APPENDIX

C. OPEN CHANNEL FLOW DESIGN AIDS

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C. OPEN CHANNEL FLOW DESIGN AIDS

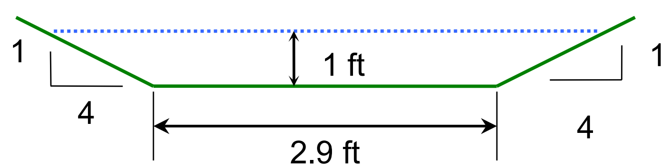
The nomographs in Figures C-1 through C-3 can be used as desktop aides for open channel flow calculations. The purpose of each nomograph is:

Figure C-1	Area, Hydraulic Radius, and Top Width of Trapezoidal Channels
Figure C-2	Normal Depth Velocity for a General Cross Section
	Normal Depth Velocity in a Circular Pipe
Figure C-3	Normal Depth in a Trapezoidal Channel

Figure C-1 can be used to solve Example C.1 below and the Geometry of Examples 3.1-1 through 3.1-4 in Chapter 3 of this document.

EXAMPLE C.1 – GEOMETRIC ELEMENTS

Given: Depth = 1.0 ft
Trapezoidal Cross Section shown below



Calculate: Area, Wetted Perimeter, Hydraulic Radius, Top Width, and Hydraulic Depth

Water Area

$$A = a = bd + zd^2$$
$$a = (2.9 \times 1) + 4(1)^2 = 6.9 \text{ ft}^2$$

Wetted Perimeter

$$P = b + 2d\sqrt{z^2 + 1}$$
$$P = 2.9 + (2 \times 1)\sqrt{4^2 + 1} = 11.146 = 11.1 \text{ ft}$$

Hydraulic Radius

$$R = r = \frac{bd + zd^2}{b + 2d\sqrt{z^2 + 1}}$$

$$r = \frac{(2.9 \times 1) + 4(1)^2}{2.9 + (2 \times 1)\sqrt{4^2 + 1}} = 0.619 = 0.62 \text{ ft}$$

Top Width

$$T = b + 2zd$$
$$T = 2.9 + (2 \times 4 \times 1) = 10.9 \text{ ft}$$

Hydraulic Depth

$$D = \frac{A}{T} = \frac{6.9}{10.9} = 0.63 \text{ ft}$$

This problem can also be solved using nomographs

This example is solved in the lower right hand corner of Figure C-1

EXAMPLE C.2 – GEOMETRIC ELEMENTS

Determine Normal Depth for Standard Ditch and Narrow Ditch given in Chapter 3, Example 3.1-4 using Figure C-3.

Standard Ditch:

Solve for $\frac{Qn}{b^{8/3} S^{1/2}} = \frac{(25)(0.04)}{5^{8/3}(0.005)^{1/2}} = 0.193$

The average value of z is (6 + 4) / 2 = 5

From Figure C-3, $\frac{d}{b} = 0.22$

$d = 0.43b = 0.22(5) = 1.1 ft.$

Using a trial and error procedure to solve Manning's Equation, normal depth = 1.12'

Narrow Ditch:

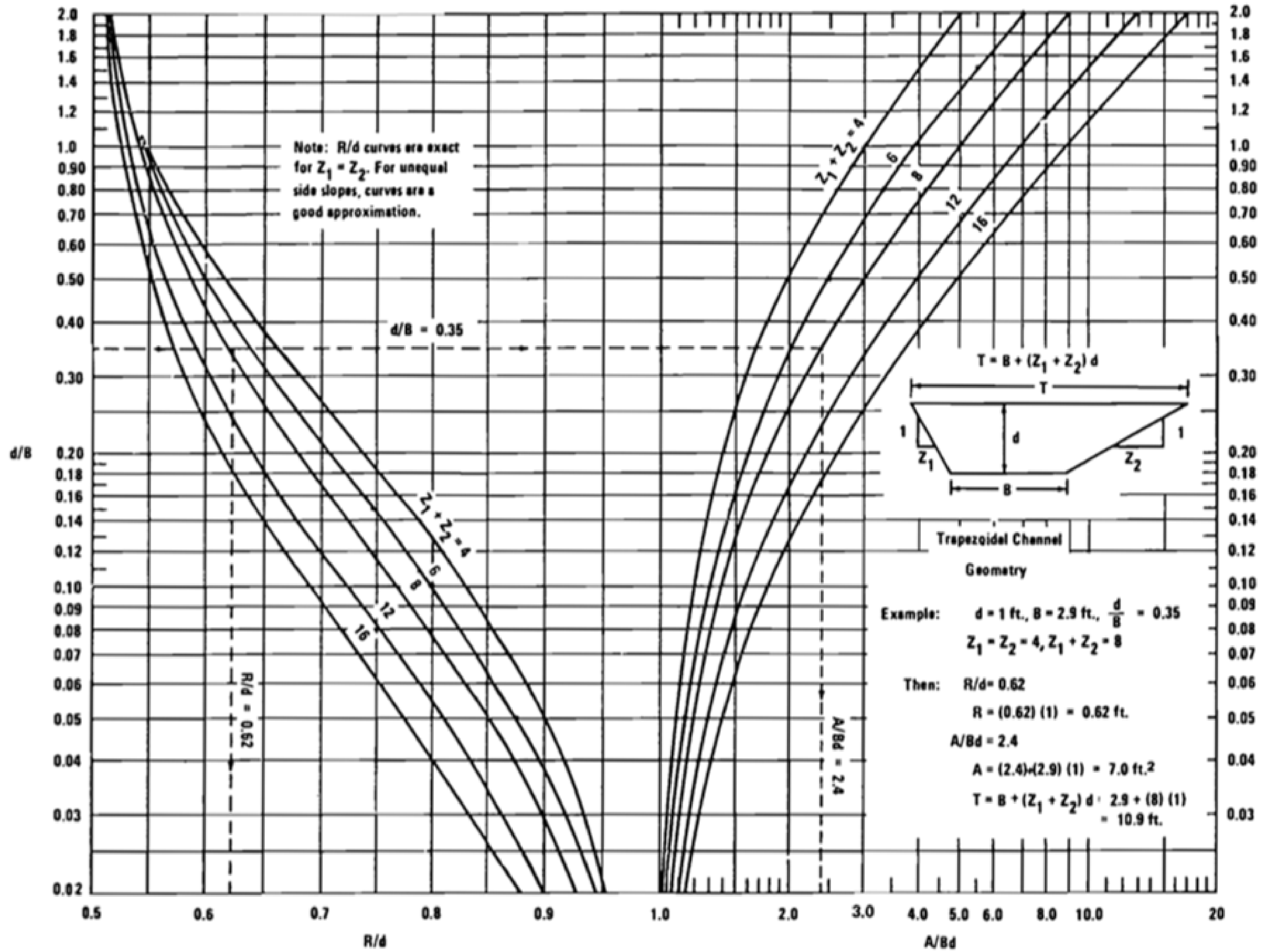
Solve for $\frac{Qn}{b^{8/3} S^{1/2}} = \frac{(25)(0.04)}{3.5^{8/3}(0.005)^{1/2}} = 0.501$

The average value of z is (6 + 4) / 2 = 5

From Figure C-3, $\frac{d}{b} = 0.34$

$$d = 0.34b = 0.34(3.5) = 1.2\,ft.$$

Using a trial and error procedure to solve Manning's Equation, normal depth = 1.25'



Reference: USDOT, FHWA, HEC-15 (1975).

Figure C-1: Trapezoidal Channel Geometry

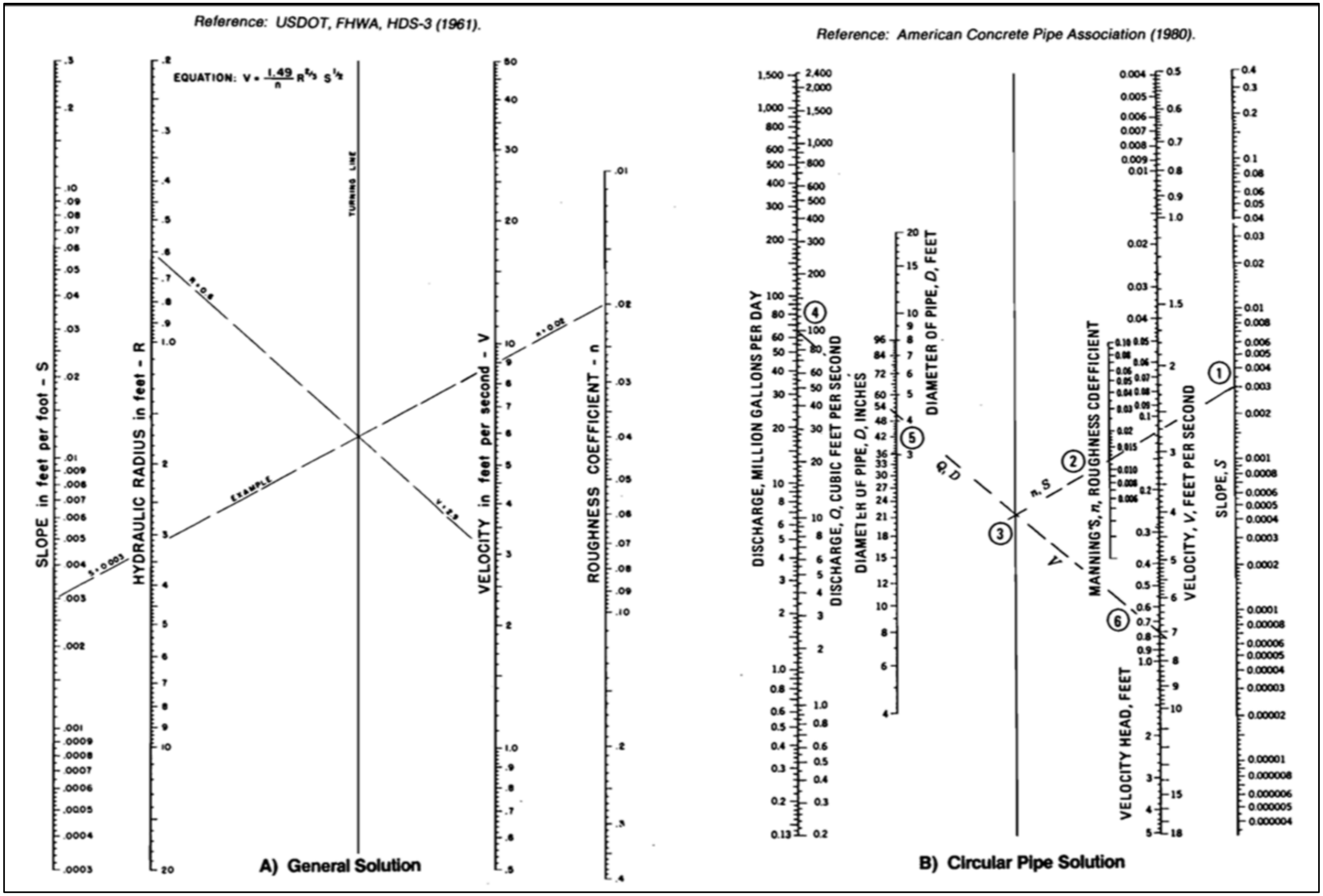


Figure C-2: Nomographs for the Solution of Manning's Equation

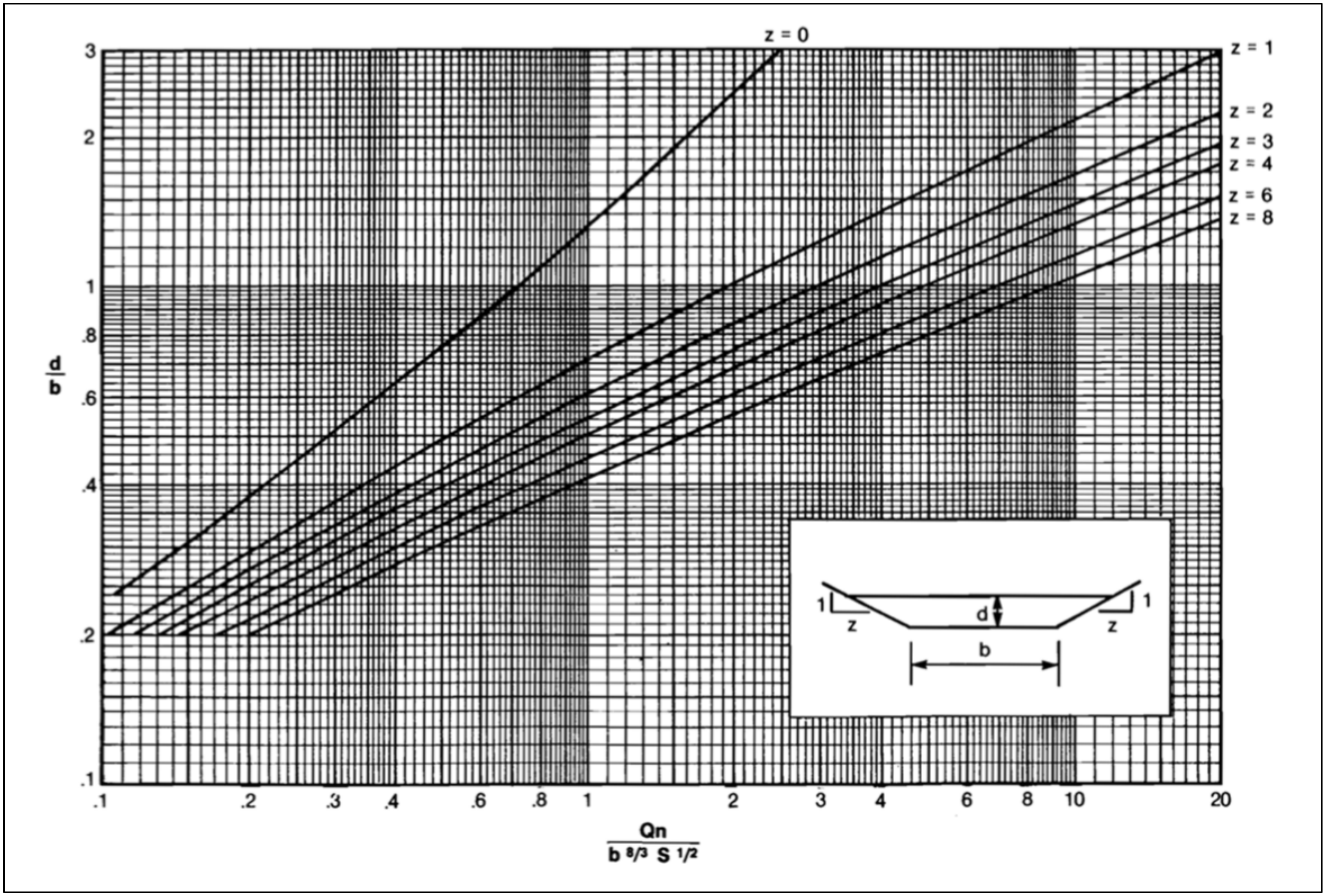
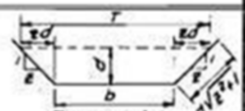
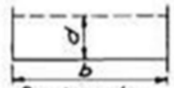
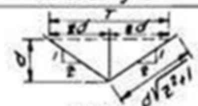
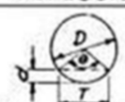
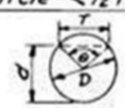


Figure C-3: Trapezoidal Channel Capacity Chart

Section	Area a	Wetted Perimeter p	Hydraulic Radius r	Top Width T
 Trapezoid	$bd+zd^2$	$b+2d\sqrt{z^2+1}$	$\frac{bd+zd^2}{b+2d\sqrt{z^2+1}}$	$b+2zd$
 Rectangle	bd	$b+2d$	$\frac{bd}{b+2d}$	b
 Triangle	zd^2	$2d\sqrt{z^2+1}$	$\frac{zd}{2\sqrt{z^2+1}}$	$2zd$
 Parabola	$\frac{2}{3}dT$	$T+\frac{8d^2}{3T}$ [1]	$\frac{2dT^2}{3T^2+8d^2}$ [1]	$\frac{3a}{2d}$
 Circle - <½ full [2]	$\frac{D^2}{8}\left(\frac{\pi\theta}{180}-\sin\theta\right)$	$\frac{\pi D\theta}{360}$	$\frac{45D}{\pi\theta}\left(\frac{\pi\theta}{180}-\sin\theta\right)$	$D\sin\frac{\theta}{2}$ or $2\sqrt{d(D-d)}$
 Circle - >½ full [3]	$\frac{D^2}{8}\left(2\pi-\frac{\pi\theta}{180}+\sin\theta\right)$	$\frac{\pi D(360-\theta)}{360}$	$\frac{45D}{\pi(360-\theta)}\left(2\pi-\frac{\pi\theta}{180}+\sin\theta\right)$	$D\sin\frac{\theta}{2}$ or $2\sqrt{d(D-d)}$

[1] Satisfactory approximation for the interval $0<\frac{d}{T}\leq 0.25$
When $d/T>0.25$, use $p=\frac{1}{2}\sqrt{16d^2+T^2}+\frac{T^2}{8d}\sinh^{-1}\frac{4d}{T}$

[2] $\theta=4\sin^{-1}\sqrt{d/D}$
[3] $\theta=4\cos^{-1}\sqrt{d/D}$
Insert θ in degrees in above equations

Reference: USDA, SCS, NEH-5 (1956).

Figure C-4: Open Channel Geometric Relationships for Various Cross Sections