Appendix 7A-1 Definitions and Abbreviations

Abbreviations:

BRI-STARS	Bridge Stream Tube Model for Sediment Routing Alluvial River Simulation
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
NTIS	National Technical Information Service
USCOE/USACE	United States Corps of Engineers
VDOT	Virginia Department of Transportation

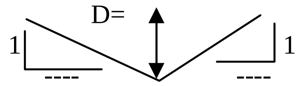
Appendix 7A-2 Symbols

SYMBOL	DEFINITION	UNITS
A	Cross-sectional area of flow	ft^2
α	Velocity distribution coefficient	-
C	Stone size correction factor	-
C_{sg}	Adjustment to the specific gravity of stone	-
C_{SF}	Adjustment to the stability factor	-
d	Depth of flow	ft
D_{50s}	Required D_{50} for side slopes	ft
d_c	Critical depth	ft
d_n	Normal depth	ft
d_{avg}	Average flow depth in the main channel	ft
E	Specific energy	ft
F_r	Froude Number	-
g	Acceleration due to gravity	ft/s^2
h_L	Total head loss due to local minor and friction losses	ft
h	Stage or head	ft
h_f	Friction loss	ft
H_D	Average hydraulic depth	ft
h_o	Summation of minor losses	ft
K	Channel conveyance	-
L	Discharge-weighted or conveyance reach length	ft
n	Manning's roughness coefficient	-
P	Wetted perimeter	ft
Q	Discharge	cfs
R	Hydraulic radius	ft
S_o	Channel slope	ft/ft
S	Slope of the energy grade line	ft/ft
S_A	Average slope of the energy grade line	ft/ft
S_g	Specific gravity of rock riprap	-
SF	Stability factor applied	
T	Top width at the water surface	ft
τ_o	Average tractive force	lbs/ft^2
τ_{max}	Maximum tractive force	lbs/ft^2
τ_p	Permissible shear stress	lbs/ft^2
τ_s	Side slope shear stress	lbs/ft^2
TW	Tailwater depth above invert of culvert	ft
V	Mean velocity	ft/s
V_a	Average velocity in main channel	ft/s
z	Elevation head	ft
S_f	Mean slope of the energy grade line	ft/ft
γ	Unit weight of water	lb/ft^3
θ	Side slope angle	deg.
ϕ	Angle of repose of material	deg.

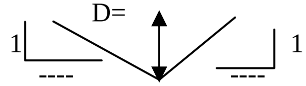
Appendix 7B-1 LD-268 Roadside and Median Ditch Design Form

LD-268

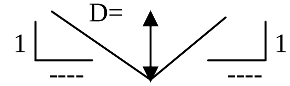
____LANE
____SIDE



CUT



MED.

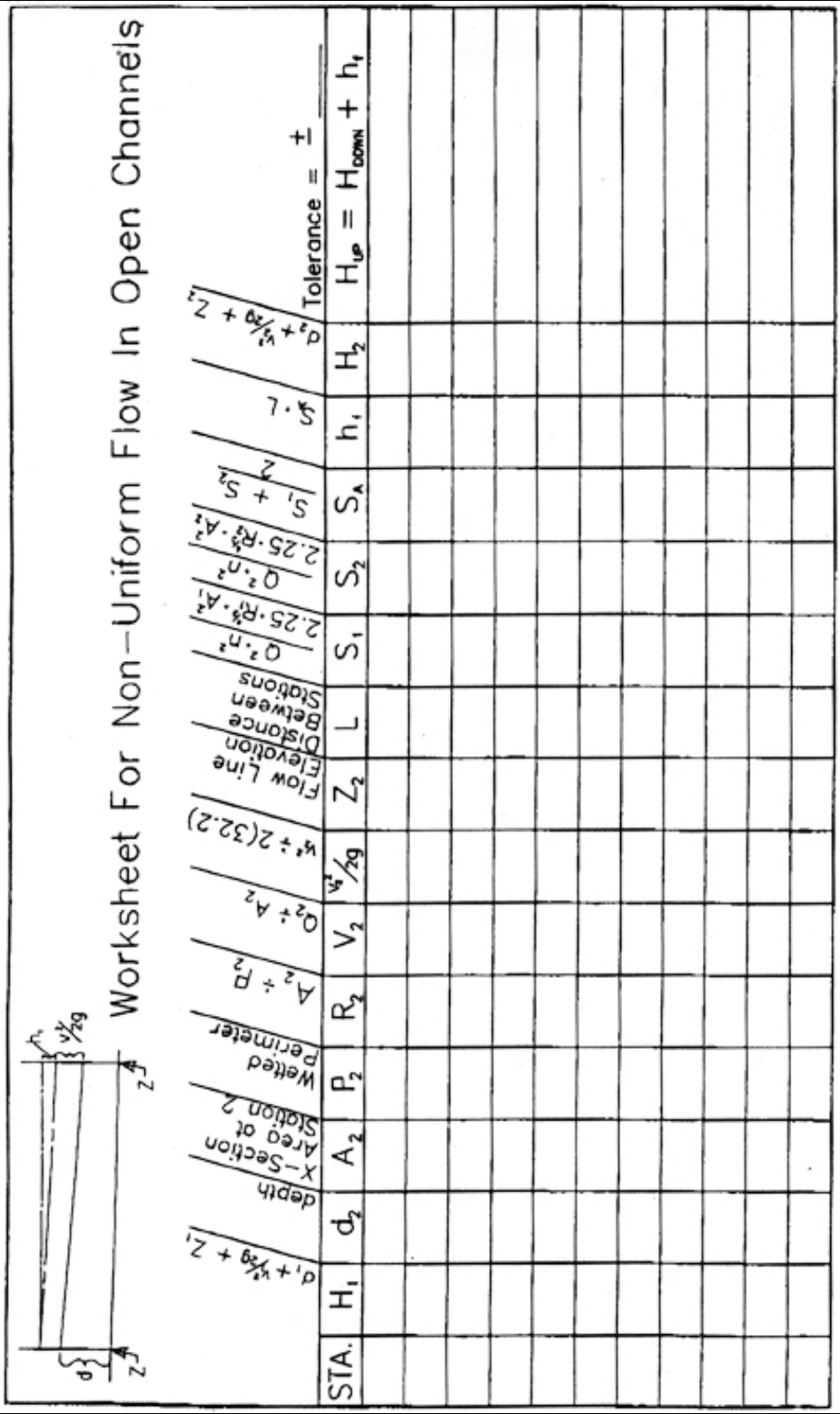


FILL

PROJECT________________________.
BY______________________________.
DATE____________________________.
SHEET ________ of ________.

														Earth	Protective Lining								
STA. TO STA.		FLOW	0.9	0.5	0.3	CA		Tc	I_2	Q_2	C or F	Slope Ft/Ft	ALLOW VEL.	n=.03	n=.05			n=.015		I_{10}	Q_{10}	DEP	REMARKS
			WS/ CA	WS/ CA	WS/ CA	INCR.	ACC.							VEL.	Qn	VEL	DEP	Qn	DEP				

Appendix 7B-2 Water Surface Profile Calculation Form



Source:

Appendix 7B-3 CHANNEL STABILITY WORK SHEET

CHANNEL DATA

Q = _____(cfs)	P = _____(ft.)	Native Material
S_o = _____(ft/ft)	R = _____(ft.)	D_{50} = _____
d_n = _____(ft.)	V_n = _____(fps)	D_{75} = _____
A = _____(ft^2)	Side Slope = _____ :1	n = _____

STABILITY OF NATIVE MATERIAL

τ_o= 62.4 • R • S_o = 62.4 • _____ • _____ = _____

τ_p Bed = _____ (Appendix 7E-2 or 3)

For D_{50} = _____ ϕ = _____^{o} (Appendix 7E-1)

For D_{75} = _____ ϕ = _____^{o} (Appendix 7E-9)

Side Slope = ___ :1 θ = _____^{o}

$K_1 = [1 - (\sin^2 \theta / \sin^2 \phi)]^{0.5}$

$K_1 = [1 - (\sin^2$ _____$^o / \sin^2$ _____$^o)]^{0.5}$ = _____

τ_s Side Slope (SS) = τ_p Bed • K = _____ • _____ = _____

τ_p Bed (_____) (<) (=) (>) τ_o (_____)

∴ Native Material on Bed is (stable) (unstable)

τ_s SS (_____) (<) (=) (>) τ_o (_____)

∴ Native Material on Side Slope is (stable) (unstable)

Source: VDOT

Appendix 7B-4 RIPRAP DESIGN WORK SHEET FOR STANDARD VDOT RIPRAP SIZES ONLY

CHANNEL DATA

Q = _____(cfs) P = _____(ft.) n = _____

S_o = _____(ft/ft) R = _____(ft.)

d_n = _____(ft.) V_n = _____(fps)

A = _____($ft.^2$) Side Slope = _____ :1

DETERMINE RIPRAP SIZE

$\phi = 42^o$ Side Slope = _____ :1 θ = _____^{o}

$K_1 = [1 - (\sin^2 \theta / \sin^2 \phi)]^{0.5}$

$K_1 = [1 - (\sin^2$ _____$^o / \sin^2 42^o)]^{0.5}$ = _____

For Specific Gravity = 2.65 and Stability Factor = 1.2

$D_{50} = 0.001 \bullet V_a^3 / (d_{avg}^{0.5} \bullet K_1^{1.5})$

$D_{50} = 0.001 \bullet$ _____^{3} / (_____$^{0.5} \bullet$ _____$^{1.5}$)

D_{50} Computed = _____

Note: All VDOT standard riprap (Class AI through Type II) is assumed to have a ϕ of approximately 42^o and a Specific Gravity of 2.65. Therefore, the Computed D_{50} should be adjusted by the Stability Correction Factor (C_{SF}) (if any) to derive a Final D_{50}. The VDOT standard class of riprap with the next higher D_{50} should be specified.

Correction Factor For Stability Factor (SF) other than 1.2 (Default = 1.0)

$C_{SF} = (SF / 1.2)^{1.5}$ = (_____ / 1.2)$^{1.5}$ = _____

Final $D_{50} = C_{SF} \bullet$ Computed D_{50} = _____ • _____ = _____

RIPRAP RECOMMENDATION: VDOT (Class) (Type) _____

Thickness (T) = _____" ($2 \bullet D_{50}$ MSD minimum)

Source: VDOT

Appendix 7B-5 RIPRAP DESIGN WORK SHEET FOR OTHER THAN VDOT STANDARD RIPRAP SIZES

CHANNEL DATA

Q = _____(cfs) P = _____(ft.) n = _____

S_o = _____(ft/ft) R = _____(ft.)

d_n = _____(ft.) V_n = _____(fps)

A = _____(ft^2) Side Slope = _____ :1

ASSUMED RIPRAP SIZE - D_{50} = _____

VERIFY ASSUMED RIPRAP SIZE

ϕ = _____^{o} (Appendix 7E-1)
Side Slope = _____ : 1 θ = _____^{o}
$K_1 = [1 - (\sin^2 \theta / \sin^2 \phi)]^{0.5}$
$K_1 = [1 - (\sin^2$ _____$^o / \sin^2$ _____$^o)]^{0.5}$ = _____

For Specific Gravity = 2.65 and Stability Factor = 1.2

$D_{50} = 0.001 \bullet V_a^3 / (d_{avg}^{0.5} \bullet K_1^{1.5})$

$D_{50} = 0.001 \bullet$ _____^{3} / (_____$^{0.5} \bullet$ _____$^{1.5}$) = _____

D_{50} Computed (_____) (<) (=) (>) D_{50} Assumed (_____)

Assumed D_{50} is (correct) (incorrect)

Note: The above process of assuming a D_{50} size, determining the natural angle of repose (ϕ) and computing a D_{50} size should be repeated until the Assumed D_{50} size equals the Computed D_{50} size. Once the D_{50} size determination has been made, it should be adjusted for the Specific Gravity Correction Factor C_{sg} (if any) and the Stability Correction Factor (C_{SF}) (if any) to derive a Final D_{50}.

Correction Factor For Riprap Specific Gravity (S_s) other than 2.65 (Default = 1.0)

$C_{sg} = 2.12 / (S_s - 1)^{1.5}$ = 2.12 / (_____ - 1)$^{1.5}$ = _____

Correction Factor For Stability Factor (SF) other than 1.2 (Default = 1.0)

$C_{SF} = (SF / 1.2)^{1.5}$ = (_____ / 1.2)$^{1.5}$ = _____

Final Correction Factor = C = $C_{sg} \bullet C_{SF}$ = _____ • _____ = _____

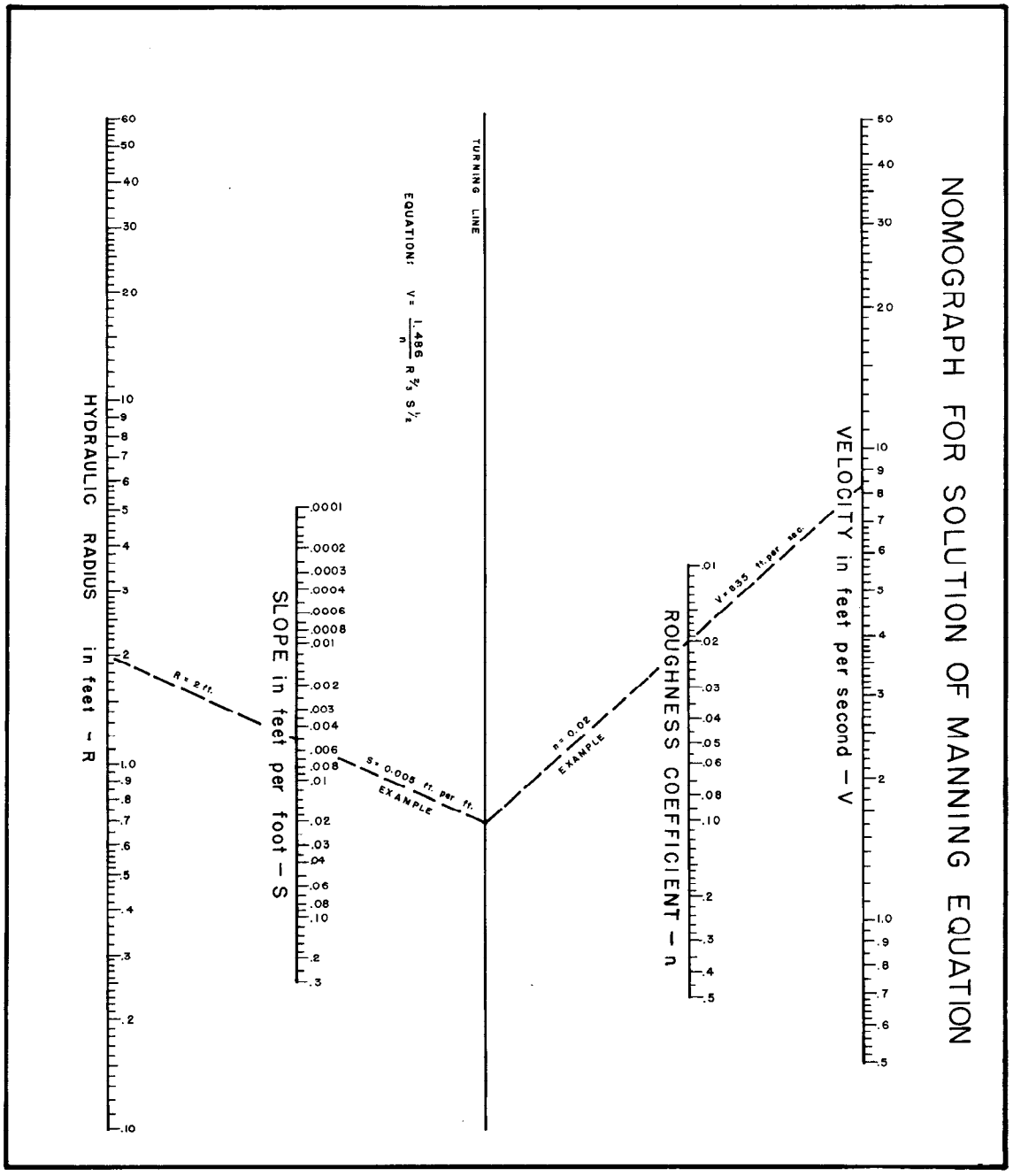
Final D_{50} = C • Computed D_{50} = _____ • _____ = _____

RIPRAP RECOMMENDATION: _____

Thickness (T) = _____" (2 • D_{50} MSD minimum)

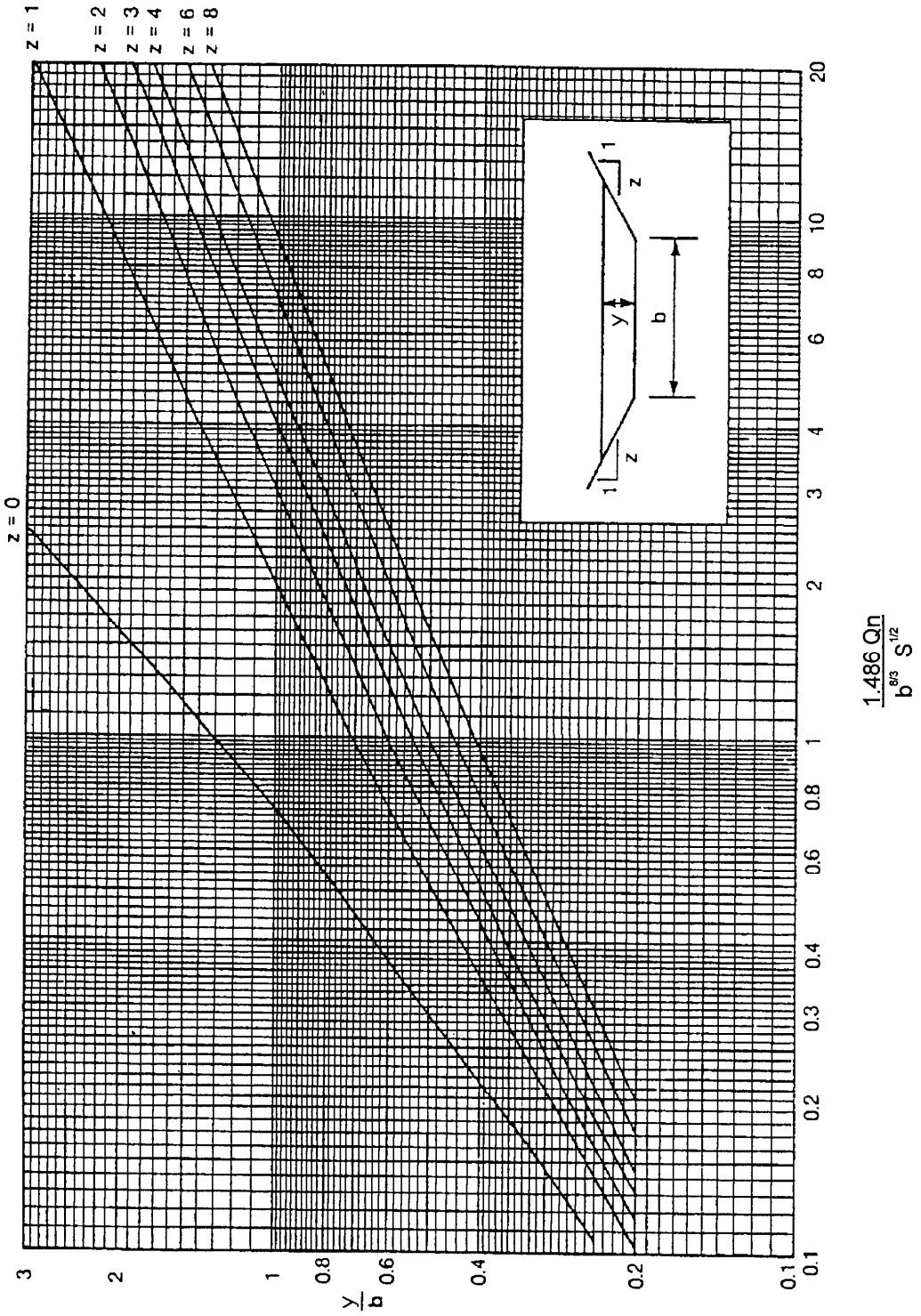
Source: VDOT

Appendix 7C-1 Nomograph for Solution of Manning's Equation



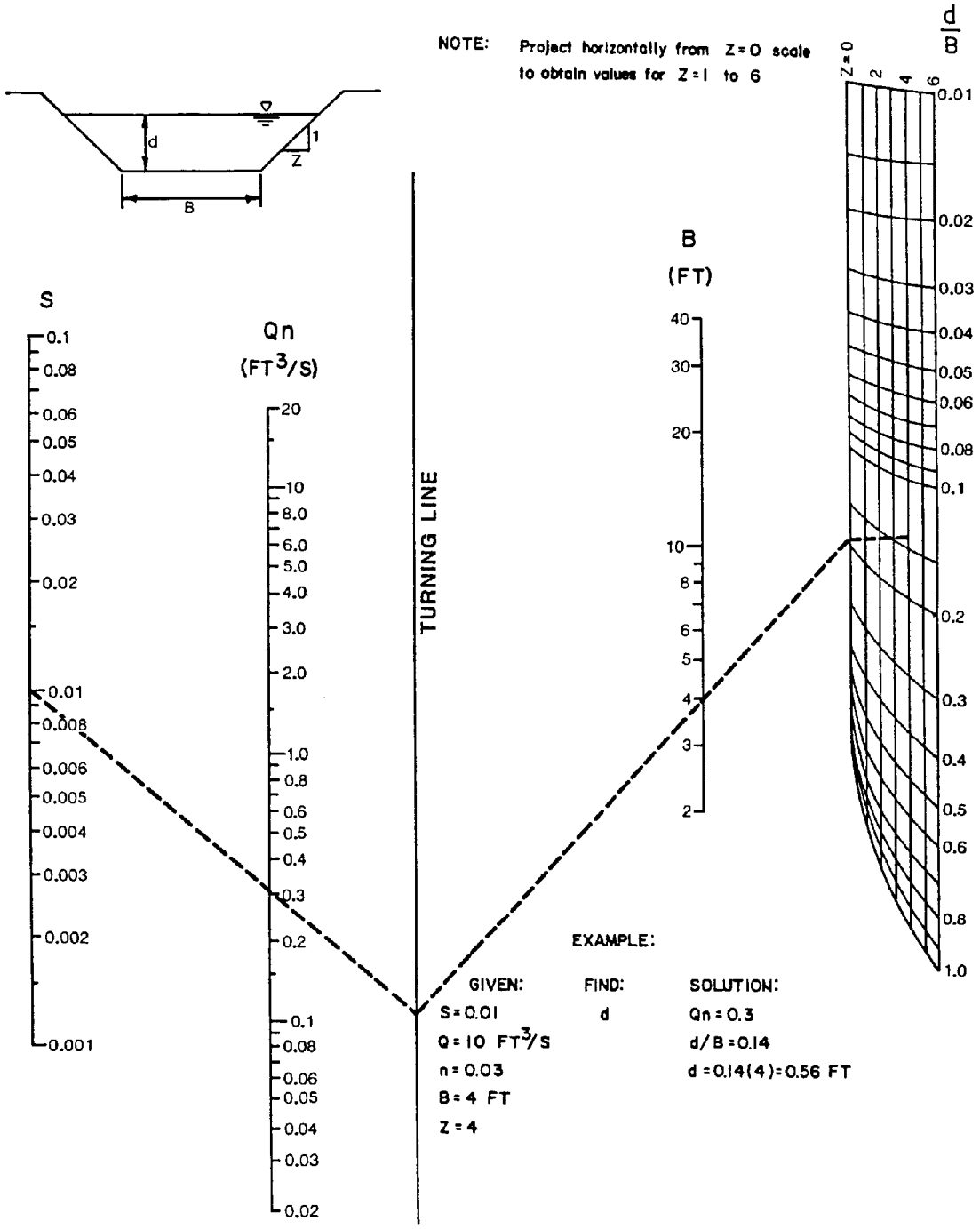
Source: VDOT

Appendix 7C-2 Trapezoidal Channel Capacity Chart



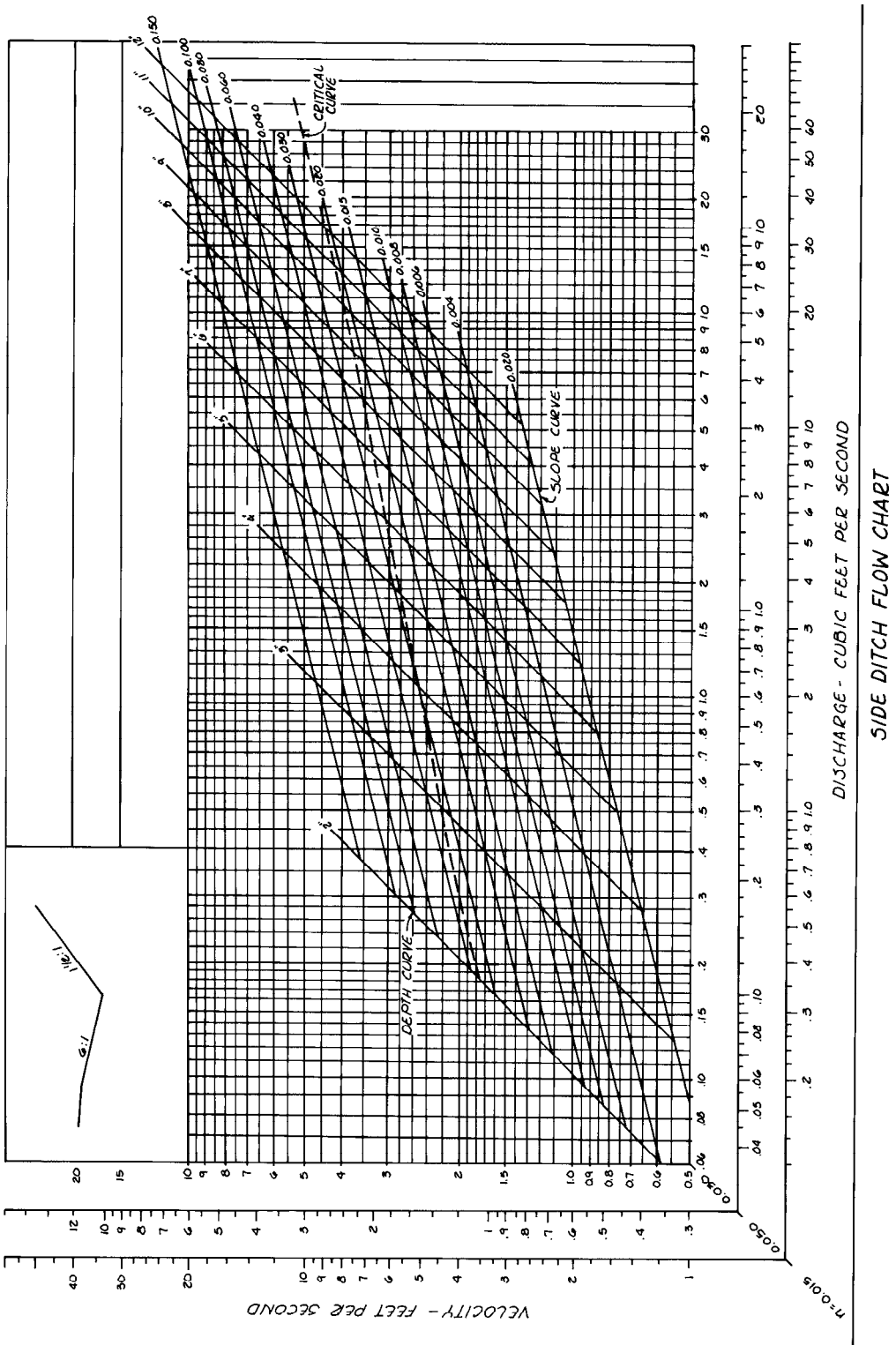
Source:

Appendix 7C-3 Nomograph for Solution of Normal Depth



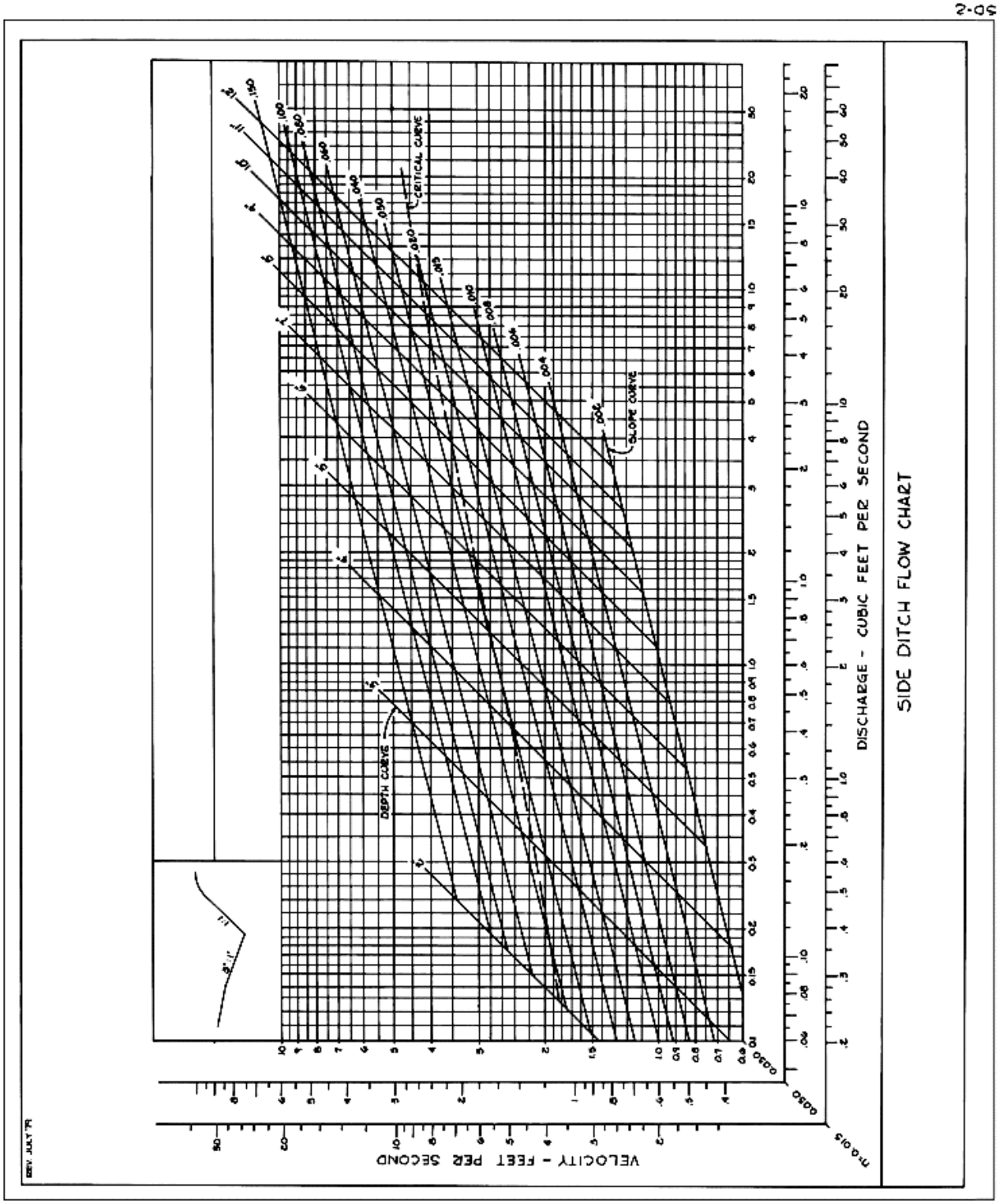
Source: HEC-15 (Archived) 1988

Appendix 7C-4 Side Ditch Flow Chart (Side Slopes = 6:1, 1.5:1)



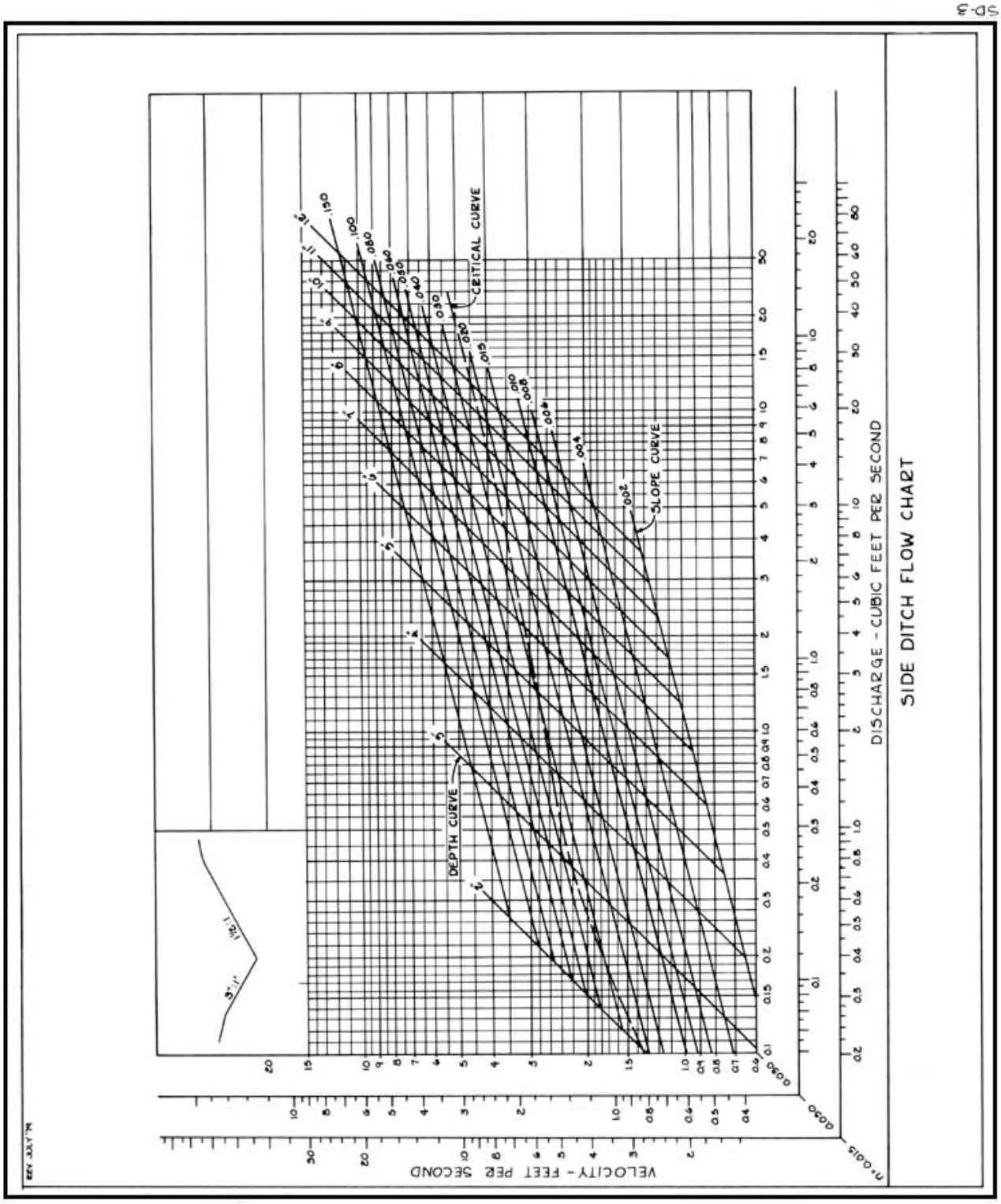
Source: VDOT

Appendix 7C-5 Side Ditch Flow Chart (Side Slopes = 4:1, 1:1)



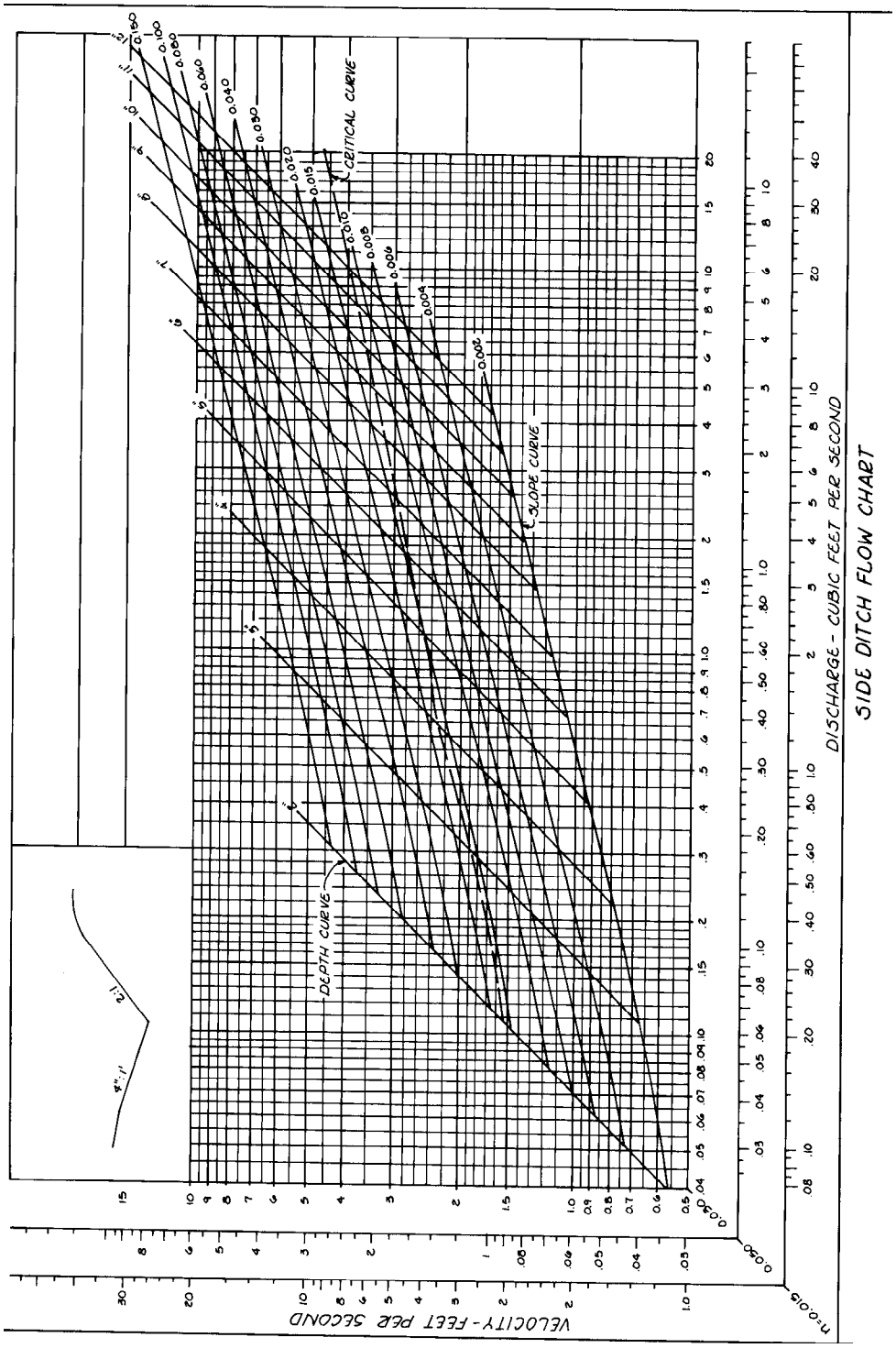
Source: VDOT

Appendix 7C-6 Side Ditch Flow Chart (Side Slopes = 4:1, 1.5:1)



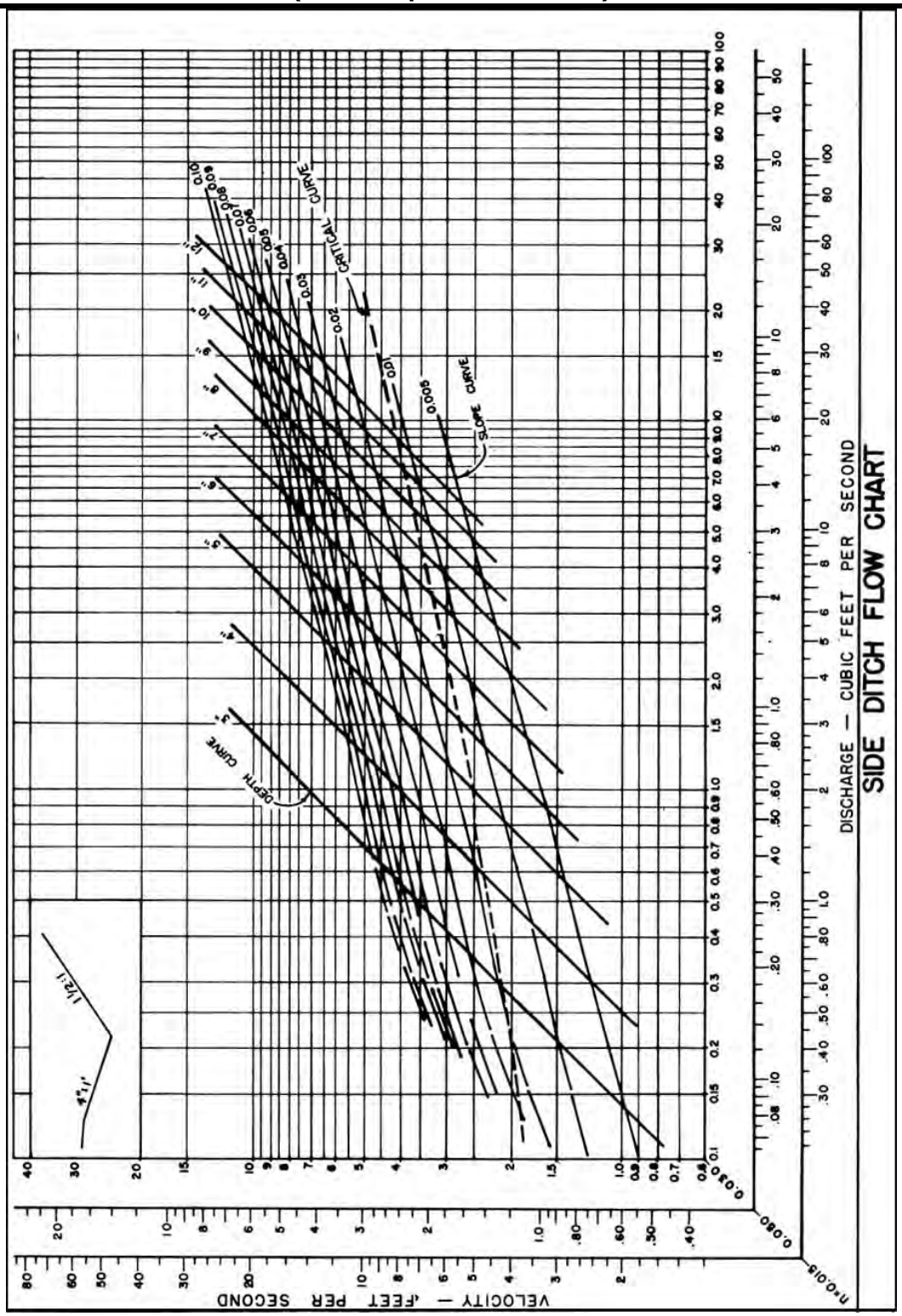
Source: VDOT

Appendix 7C-7 Side Ditch Flow Chart (Side Slopes = 3:1, 2:1)



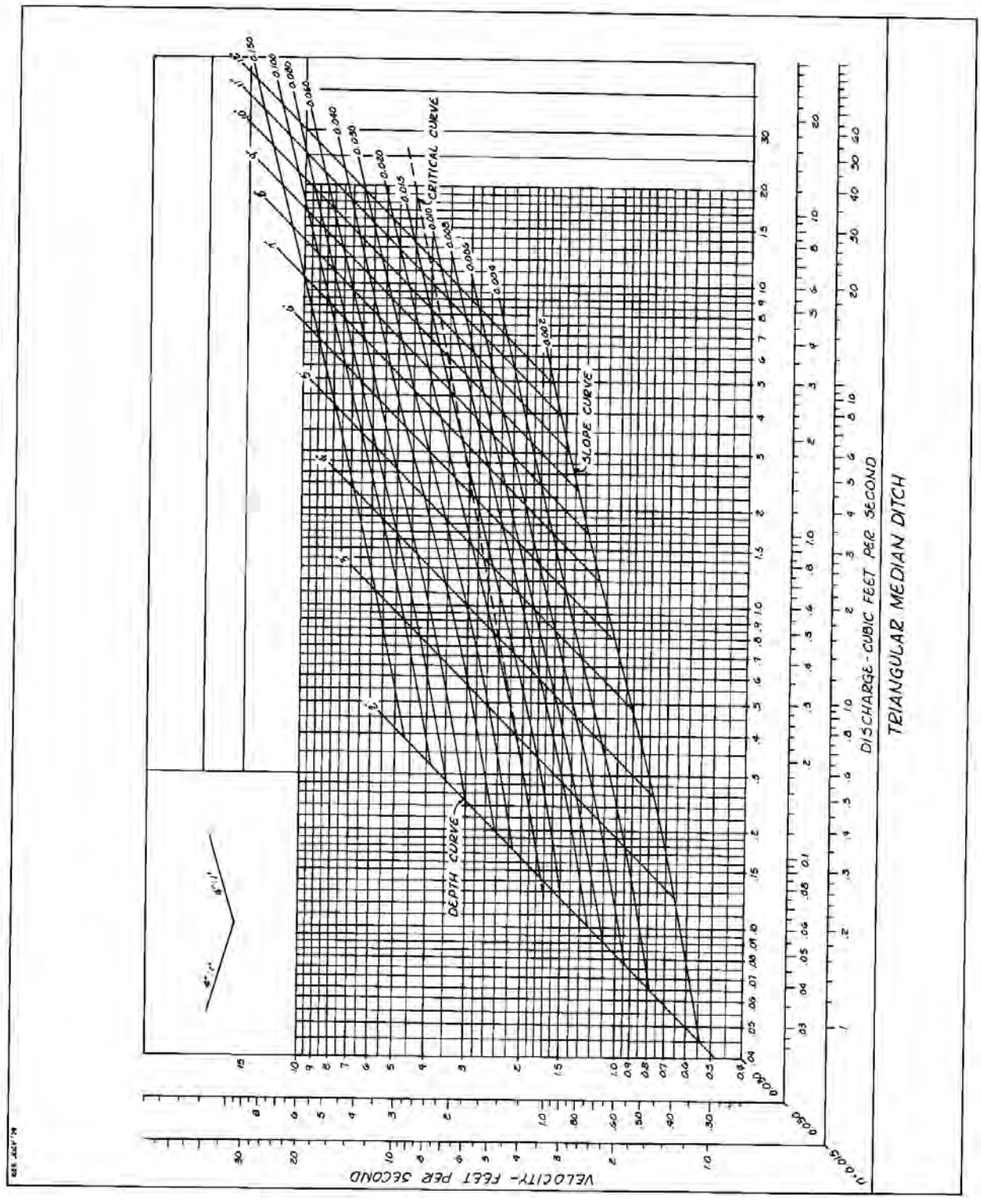
Source:

Appendix 7C-8 Side Ditch Flow Chart (Side Slopes = 3:1, 1.5:1)



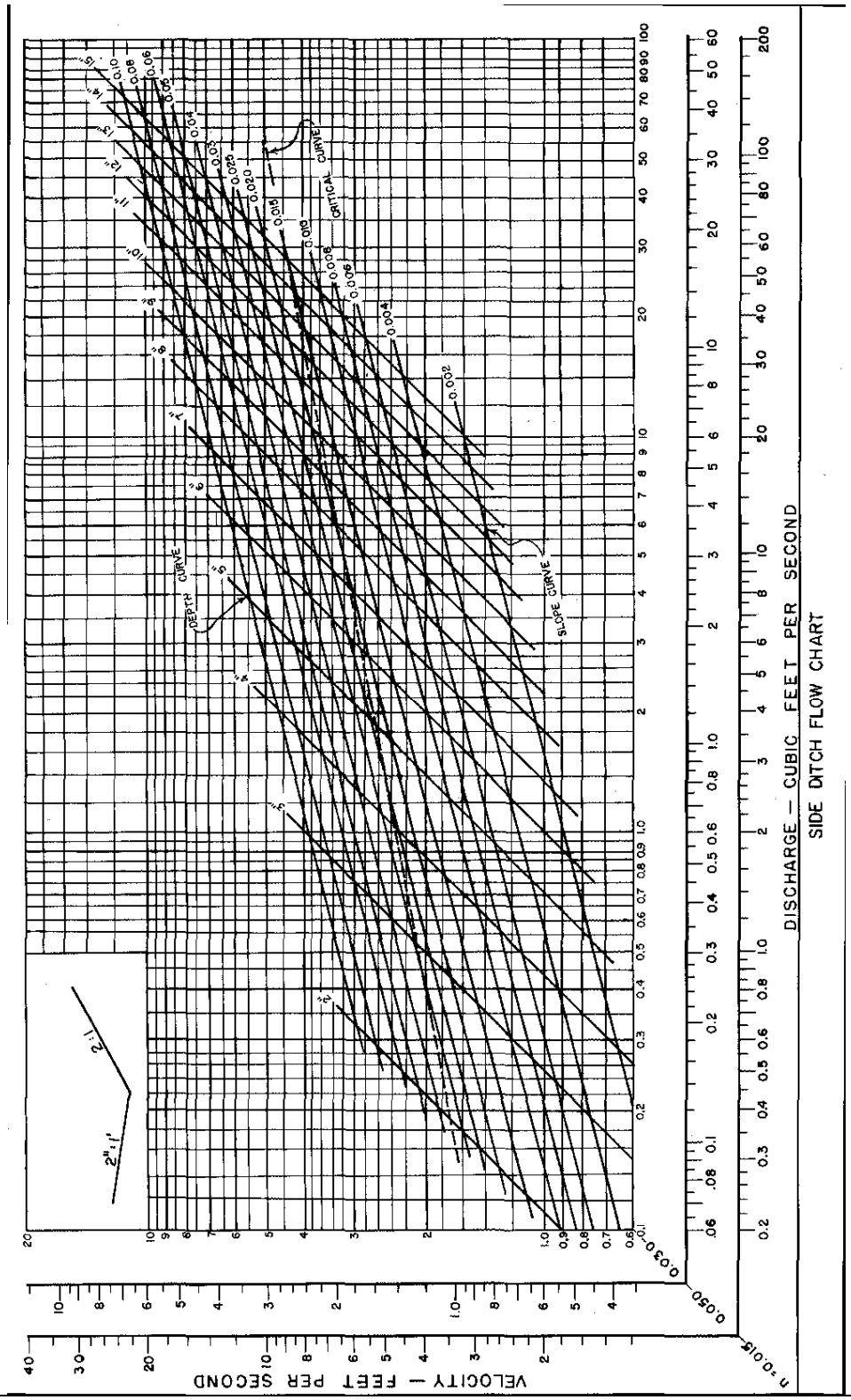
Source: VDOT

Appendix 7C-9 Side Ditch Flow Chart (Side Slopes = 3:1, 3:1)



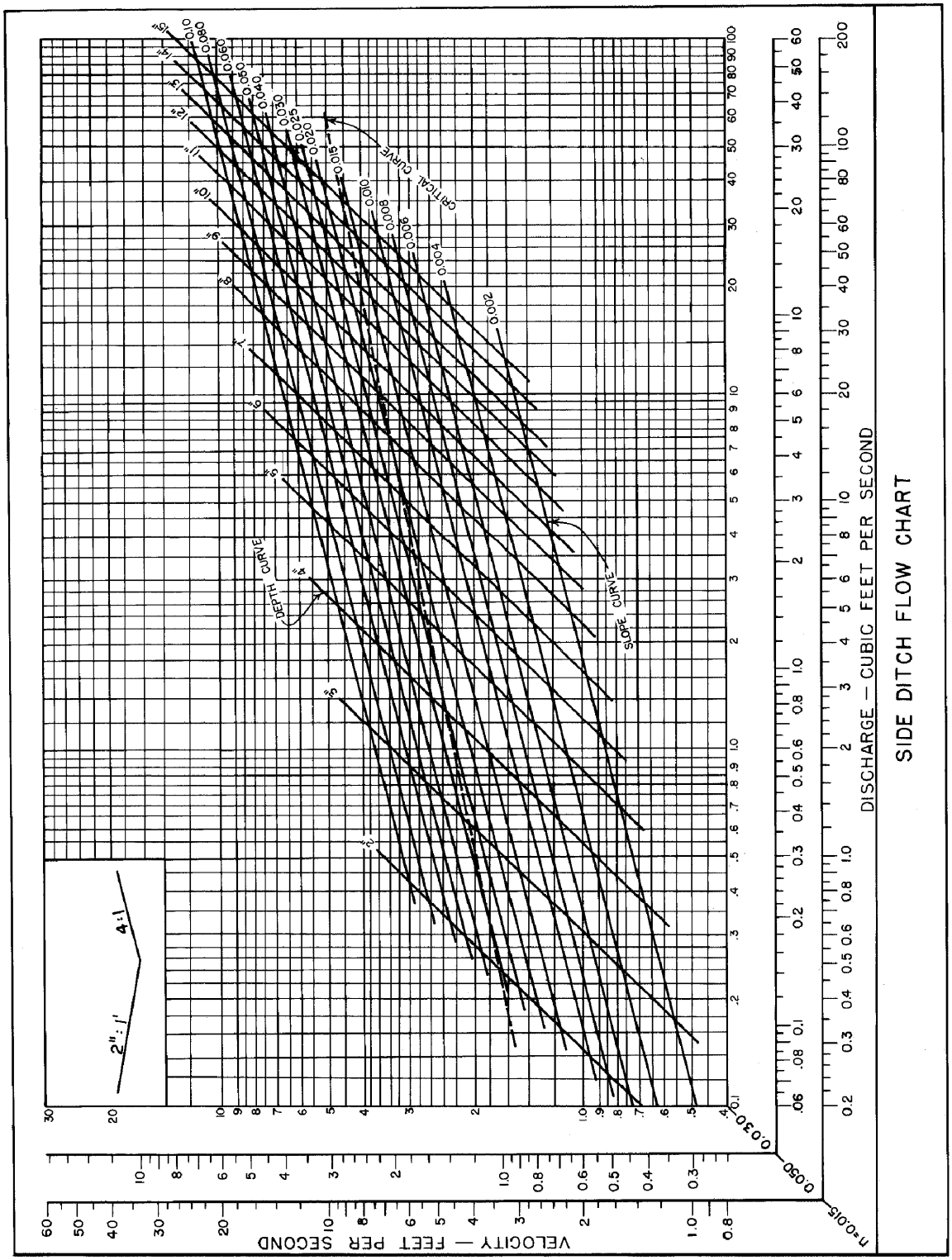
Source: VDOT

Appendix 7C-10 Side Ditch Flow chart (Side Slopes = 6:1, 2:1)



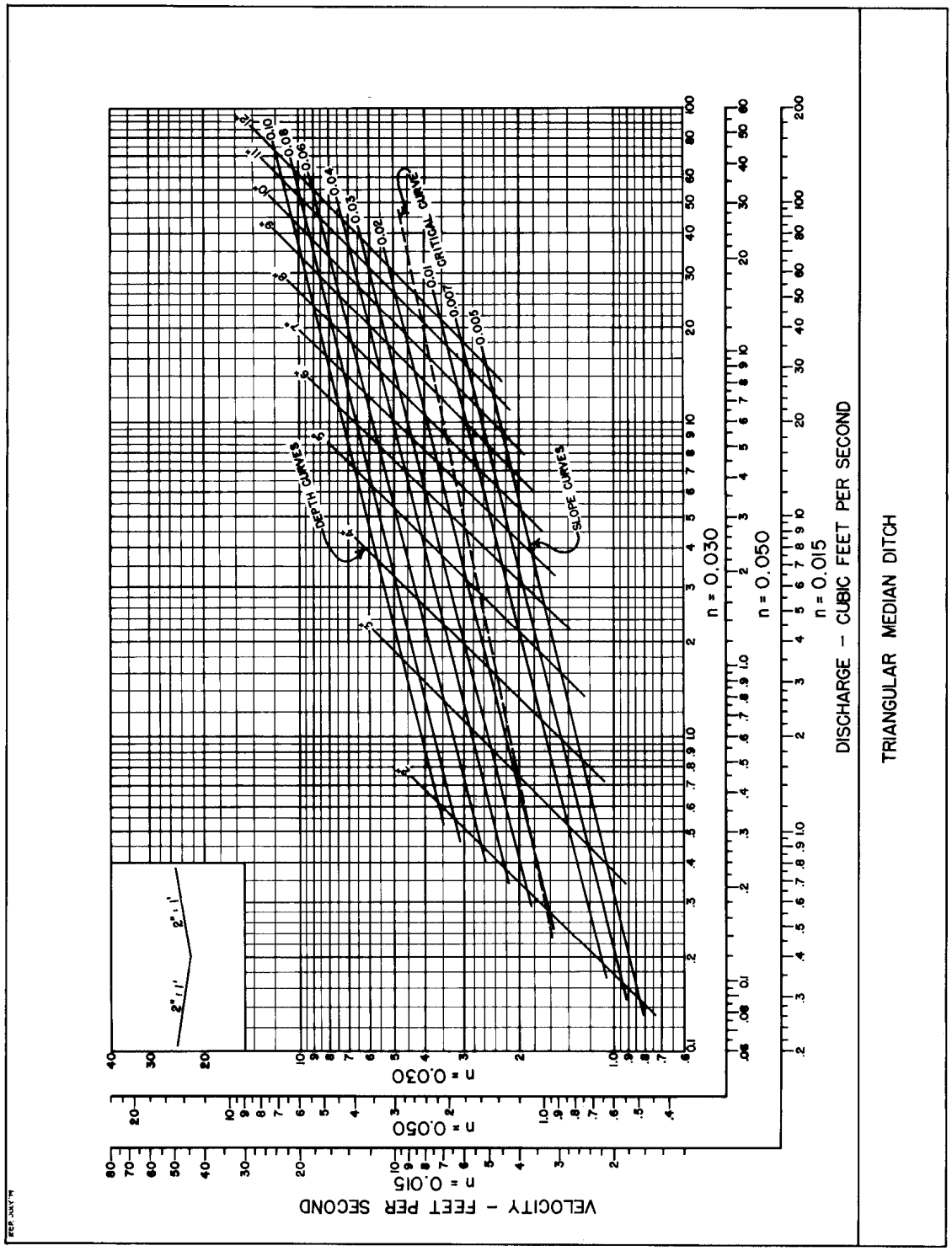
Source: VDOT

Appendix 7C-11 Side Ditch Flow Chart (Side Slopes = 6:1, 4:1)



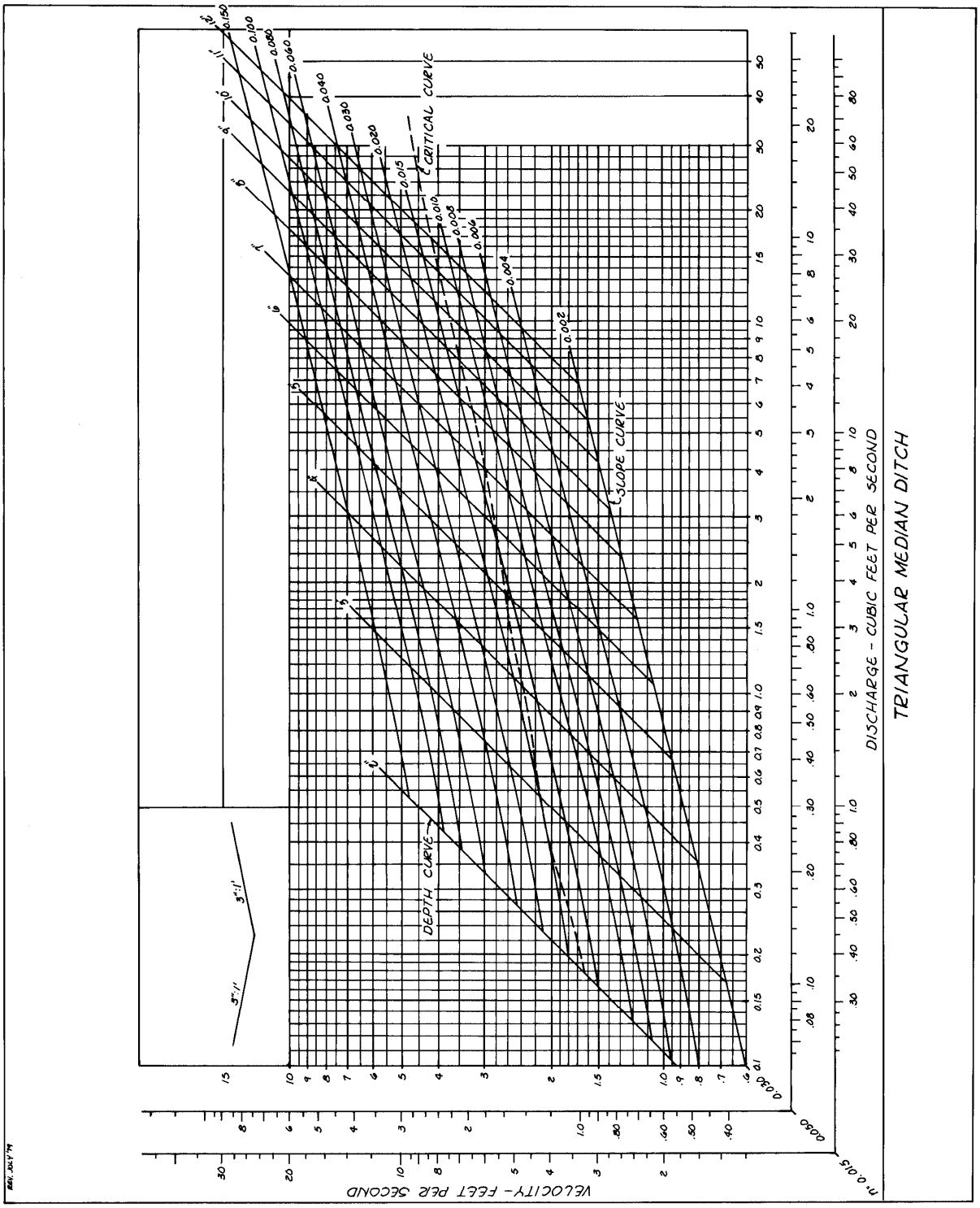
Source: VDOT

Appendix 7C-12 Triangular Median Ditch Flow Chart (Side Slopes = 6:1, 6:1)



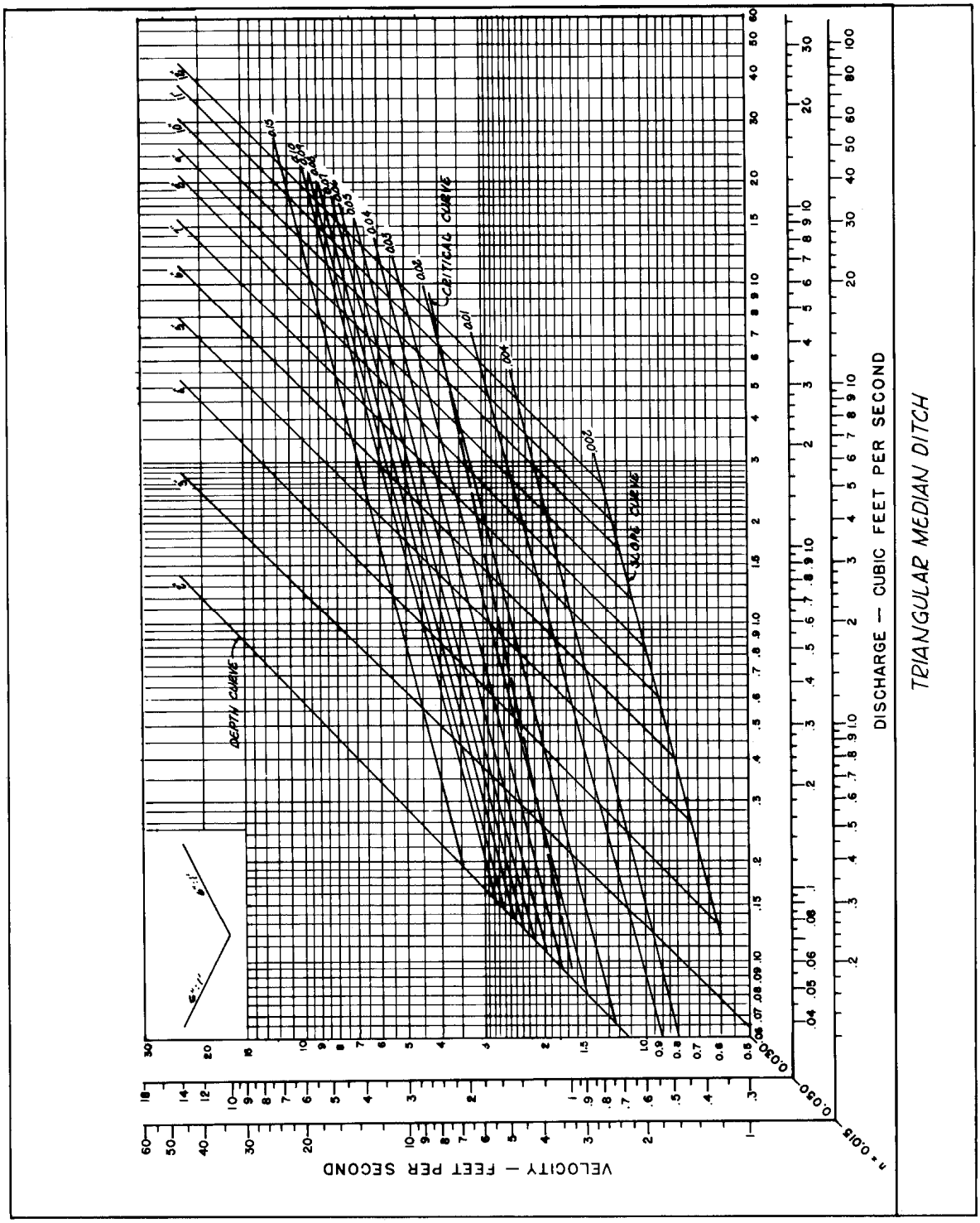
Source: VDOT

Appendix 7C-13 Triangular Median Ditch Flow Chart (Side Slopes = 4:1, 4:1)



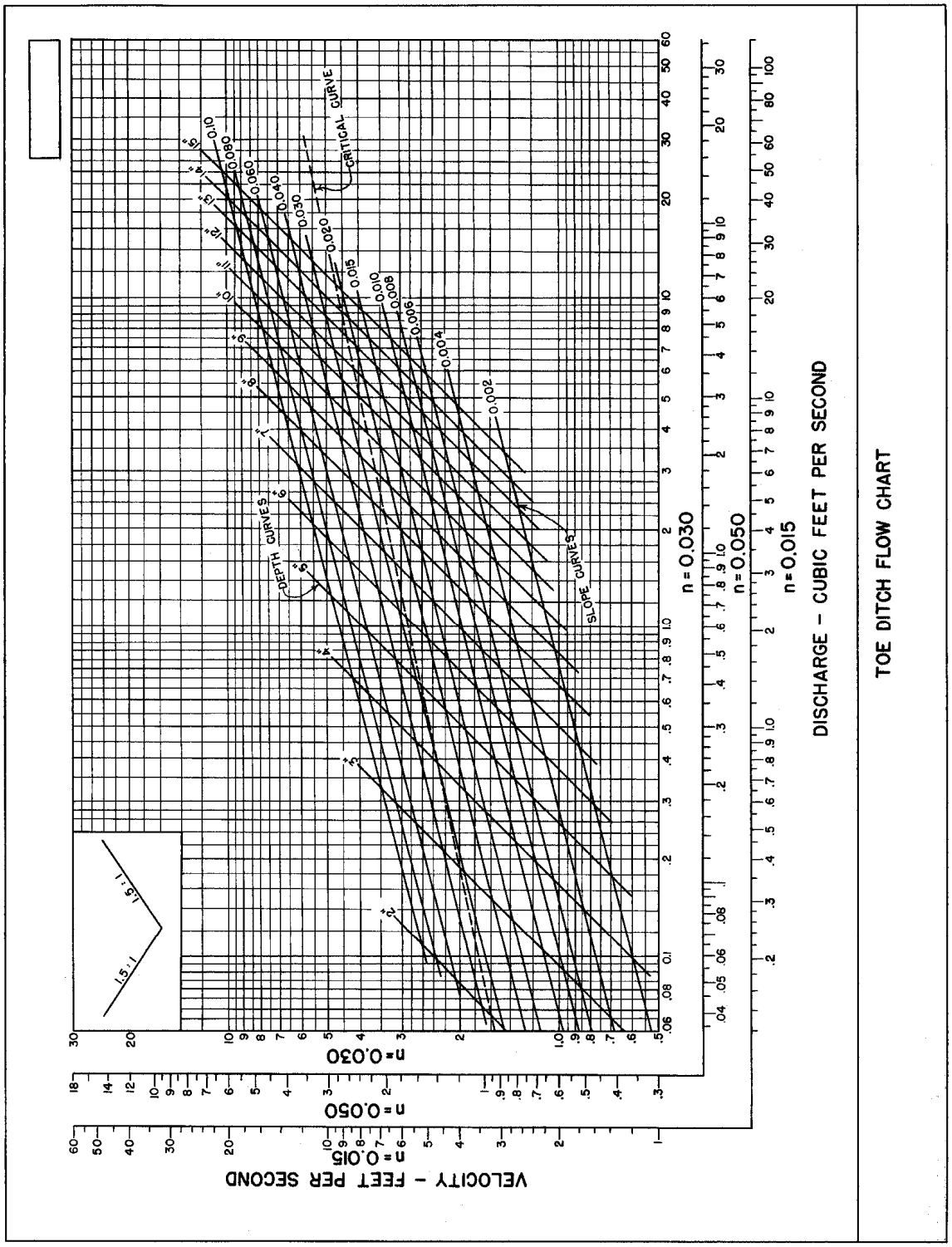
Source: VDOT

Appendix 7C-14 Triangular Median Ditch Flow Chart (Side Slopes = 2:1, 2:1)



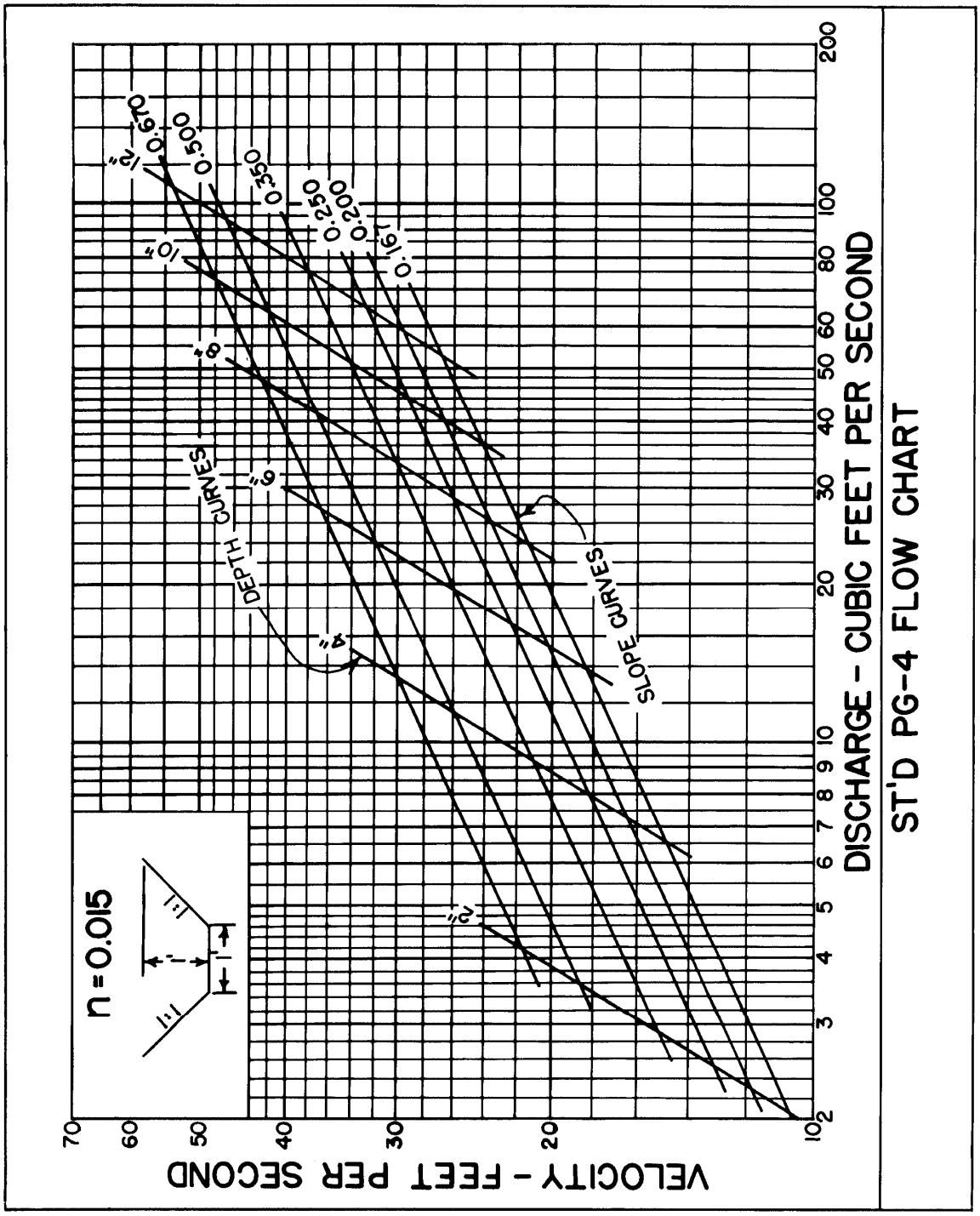
Source: VDOT

Appendix 7C-15 Toe Ditch Flow Chart (Side Slopes = 1.5:1, 1.5:1)



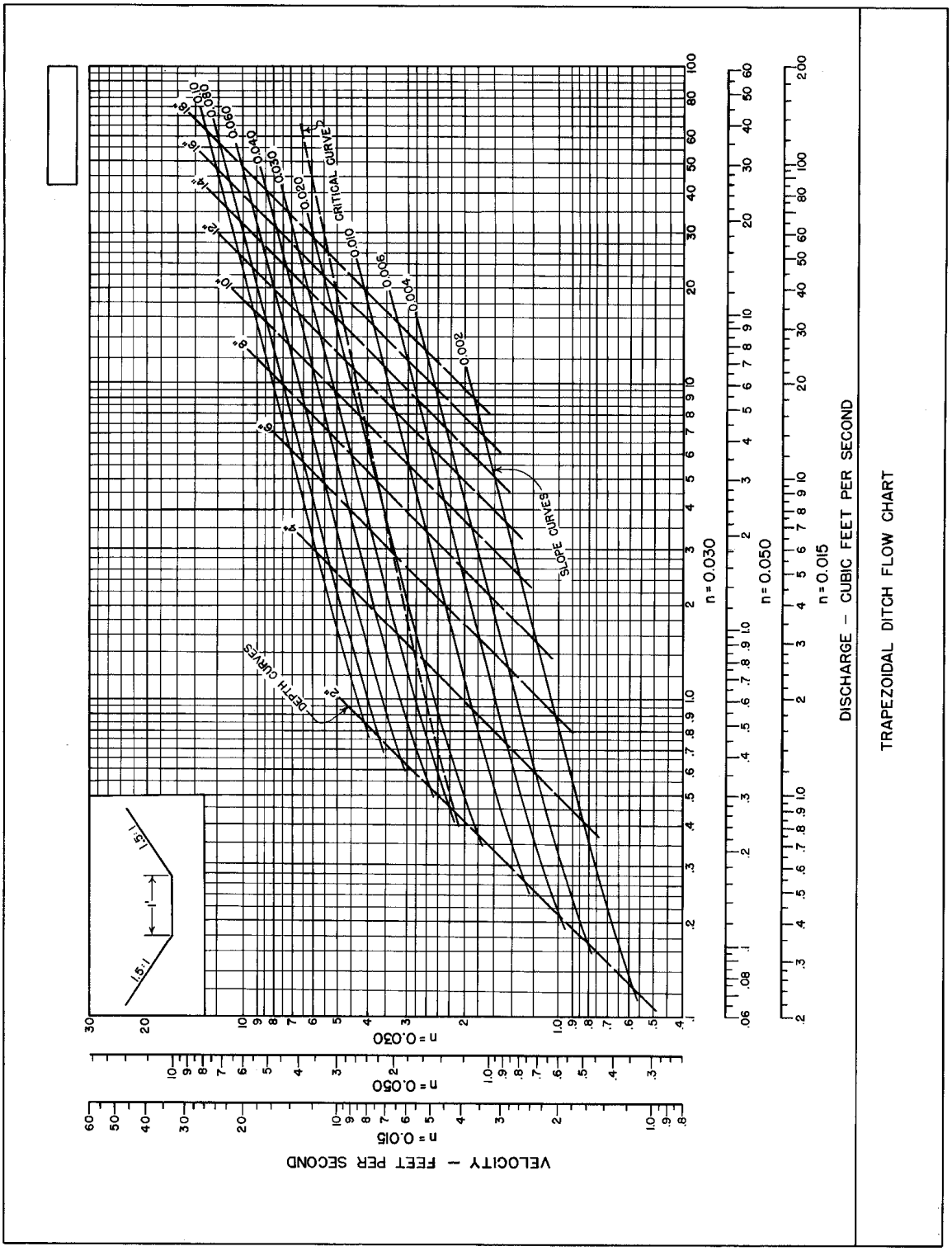
Source: VDOT

Appendix 7C-16 Standard PG-4 Flow Chart



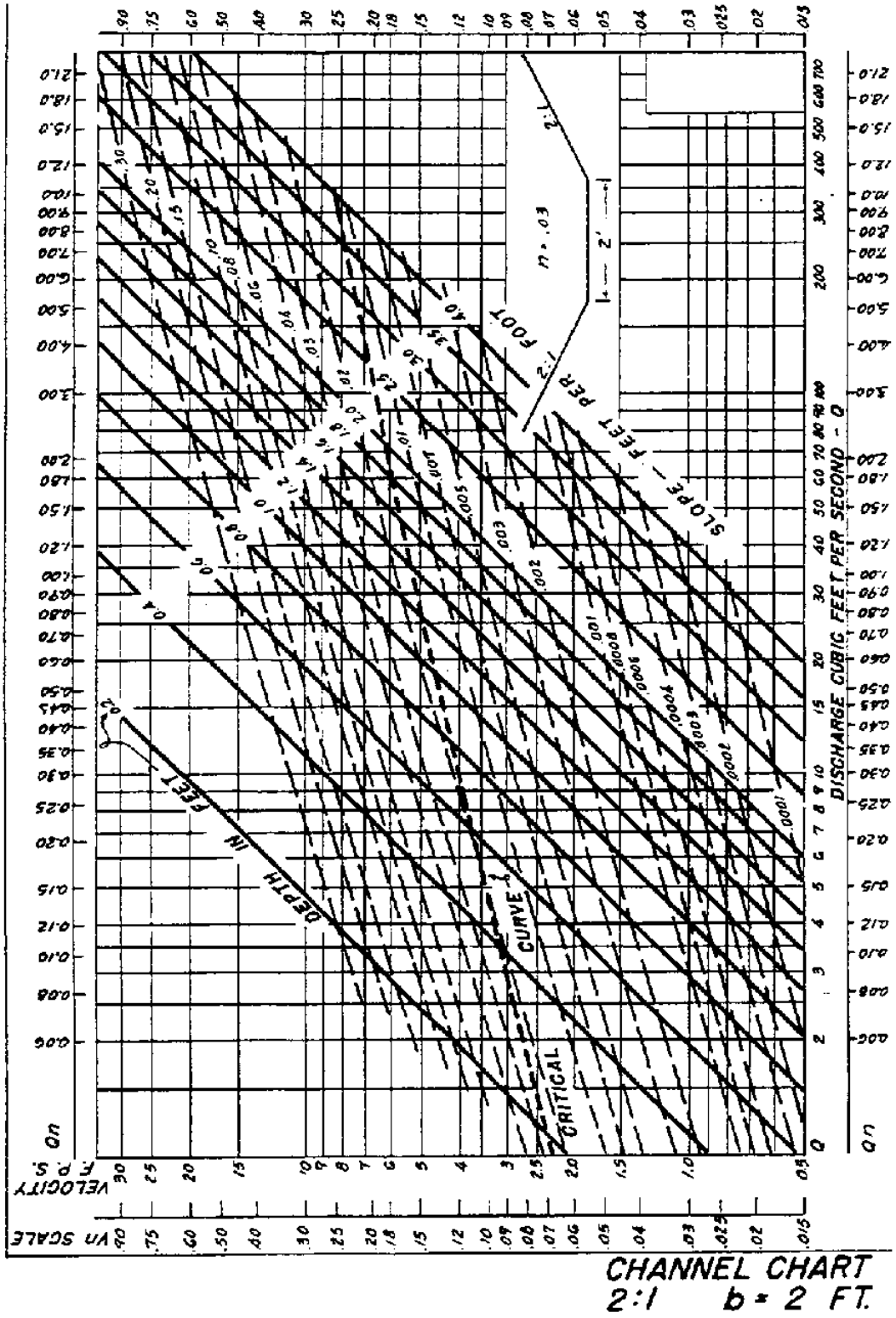
Source: VDOT

Appendix 7C-17 Trapezoidal Ditch Flow Chart (B=1', Side Slopes = 1.5:1)



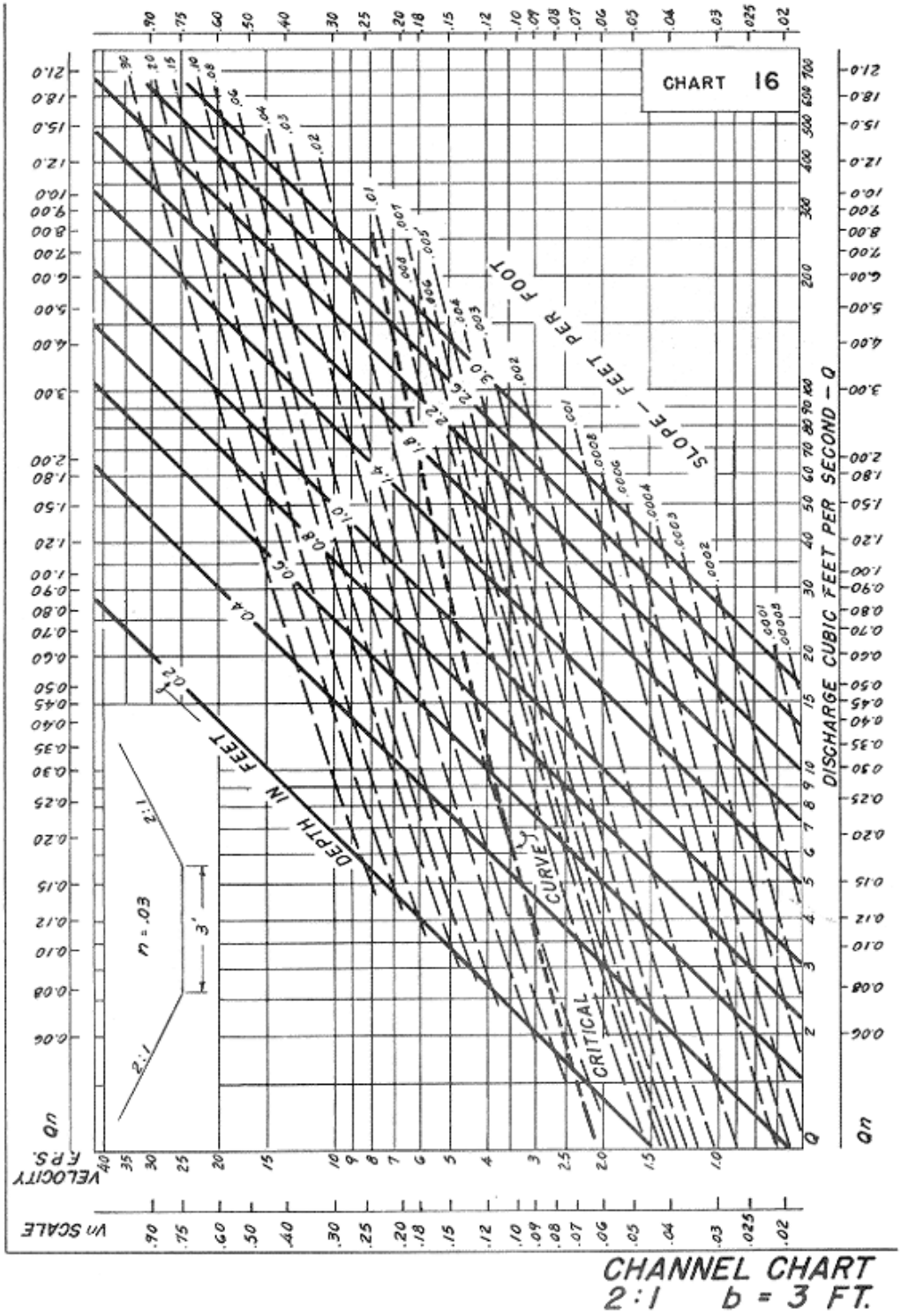
Source: HDS-3

Appendix 7C-18 Trapezoidal Channel Flow Chart (B=2', Side Slopes = 2:1)



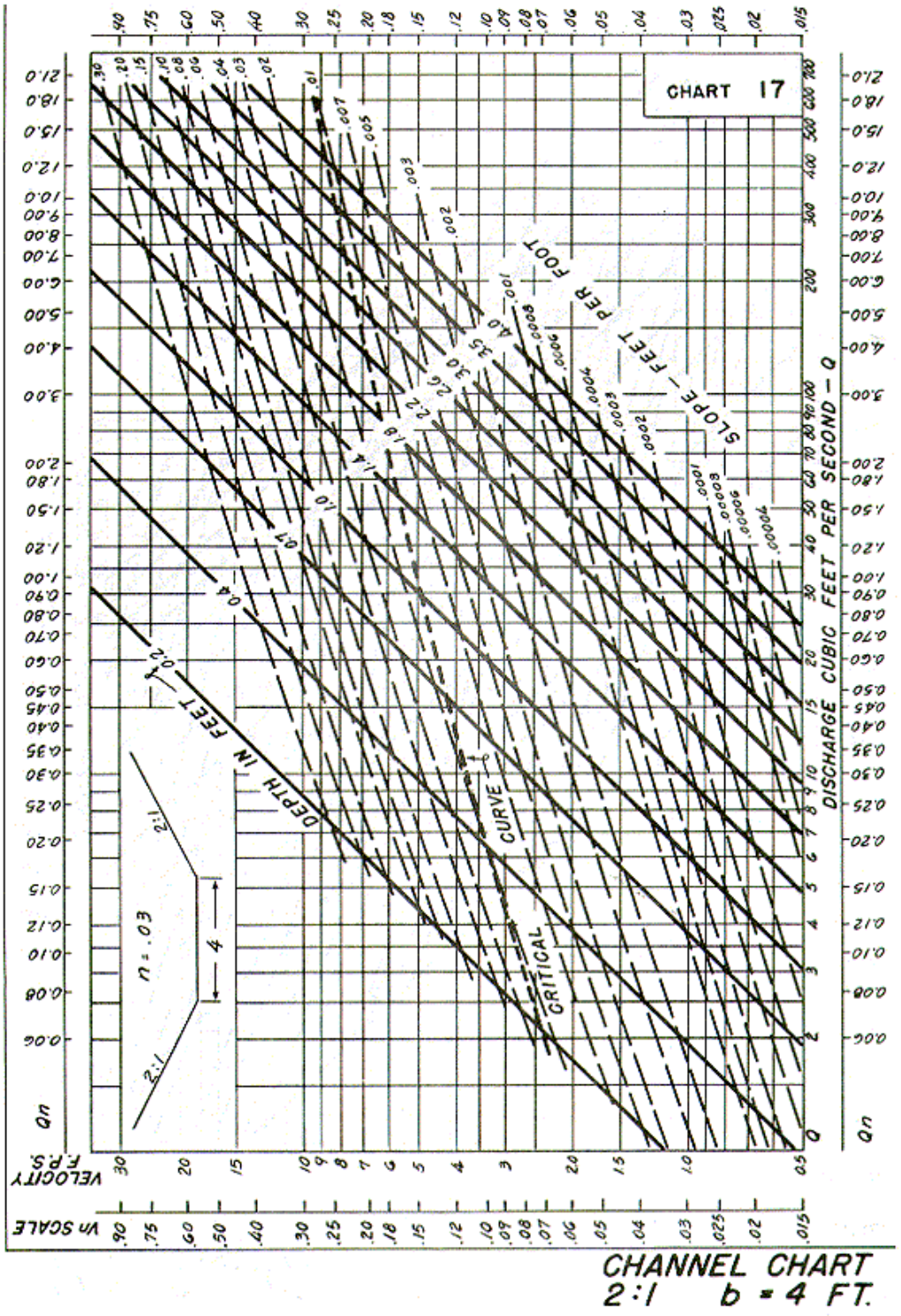
Source: HDS-3

Appendix 7C-19 Trapezoidal Channel Flow Chart (B=3', Side Slopes = 2:1)



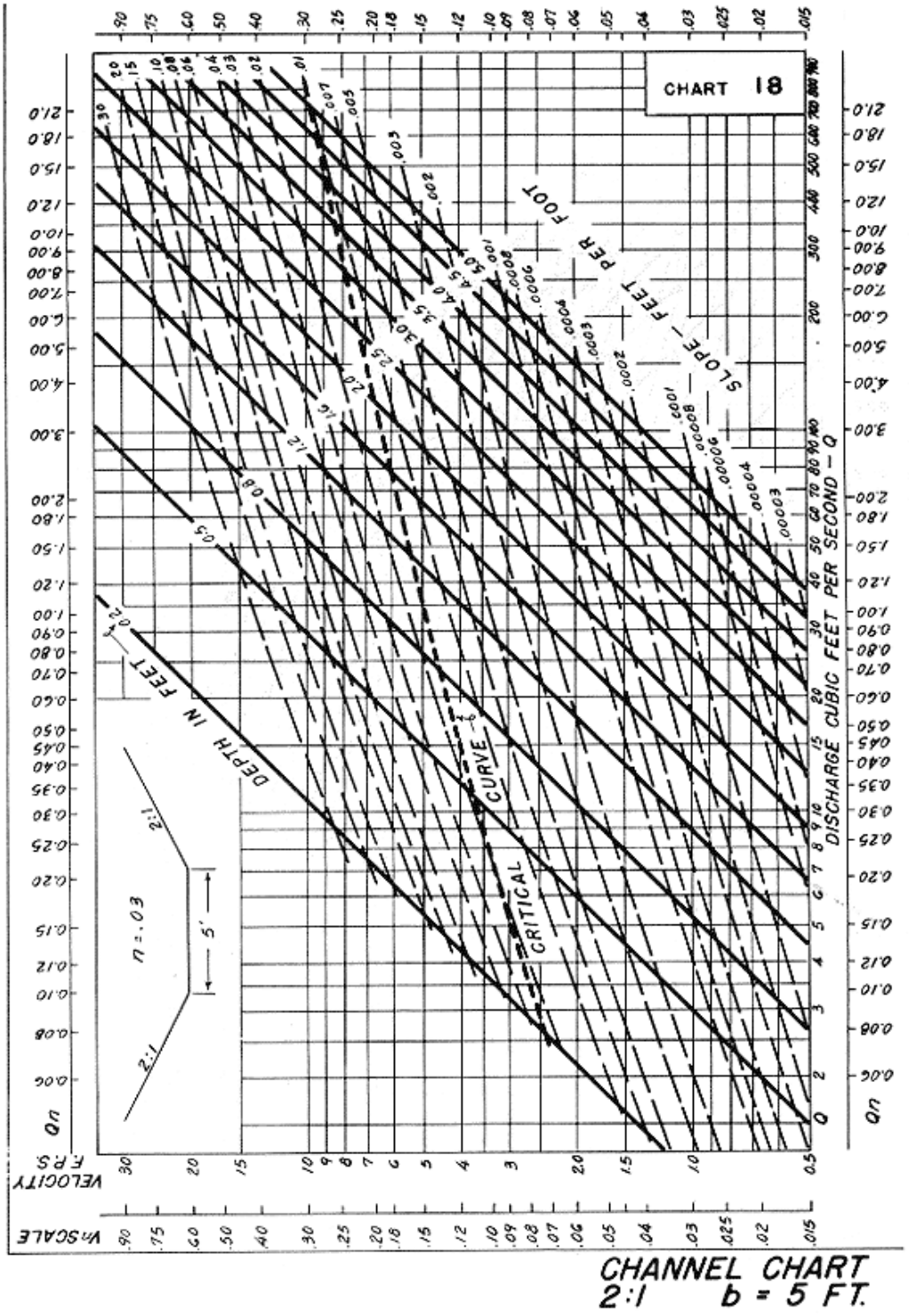
Source: HDS-3

Appendix 7C-20 Trapezoidal Channel Flow Chart (B=4', Side Slopes = 2:1)



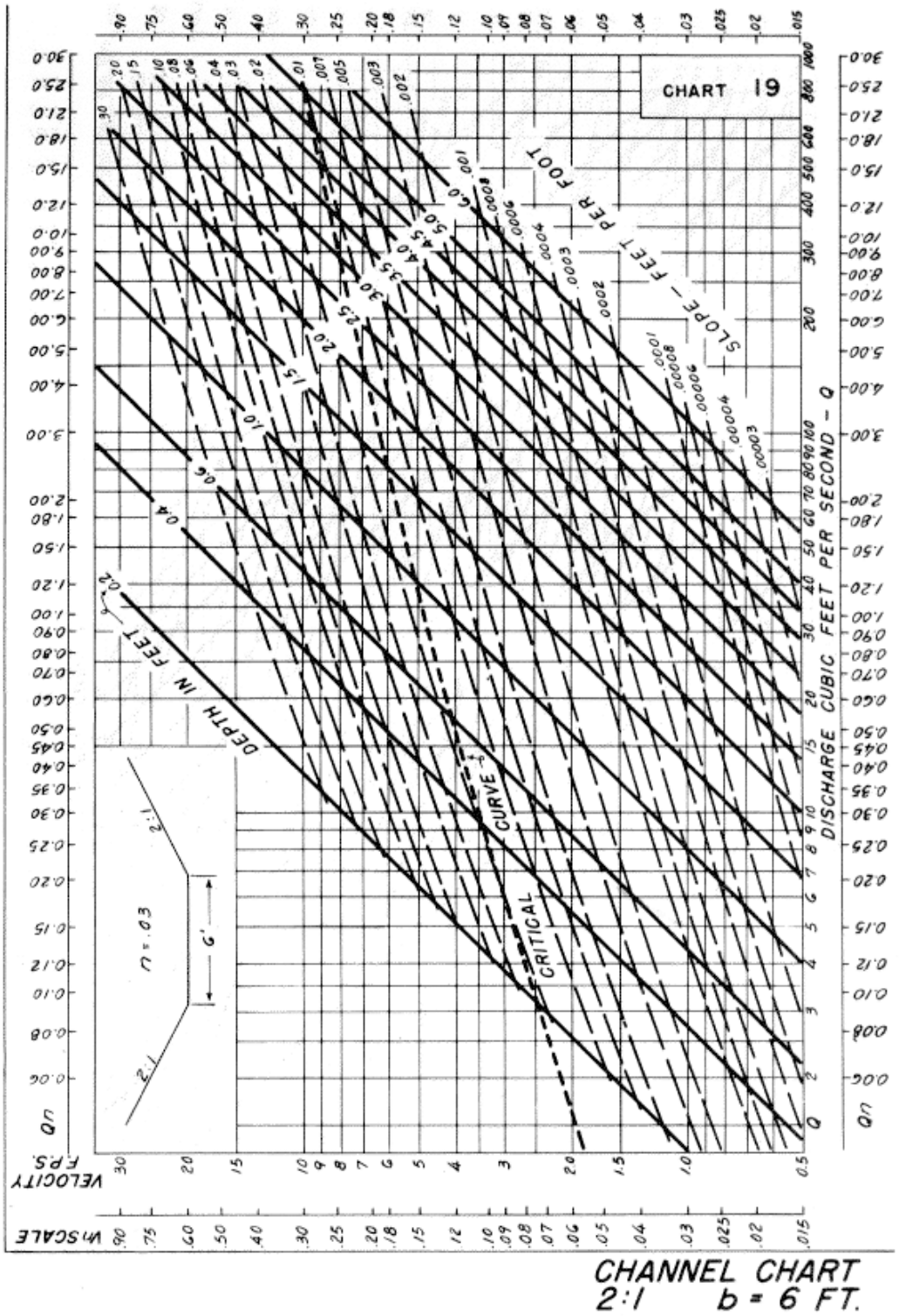
Source: HDS-3

Appendix 7C-21 Trapezoidal Channel Flow Chart (B = 5', Side Slopes = 2:1)



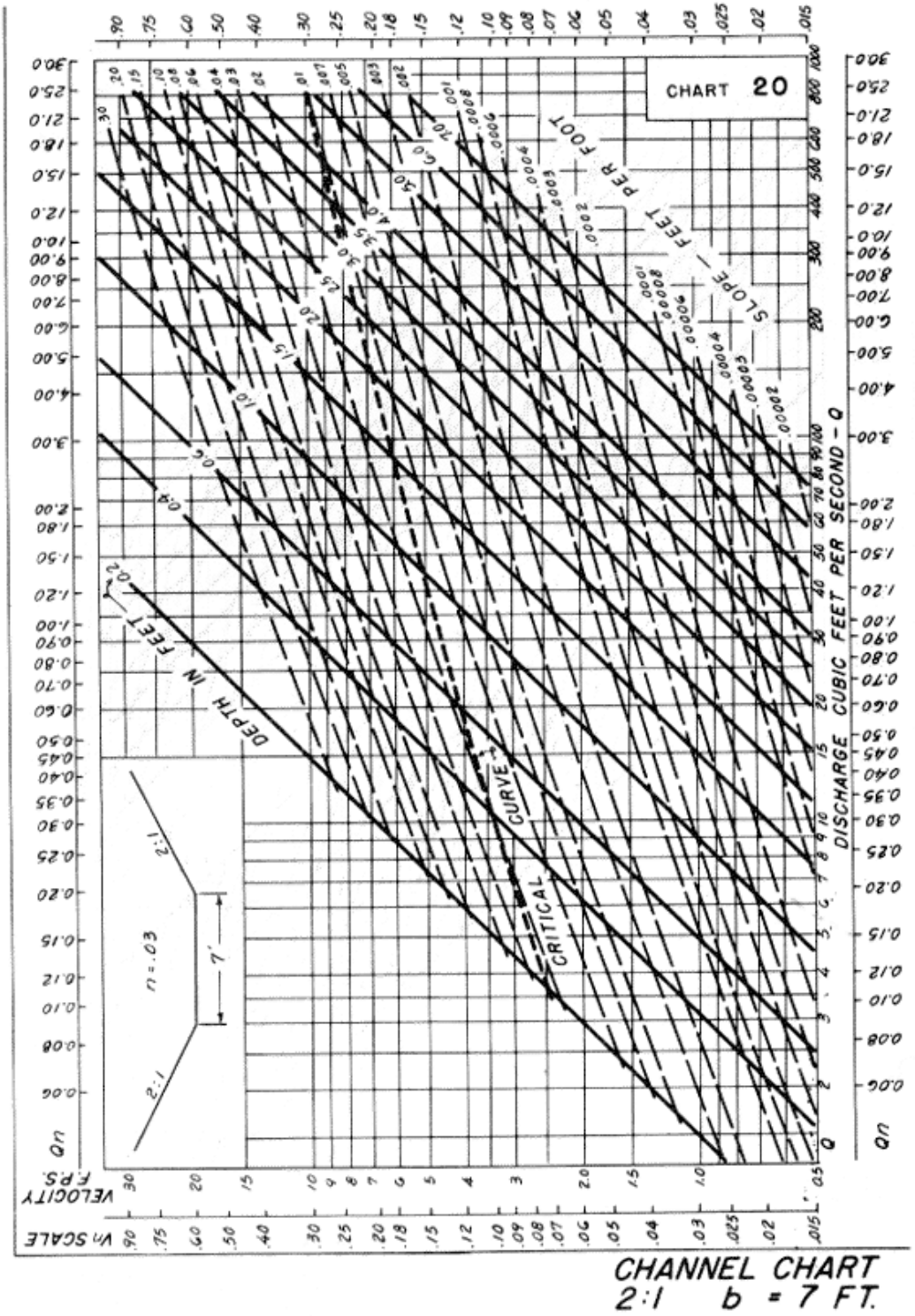
Source: HDS-3

Appendix 7C-22 Trapezoidal Channel Flow Chart (B = 6', Side Slopes 2:1)



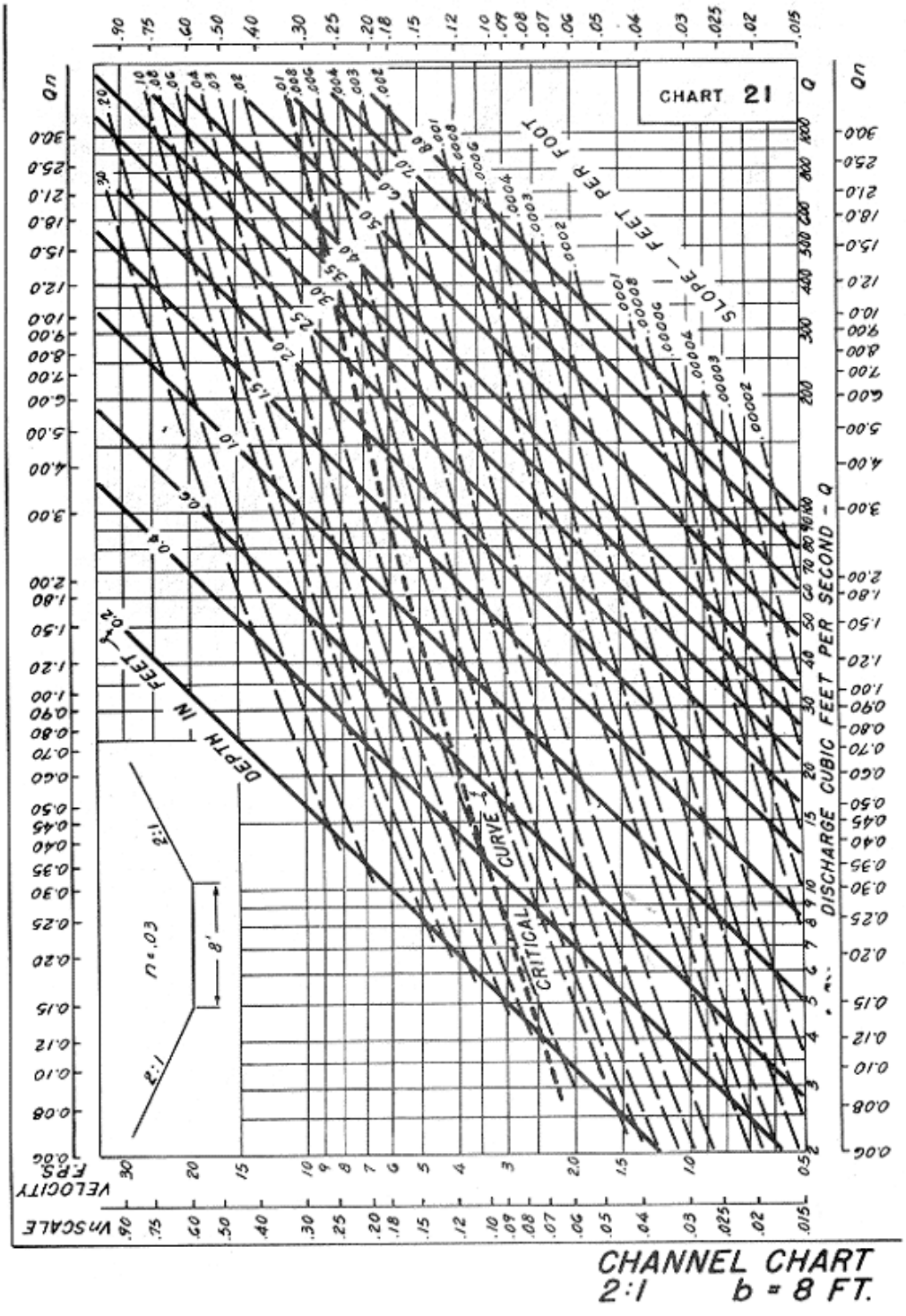
Source: HDS-3

Appendix 7C-23 Trapezoidal Channel Flow Chart (B = 7', Side Slopes = 2:1)



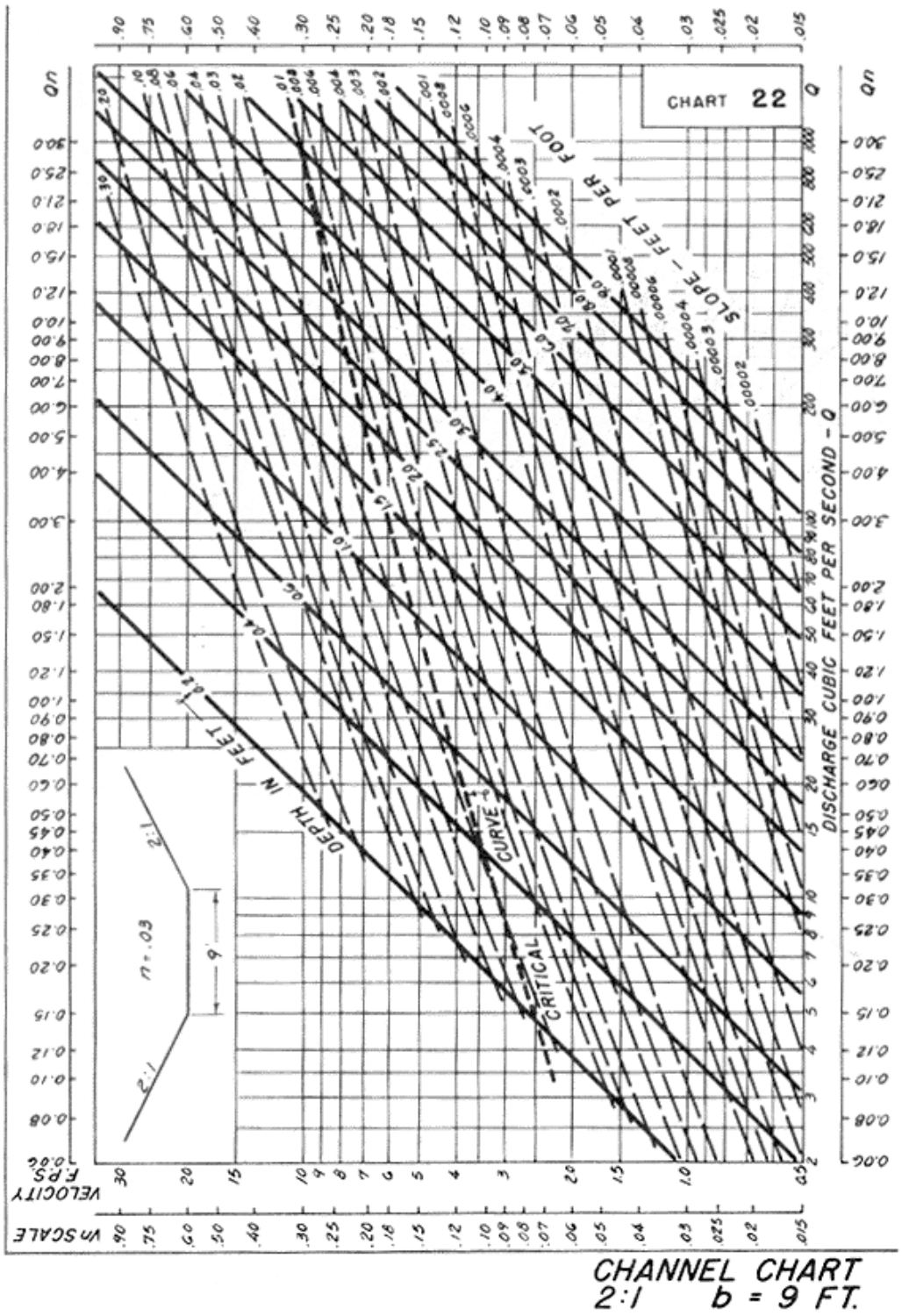
Source: HDS-3

Appendix 7C-24 Trapezoidal Channel Flow Chart (B = 8', Side Slopes = 2:1)



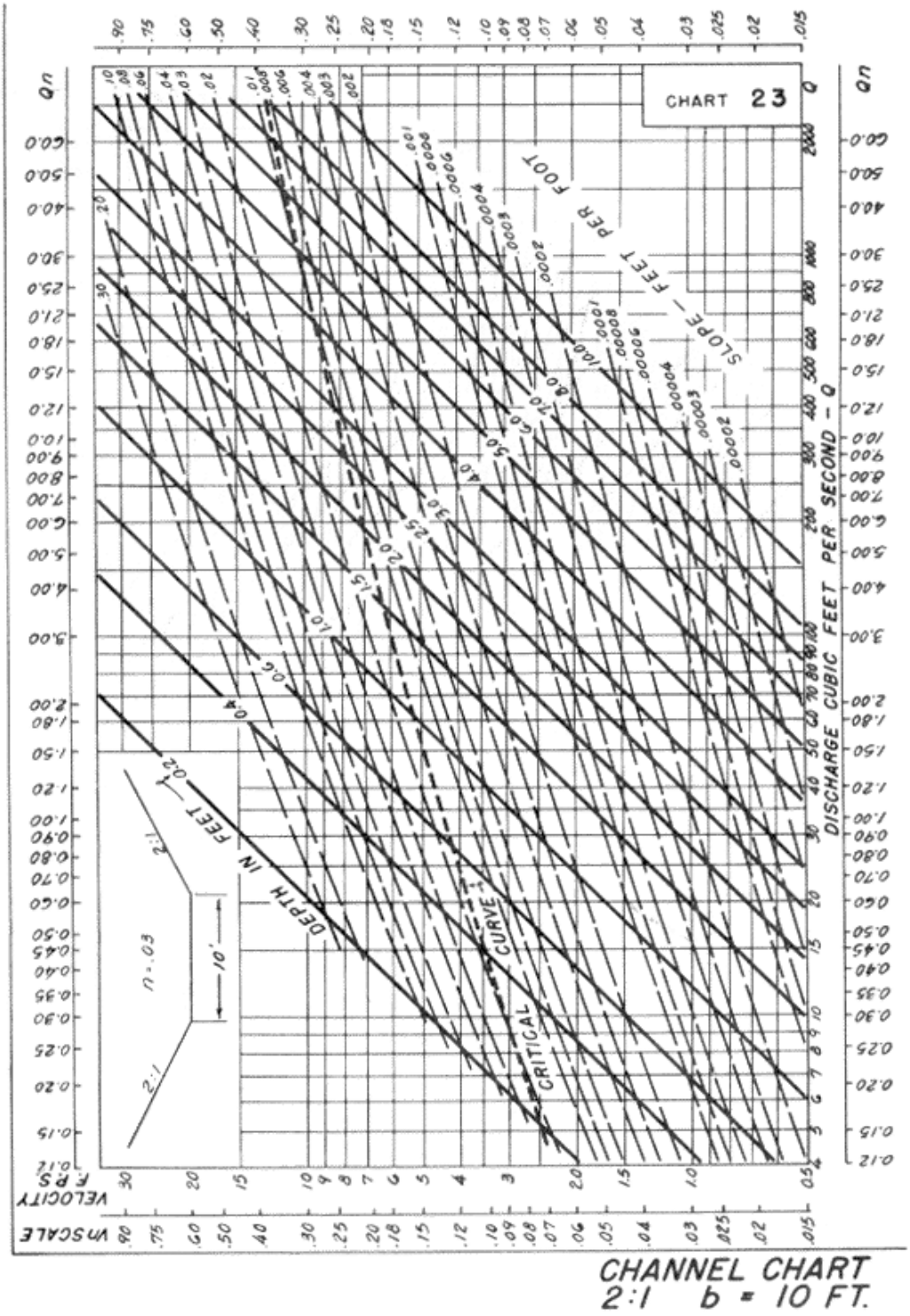
Source: HDS-3

Appendix 7C-25 Trapezoidal Channel Flow Chart (B = 9', Side Slopes = 2:1)



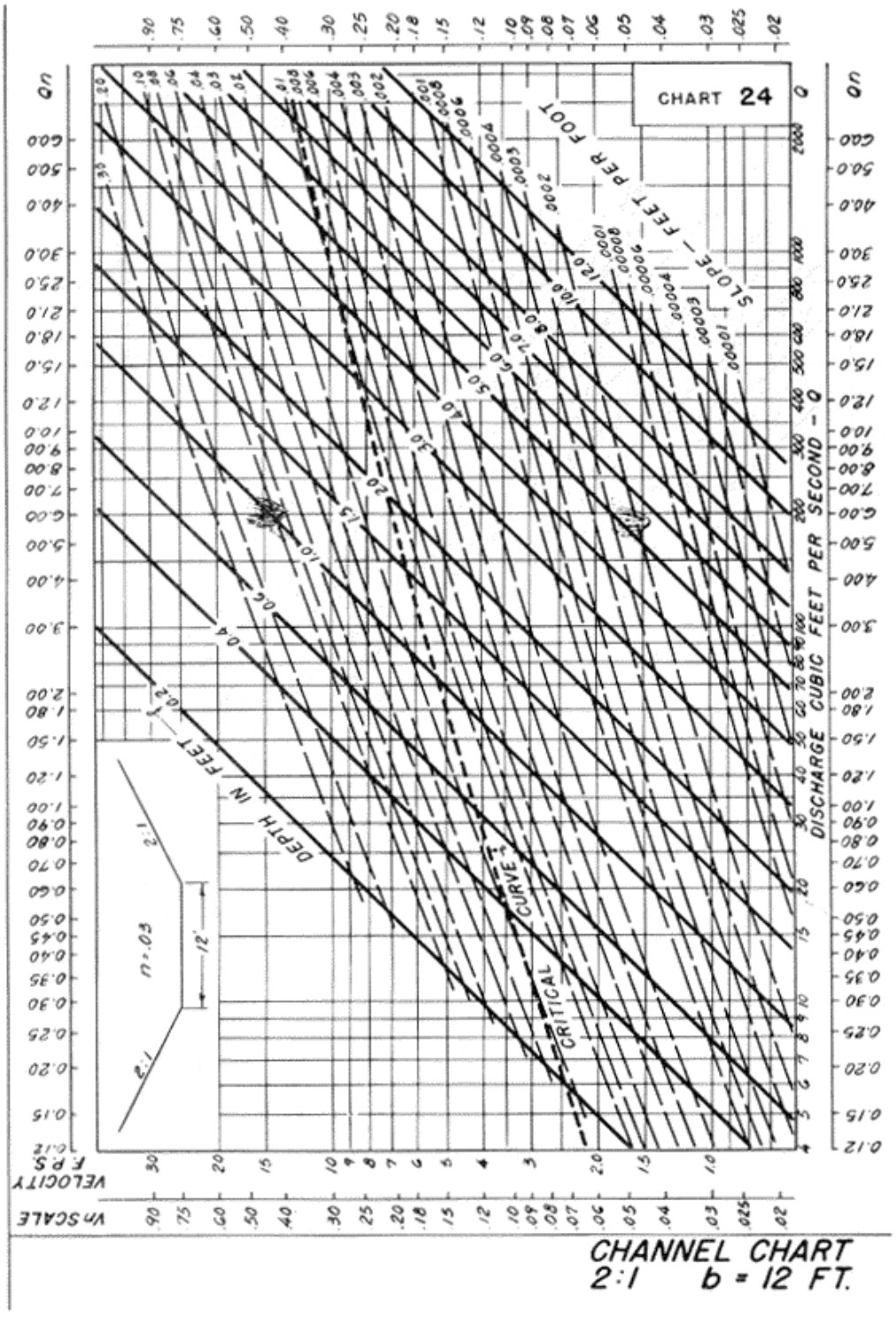
Source: HDS-3

Appendix 7C-26 Trapezoidal Channel Flow Chart (B = 10', Side Slopes = 2:1)



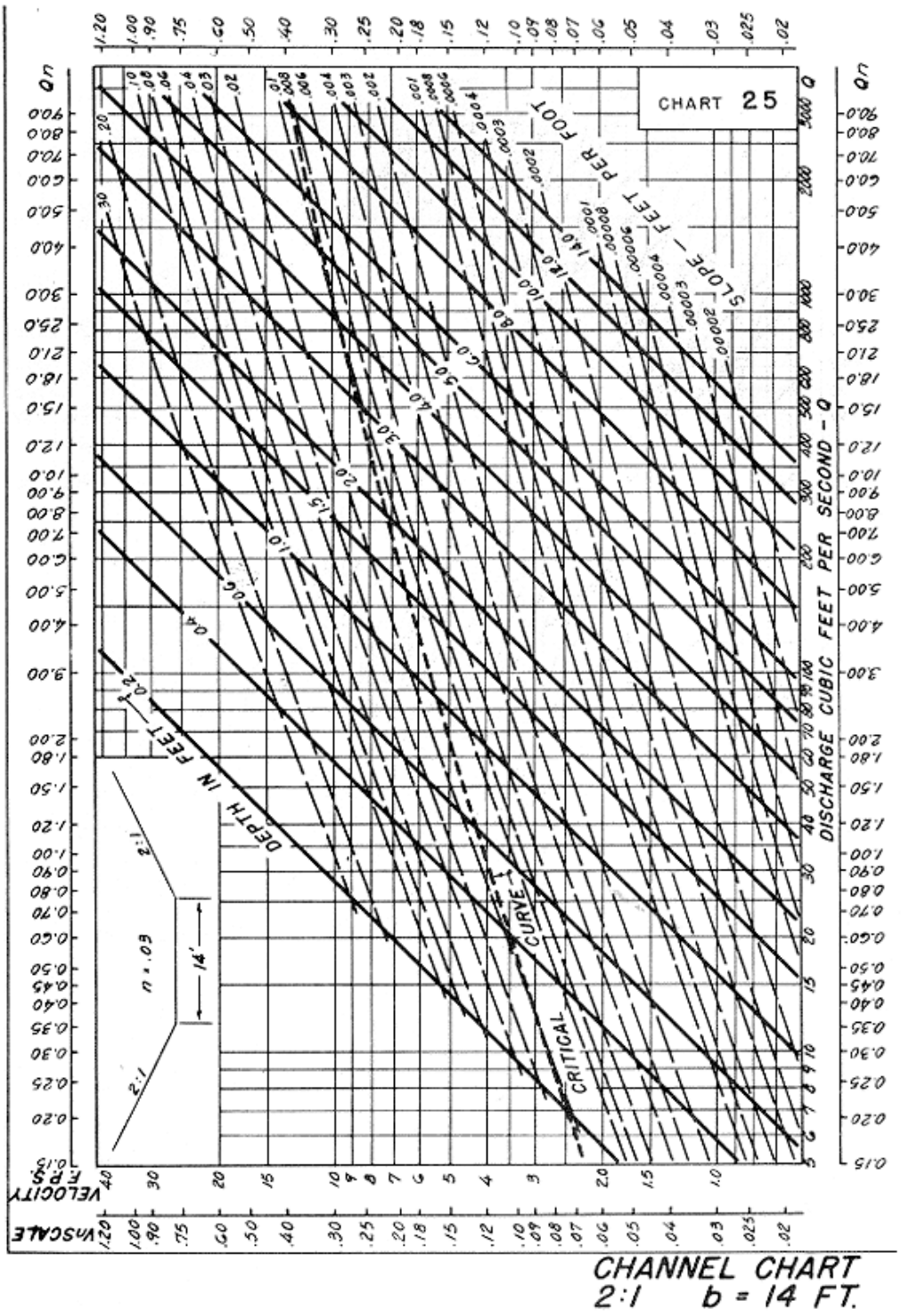
Source: HDS-3

Appendix 7C-27 Trapezoidal Channel Flow Chart (B = 12', Side Slopes = 2:1)



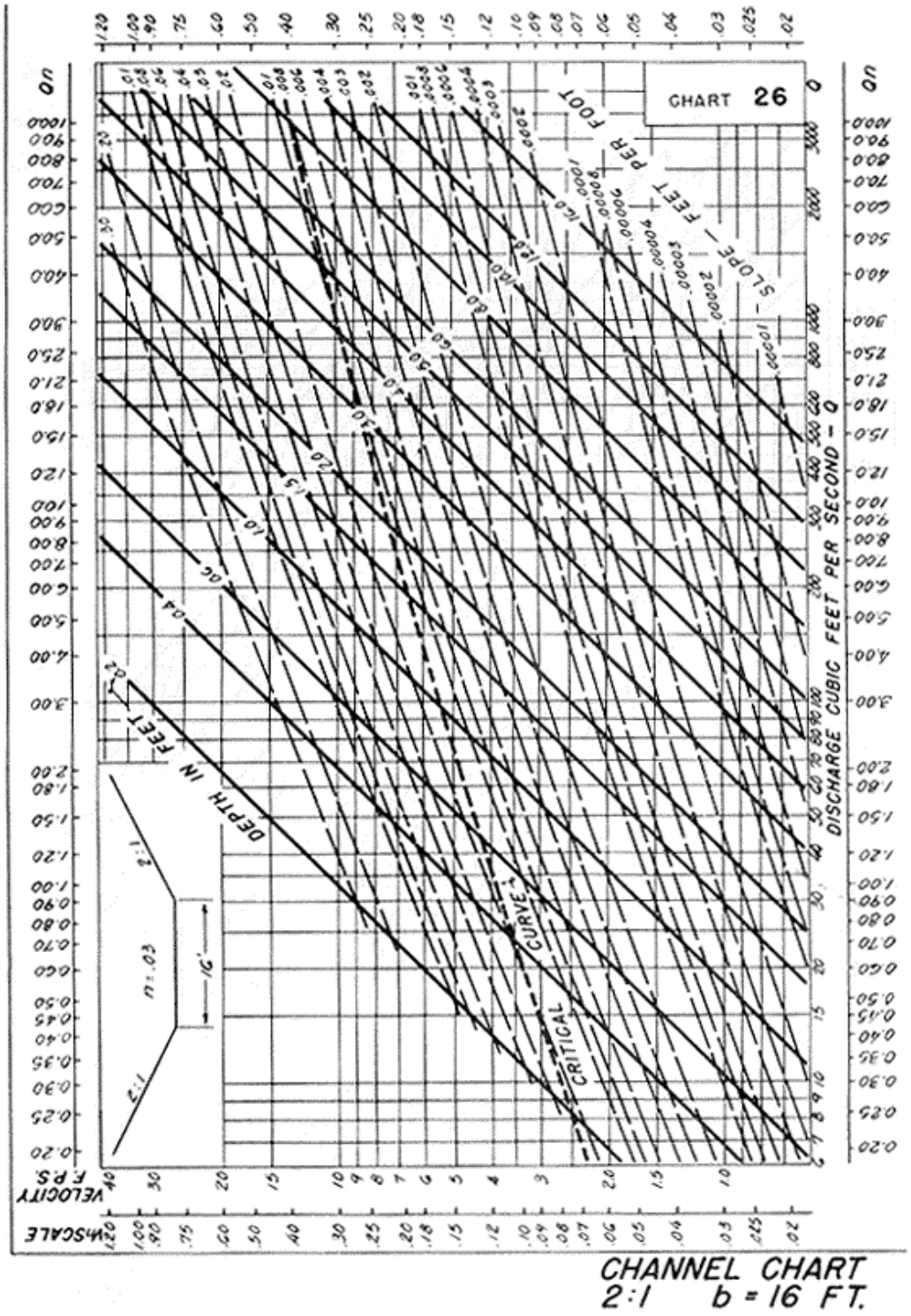
Source: HDS-3

Appendix 7C-28 Trapezoidal Channel Flow Chart (B = 14', Side Slopes = 2:1)



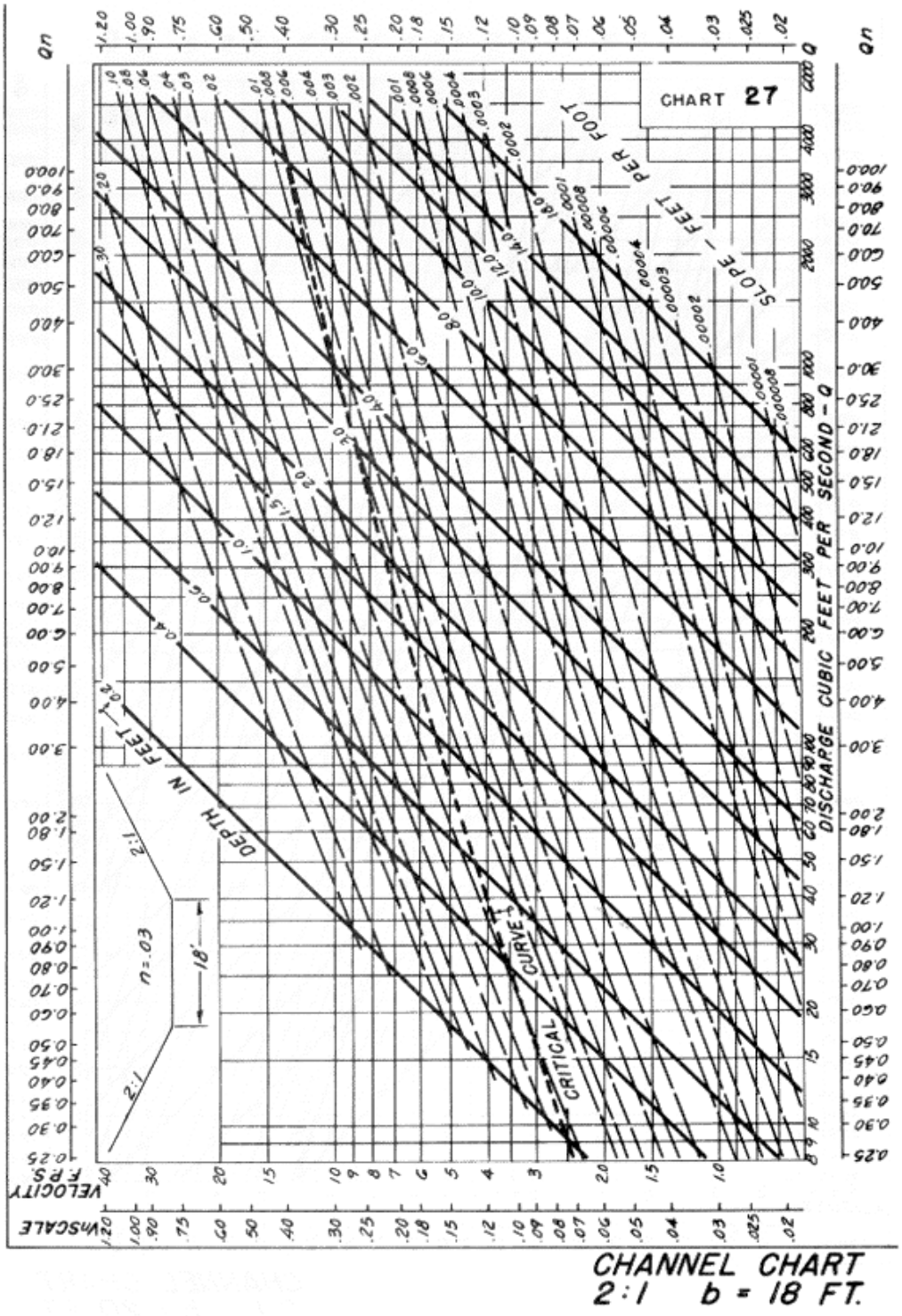
Source: HDS-3

Appendix 7C-29 Trapezoidal Channel Flow Chart (B = 16', Side Slopes = 2:1)



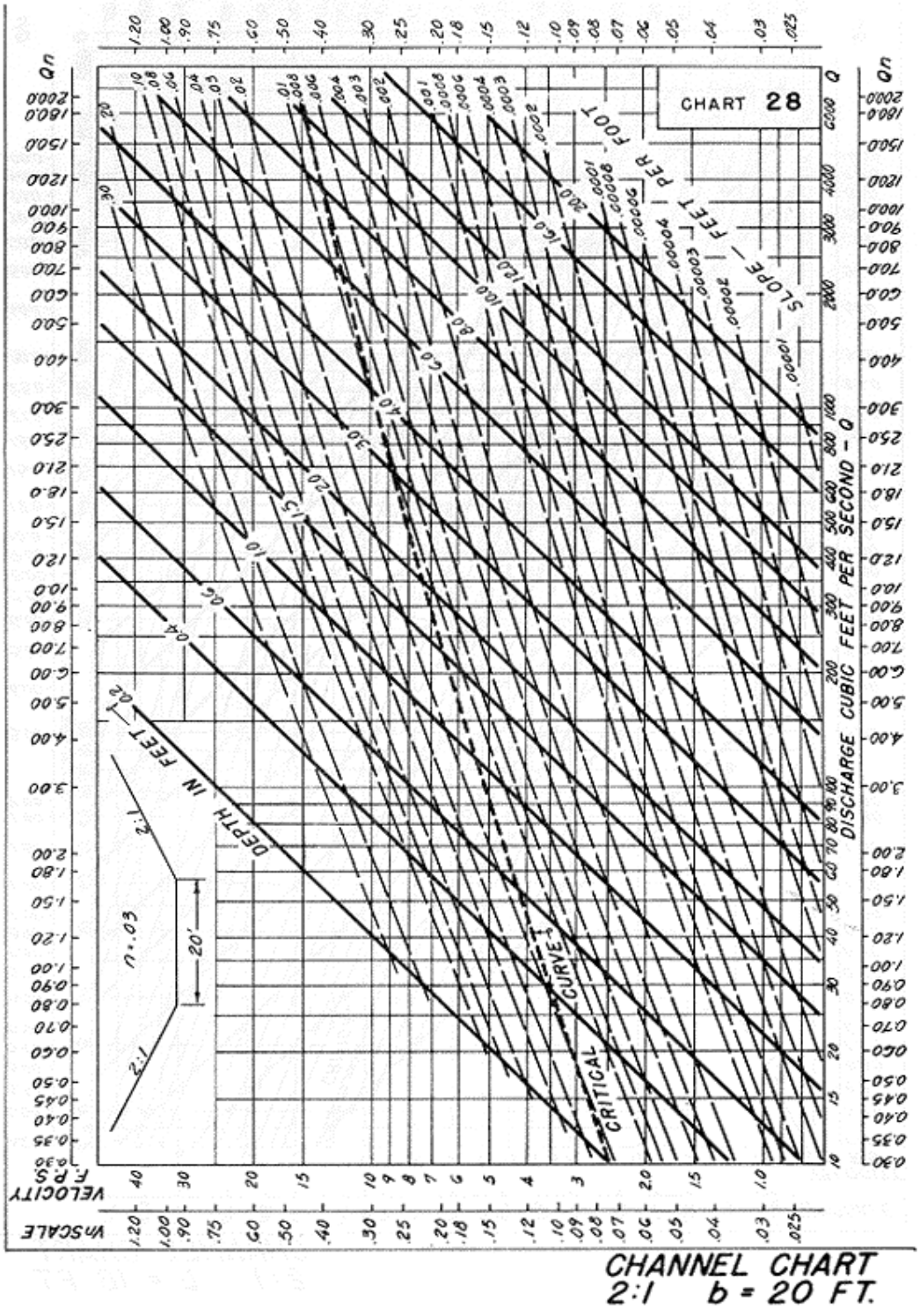
Source: HDS-3

Appendix 7C-30 Trapezoidal Channel Flow Chart (B = 18', Side Slopes = 2:1)



Source: HDS-3

Appendix 7C- 31 Trapezoidal Channel Flow Chart (B = 20', Side Slopes = 2:1)



Source: HDS-3

Appendix 7D-1 Values of Roughness Coefficient n (Uniform Flow)

Type of Channel and Description	Minimum	Normal	Maximum
LINED CHANNELS (Selected linings)			
a. Concrete			
1. Trowel finish	0.011	0.013	0.015
2. Float finish	0.013	0.015	0.016
3. Gunite, good section	0.016	0.019	0.023
b. Asphalt			
1. Smooth	0.013	0.013	-
2. Rough	0.016	0.016	-
c. Riprap (st'd VDOT sizes)*			
1. Class 1A	0.033	0.038	-
2. Class 1	0.035	0.040	-
3. Class 2	0.037	0.042	-
4. Class 3	0.039	0.045	-
5. Type I	0.041	0.047	-
6. Type II	0.044	0.050	-
EXCAVATED OR DREDGED			
a. Earth, straight and uniform			
1. Clean, recently completed	0.016	0.018	0.020
2. Clean, after weathering	0.018	0.022	0.025
3. Gravel, uniform section, clean	0.022	0.025	0.030
4. With short grass, few weeds	0.022	0.027	0.033
b. Earth, winding and sluggish			
1. No vegetation	0.023	0.025	0.030
2. Grass, some weeds	0.025	0.030	0.033
3. Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
4. Earth bottom and rubble sides	0.025	0.030	0.035
5. Stony bottom and weedy sides	0.025	0.035	0.045
6. Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline excavated or dredged			
1. No vegetation	0.025	0.028	0.033
2. Light brush on banks	0.035	0.050	0.060
d. Rock cuts			
1. Smooth and uniform	0.025	0.035	0.040
2. Jagged and irregular	0.035	0.040	0.050
e. Channels not maintained, weeds and brush uncut			
1. Dense weeds, high as flow depth	0.050	0.080	0.120
2. Clean bottom, brush on sides	0.040	0.050	0.080
3. Same, highest stage of flow	0.045	0.070	0.110
4. Dense brush, high stage	0.080	0.100	0.140
NATURAL STREAMS			
1. Minor streams (top width at flood stage <100 ft)			
a. Streams on Plain			
1. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
2. Same as above, but more stones/weeds	0.030	0.035	0.040
3. Clean, winding, some pools/shoals	0.033	0.040	0.045
4. Same as above, but some weeds/stones	0.035	0.045	0.050
5. Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
6. Same as 4, but more stones	0.045	0.050	0.060
7. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080

* Rev 7/09

Appendix 7D-1 Values of Roughness Coefficient n (Uniform Flow)

Type of Channel and Description	Minimum	Normal	Maximum
8. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
b. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
1. Bottom: gravels, cobbles and few boulders	0.030	0.040	0.050
2. Bottom: cobbles with large boulders	0.040	0.050	0.070
2. Floodplains			
a. Pasture, no brush			
1. Short grass	0.025	0.030	0.035
2. High grass	0.030	0.035	0.050
b. Cultivated area			
1. No crop	0.020	0.030	0.040
2. Mature row crops	0.025	0.035	0.045
3. Mature field crops	0.030	0.040	0.050
c. Brush			
1. Scattered brush, heavy weeds	0.035	0.050	0.070
2. Light brush and trees, in winter	0.035	0.050	0.060
3. Light brush and trees, in summer	0.040	0.060	0.080
4. Medium to dense brush, in winter	0.045	0.070	0.110
5. Medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. Dense Willows, summer, straight	0.110	0.150	0.200
2.Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
3. Same as above, but with heavy growth of sprouts	0.050	0.060	0.080
4. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
5. Same as above, but with flood stage reaching branches	0.100	0.120	0.160
3. Major Streams (top width at flood stage > 100 ft)			
The n-value is less than that for minor streams of similar description, because banks offer less effective resistance.			
a. Regular section with no boulders or brush	0.025	-	0.060
b. Irregular and rough section	0.035	-	0.100

Source: Chow, V.T., FHWA's HDS-6 publication*

* For bare earth linings when the soil classifications in accordance with either AASHTO or USCS designations are known, use the Manning's "n" values recommended in the appropriate table from Appendix 7D-2

* Rev 7/09

Appendix 7D-2 Recommended Maximum Water Velocities and Manning's n as a Function of Soil Type and Flow Depth

ASSHTO Classification	ASSHTO Soil Description	Fortier and Scobey Soil Description	Maximum Water Velocity (ft/s)	Manning's n -Flow Depth 0.5-2.0 ft
	BROKEN ROCK and COBBLES	Cobbles and Shingles	5.5	0.030
A-1-a	Stone fragments or **GRAVEL,** with or without well-graded [1] binder[2]	Coarse gravel, non-colloidal	4.5	0.025
same	same	Fine gravel	3.5	0.020
A-1-b	Coarse **SAND**, with or without well-graded [1] binder[2]	Graded loam to cobbles when non-colloidal	4.0	0.030
A-2 (A-2-4. A-2-5. A-2-6, A-2-7)	Mixture of **GRAVEL** and **SAND**, with silty or clay fines[3], or nonplastic silt fines	Graded silts to cobbles when colloidal	4.5	0.030
same	same	Sandy loam, non-colloidal	2.0	0.020
A-3	Fine **SAND,** without silty clay fines; e.g. beach sand or stream-deposited fine sand	Fine Sand, non-colloidal	1.5	0.020
same	same	Silt loam, non-colloidal	2.3	0.020
A-4	Non- to moderately plastic[4] **SILT;** mixtures of silt, sand, and/or gravel, with a minimum silt content of 36%	Alluvial silts, non-colloidal	2.3	0.020
A-5	Moderately to highly plastic [4] **SILT**. Soil; mixtures of silt, sand, and/or gravel, with a minimum fines[3] content of 36%	Ordinary firm loam	2.5	0.020
A-6	Plastic[4] **CLAY** soil; mixtures of clay, sand, and/or gravel, with a minimum fines[3] content of 36%	Alluvial silts, colloidal	3.5	0.025
A-7	Moderately to highly plastic, **CLAY**; mixtures of clay, sand, and/or gravel, with a minimum clay content of 36%	Stiff clay, very colloidal	4.0	0.025

1) Well-graded-containing a broad range of particle sizes with no intermediate sizes missing.
1) Binder - soil particles consisting of fine sand, silt, and clay.
2) Fines - particle sizes finer than 0.074 mm (e.g., silt and clay particles).
3) Plasticity - ability of a soil mass to deform at constant volume without cracking or crumbling.

\+ Relationship between AASHTO classification and Fortier and Scobey description is loosely correlated.

USCS Classification	USCS Soil Description	Fortier and Scobey Soil Description	Maximum Water Velocity (ft/s)	Manning's n -Flow Depth 0.5-2.0 ft
	BROKEN ROCK and COBBLES	Cobbles and Shingles	5.5	0.030
GP, GW, SW, SP	Poorly graded gravel, well graded gravel, well graded sand, poorly graded sand	Coarse gravel, non-colloidal	4.5	0.025
		Fine gravel	3.5	0.020
SW	Well graded sand	Graded loam to cobbles when non-colloidal	4.0	0.030
GC, SC	Clayey gravel, clayey sand	Graded silts to cobbles when colloidal	4.5	0.030
SM	Silty sand	Sandy loam, non-colloidal	2.0	0.020
SP, SW	Poorly graded sand, well graded sand	Fine Sand, non-colloidal	1.5	0.020
ML	Silt	Silt loam, non-colloidal	2.3	0.020
CL	Lean clay	Alluvial silts, non-colloidal	2.3	0.020
ML, CL	Silt, lean clay	Ordinary firm loam	2.5	0.020
CL	Lean clay	Alluvial silts, colloidal	3.5	0.025
CH	Fat clay	Stiff clay, very colloidal	4.0	0.025

Note: Relationship between Unified Soil Classification System (USCS) classification and Fortier and Scobey description is loosely correlated.

Appendix 7D-3 Standard VDOT Riprap Classifications, Weights, and Blanket Thickness

Classification	D_{50} (ft)	W_{50} (lbs)	T (in)
Class AI	0.8	50	20
Class I	1.1	100	26
Class II	1.6	300	38
Class III	2.2	1000	53
Type I	2.8	2000	60
Type II	4.5	8000	97

Appendix 7D-4 Approximate Rock Dimensions and Equivalent Weights for Riprap

WEIGHT	MEAN SPERICAL DIAMETER	RECTANGULAR SHAPE	
		LENGTH	HT./WIDTH
25 lbs.	0.7’	1.1’	0.4’
50 lbs.	0.8’	1.4’	0.5’
75 lbs.	1.0’	1.6’	0.5’
100 lbs.	1.1’	1.75’	0.6’
150 lbs.	1.3’	2.0’	0.67’
300 lbs.	1.6’	2.6’	0.9’
500 lbs.	1.9’	3.0’	1.0’
1000 lbs.	2.2’	3.7’	1.25’
1500 lbs	2.6’	4.7’	1.5’
2000 lbs.	2.75’	5.4’	1.8’
2 tons	3.6’	6.0’	2.0’
3 tons	4.0’	6.9’	2.3’
4 tons	4.5’	7.6’	2.5’
10 tons	6.1’	10.0’	3.3’

Appendix 7D-5 Selection of Stability Factors

CONDITION	STABILITY FACTOR RANGE
Uniform flow; straight or mildly curving reach (curve radius/ channel width >30); impact from wave action and floating debris is minimal; little or no uncertainty in design parameters.	1.0 - 1.2
Gradually varying flow; moderate bend curvature (30 > curve radius/channel width > 10); impact from waves or floating debris is moderate.	1.3 - 1.6
Approaching rapidly varying flow; sharp bend curvature (30 > curve radius/channel width >10); significant impact potential from floating debris and/or ice; significant wind and/or bore generated wves (1-2 ft); high flow turbulence; mixing flow at bridge abutments; significant uncertainty in design parameters.	1.6 - 2.0
Channel bends when ratio of curve radius to channel width (R/W) > 30.	1.2
Channel bends when 30 > R/W > 10.	1.3 - 1.6
Channel bends when R/W < 10.	1.7

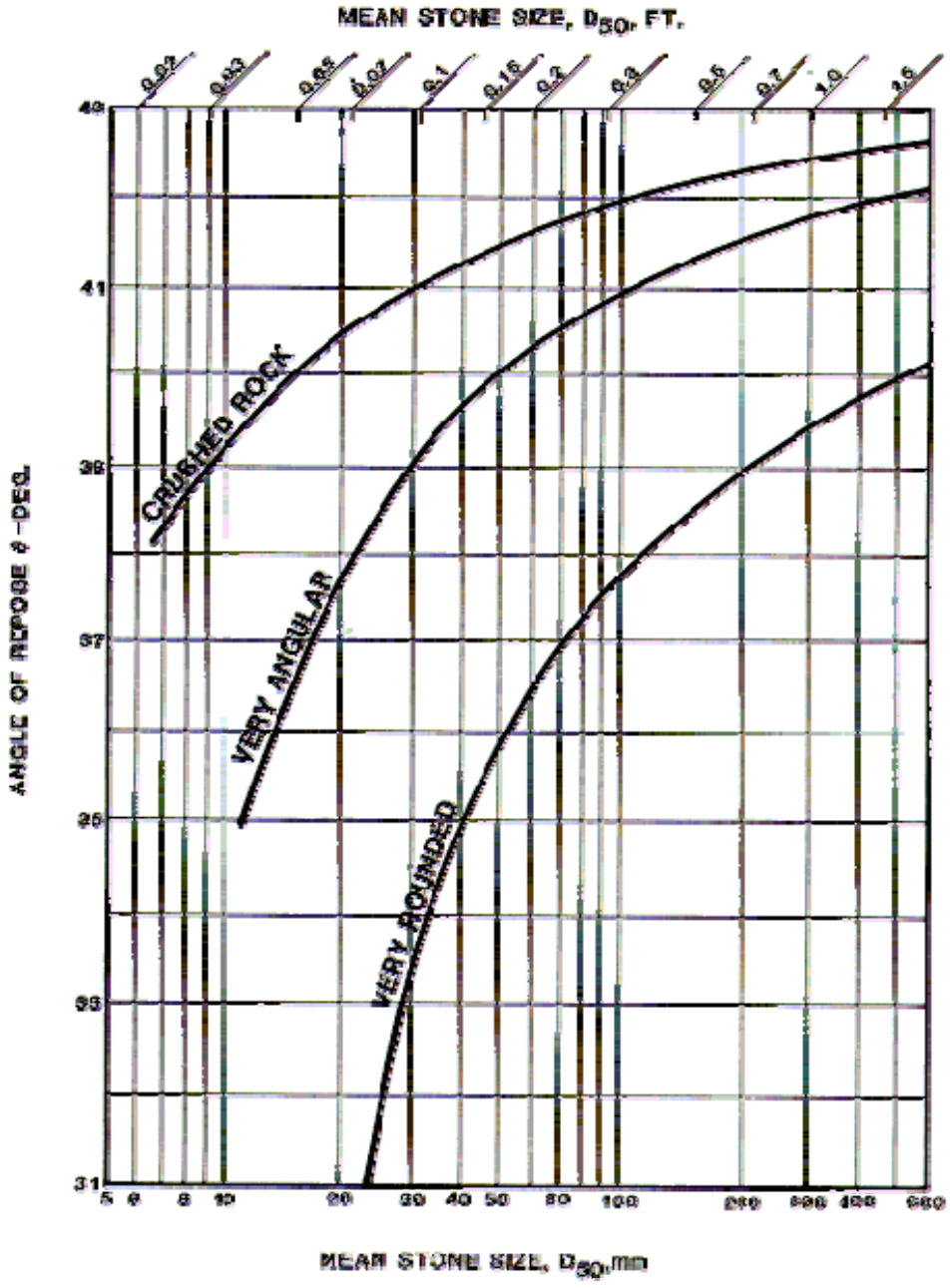
Appendix 7D-6 Permissible Velocities for Erodible Linings

Permissible velocities for channels with erodible linings, based on uniform flow in continuously wet, aged channels[1]:

Soil type or lining (earth; no vegetation)	Maximum permissible velocities for		
	Clear water	Water carrying fine silts	Water carrying sand and gravel
	F.p.s.	*F.p.s.*	*F.p.s.*
Fine sand (noncolloidal)	1.5	2.5	1.5
Sandy loam (noncolloidal)	1.7	2.5	2.0
Silt loam (noncolloidal)	2.0	3.0	2.0
Ordinary firm loam	2.5	3.5	2.2
Volcanic ash	2.5	3.5	2.7
Fine gravel	2.5	5.0	3.7
Stiff clay (very colloidal)	3.7	5.0	3.0
Graded, loam to cobbles (noncolloidal)	3.7	5.0	5.0
Graded, silt to cobbles (colloidal)	4.0	5.5	5.0
Alluvial silts (noncolloidal)	2.0	3.5	2.0
Alluvial silts (colloidal)	3.7	5.0	3.0
Coarse gravel (noncolloidal)	4.0	6.0	6.5
Cobbles and shingles	5.0	5.5	6.5
Shales and hard pans	6.0	6.0	5.0

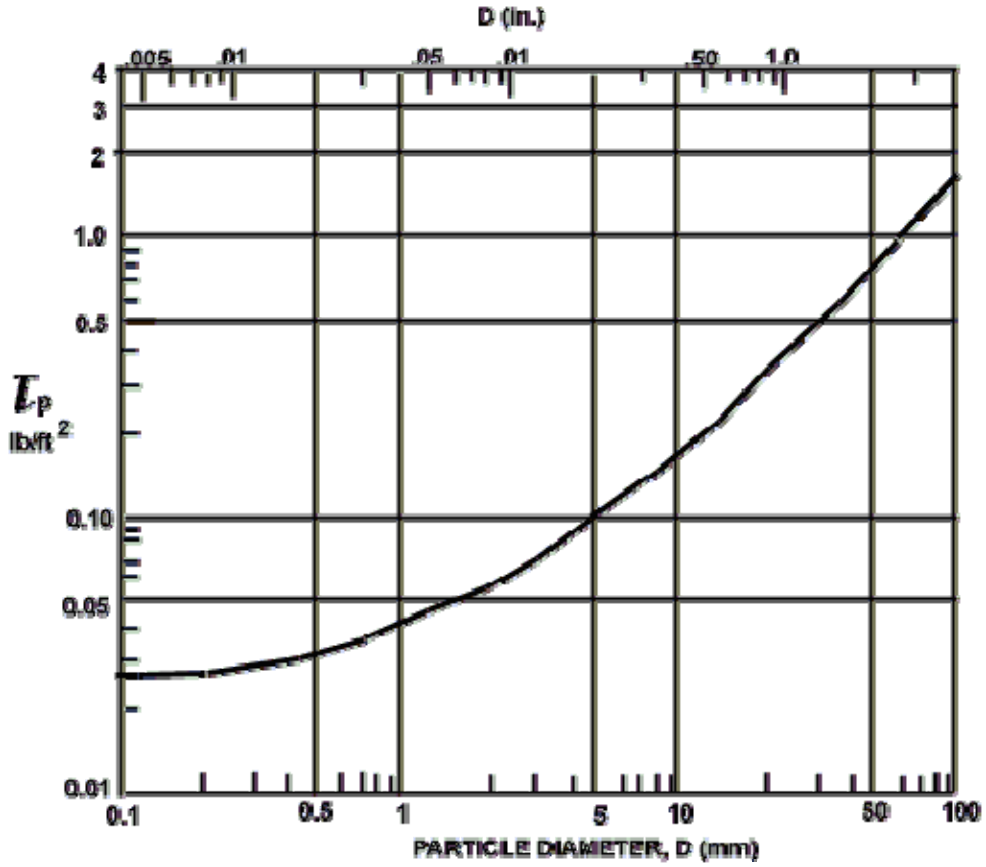
Source: [1]As recommended by Special Committee on Irrigation Research, American Society of Civil Engineers, 1926.

Appendix 7E-1 Angle of Repose of Riprap in Terms of Mean Size and Shape of Stone



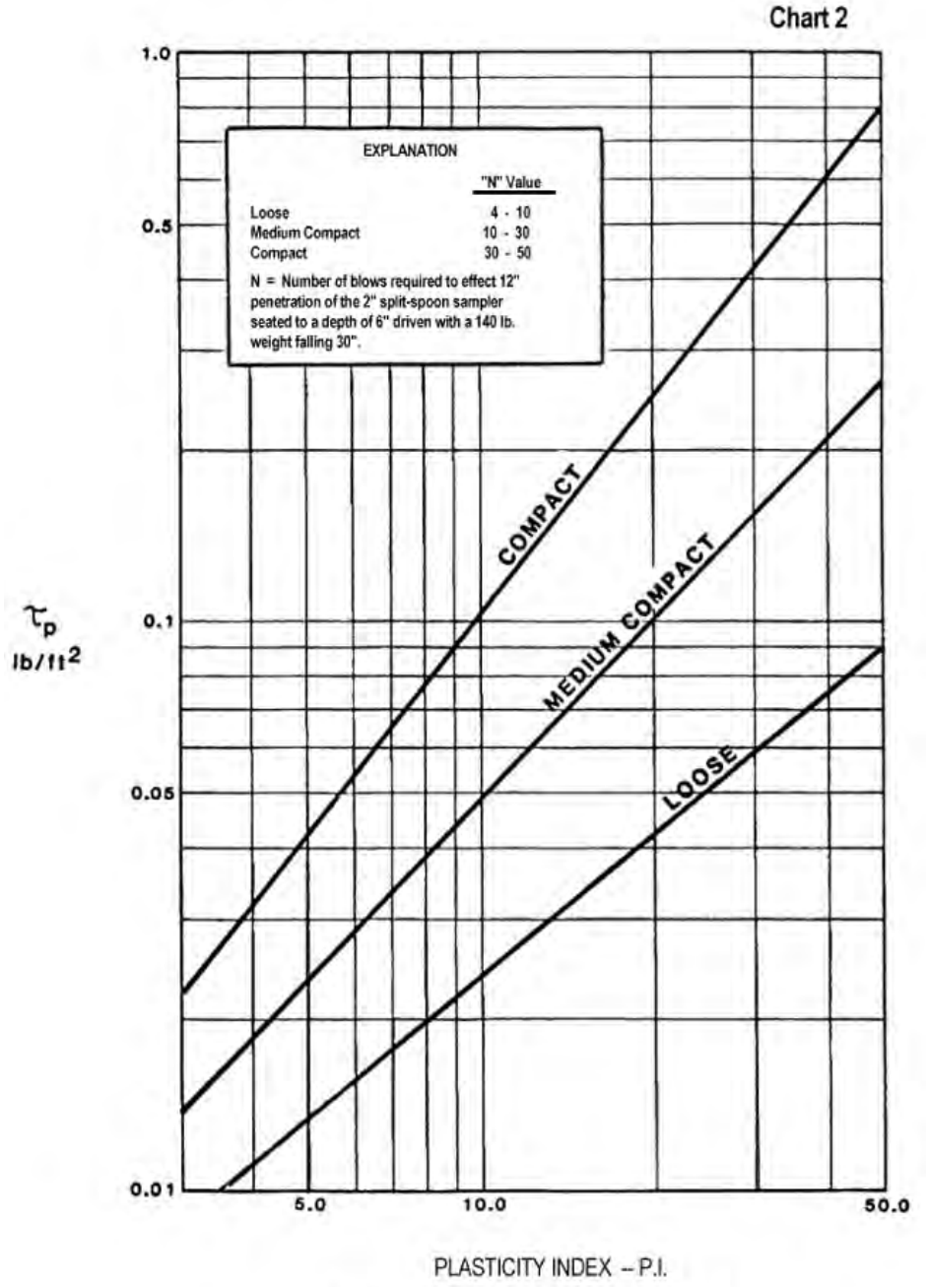
Source: HEC-15 (Archived 1988)

Appendix 7E-2 Permissible Shear Stress for Non-Cohesive Soils



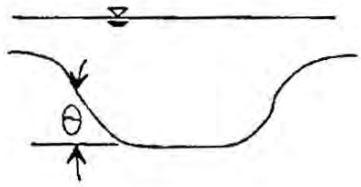
Source: HEC-15 (Archived) 1988

Appendix 7E-3 Permissible Shear Stress for Cohesive Soils



Source: HEC-15 (Archived) 1988

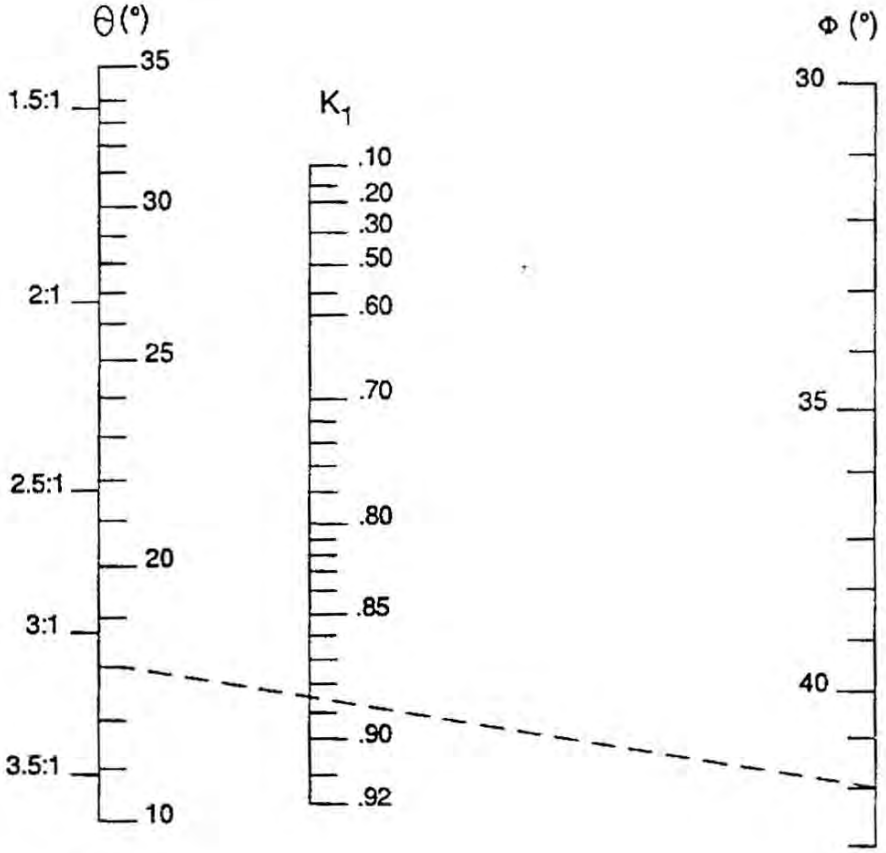
Appendix 7E-4 Bank Angle Correction Factor (K_1) Nomograph



$$K_1 = \left[1 - \frac{\sin^2\theta}{\sin^2\Phi}\right]^{0.5}$$

θ = Bank angle with horizontal

Φ = Material angle of repose (See chart 4)



Example

Given:
$\theta = 18°$
Very Angular
$D_{50} = 1.5$ ft.

Find:
K_1

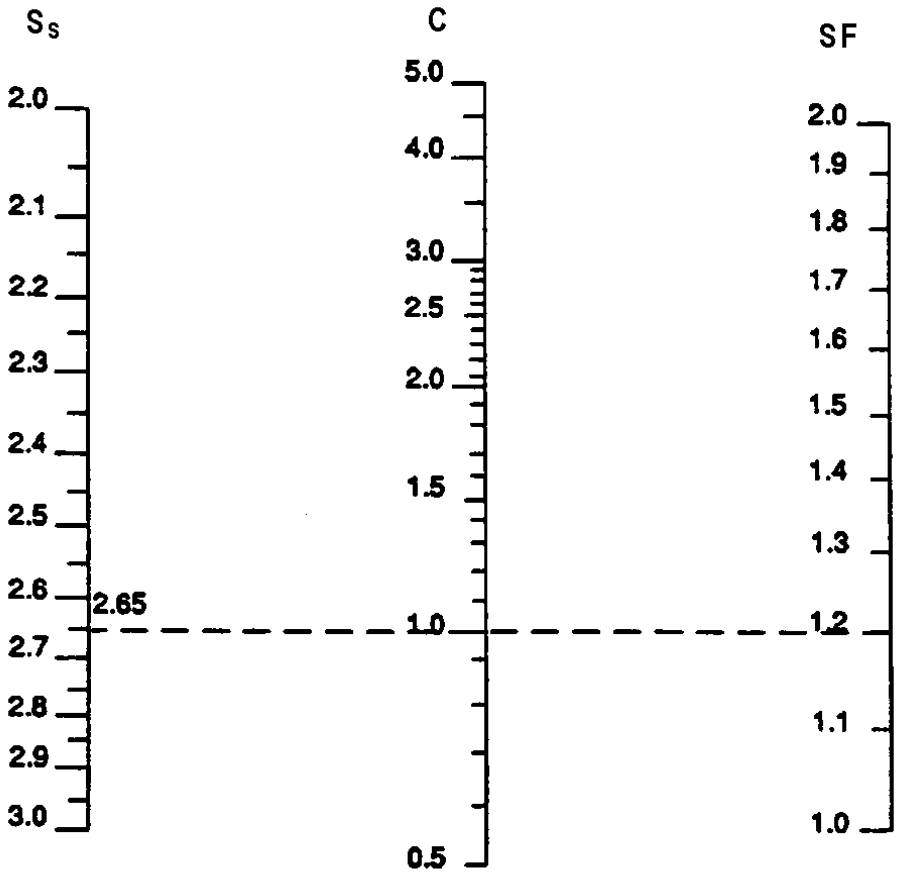
Solution:
$\Phi = 42°$
$K_1 = 0.885$

Source: HEC-11

Appendix 7E-5 Correction Factor for Riprap Size

$$C = 1.61\ SF^{1.5} / (S_S - 1)^{1.5}$$

C = D_{50} CORRECTION FACTOR
SF = STABILITY FACTOR
S_S = SPECIFIC GRAVITY OF ROCK



Example:

Given:
S_S = 2.65
SF = 1.2

Solution:
C = 1.0

Source: HEC-11
Comment: S_s=S_g (text)

Appendix 7E-6 Riprap Size Relationship

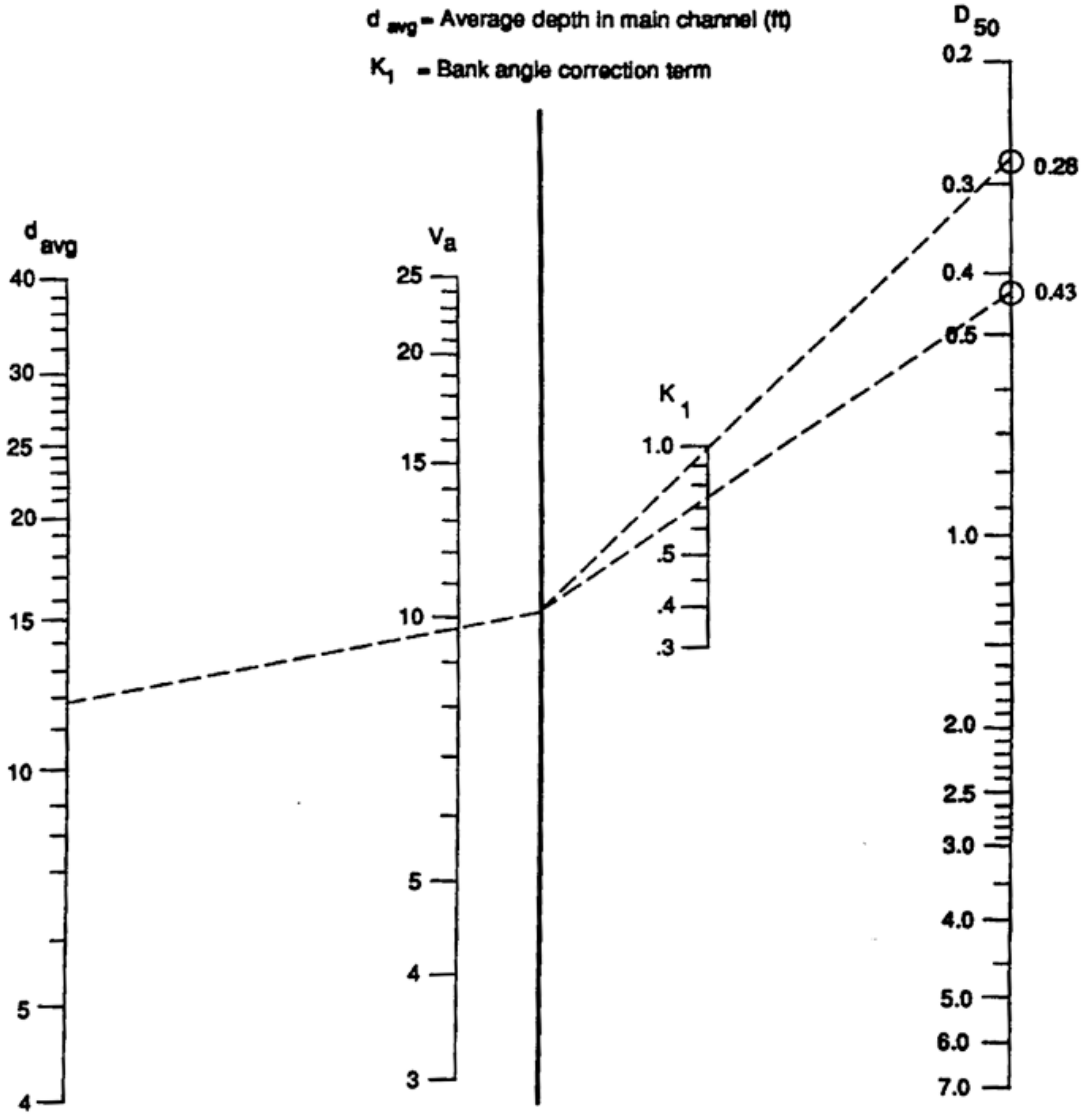
$D_{50}=0.001\ V_a^3/(d_{avg}^{1/2}K_1^{3/2})$

D_{50} = Median Riprap Size (ft.)

V_a = Average velocity in main channel (ft/sec)

d_{avg} = Average depth in main channel (ft)

K_1 = Bank angle correction term



Example

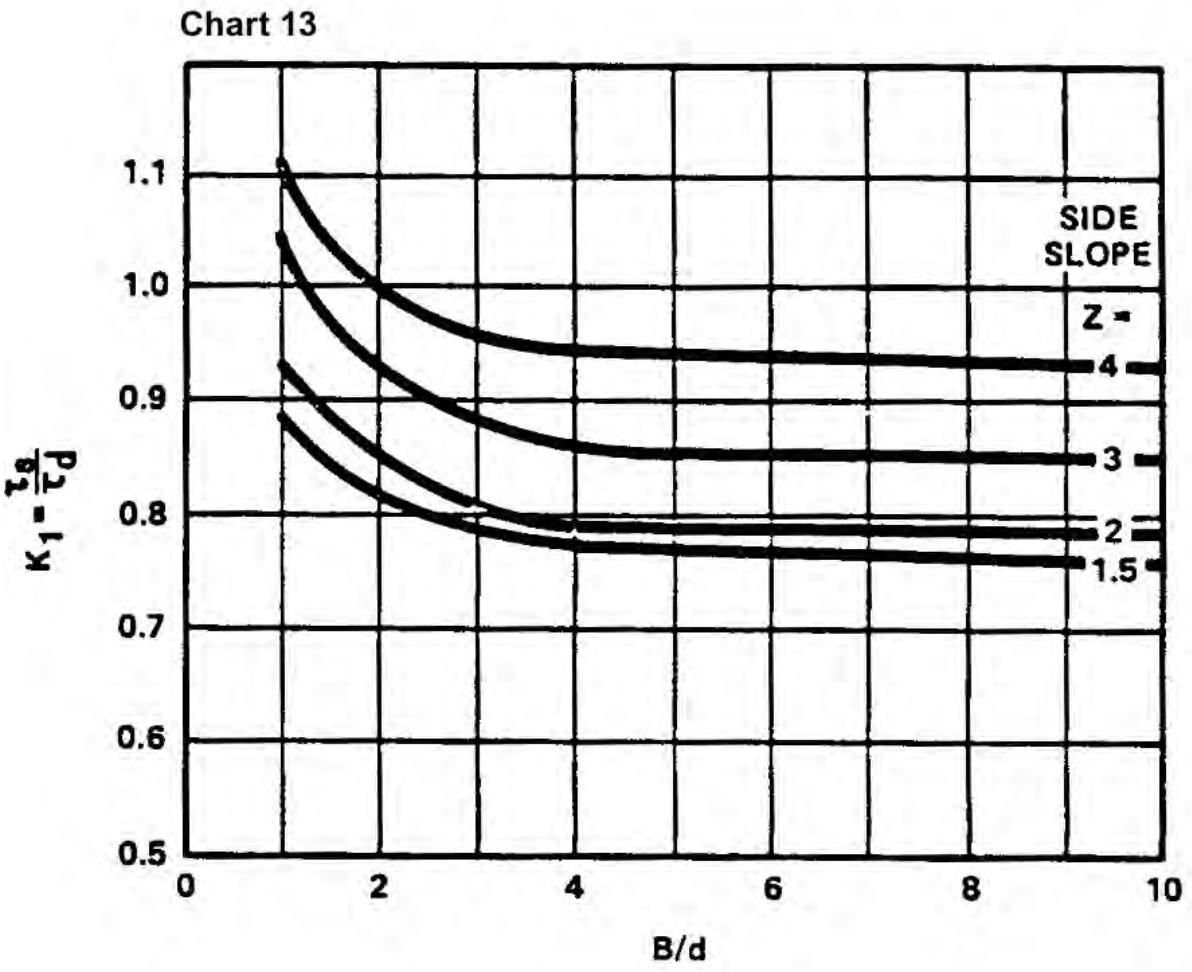
Given:
V_a = 9.7
d_{avg} = 11.8 ft.
K_1 = 0.73

Find:
D_{50}

Solution:
D_{50} = 0.43

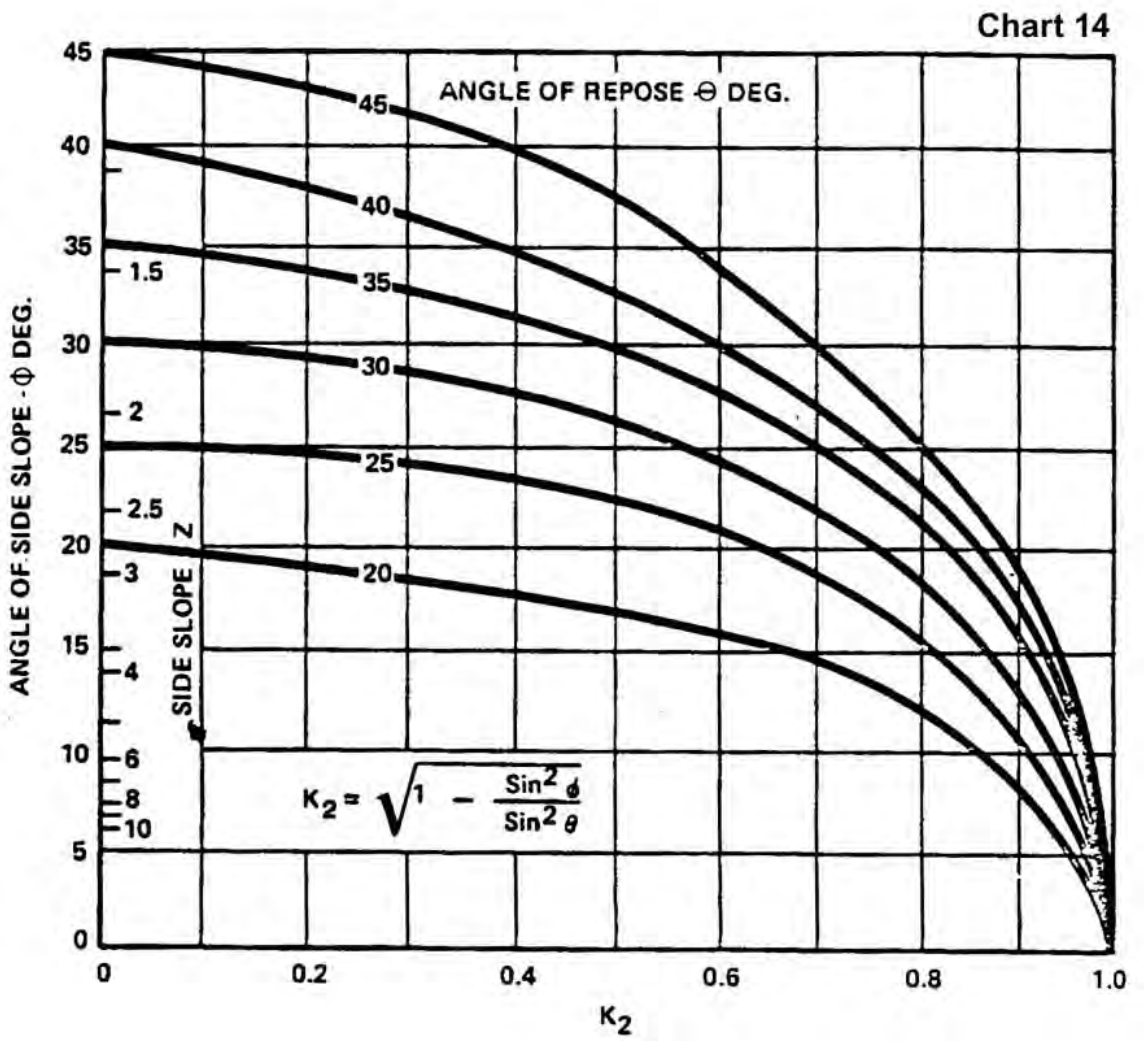
Source: HEC-11

Appendix 7E-7 Channel Side Shear Stress to Bottom Shear Stress Ratio



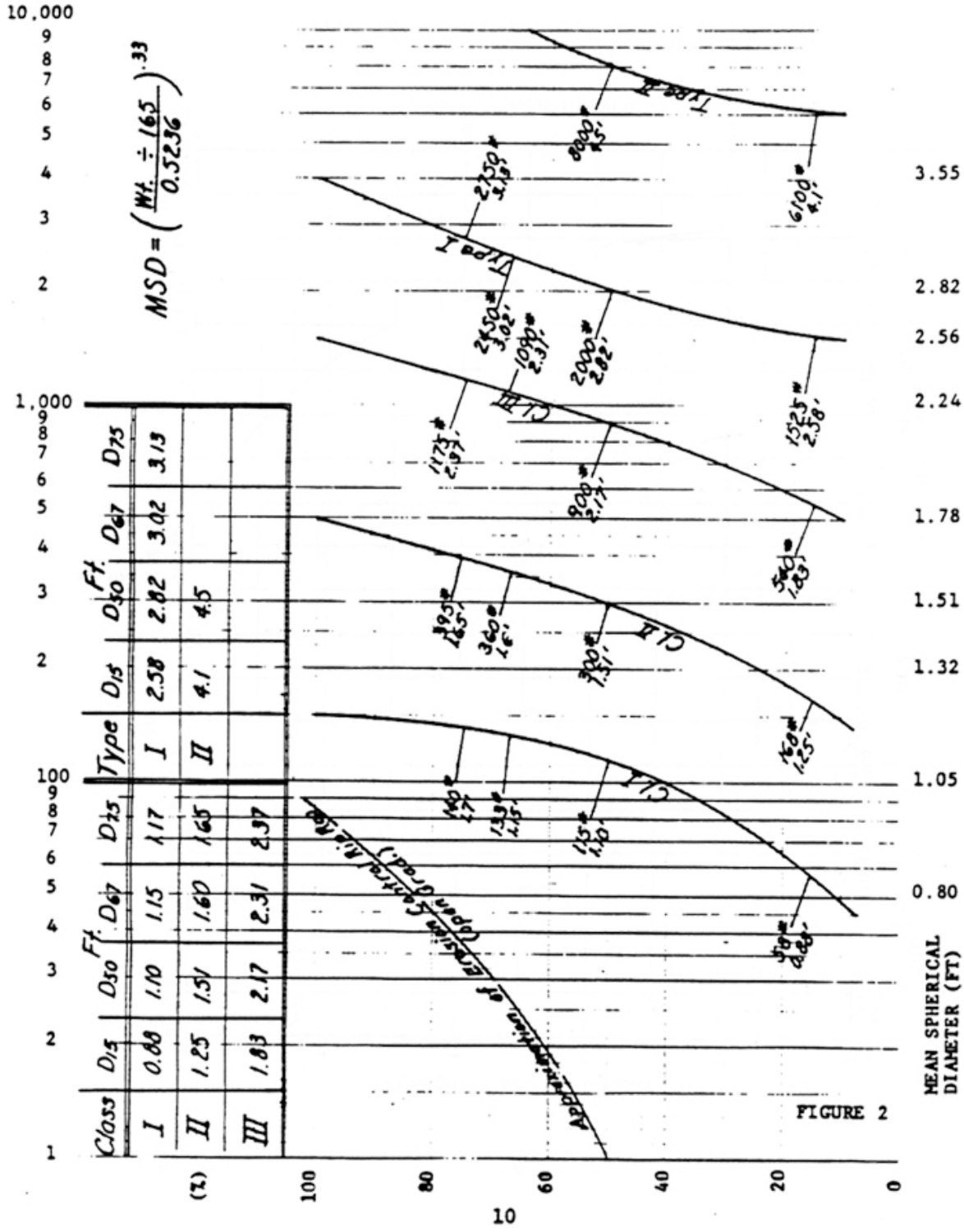
Source: HEC-15 (Archived 1988)

Appendix 7E-8 Tractive Force Ratio (K_2)



Source: HEC-15 (Archived 1988)
Comment: The symbols of Φ and θ are reversed from Appendix 7E-4.

Appendix 7E-9 Determination of Mean Spherical Diameter



Source: VDOT

Comment: Use this chart to obtain D_{75} information for the Channel Stability Worksheet (Appendix 7B-3).