Appendix C PIPE FLOW DESIGN CHARTS

HDS-5, *Hydraulic Design of Highway Culverts* (FHWA, 1985) contains pipe design charts. Some of these charts have been reproduced in this appendix. An index of the design charts provided is given below, not all charts included in the FHWA manual are reproduced in this document.

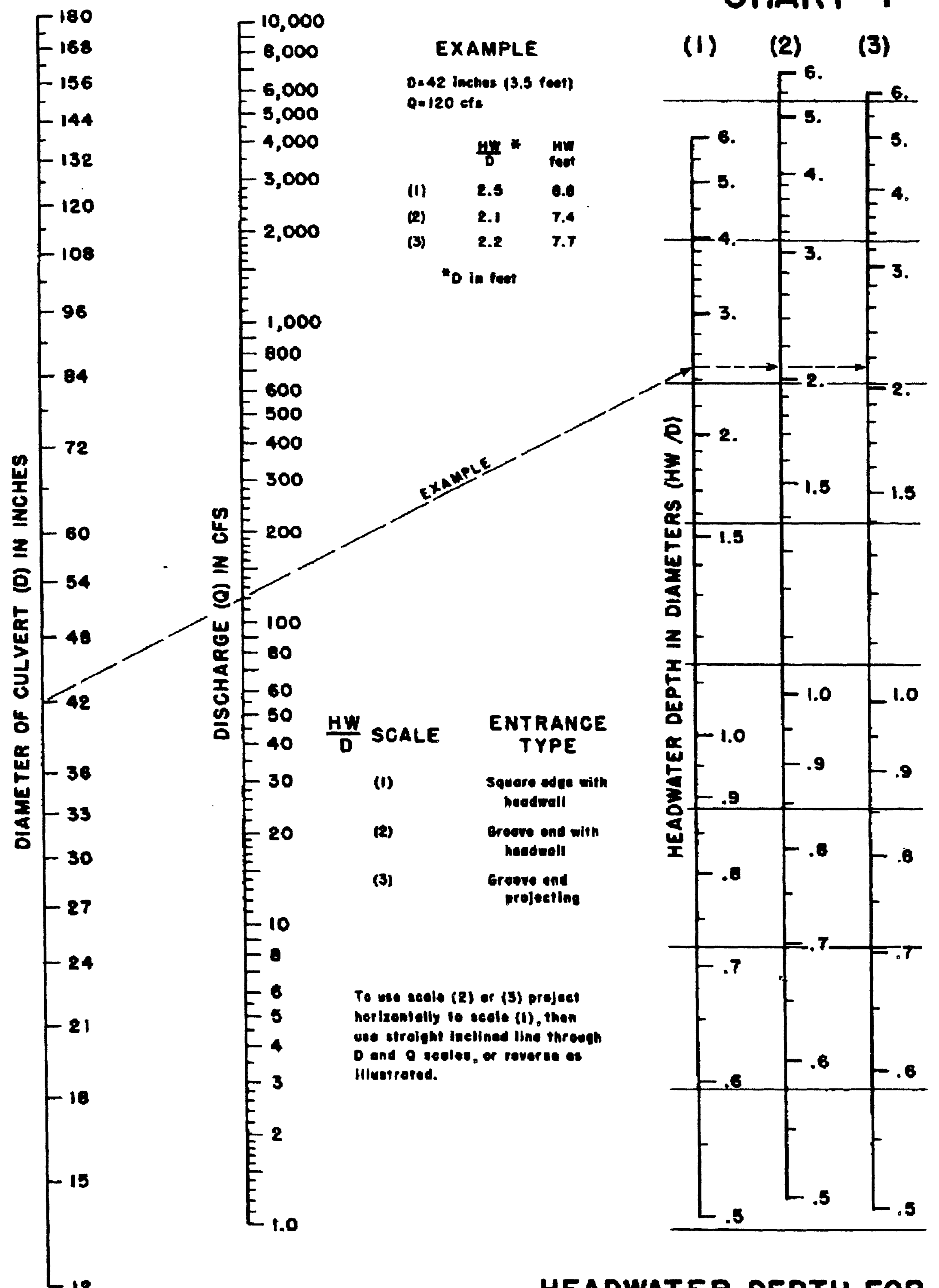
Design curves were developed for common conduit shapes, sizes and inlet edge configurations constants using a set of design equations. The design equations used to develop the inlet control nomographs are based on the research conducted by the National Bureau of Standards (NBS) under the sponsorship of the Bureau of Public Roads (now the Federal Highway Administration). Seven progress reports were produced as a result of this research. These reports were one source of the equation coefficients and exponents, along with other references and unpublished FHWA notes on the development of the nomographs.

A constant slope value of 2 percent (0.02) was selected for the development of design curves. This is because the slope effect is small and the resultant headwater is conservatively high for sites with slopes exceeding 2 percent except for mitered inlets.

In formulating inlet and outlet control design nomographs, a certain degree of error is introduced into the design process. This error is due to the fact that the nomograph construction involves graphical fitting techniques resulting in scales which do not exactly match the equations. Checks by the authors and others indicate that all of the nomographs from HDS-5 (FHWA, 1985) have a precision of ± 10 percent of the equation values in terms of headwater (inlet control) or head loss (outlet control).

Chart Number	Shape	Control Section	Material	Type
1	Circular	Inlet	Concrete	
2	Circular	Inlet	Metal	
3	Circular	Inlet	Metal	Beveled Ring Control
4	Circular	Critical		
5	Circular	Outlet	Concrete	n = 0.012
6	Circular	Outlet	Metal	n = 0.024
7	Circular	Outlet	Metal	n = 0.0328 to 0.0302
8	Box	Inlet	Concrete	
9	Box	Inlet	Concrete	Wingwalls 18° to 33.7° and 45°
10	Box	Inlet	Concrete	90° Headwall, Beveled Edges
11	Box	Inlet	Concrete	Skewed Headwalls, Beveled Edges
12	Box	Inlet	Concrete	Flared Wingwalls, Normal and Skewed
13	Box	Inlet	Concrete	Offset Flared Wingwalls, Inlet Top beveled edge
14	Box	Critical	Concrete	Rectangular
15	Box	Outlet	Concrete	n = 0.012
34	Pipe Arch	Inlet	Metal	
35	Pipe Arch	Inlet	Metal	18 in. Corner Radius
36	Pipe Arch	Inlet	Metal	31 in. Corner Radius
37	Pipe Arch	Critical		Standard
38	Pipe Arch	Critical		Structural Plate
39	Pipe Arch	Outlet	Metal	n = 0.024
40	Pipe Arch	Outlet	Metal	18 in. Corner Radius
60	Roadway	Overtopping		Discharge Coefficients

CHART 1



HEADWATER SCALES 2&3
REVISED MAY 1964

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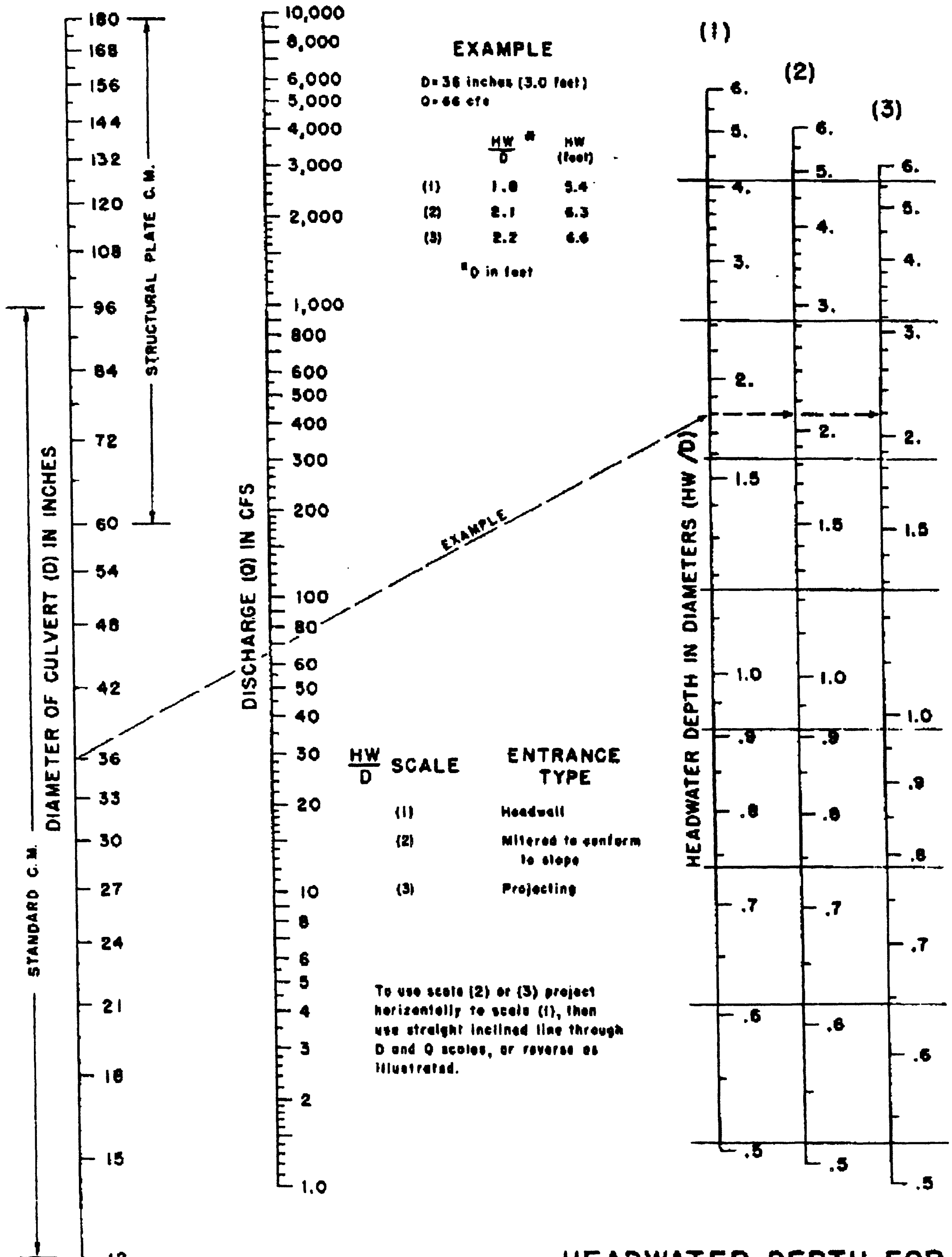
HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL

CHART 2

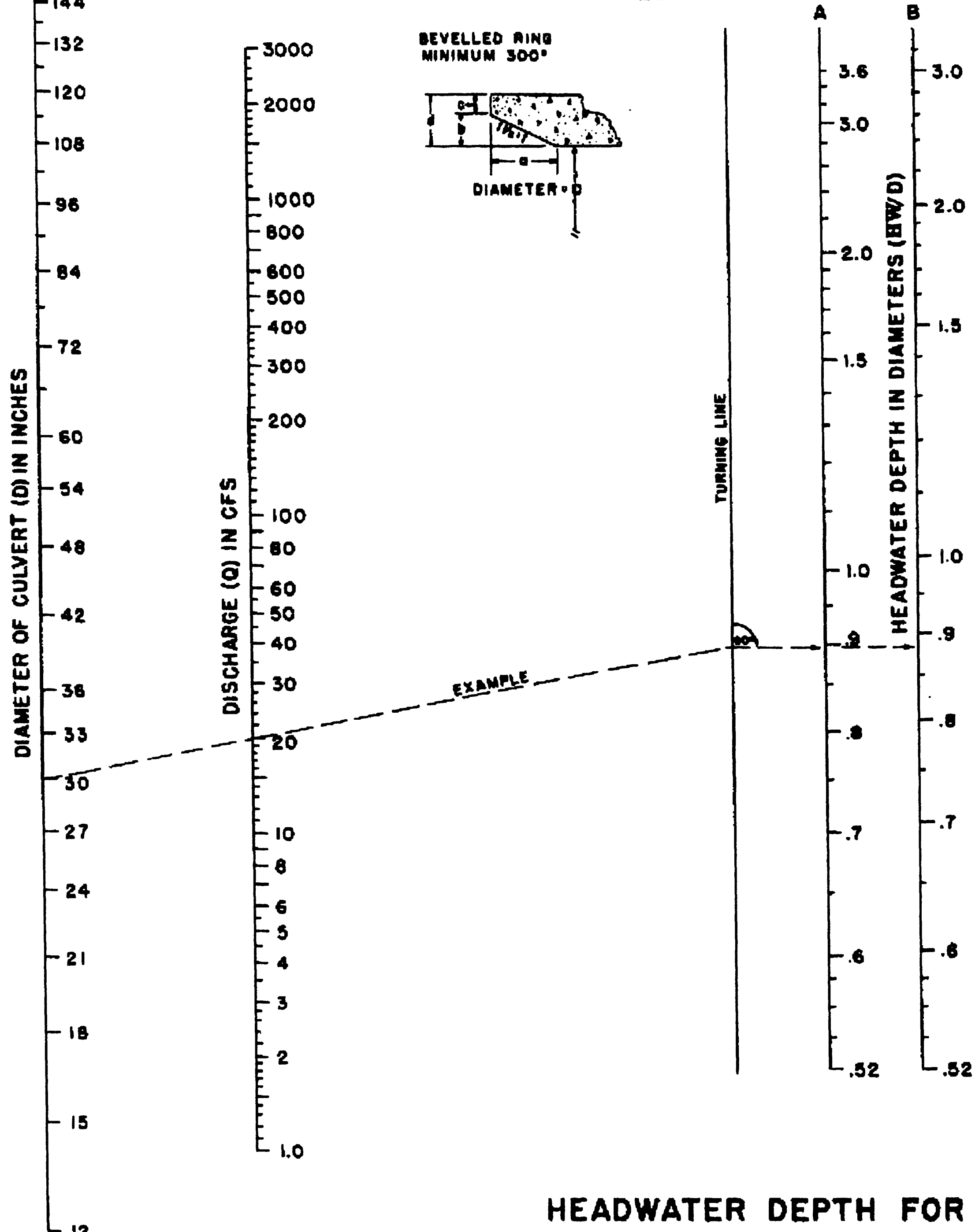


HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

CHART 3

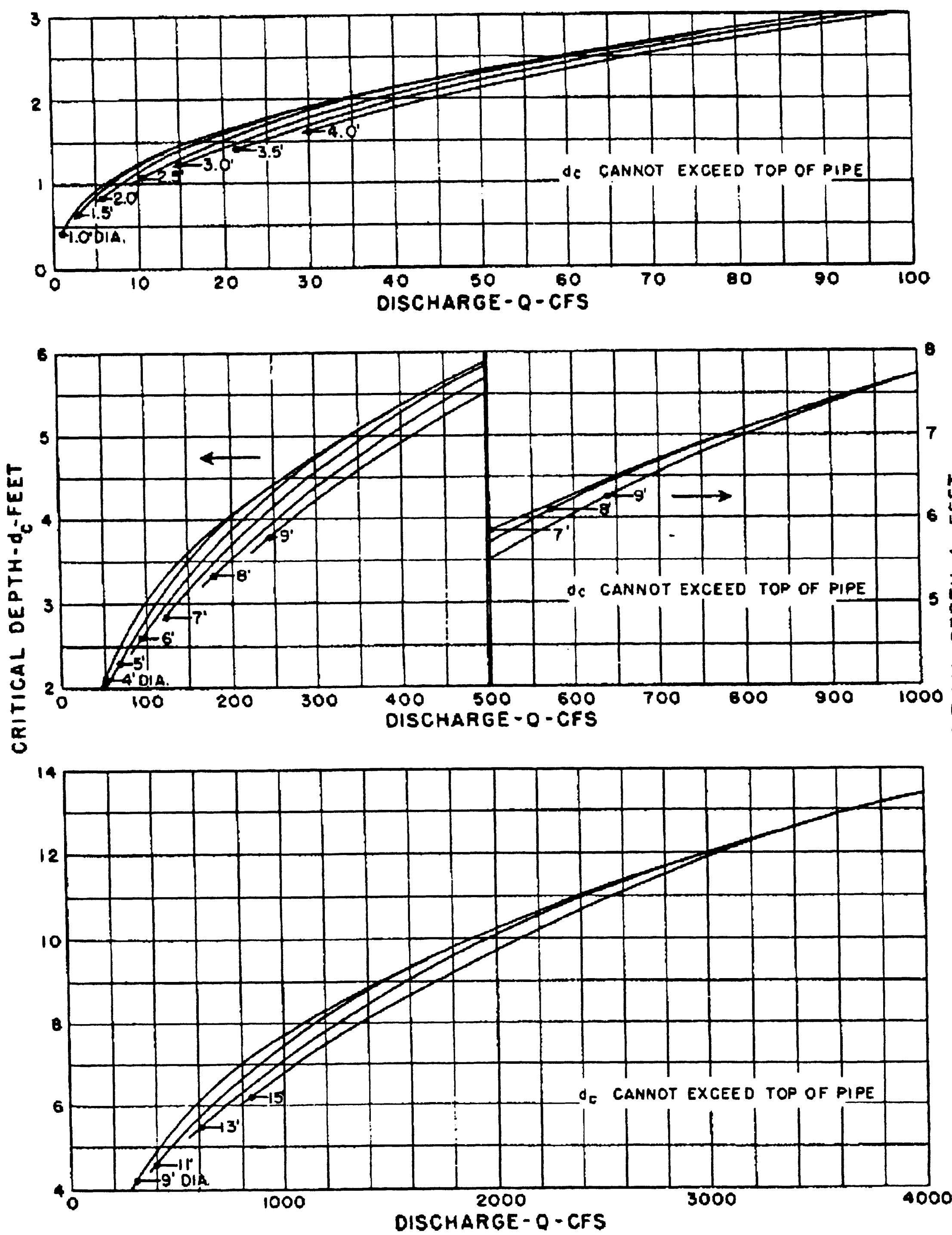
$\frac{a}{D}$	$\frac{b}{D}$	$\frac{c}{D}$	$\frac{d}{D}$	ENTRANCE TYPE
0.042	0.063	0.042	0.083	A
0.083	0.125	0.042	0.125	B



FEDERAL HIGHWAY ADMINISTATION
MAY 1973

HEADWATER DEPTH FOR CIRCULAR PIPE CULVERTS WITH BEVELED RING INLET CONTROL

CHART 4



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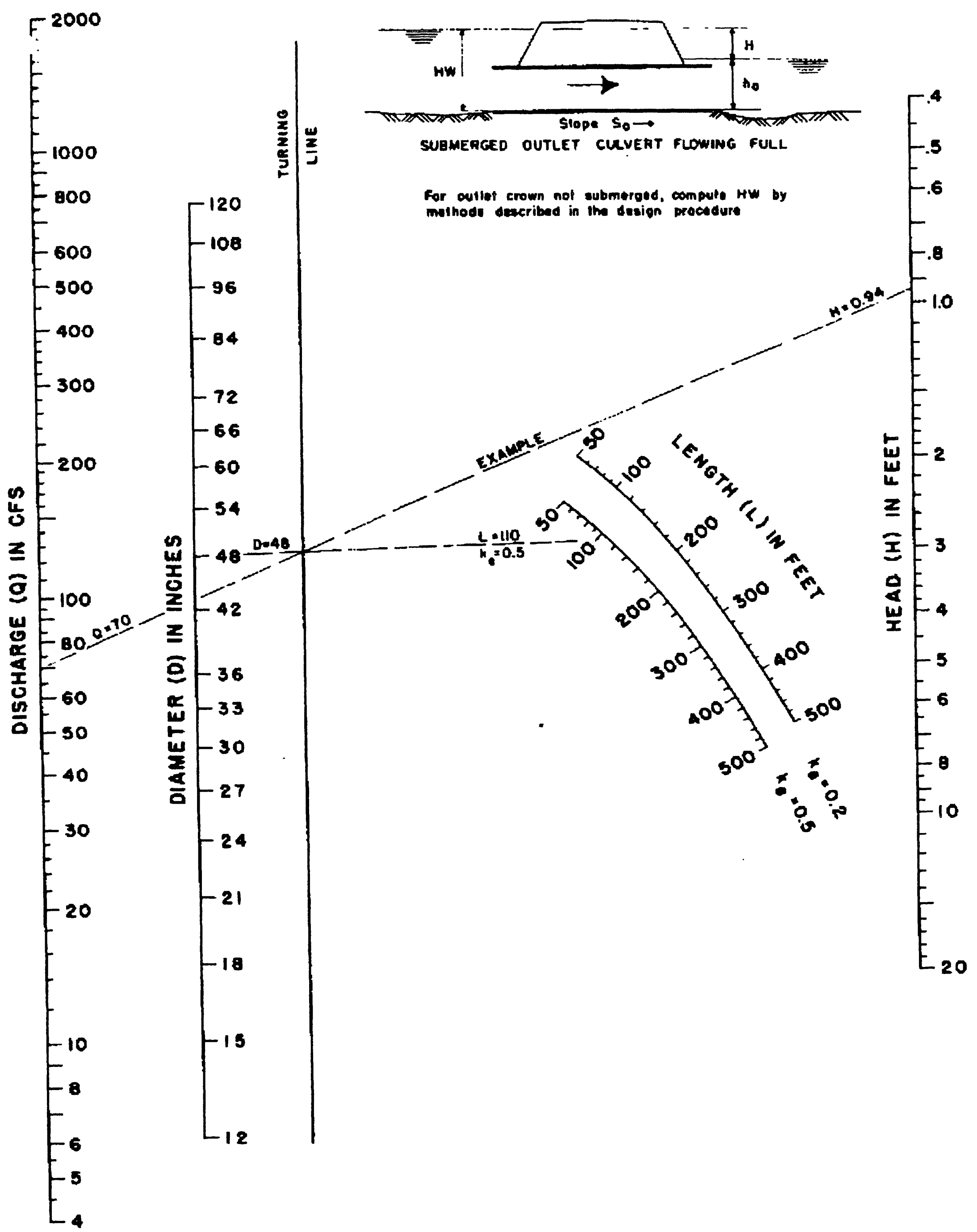
JAN. 1964

CRITICAL DEPTH
CIRCULAR PIPE

CHART 5



HEAD FOR
CONCRETE PIPE CULVERTS
FLOWING FULL
n = 0.012

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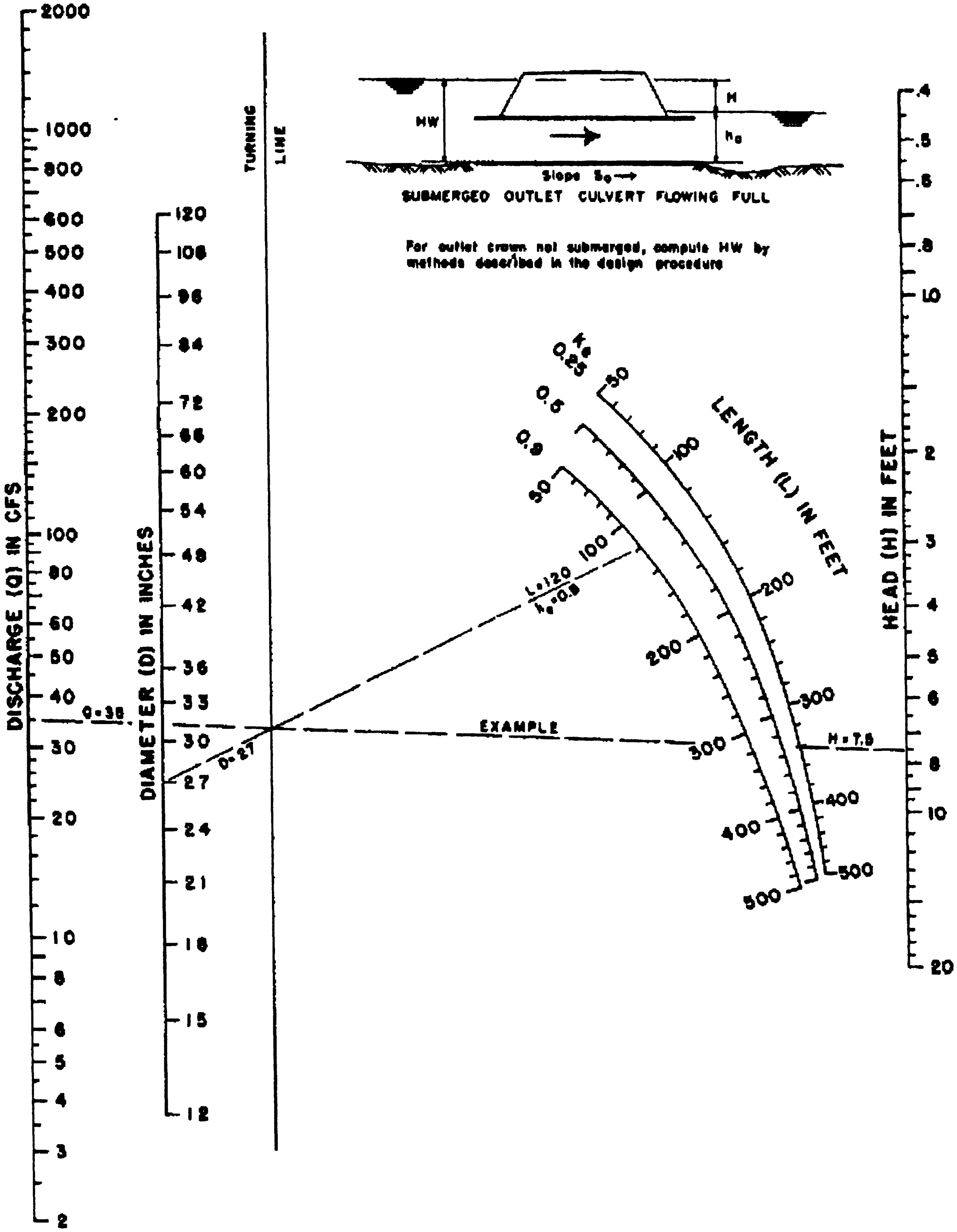
CHART 6



HEAD FOR STANDARD C. M. PIPE CULVERTS FLOWING FULL $n = 0.024$

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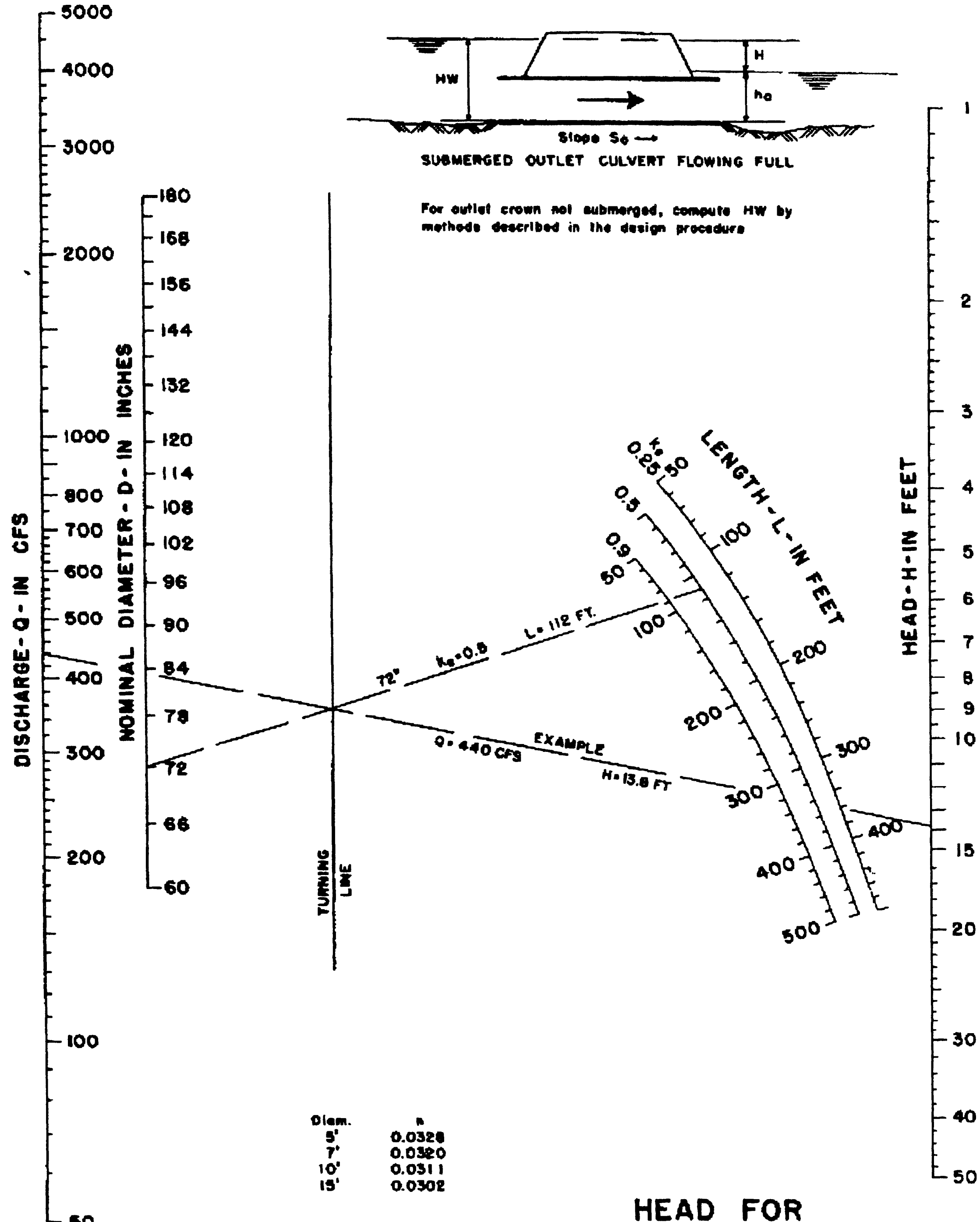
CHART 7



Diam.	n
5'	0.0328
7'	0.0320
10'	0.0311
15'	0.0302

HEAD FOR STRUCTURAL PLATE CORR. METAL PIPE CULVERTS FLOWING FULL

n = 0.0328 TO 0.0302

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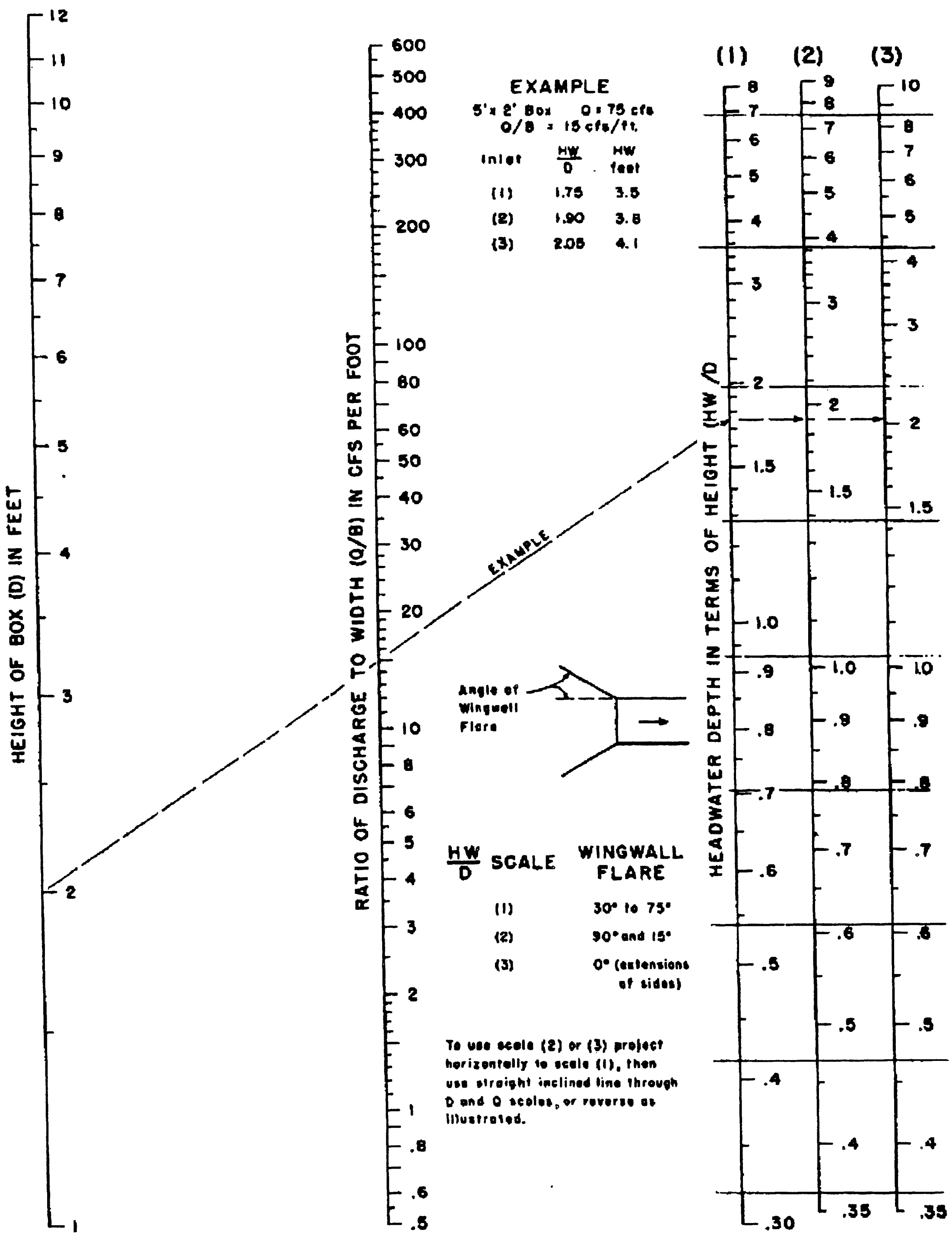
CHART 8



HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

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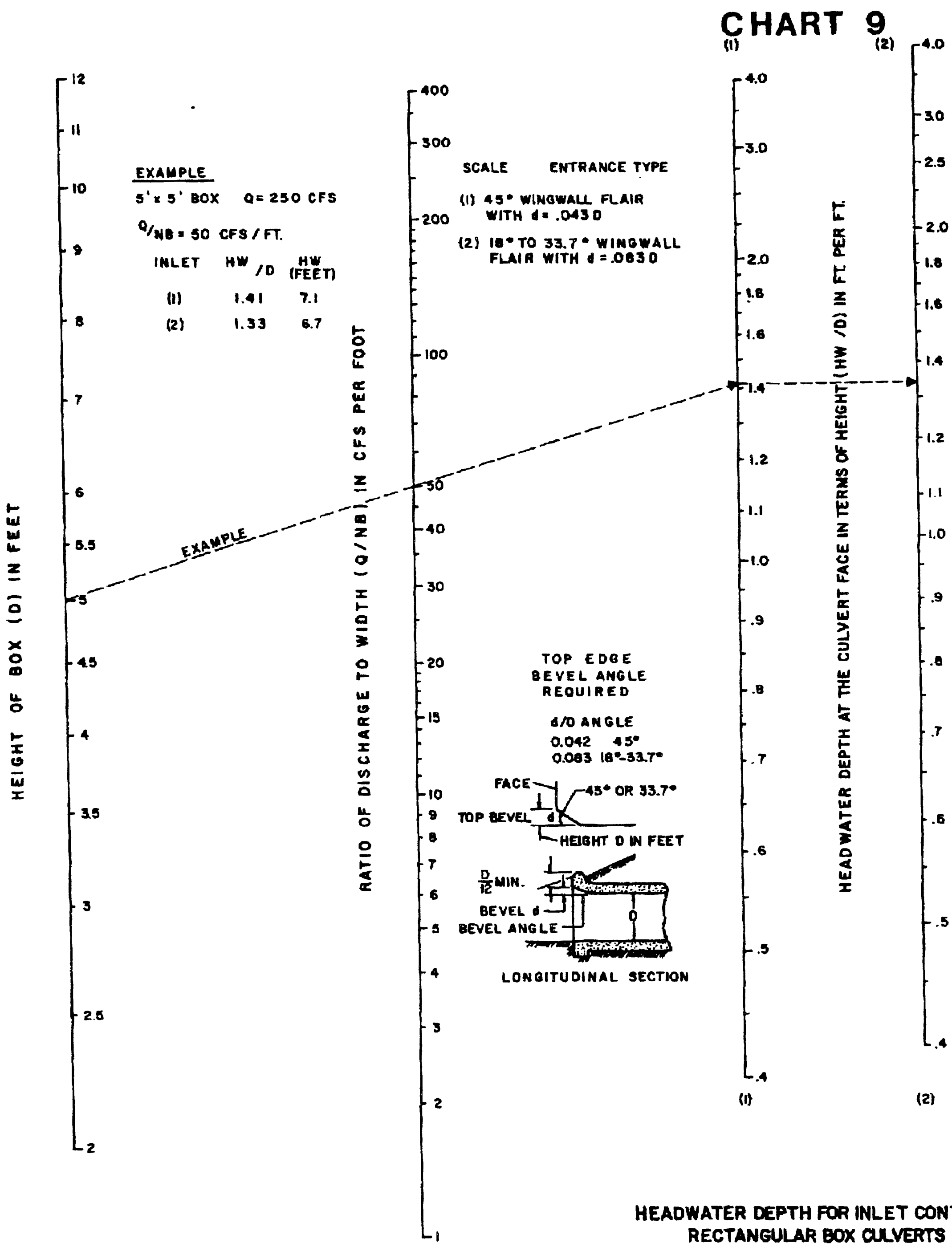
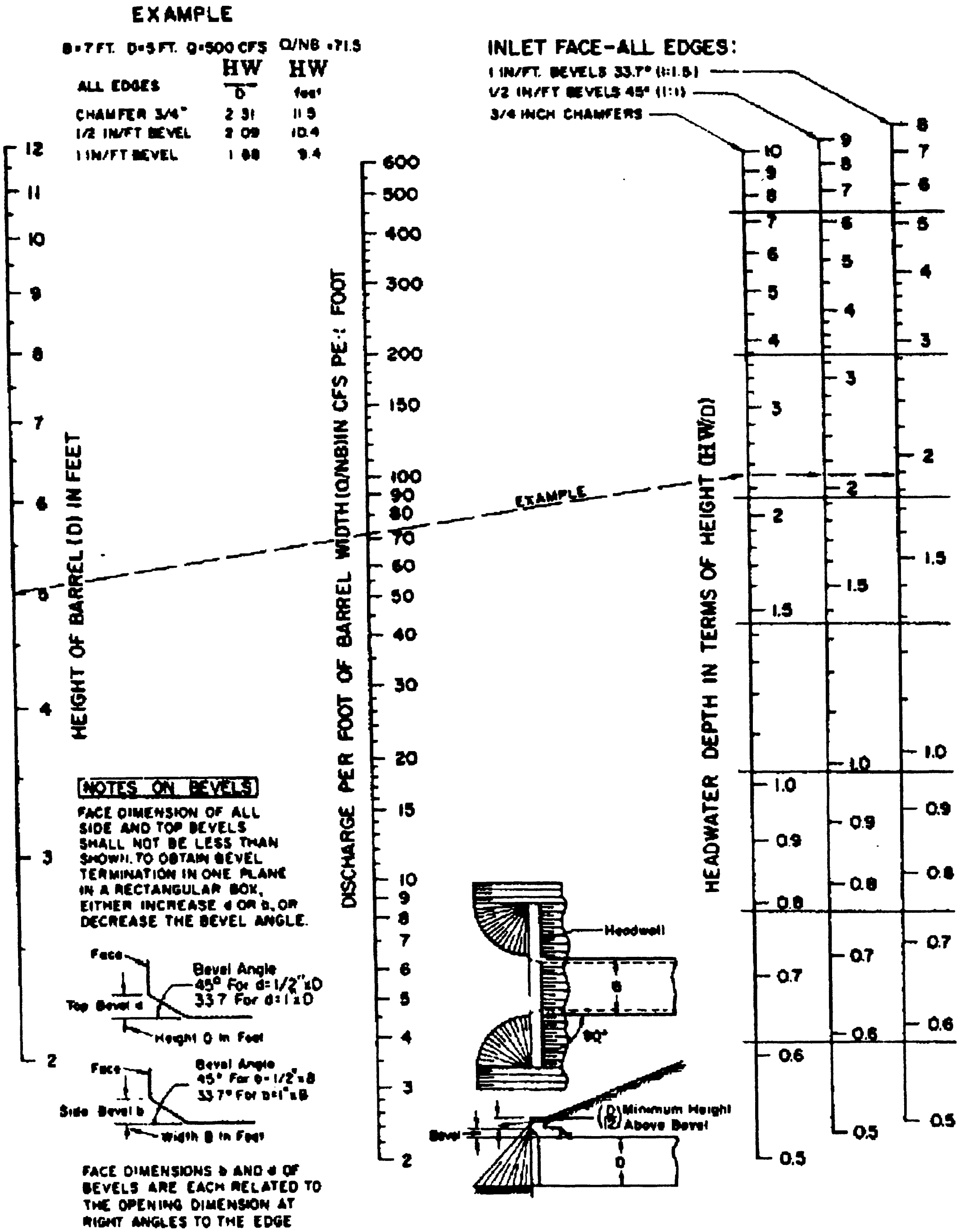


HEADWATER DEPTH FOR INLET CONTROL
RECTANGULAR BOX CULVERTS
FLARED WINGWALLS 18° TO 33.7° & 45°
WITH BEVELED EDGE AT TOP OF INLET

CHART 10



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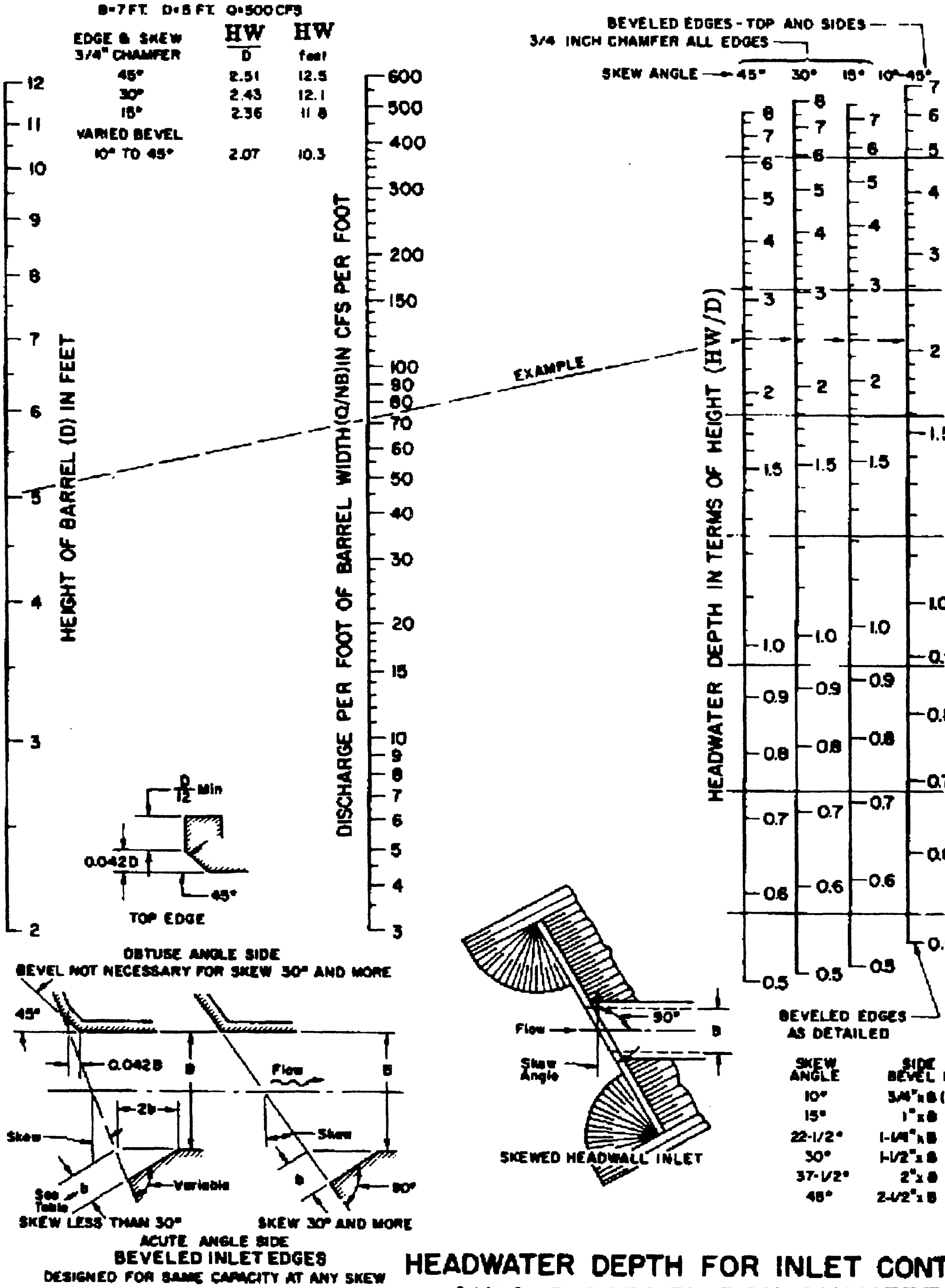
MAY 1973

HEADWATER DEPTH FOR INLET CONTROL
RECTANGULAR BOX CULVERTS
90° HEADWALL
CHAMFERED OR BEVELED INLET EDGES

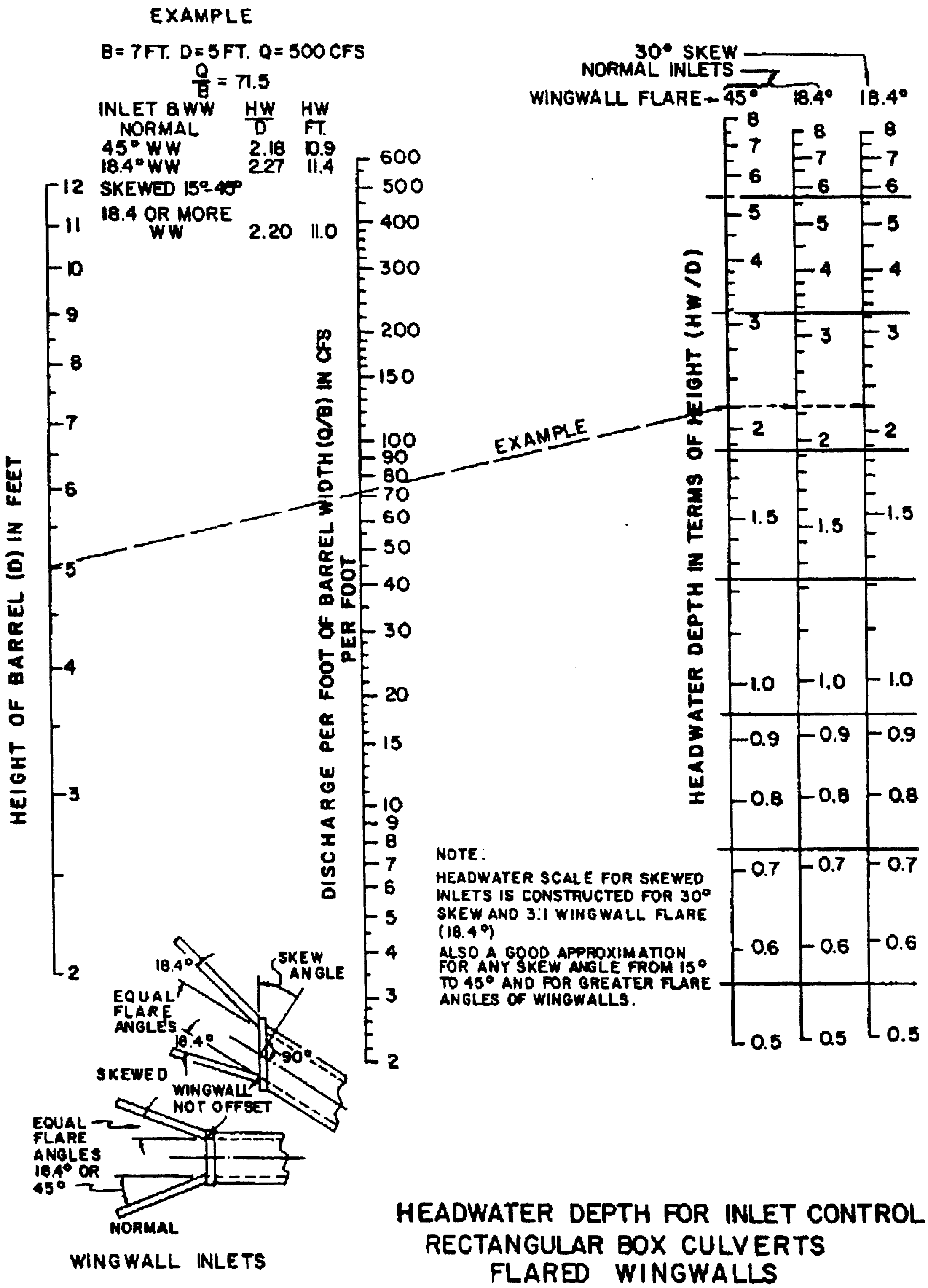
CHART 11



FEDERAL HIGHWAY ADMINISTRATION
MAY 1973

HEADWATER DEPTH FOR INLET CONTROL
SINGLE BARREL BOX CULVERTS
SKEWED HEADWALLS
CHAMFERED OR BEVELED INLET EDGES

CHART 12



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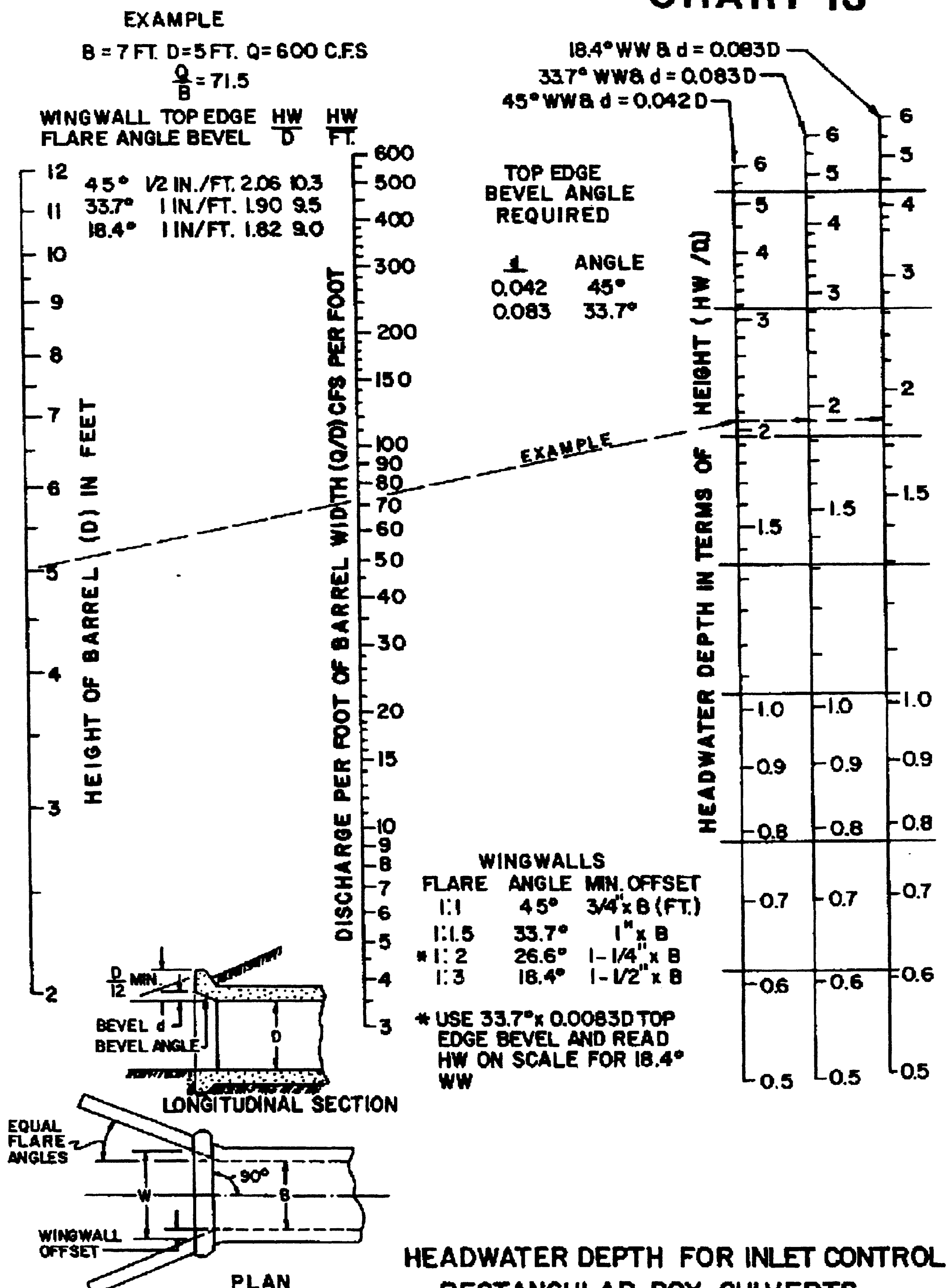
OFFICE OF R & D AUGUST 1968

HEADWATER DEPTH FOR INLET CONTROL
RECTANGULAR BOX CULVERTS
FLARED WINGWALLS
NORMAL AND SKEWED INLETS
3/4" CHAMFER AT TOP OF OPENING

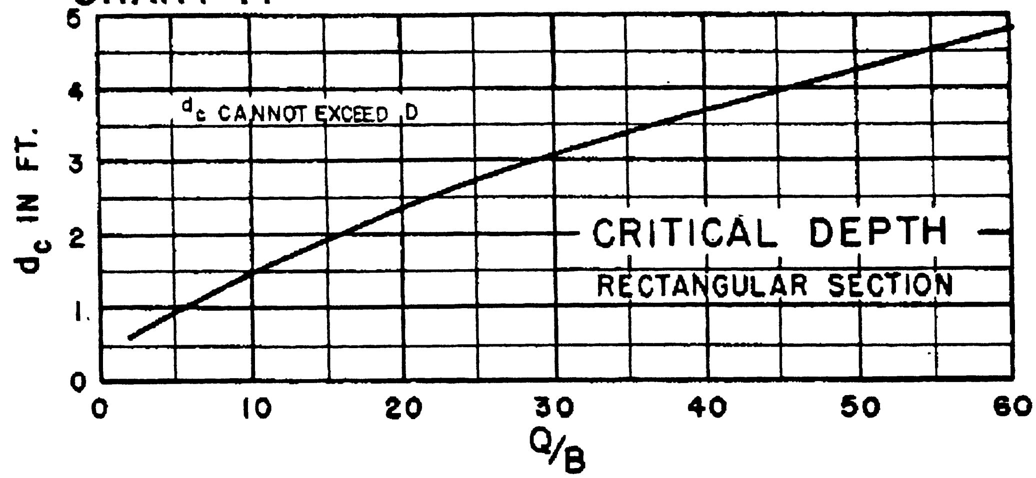
CHART 13

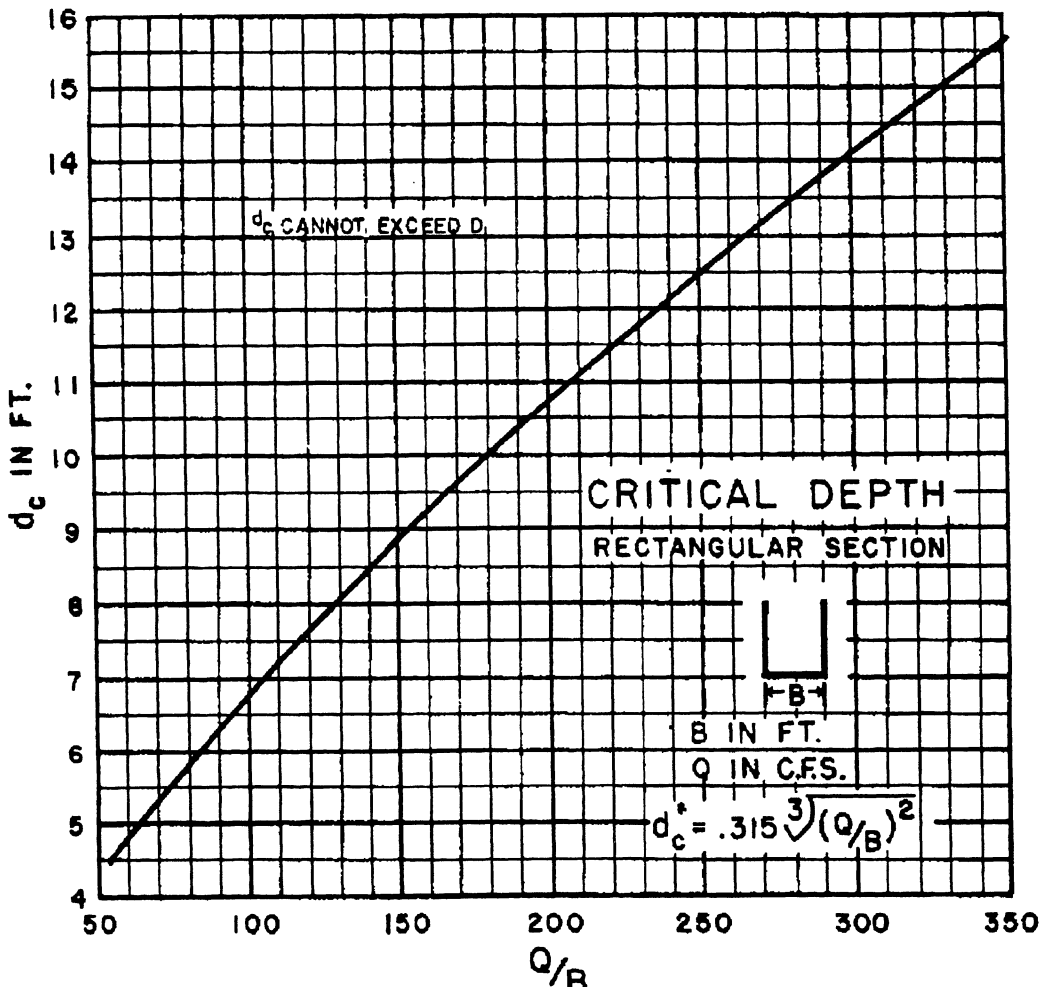


BUREAU OF PUBLIC ROADS
OFFICE OF R& D AUGUST 1968

HEADWATER DEPTH FOR INLET CONTROL
RECTANGULAR BOX CULVERTS
OFFSET FLARED WINGWALLS
AND BEVELED EDGE AT TOP OF INLET

CHART 14





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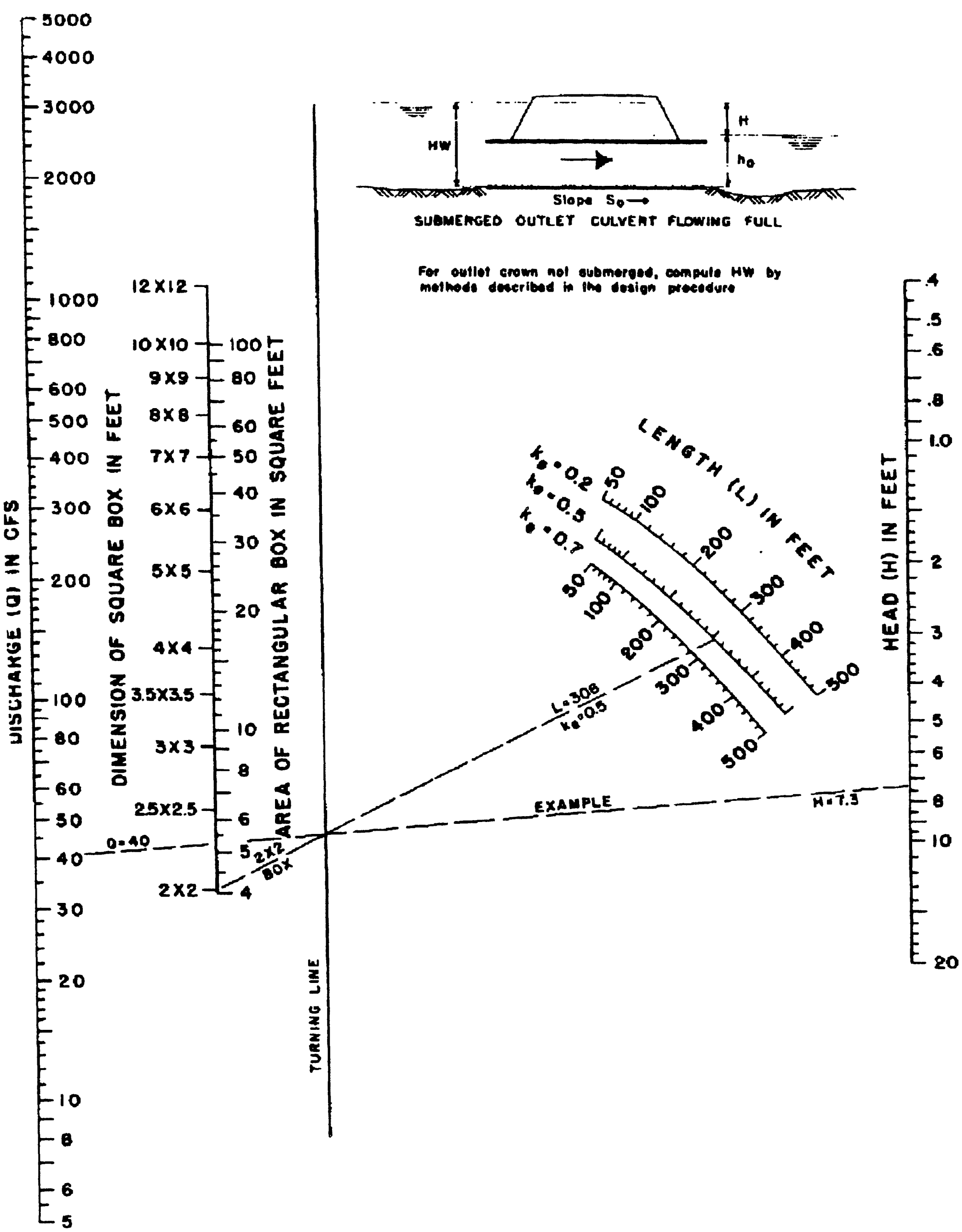
CRITICAL DEPTH
RECTANGULAR SECTION

CHART 15



HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
n = 0.012

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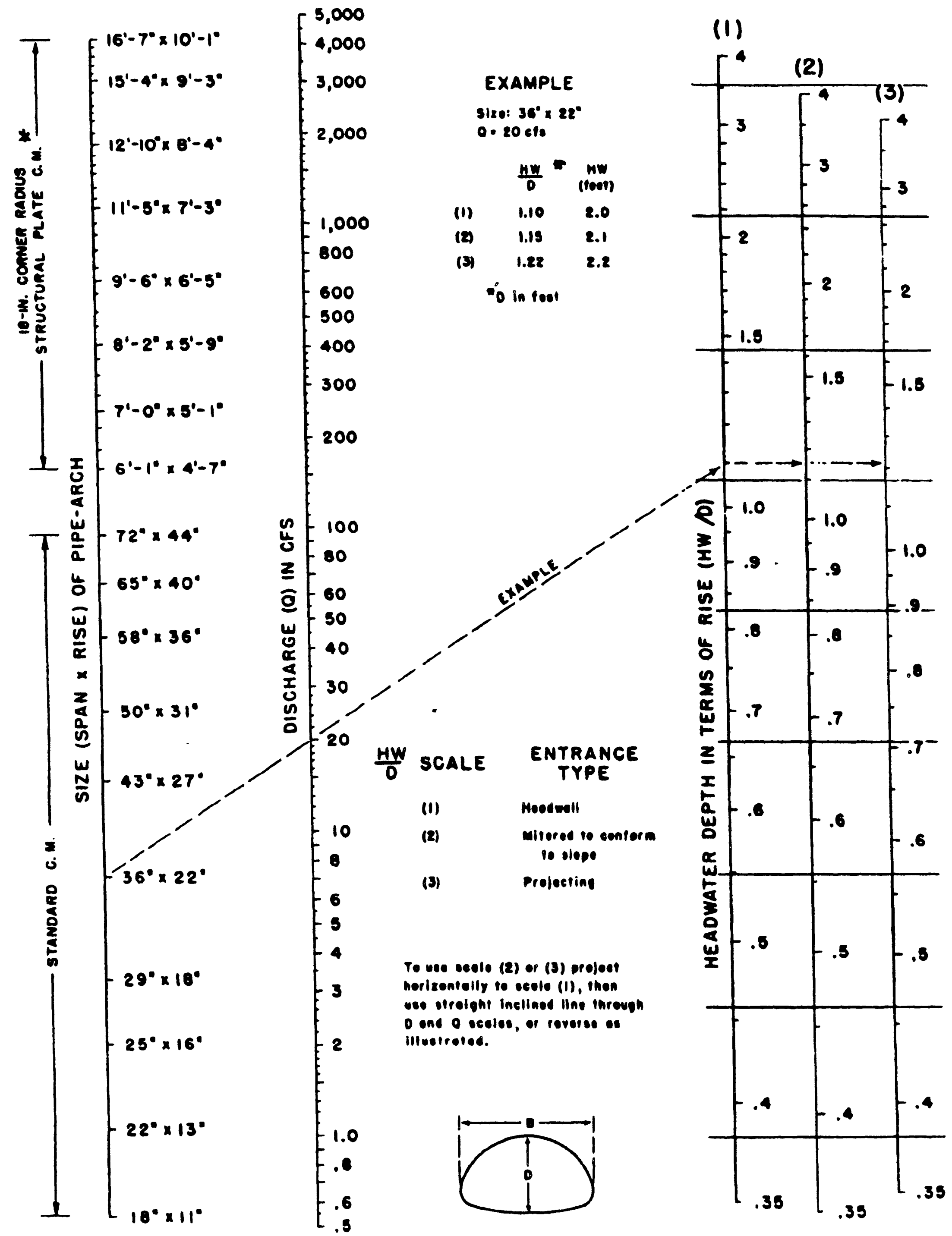
CHART 34



*ADDITIONAL SIZES NOT DIMENSIONED ARE LISTED IN FABRICATOR'S CATALOG

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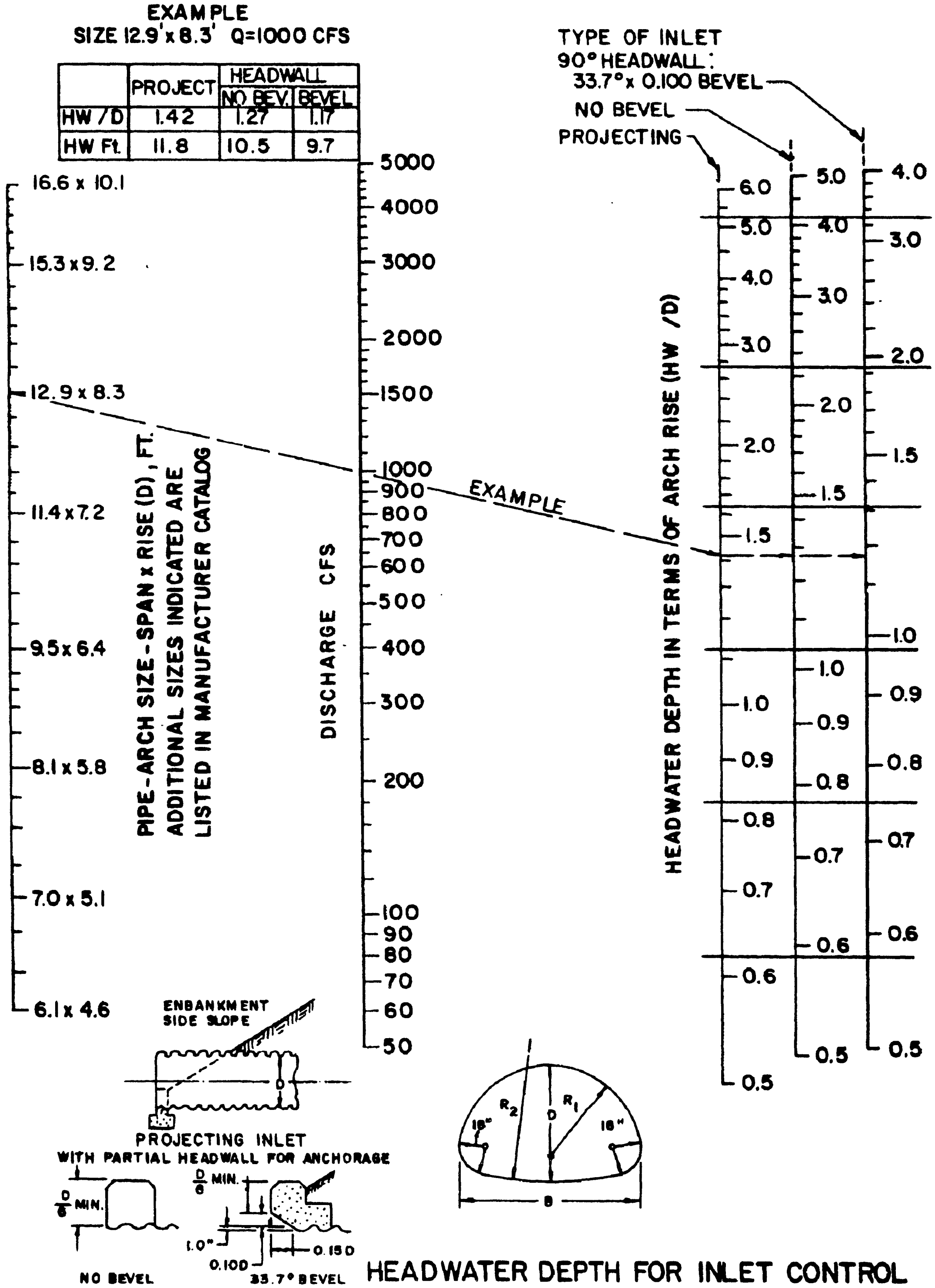
HEADWATER DEPTH FOR C. M. PIPE-ARCH CULVERTS WITH INLET CONTROL

CHART 35

EXAMPLE
SIZE 12.9' x 8.3' Q=1000 CFS

	PROJECT	HEADWALL	
		NO BEV.	BEVEL
HW / D	1.42	1.27	1.17
HW Ft.	11.8	10.5	9.7



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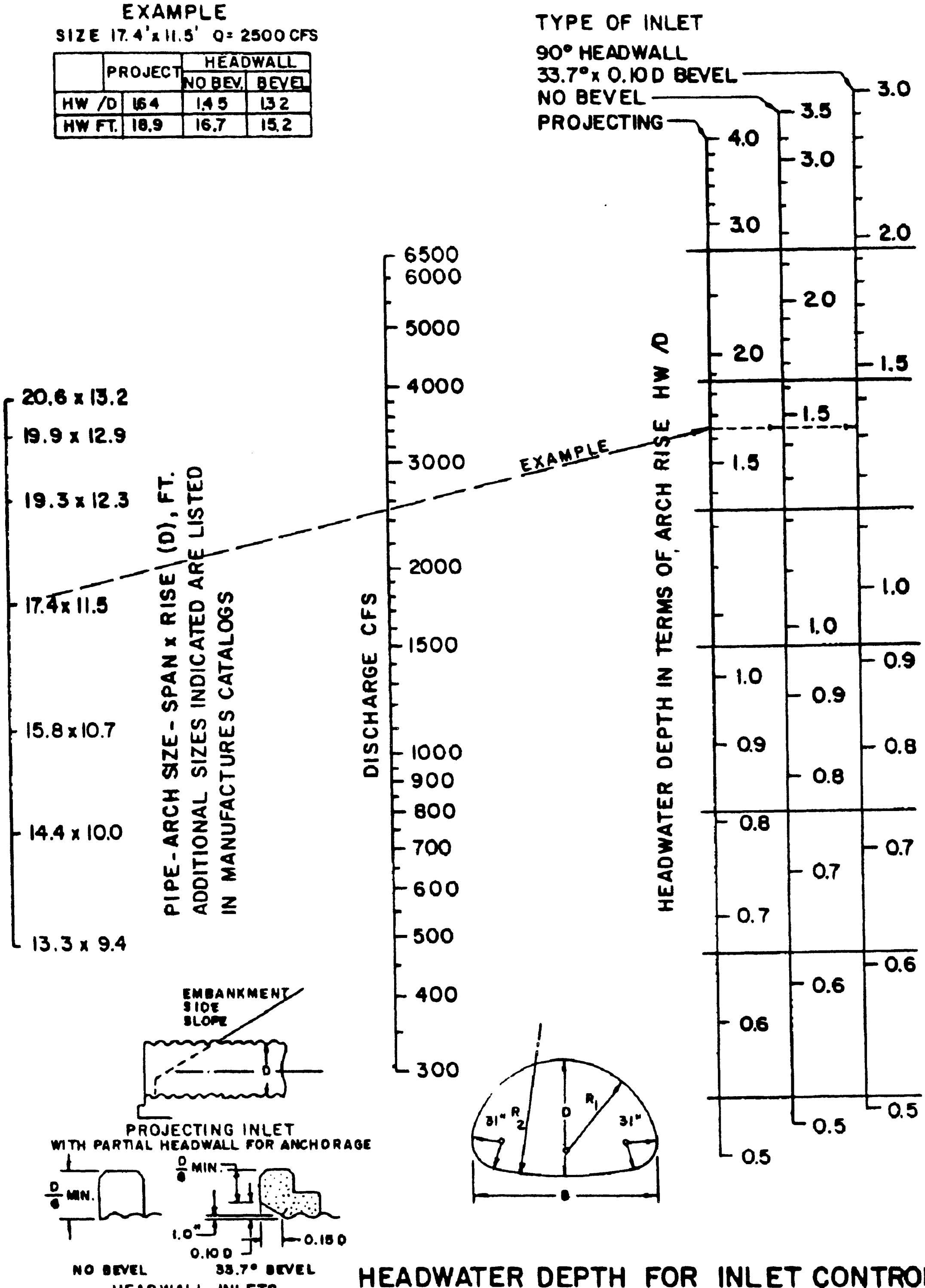
HEADWATER DEPTH FOR INLET CONTROL
STRUCTURAL PLATE PIPE-ARCH CULVERTS
18-IN. RADIUS CORNER PLATE
PROJECTING OR HEADWALL INLET
HEADWALL WITH OR WITHOUT EDGE BEVEL

CHART 36

EXAMPLE

SIZE 17.4'x 11.5' Q= 2500 CFS

	PROJECT	HEADWALL NO BEV.	HEADWALL BEVEL
HW /D	1.64	1.45	1.32
HW FT.	18.9	16.7	15.2



HEADWATER DEPTH FOR INLET CONTROL
STRUCTURAL PLATE PIPE-ARCH CULVERTS

31-IN. RADIUS CORNER PLATE
PROJECTING OR HEADWALL INLET
HEADWALL WITH OR WITHOUT EDGE BEVEL

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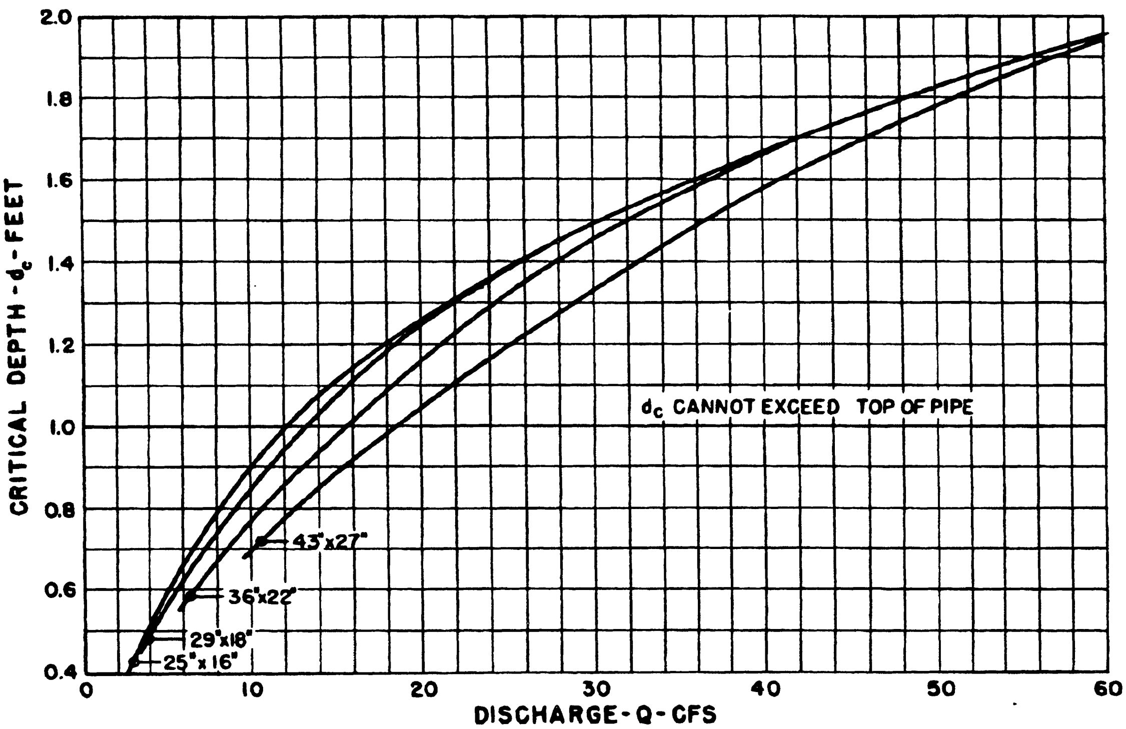
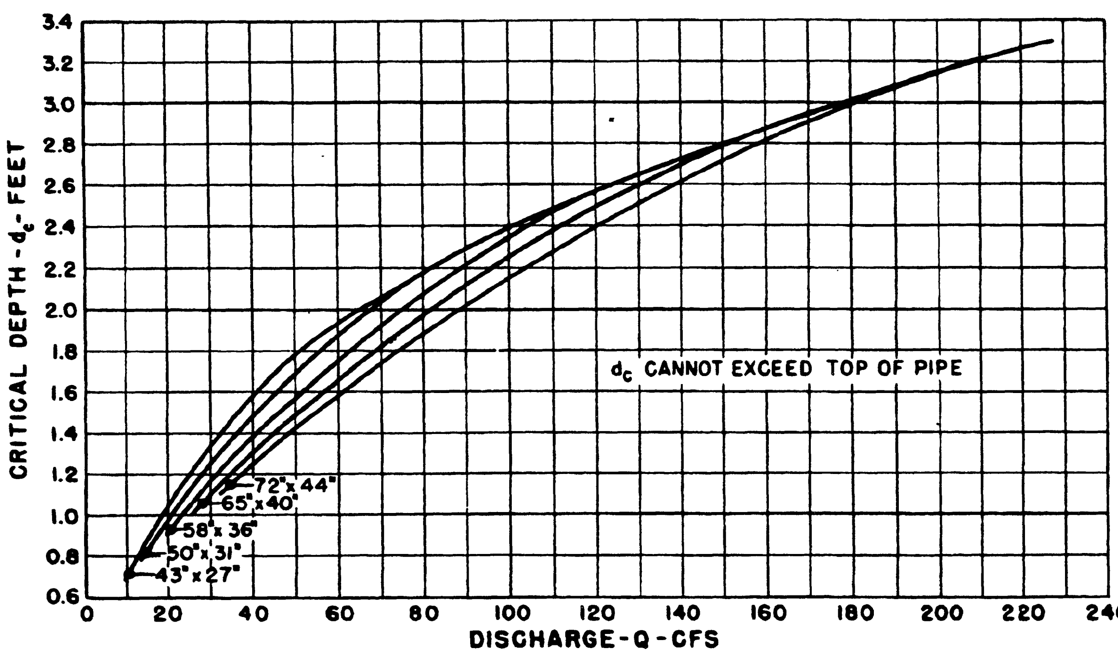
CHART 37





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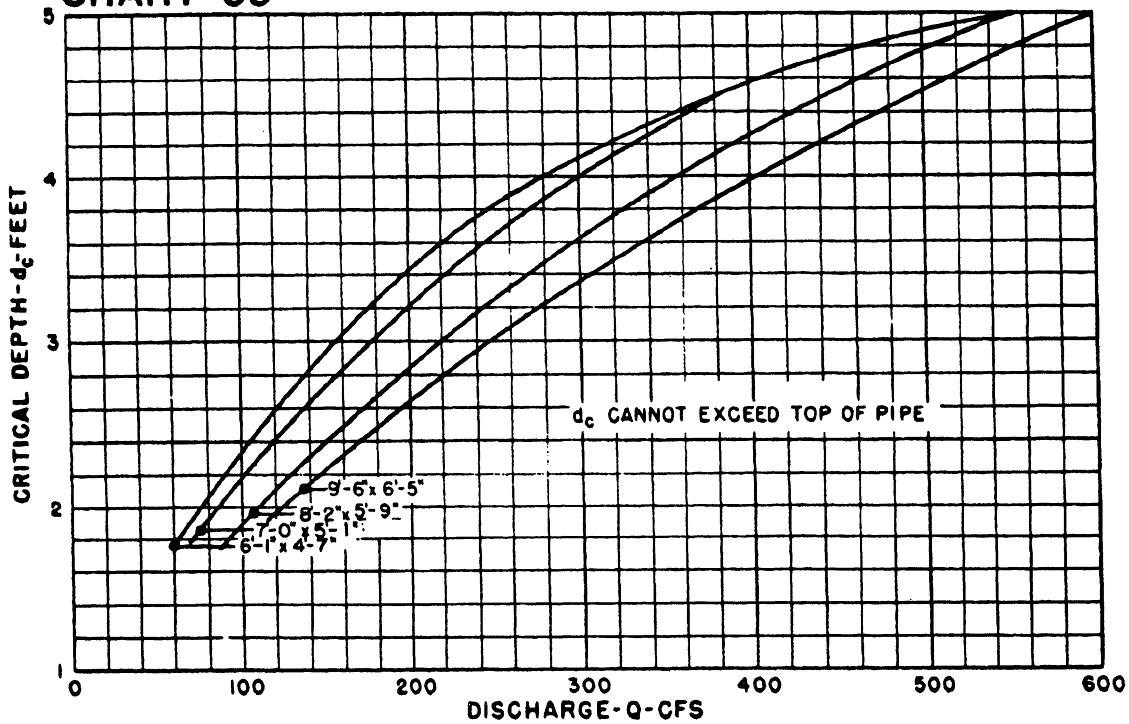
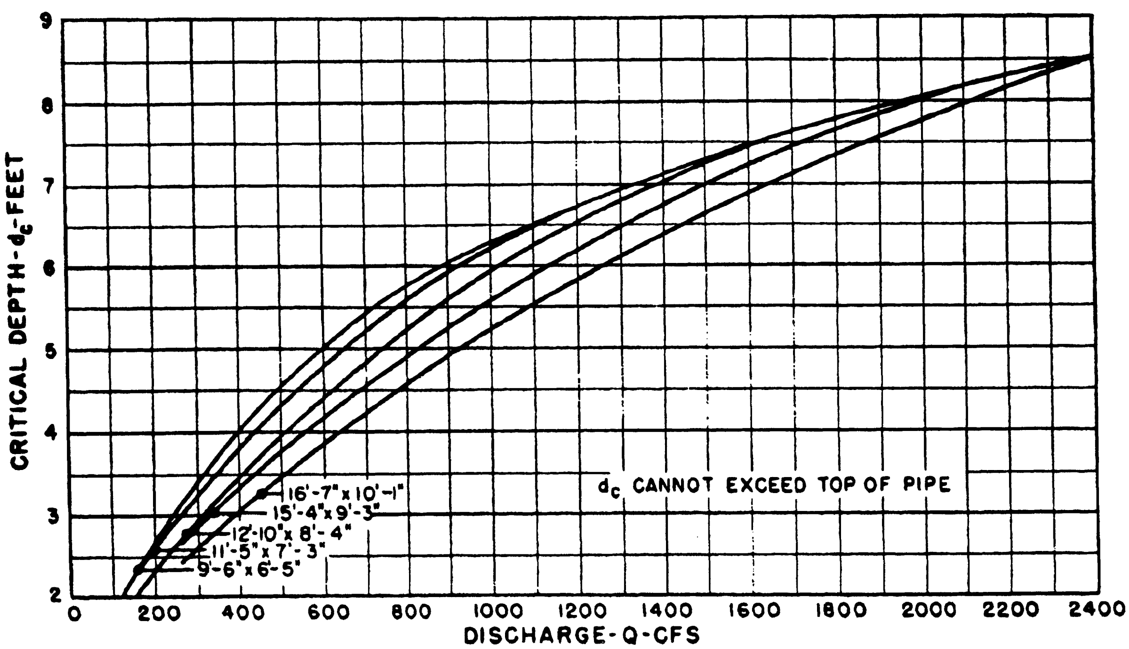
JAN. 1964

CRITICAL DEPTH
STANDARD C.M. PIPE-ARCH

Chart 37 can be used to approximate critical depth for comparably sized RCP-ARCH pipe

CHART 38





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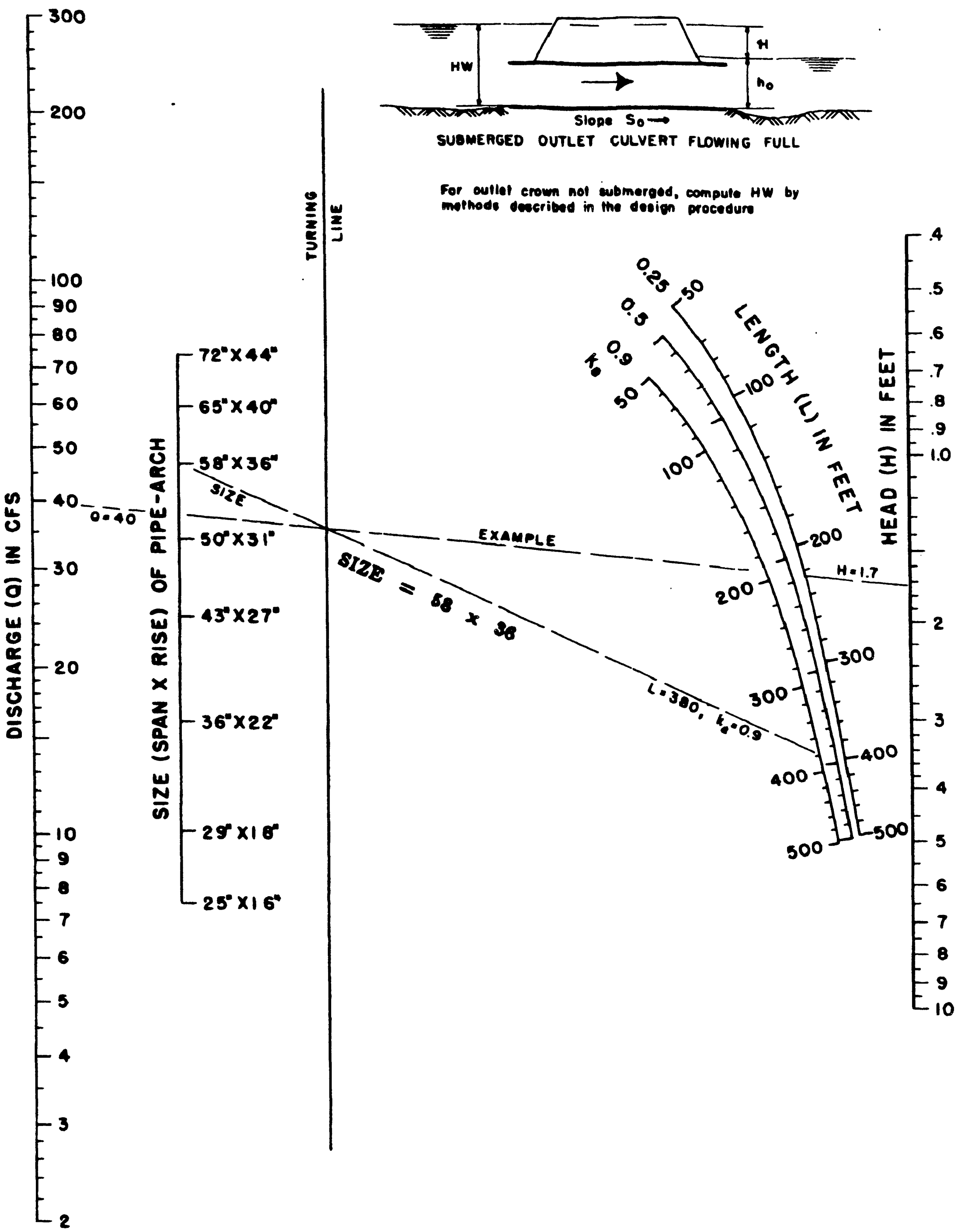
CRITICAL DEPTH
STRUCTURAL PLATE
C.M. PIPE-ARCH
18 INCH CORNER RADIUS

Chart 38 can be used to approximate critical depth for comparably sized RCP-ARCH pipe

CHART 39



HEAD FOR
STANDARD C. M. PIPE-ARCH CULVERTS
FLOWING FULL
n=0.024

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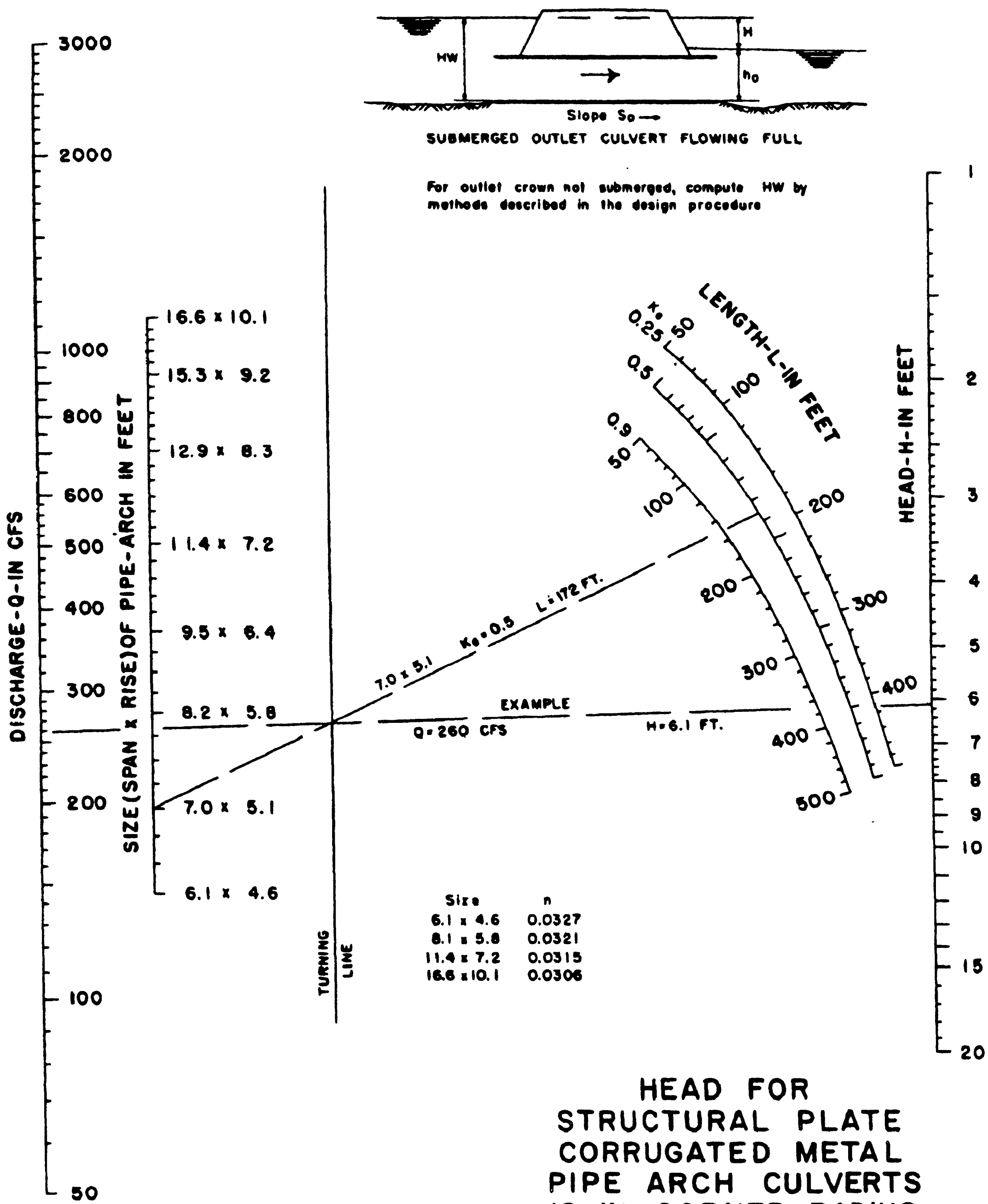
CHART 40



Size	n
6.1 x 4.6	0.0327
8.1 x 5.8	0.0321
11.4 x 7.2	0.0315
16.6 x 10.1	0.0306

HEAD FOR STRUCTURAL PLATE CORRUGATED METAL PIPE ARCH CULVERTS 18 IN. CORNER RADIUS FLOWING FULL n=0.0327 TO 0.0306

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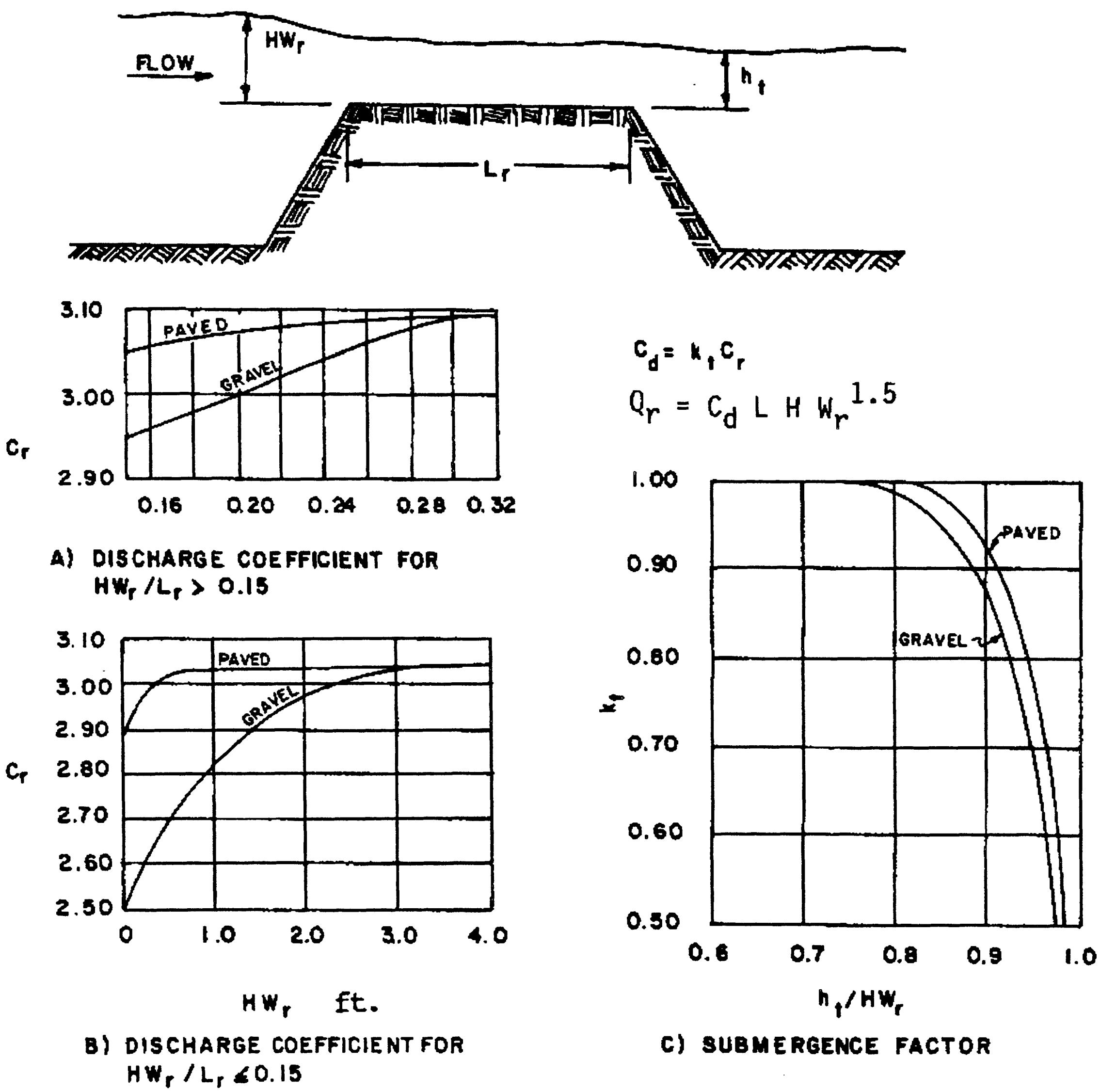
CHART 60



DISCHARGE COEFFICIENTS
FOR ROADWAY OVERTOPPING