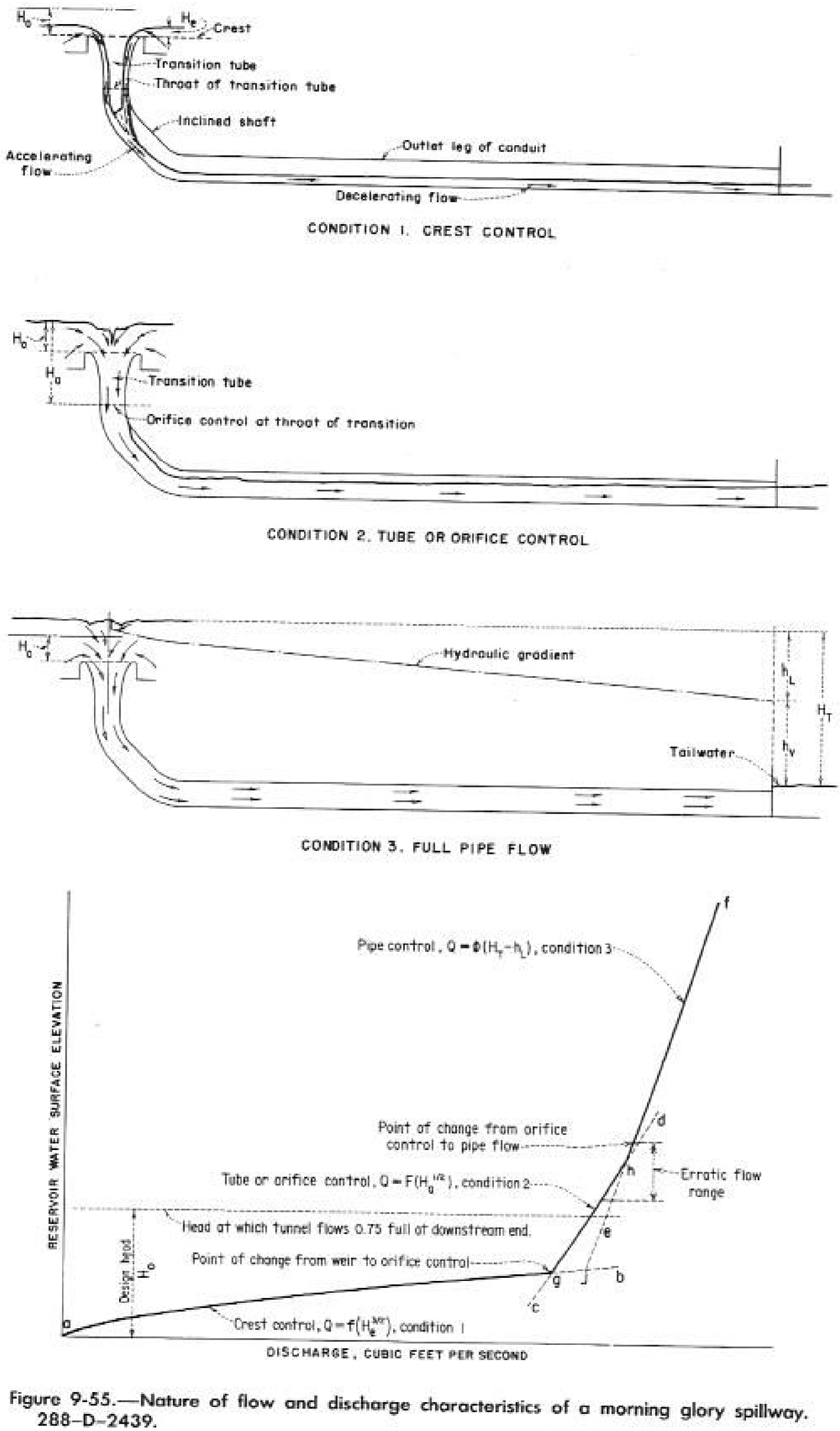


Figure 9-55.—Nature of flow and discharge characteristics of a morning glory spillway. 288-D-2439.

References:

For weir coefficient tables:

Davis, C.V. 1952. *Handbook of Applied Hydraulics.* McGraw-Hill Book Company, Inc. New York. pp.1272.

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For further information:

Chin, D.A. *Water Resources Engineering*. Prentice Hall. Upper Saddle River. pp. 750.

*Chow, V.T. 1959. *Open Channel Hydraulics*. McGraw-Hill Company, New York. pp. 680.

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†Schwab, G.O., D.D. Fangmeier, W.J. Elliot, R.K. Frevert. 1993. *Soil and Water Conservation Engineering*, 4th Ed. John Wiley & Sons, Inc. New York. pp.508.

†Tollner, E.W. 2002. *Natural Resources Engineering*. Iowa State Press, Ames. pp. 576.

*US Dept. of the Interior, Bureau of Reclamation. 1977. *Design of Small Dams*. US Government Printing Office, Washington, DC. pp. 816.

* Particularly good books for this topic

† These texts were previously used for this course