HYDRAULICS OF RIVER FLOW

UNDER ARCH BRIDGES

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PURDUE UNIVERSITY
LAFAYETTE INDIANA

by

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Final Report

HYDRAULICS OF RIVER FLOW UNDER ARCH BRIDGES

Vol. II

by

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U S Department of Commerce

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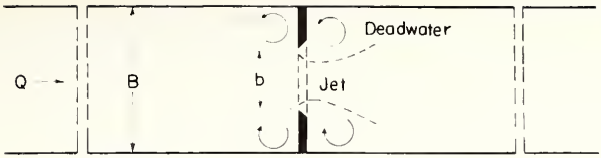
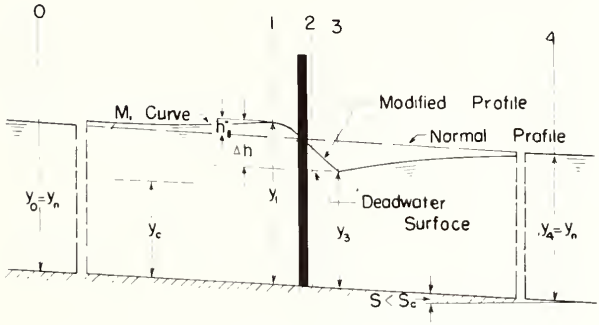


A) PLAN



B) MILD SLOPE CHANNEL

C.) WEIR PLATES

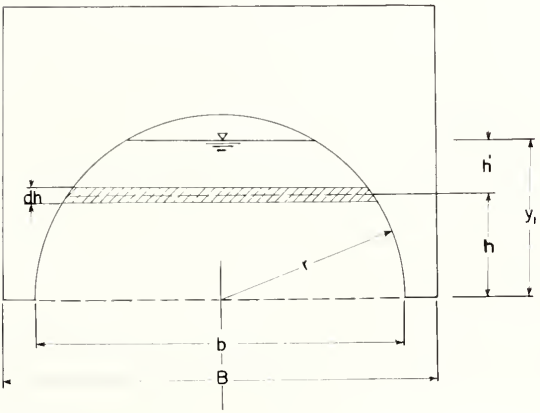


FIGURE 3 - 1 DEFINITION SKETCH

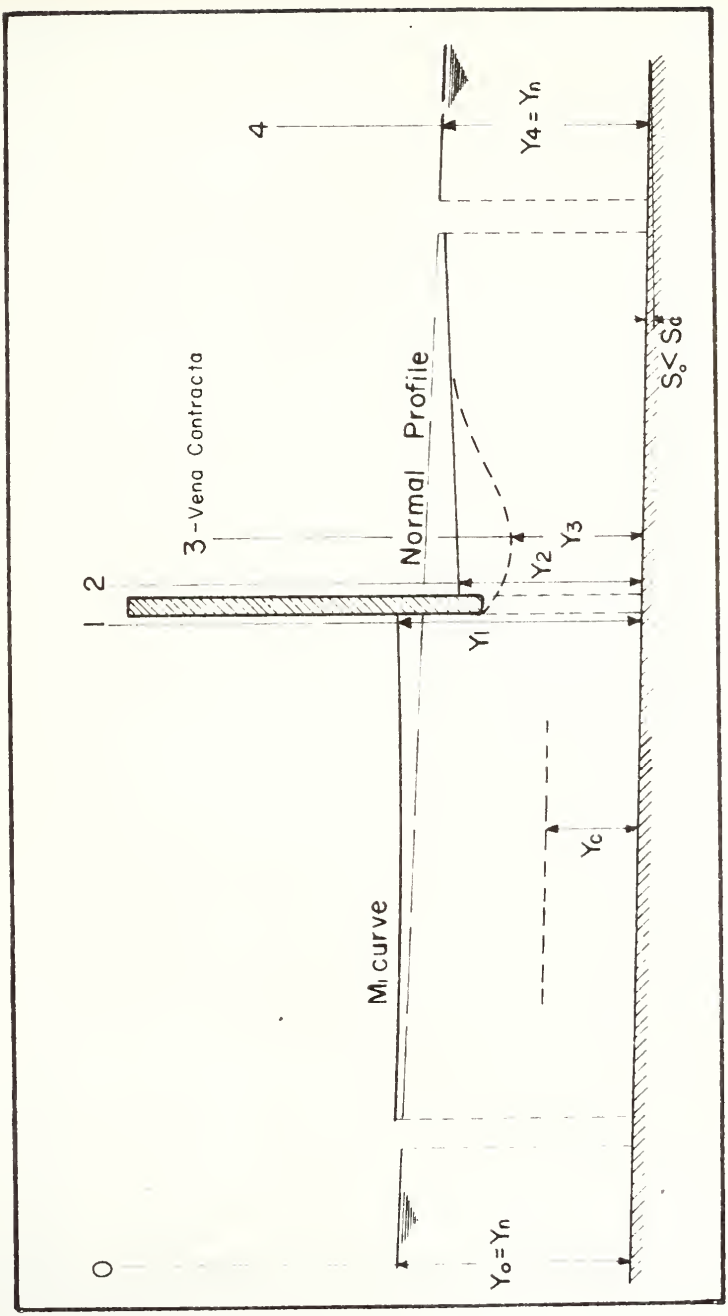
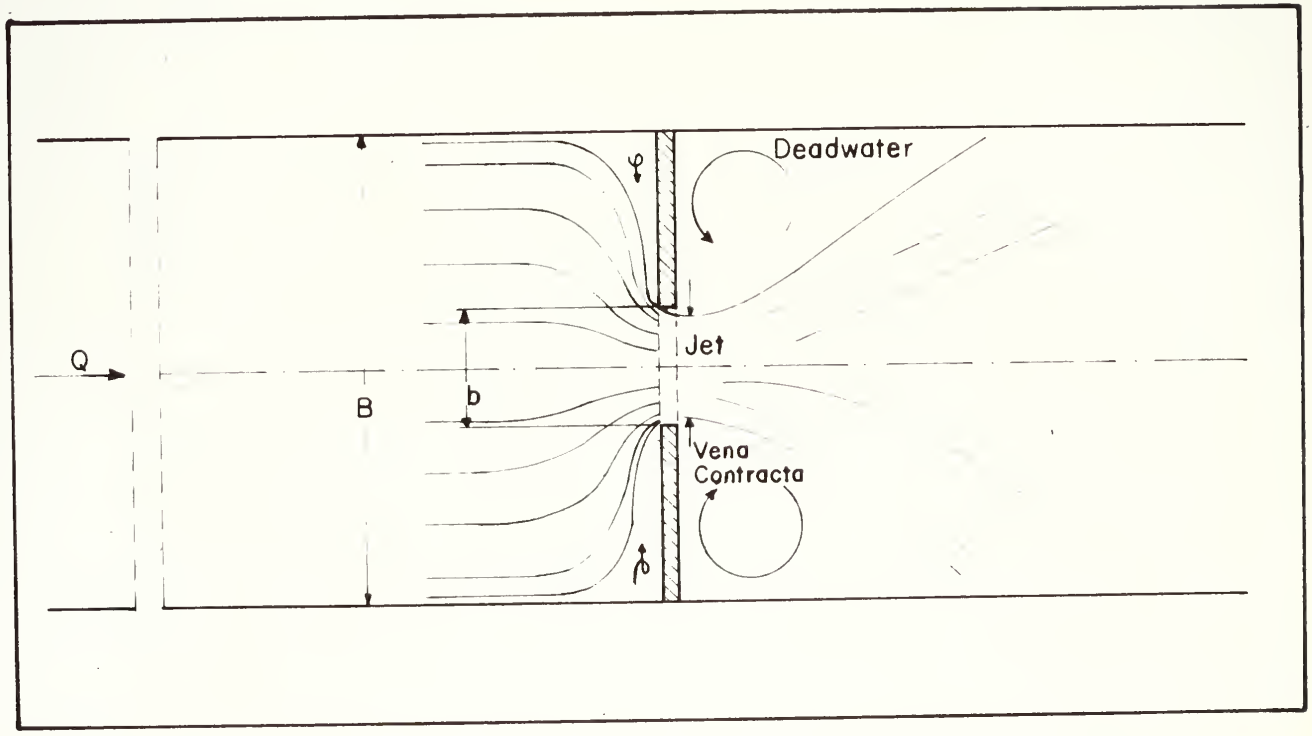


Fig 2.2 Center Line Surface Profile Near Submerged Constriction



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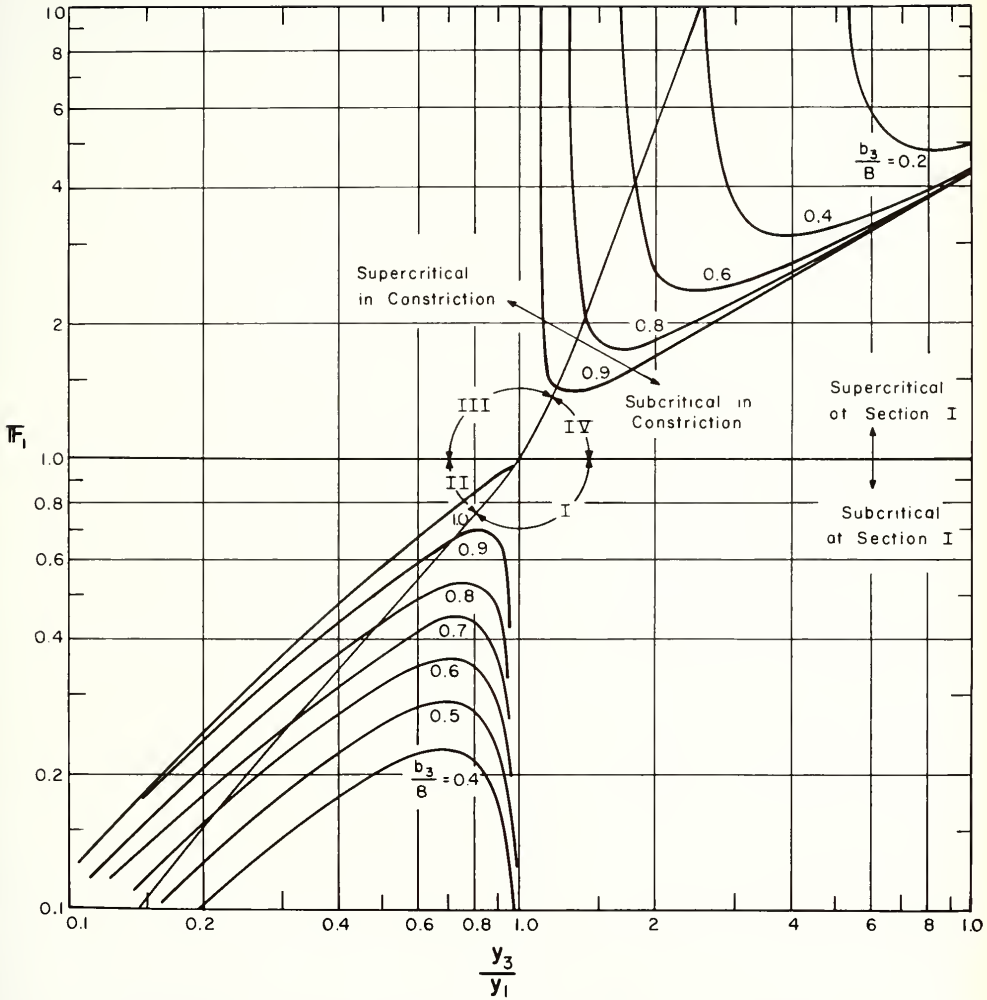

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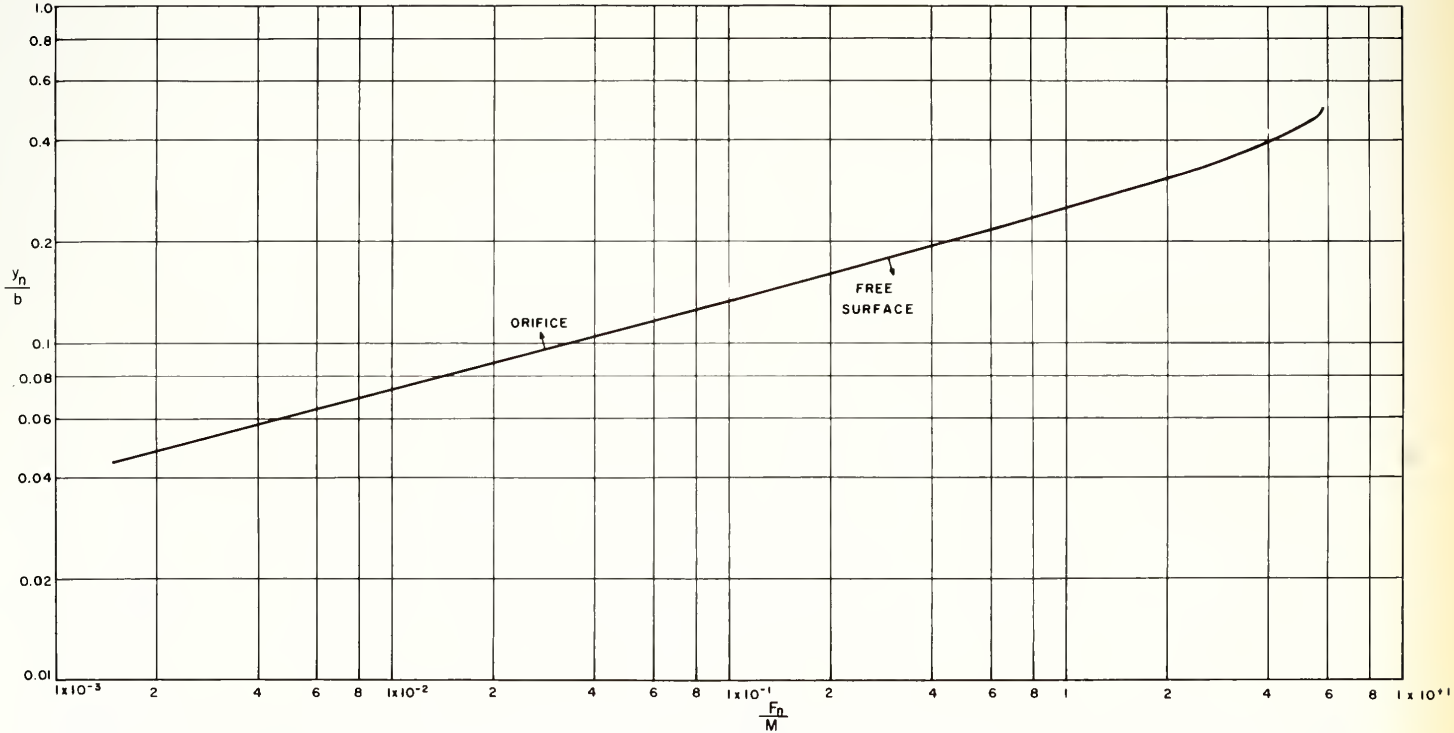

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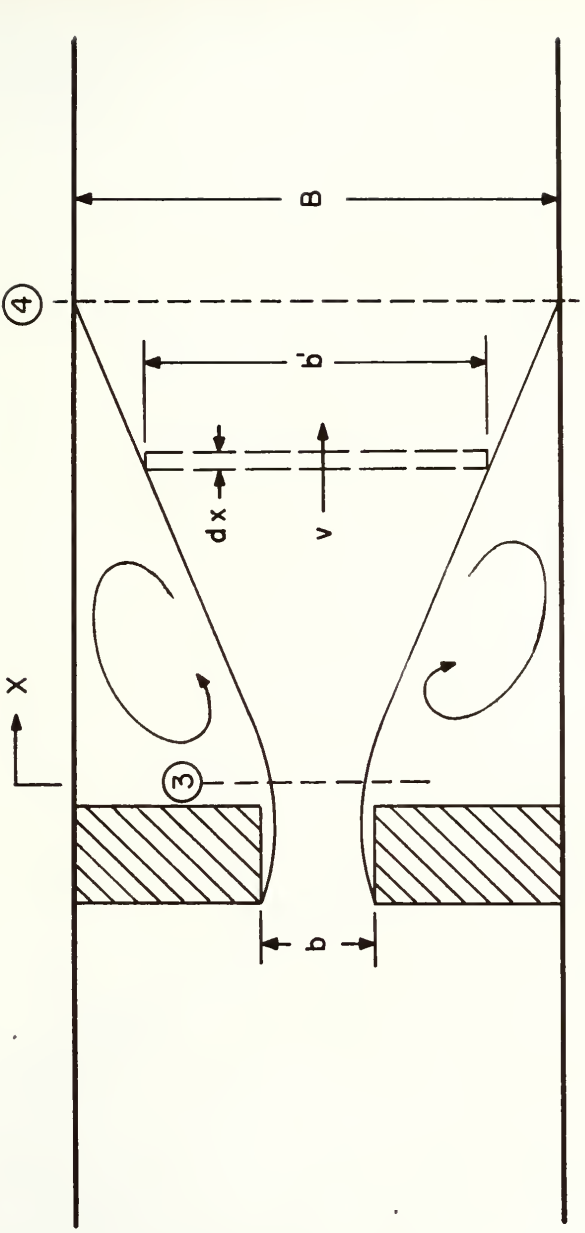

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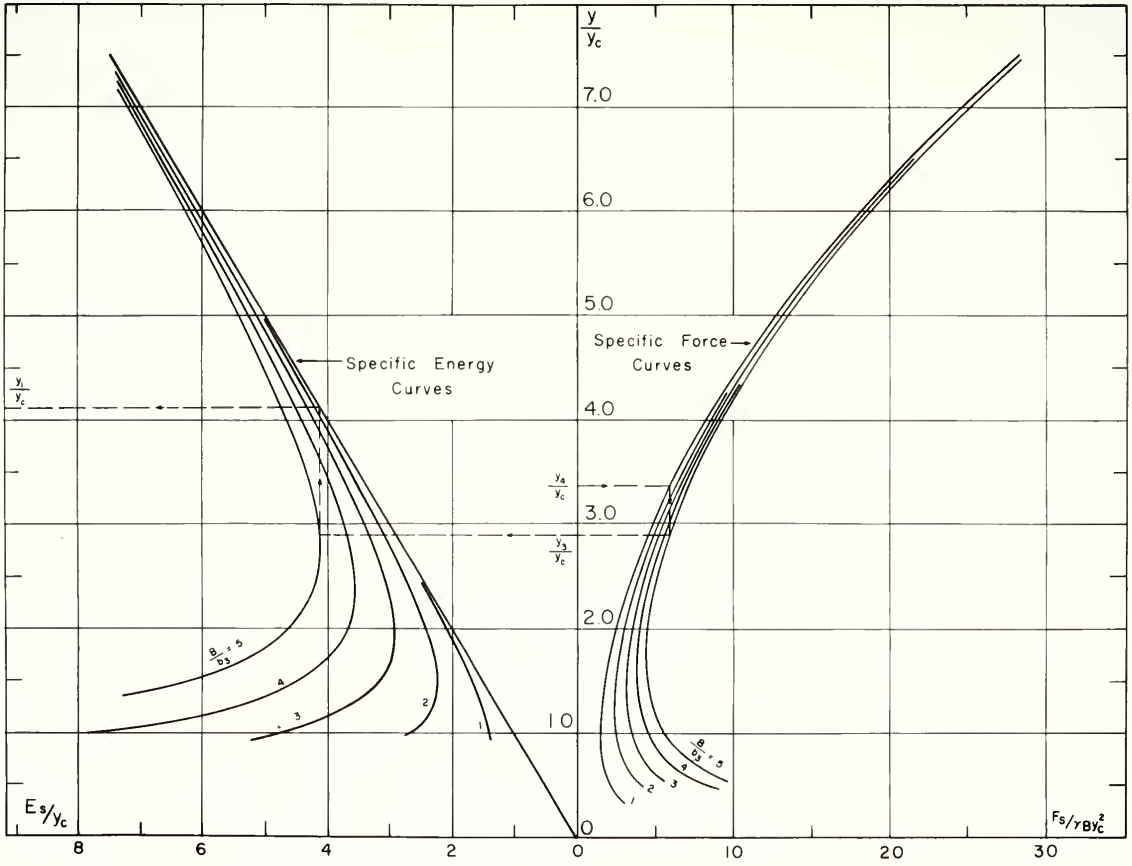


FIGURE 3-7— GRAPHICAL SOLUTION OF BACKWATER DUE TO A CONSTRICTION

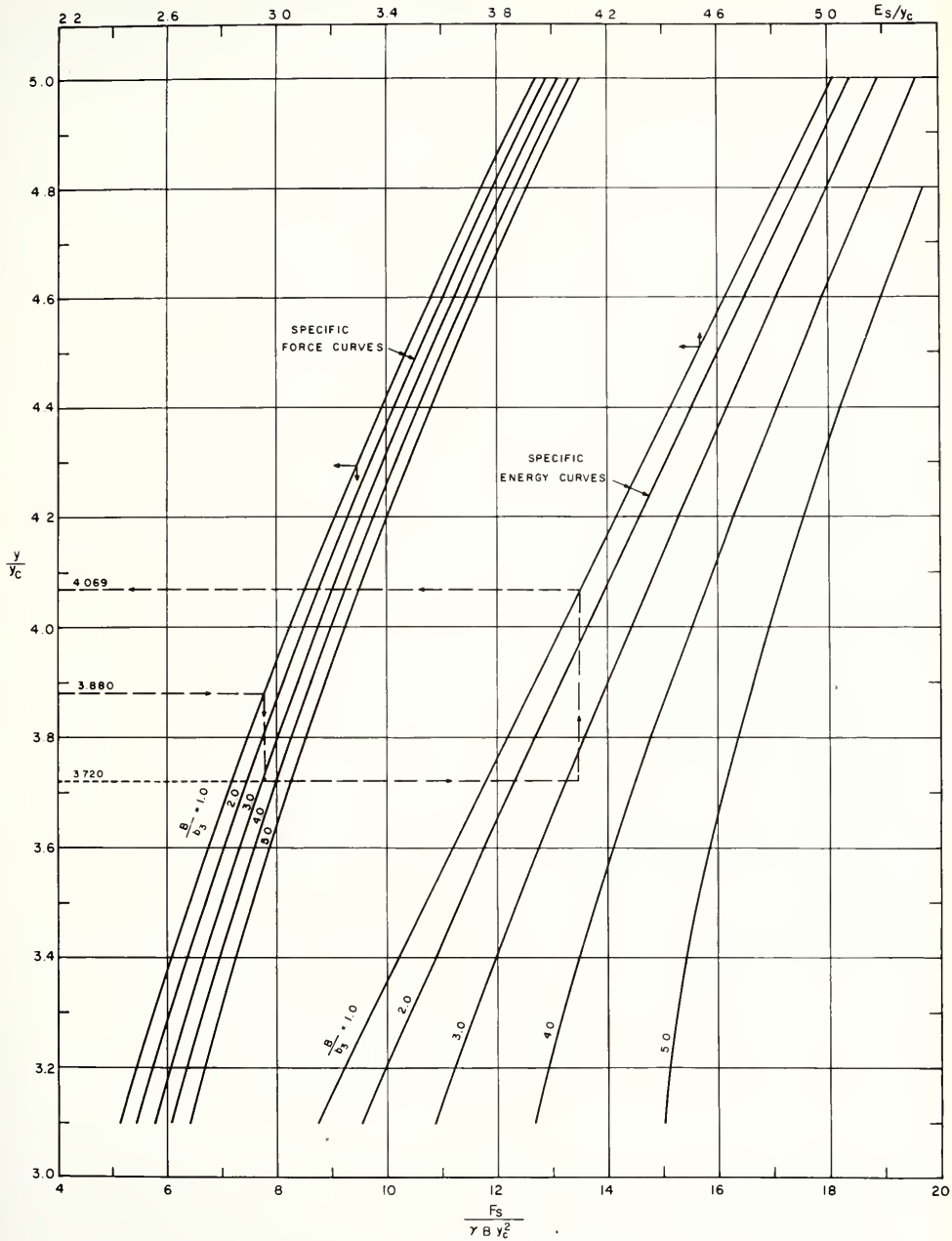


FIGURE 3-8 — DETAIL OF GRAPHICAL SOLUTION OF BACKWATER DUE TO A CONSTRICTION

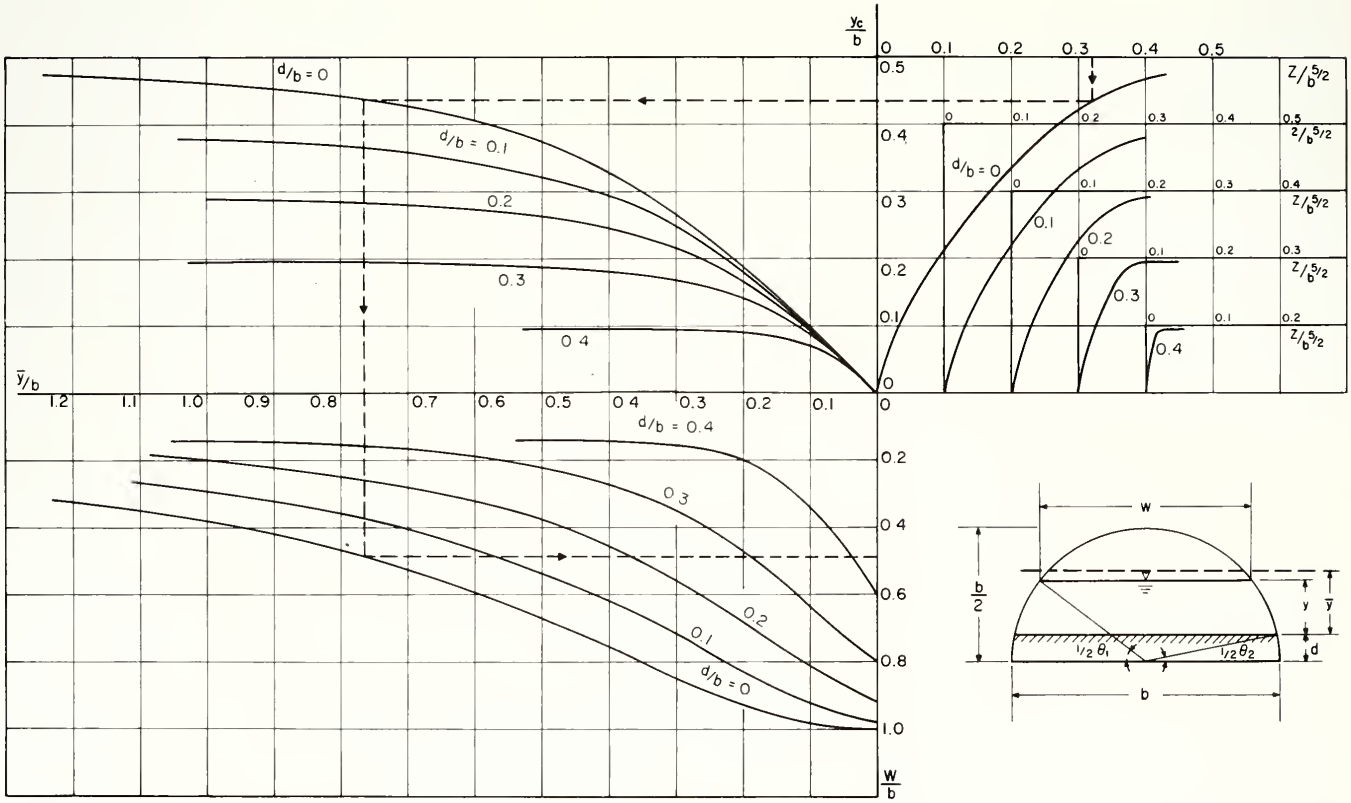


FIGURE 3 - 9 — GEOMETRIC PROPERTIES OF SEMI-CIRCULAR AND CIRCULAR SEGMENT ARCHES

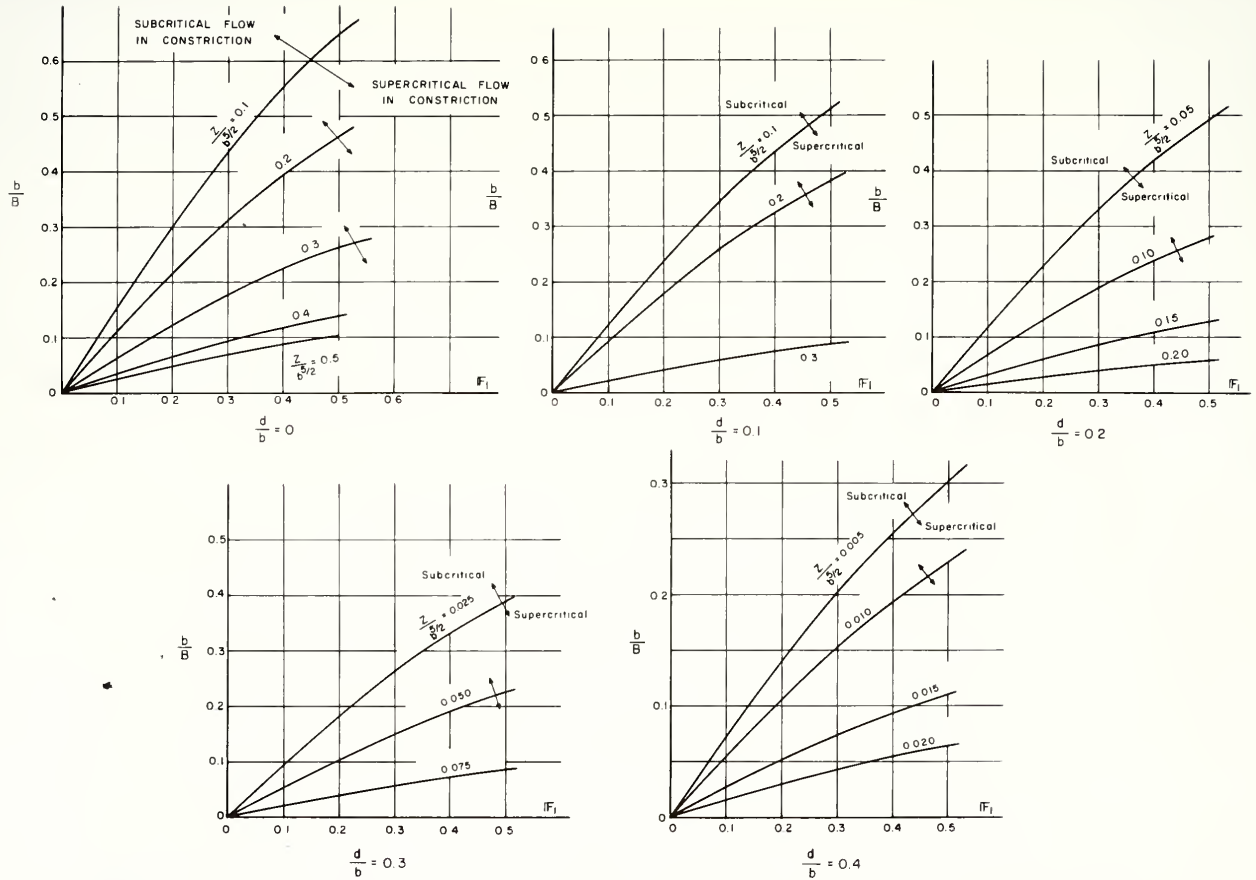


FIGURE 3-10 — LIMITING BACKWATER - BOUNDARY BETWEEN FLOWS OF CLASSES I & II SEMI - CIRCULAR AND CIRCULAR SEGMENT ARCHES

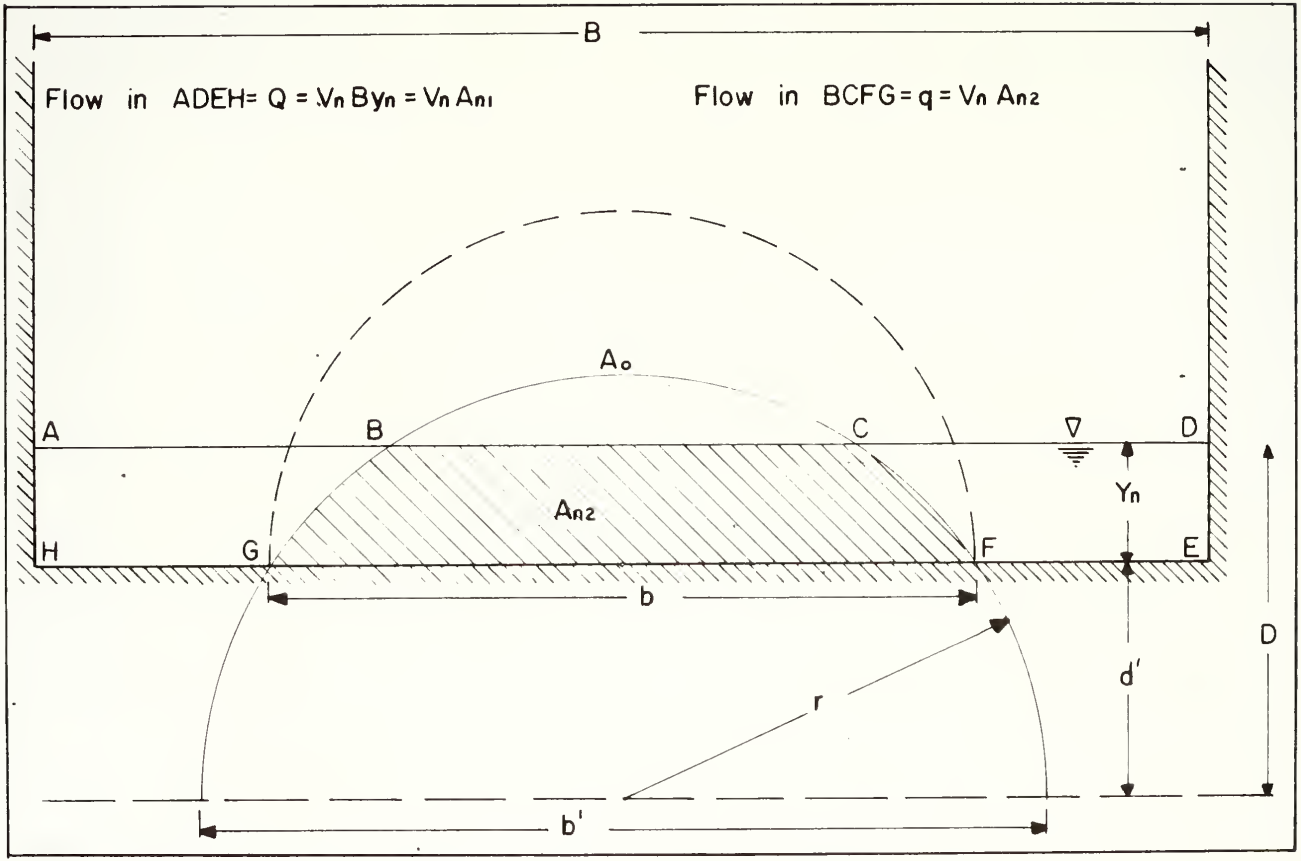


Fig 3.11 Definition Sketch for the Channel Opening Ratio

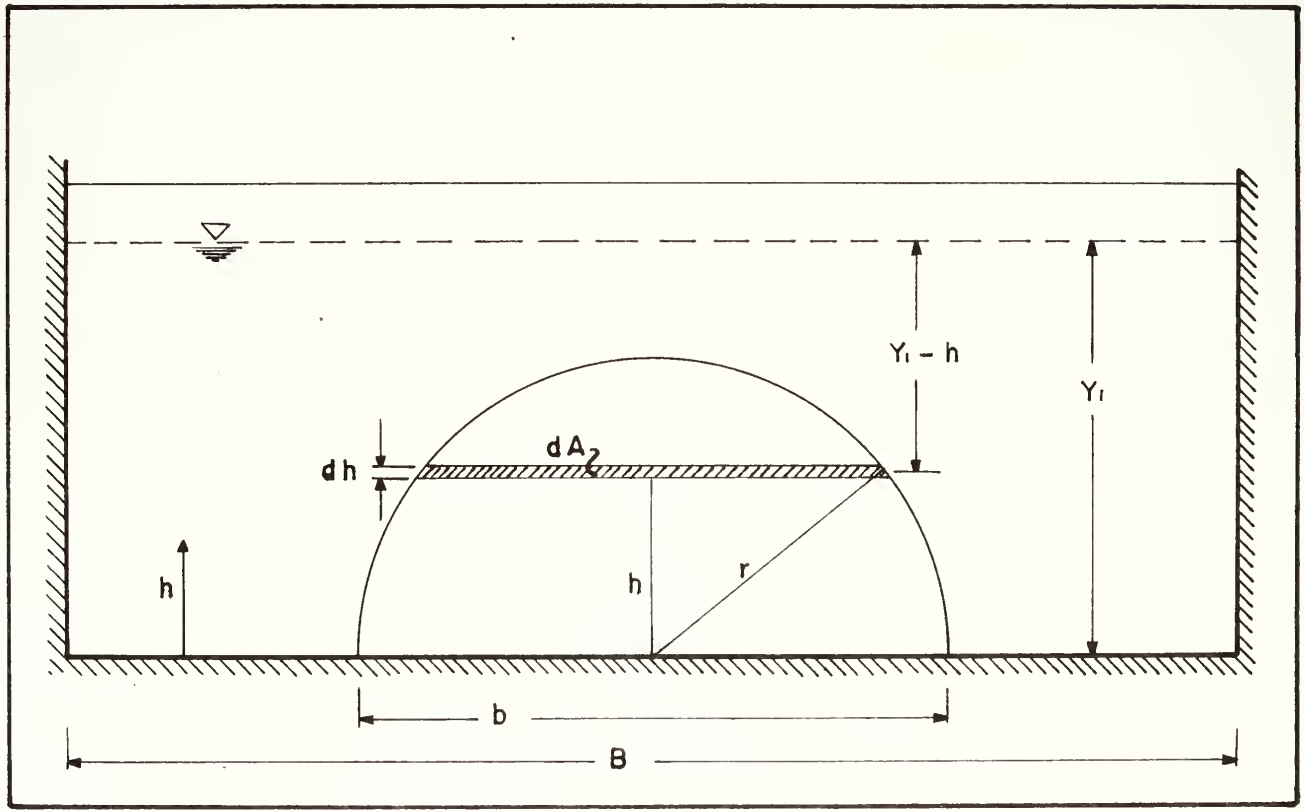
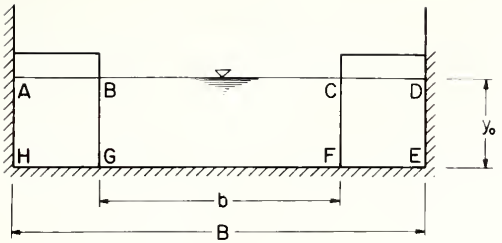
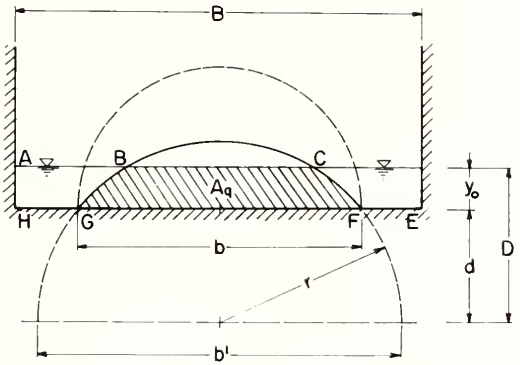


FIG 3-11a DEFINITION SKETCH FOR ORIFICE FLOW CALCULATION



FLOW IN ADEH = $Q = V_o B y_o$

FLOW IN BCFG = $q = V_o b y_o$



FLOW IN ADEH = $Q = V_o B y_o$

FLOW IN BCFG = $q = V_o b y_o$

DEFINITION SKETCH FOR THE DEVELOPMENT OF THE CONTRACTION RATIO

Figure 3-12

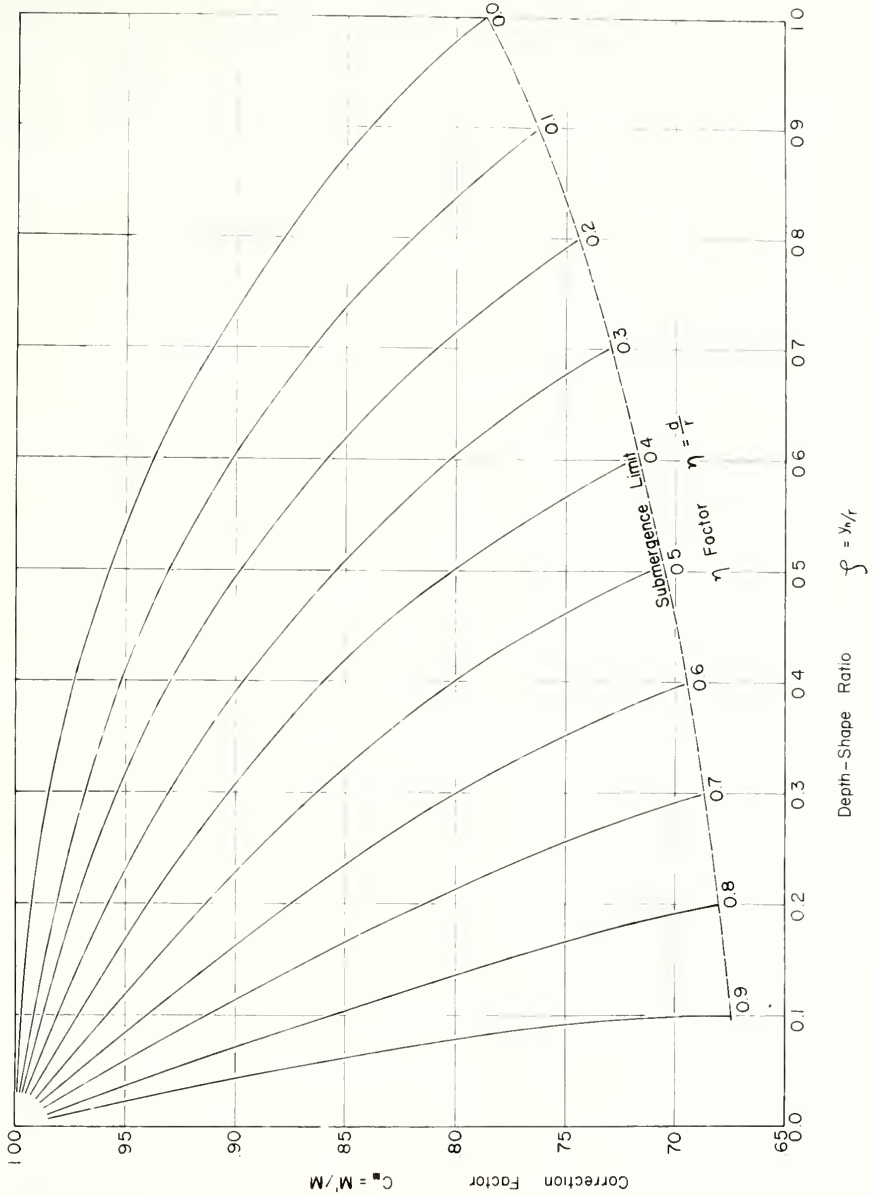


FIGURE 3-13 CORRECTION COEFFICIENT FOR THE CHANNEL OPENING RATIO

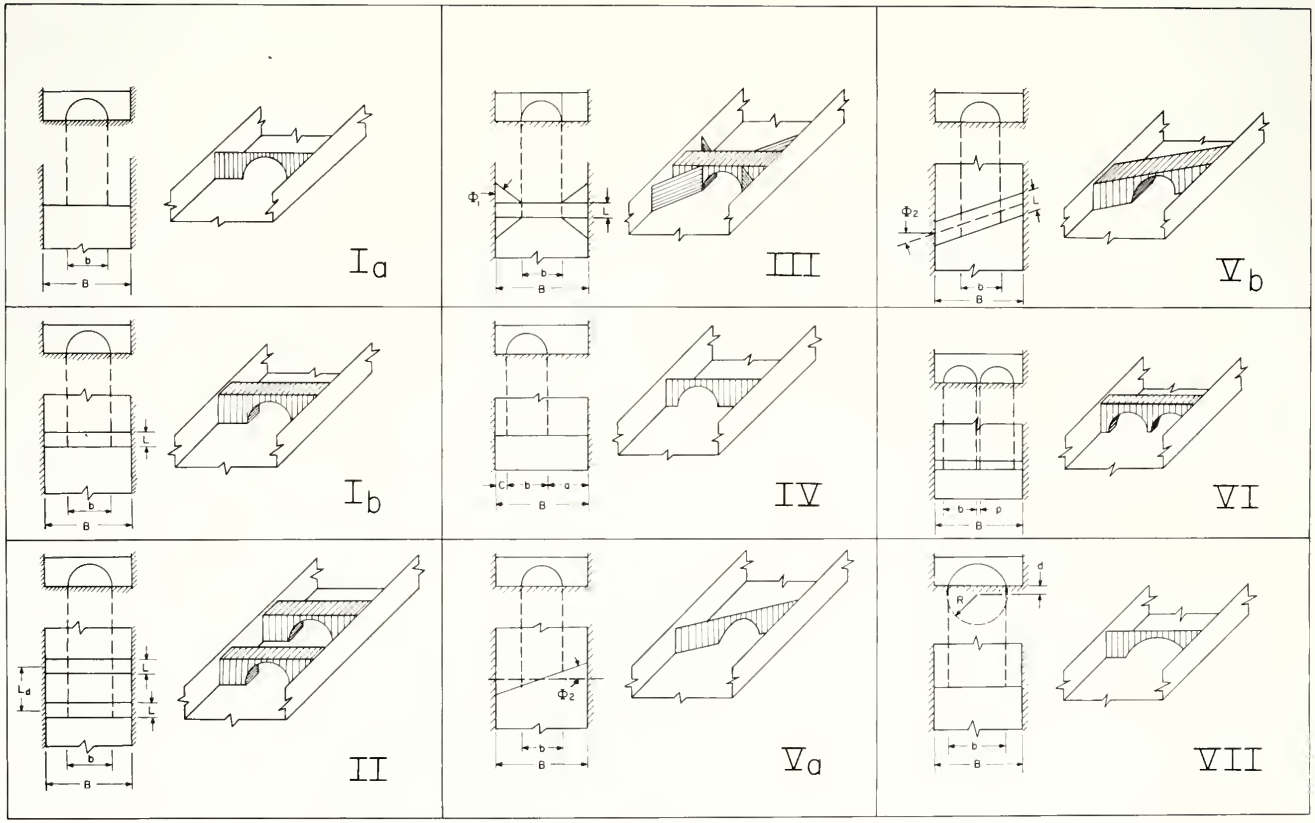


FIGURE 3-14 DEFINITION SKETCHES OF TEST GEOMETRIES

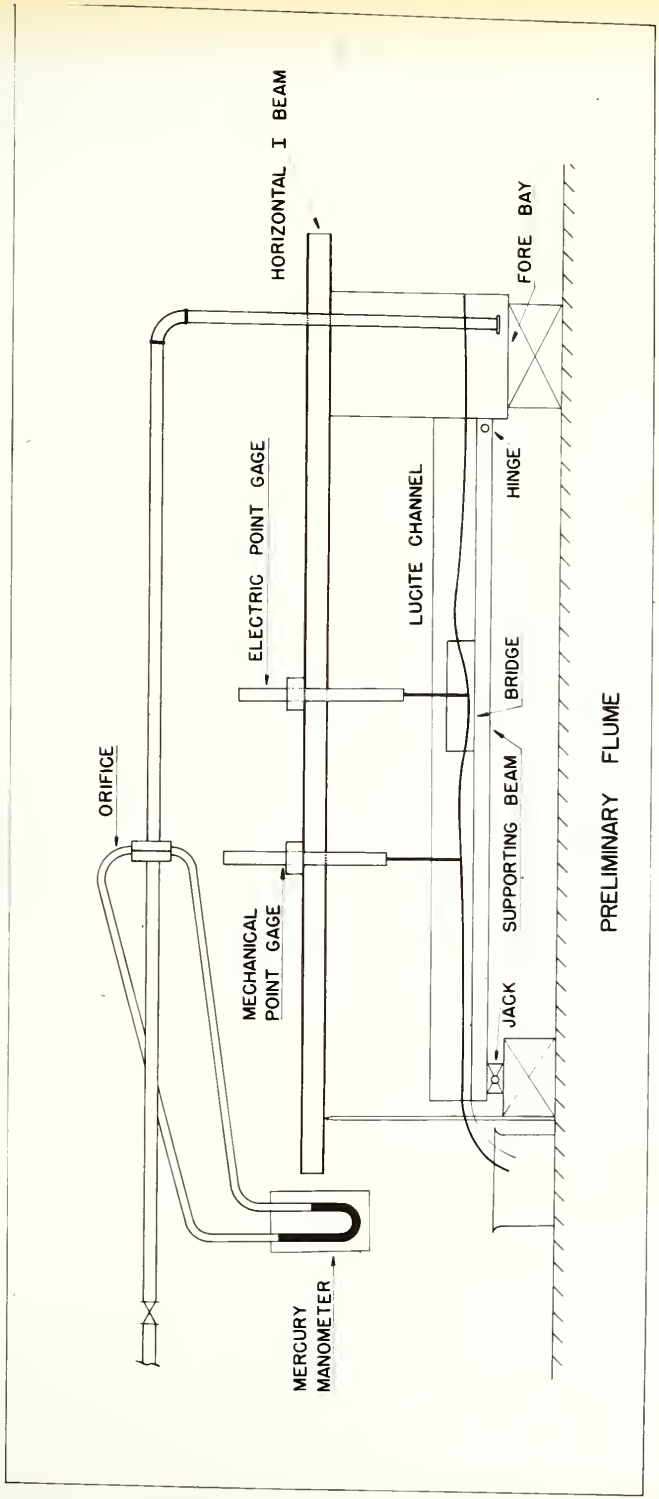
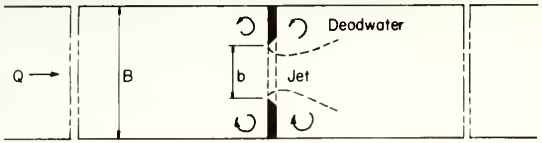
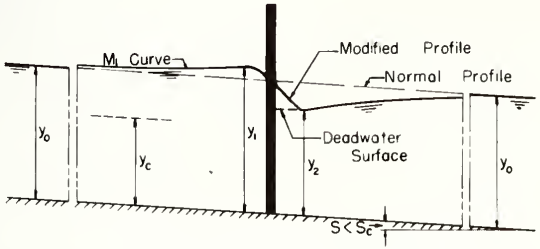

HORIZONTAL I BEAM
FORE BAY
ELECTRIC POINT GAGE
LUCITE CHANNEL
HINGE
ORIFICE
BRIDGE
MECHANICAL POINT GAGE
SUPPORTING BEAM
JACK
MERCURY MANOMETER
PRELIMINARY FLUME

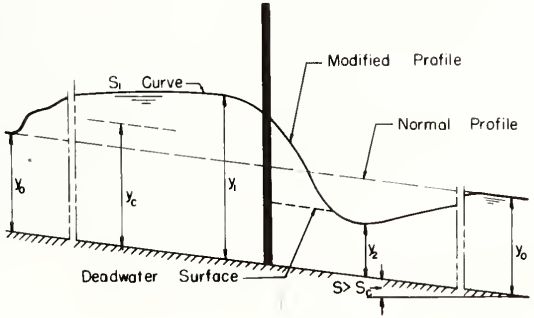
FIG. 4 - 1



A) PLAN

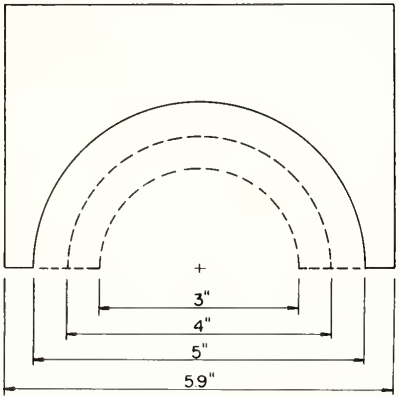


B) MILD SLOPE CHANNEL



C.) STEEP SLOPE CHANNEL

D.) WEIR PLATES



EFFECT OF CHANNEL CONSTRICTION ON WATER SURFACE PROFILE

FIG. 4-2

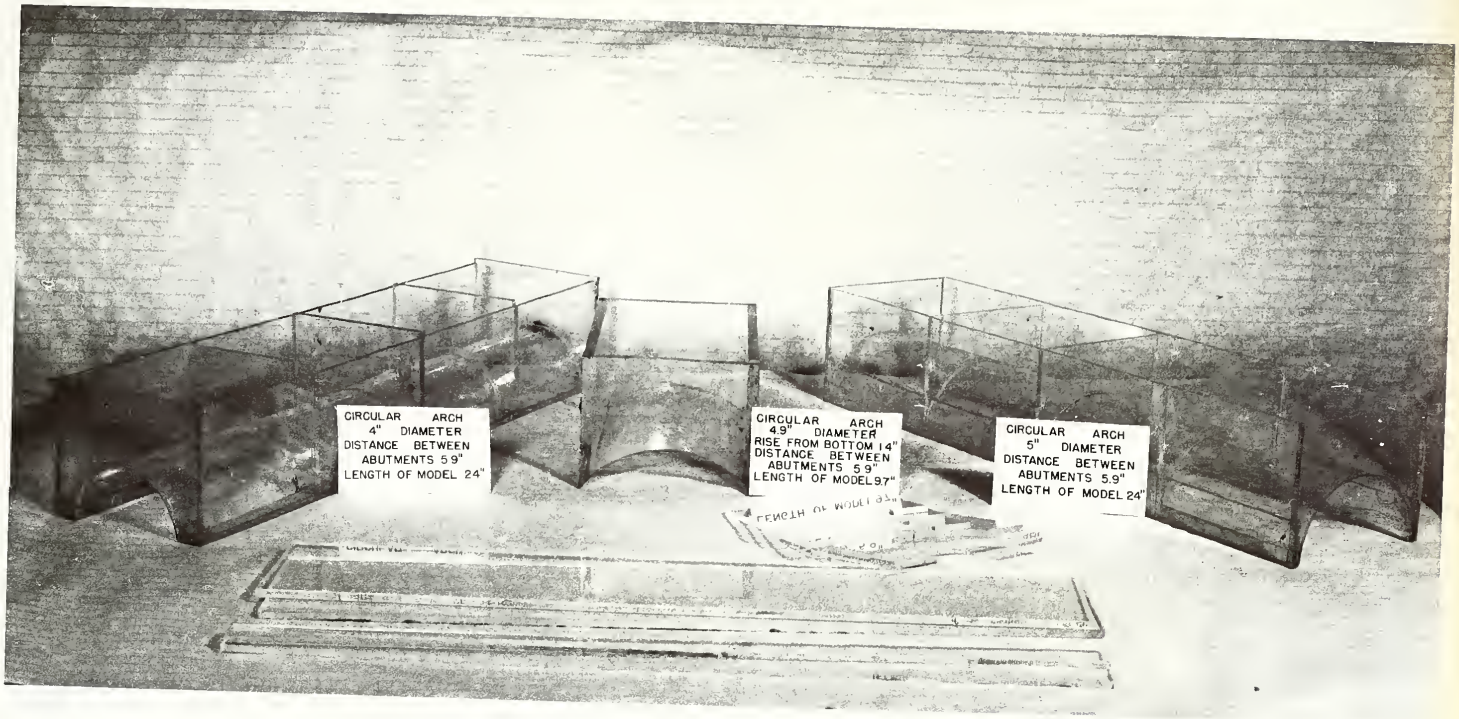


FIGURE 4-3 THREE DIMENSIONAL MODELS FOR PRELIMINARY STUDIES

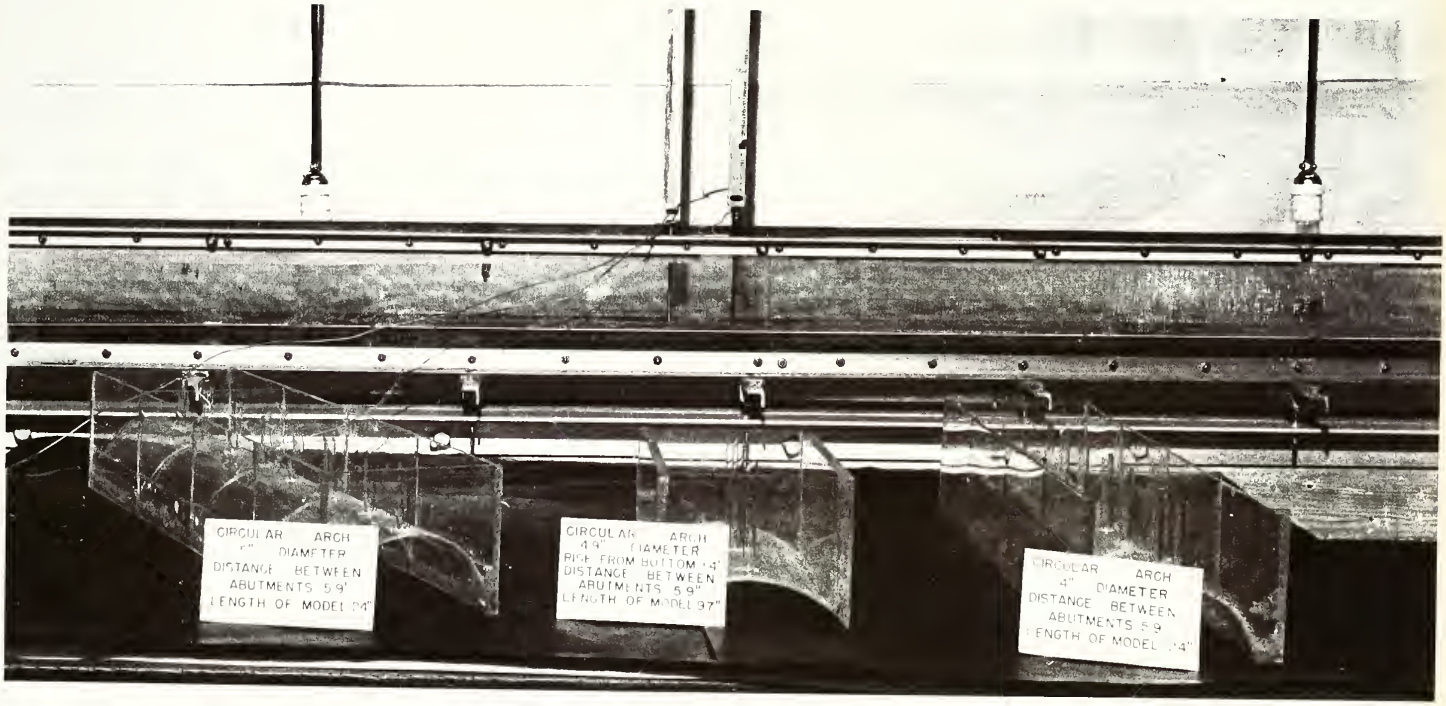
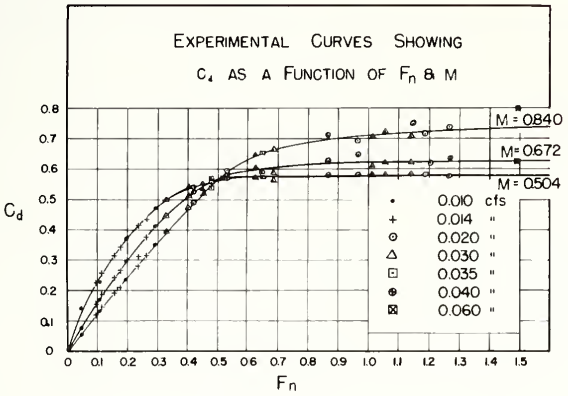


FIGURE 4-4 SMALL FLUME WITH ARTIFICIAL ROUGHNESS INSTALLED, and MECHANICAL AND ELECTRICAL GAGES



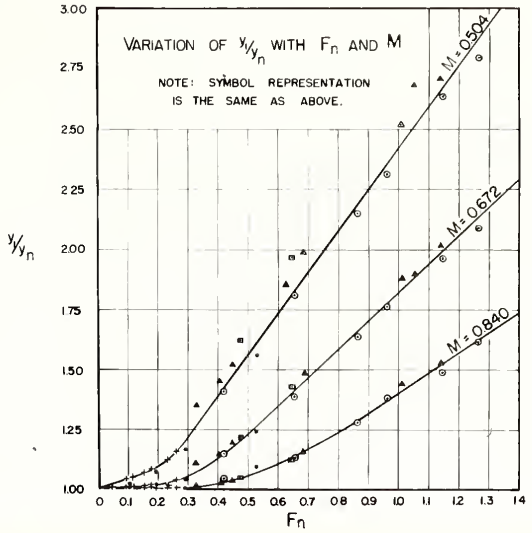
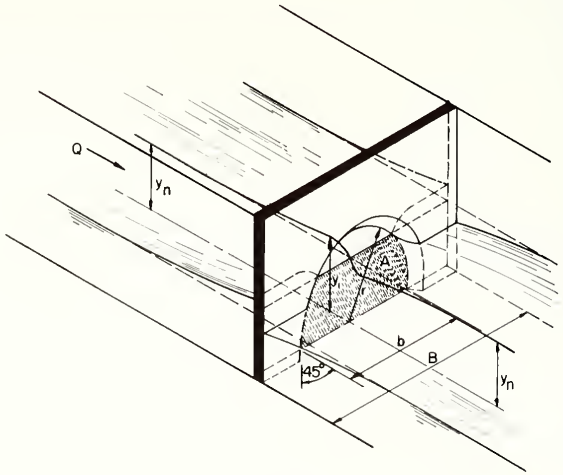


FIG. 4-5



$$Q = C y_1^{3/2} b T \qquad (1)$$

$$C = c_d \sqrt{2g}\, 17/24$$

$$T = \left[1 - 0.1294(y_1/r)^2 - 0.0177(y_1/r)^4 + \cdots\right]$$

$$y/y_n = \left(F_n \sqrt{g} / C_M A\right)^{2/3} \qquad (2)$$

$$F_n = V_n / \sqrt{g y_n}$$

$$M = b/B$$

SEMICIRCULAR WEIR TESTS

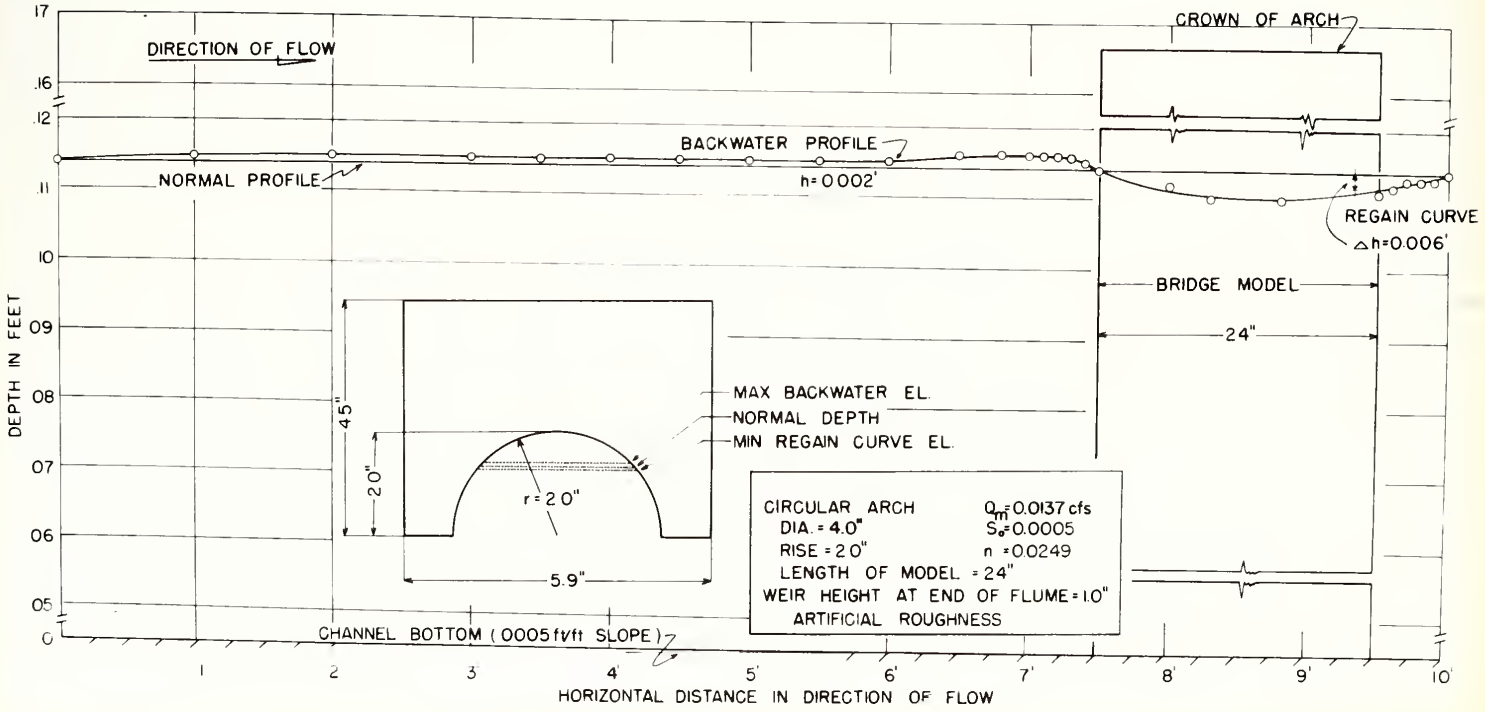
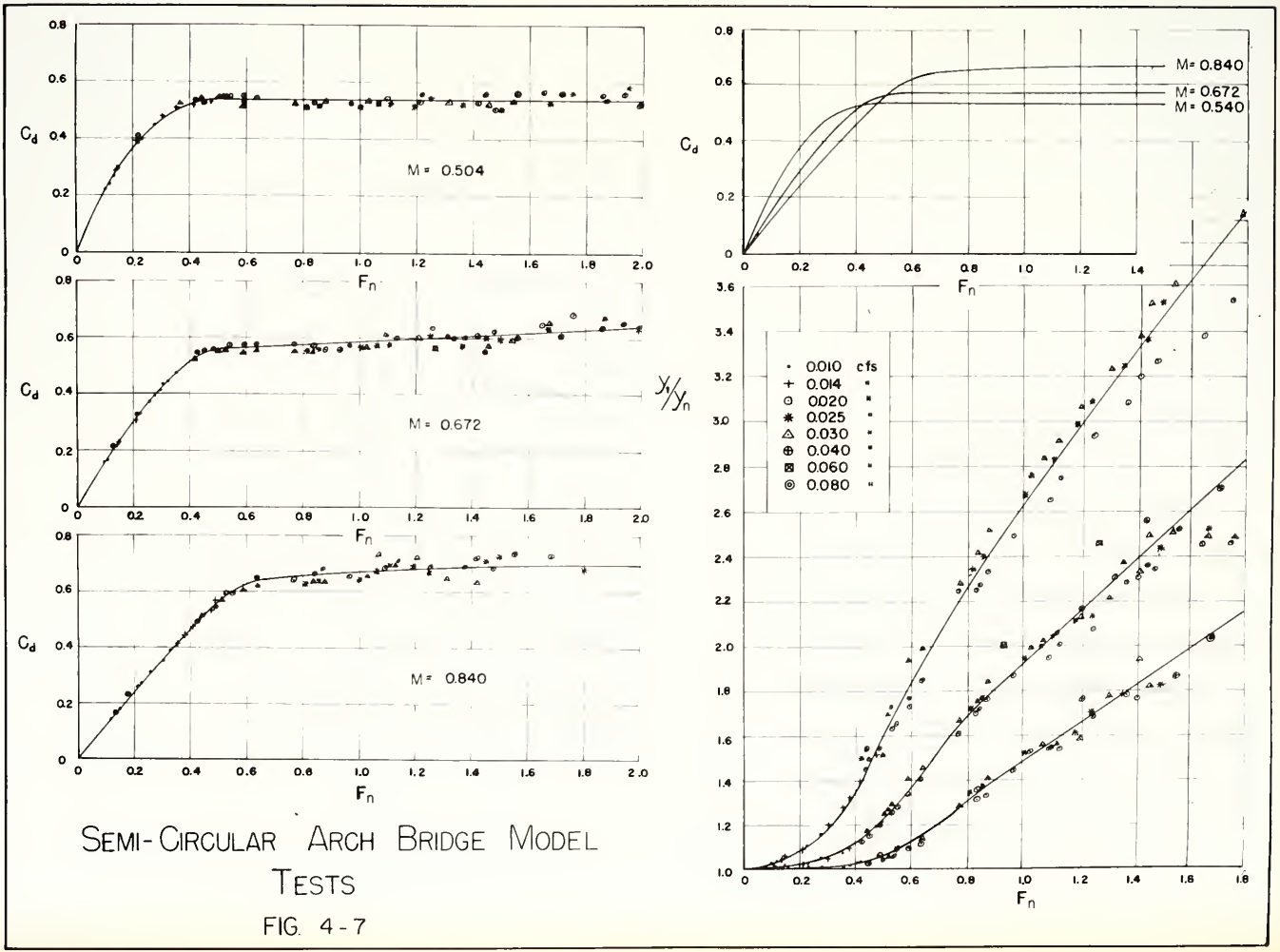
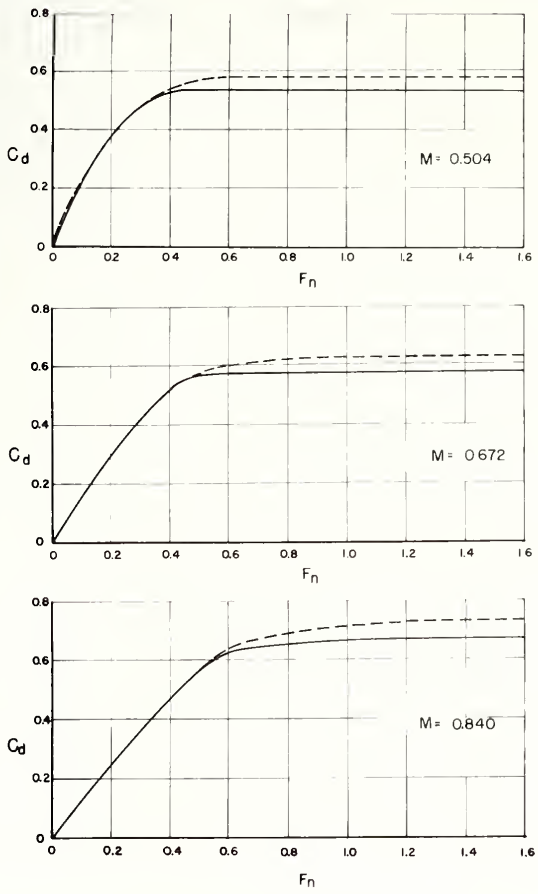

DIRECTION OF FLOW
CROWN OF ARCH
BACKWATER PROFILE
NORMAL PROFILE
h=0.002'
REGAIN CURVE
△h=0.006'
BRIDGE MODEL
24"
MAX BACKWATER EL.
NORMAL DEPTH
MIN REGAIN CURVE EL.
45"
20"
r=2.0"
5.9"
CIRCULAR ARCH
DIA.=4.0"
RISE=2.0"
LENGTH OF MODEL =24"
WEIR HEIGHT AT END OF FLUME=1.0"
ARTIFICIAL ROUGHNESS
Q_m=0.0137 cfs
S_o=0.0005
n =0.0249
CHANNEL BOTTOM (.0005 ft/ft SLOPE)
DEPTH IN FEET
HORIZONTAL DISTANCE IN DIRECTION OF FLOW
17
.16
.12
.11
10
09
08
07
06
05
0
1
2
3
4'
5'
6'
7'
8'
9'
10'

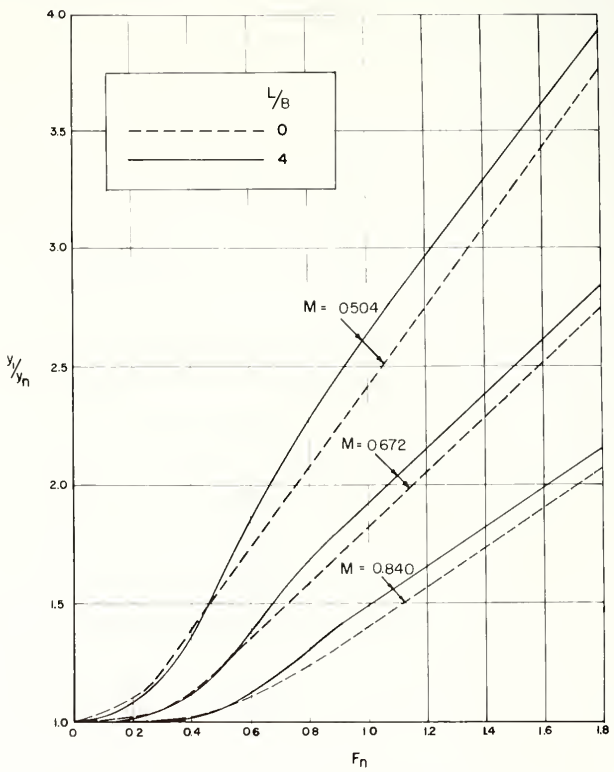
FIG. 4-6



SEMI-CIRCULAR ARCH BRIDGE MODEL TESTS

FIG. 4-7





FLOW IN RECTANGULAR CHANNELS WITH SEMI-CIRCULAR CONSTRICTIONS - COMPARISON OF TWO AND THREE DIMENSIONAL CASES

FIG. 4 - 8

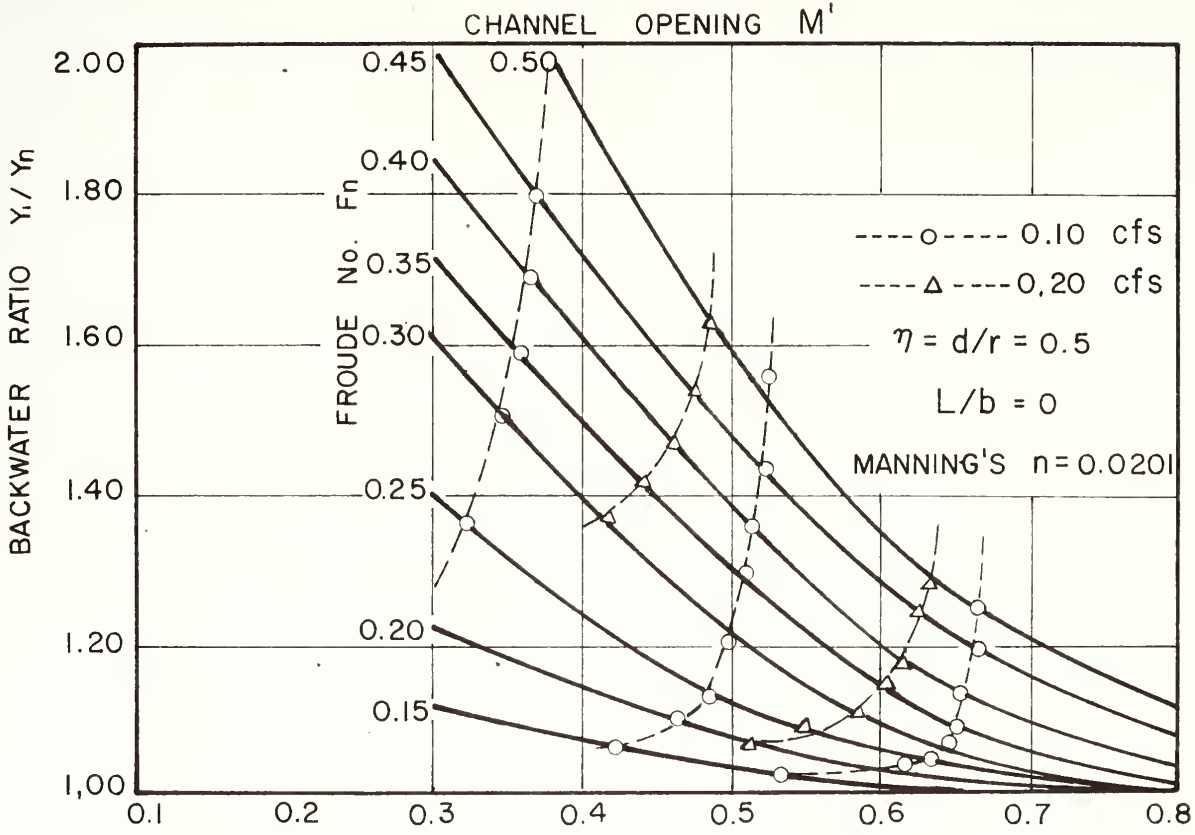
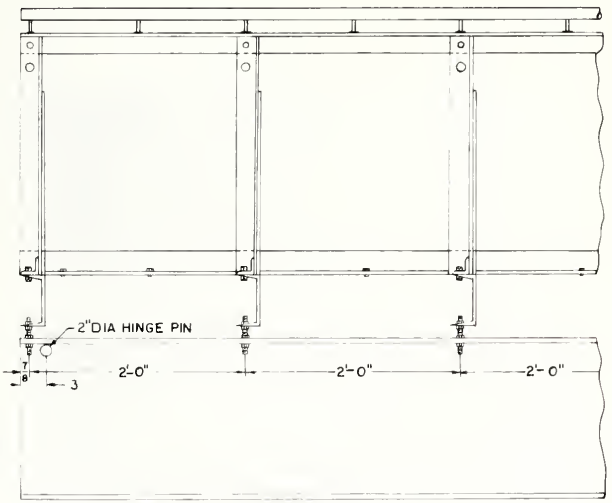
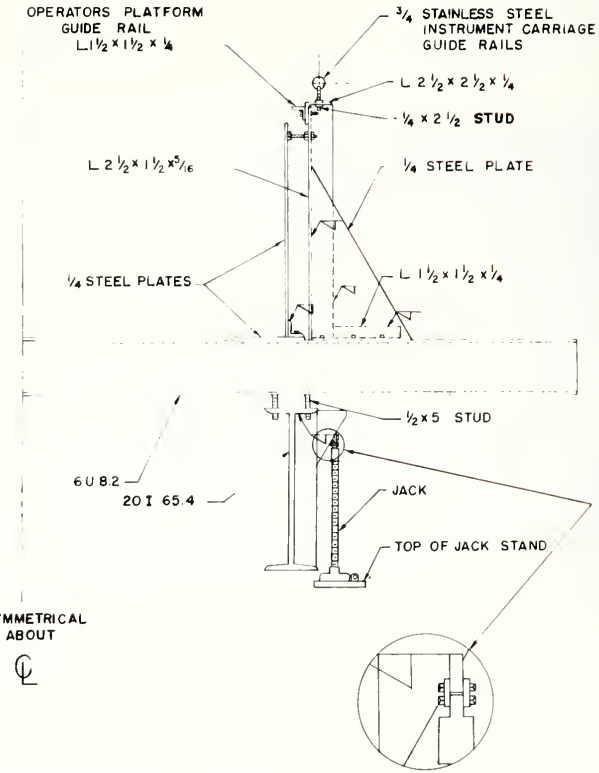


FIG 4-8a VARIATION OF THE BACKWATER RATIO FOR SEGMENT ARCHES - SMALL FLUME - ROUGH BOUNDARIES





SYMMETRICAL ABOUT ℄

FLUME CONSTRUCTION

FIGURE 5-1

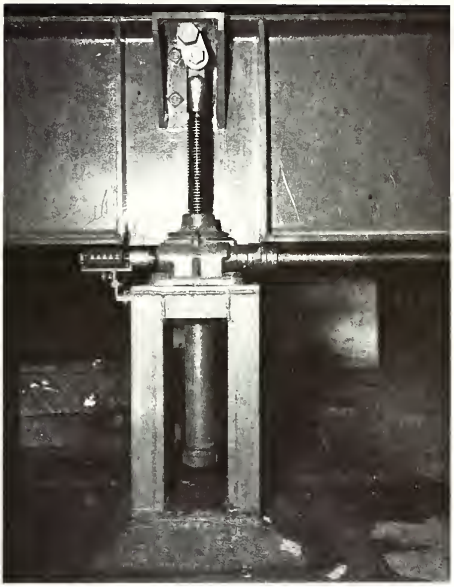


FIG 5-2 JACK DETAIL

FIG 5-3 TAIL GATE

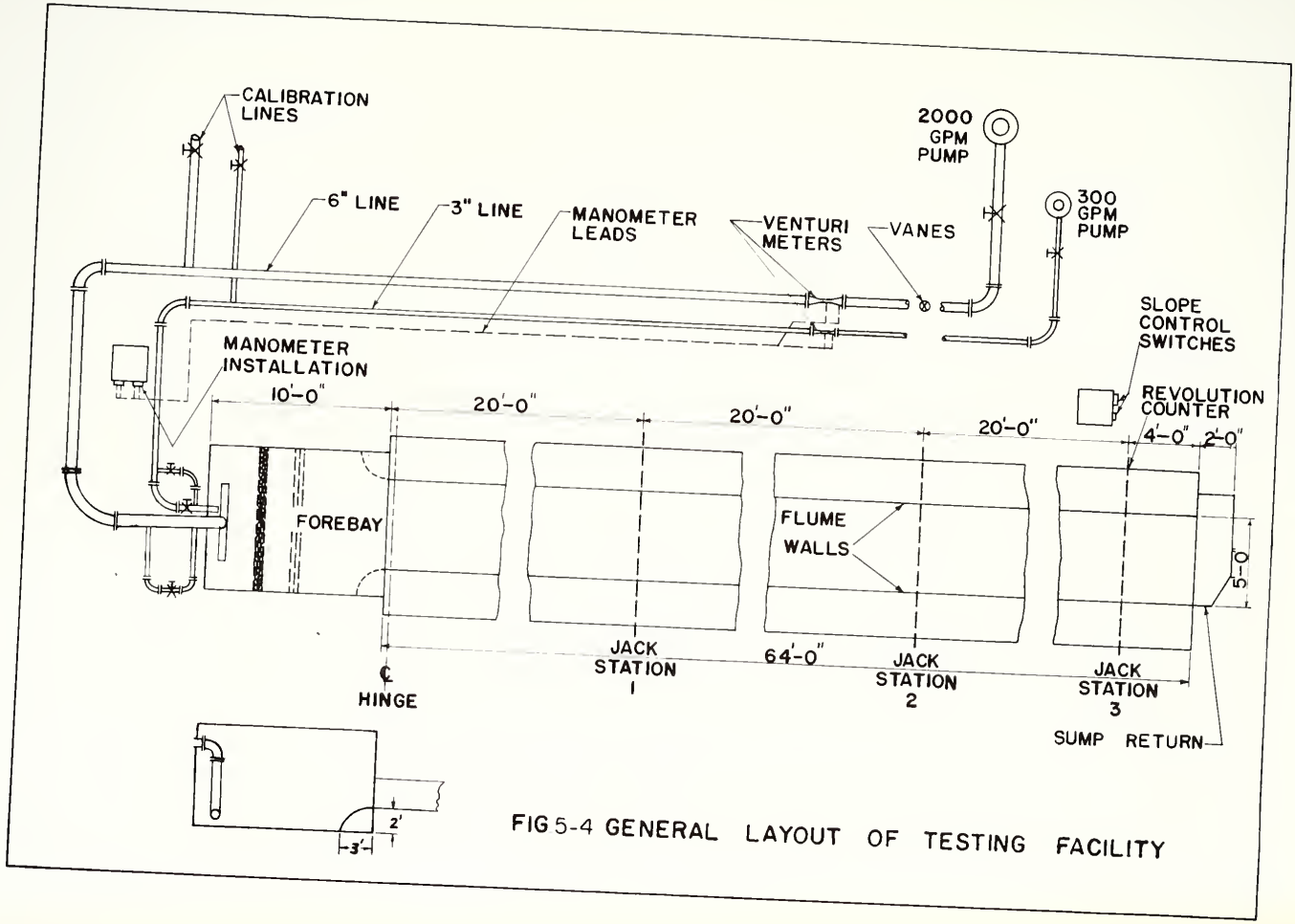


FIG 5-4 GENERAL LAYOUT OF TESTING FACILITY

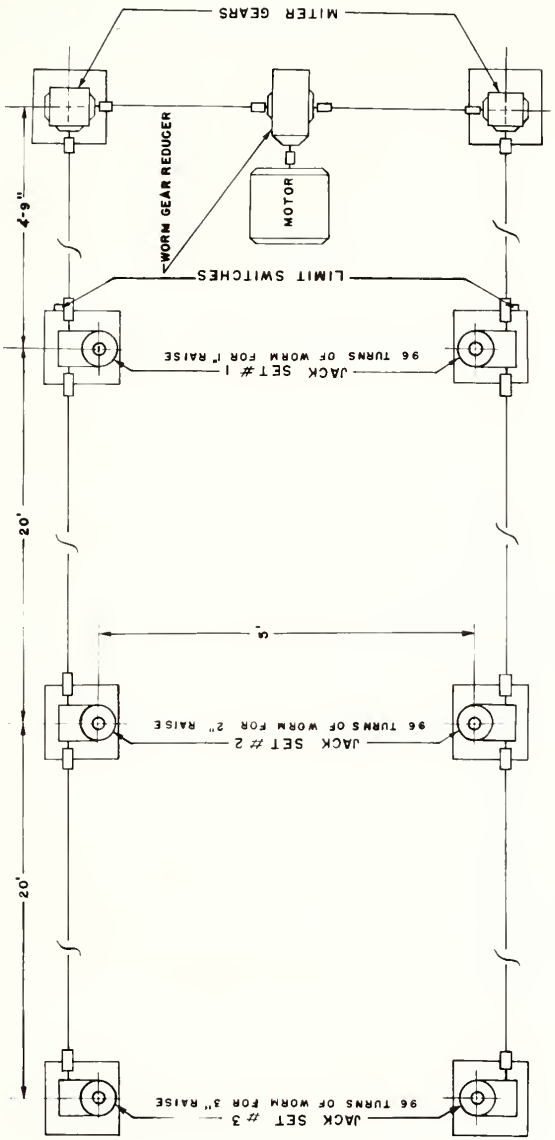


FIG 5-5 PLAN VIEW OF JACKS AND GEARS

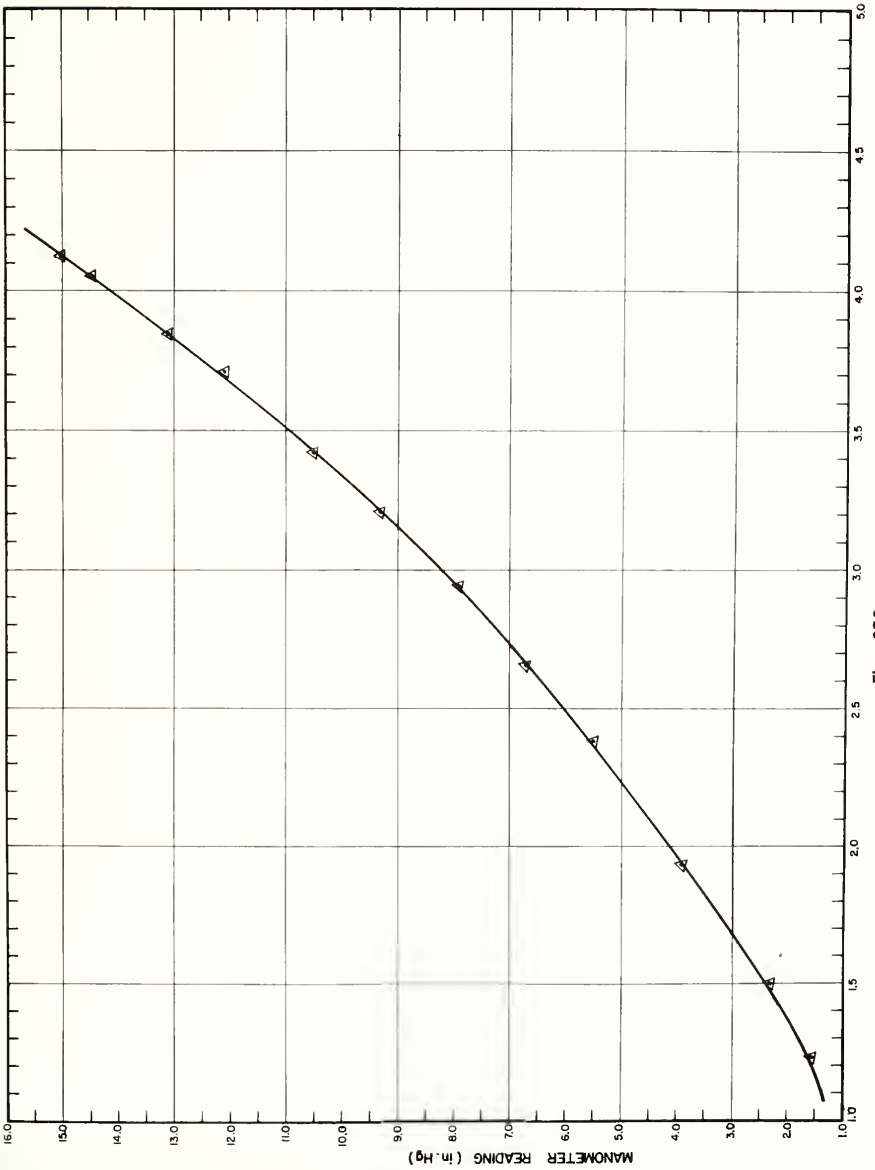


FIG.5-6 CALIBRATION CURVE FOR 6" VENTURIMETER

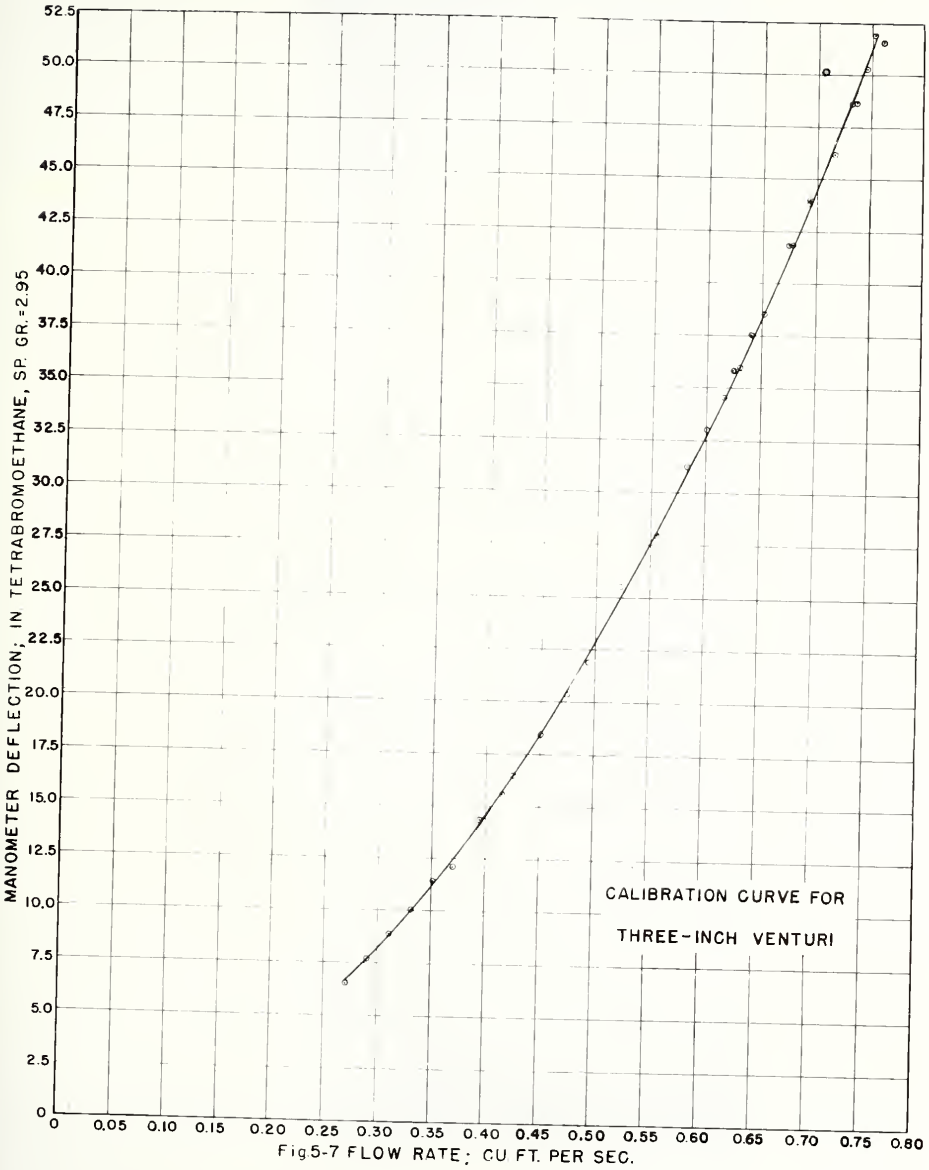


Fig5-7 FLOW RATE; CU FT. PER SEC.

FIG 5-8 TOP VIEW OF INSTRUMENT CARRIAGE

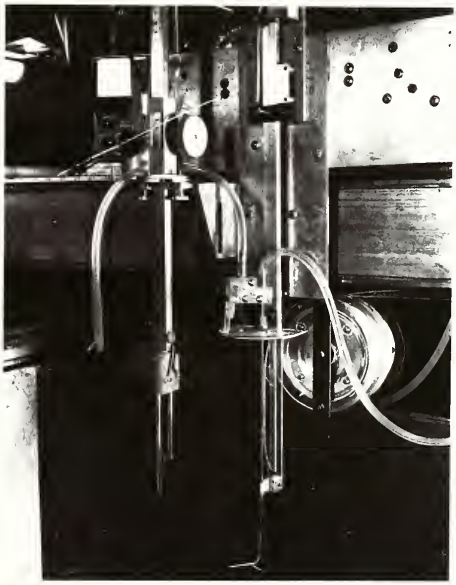


FIG 5-9 POINT GAGE AND PRANDTL TUBE

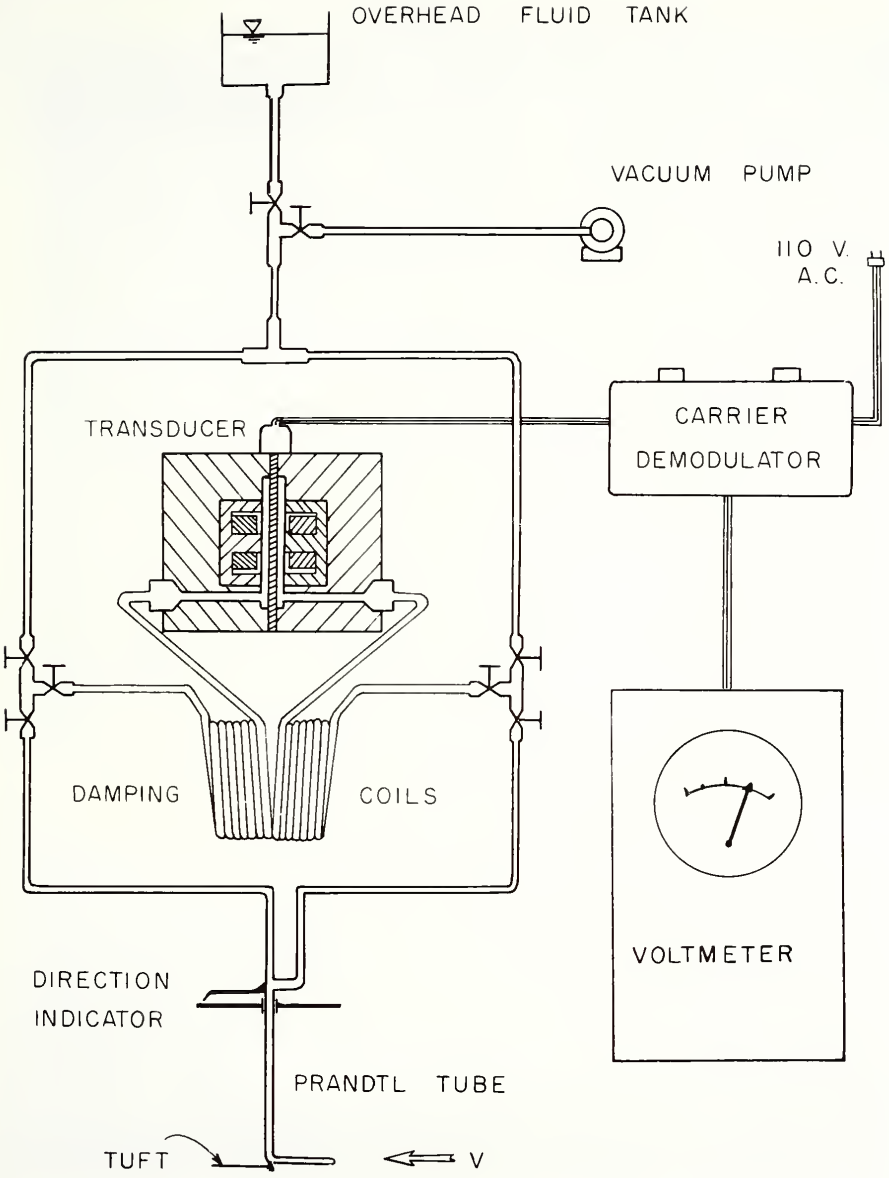
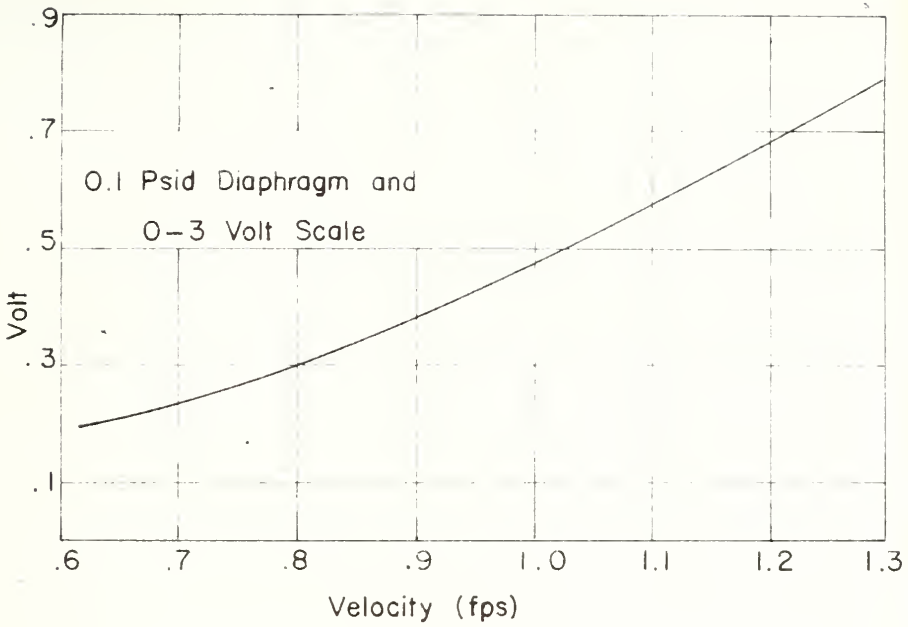


FIGURE 5-10 VELOCITY TRANSDUCER SYSTEM

FIG 5-11 CALLIBRATION APPARATUS FOR VELOCITY TRANSDUCER SYSTEM



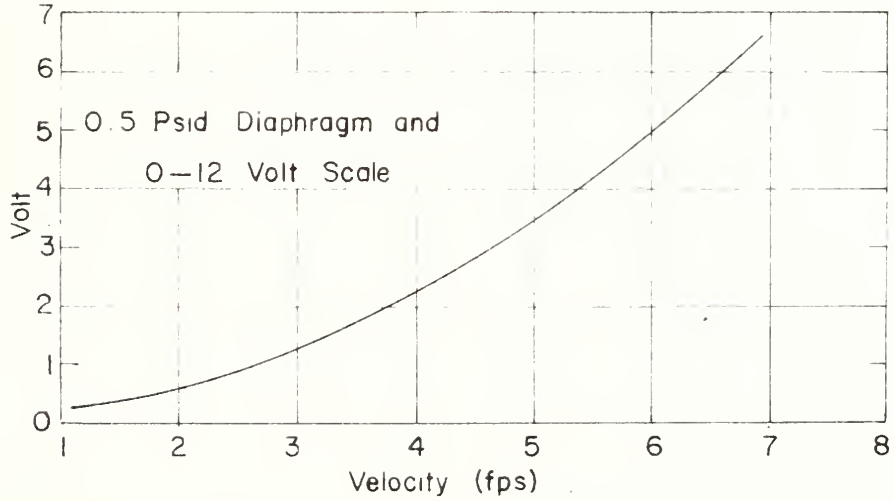


Fig. 5-12 Typical Calibration Curves for Probe

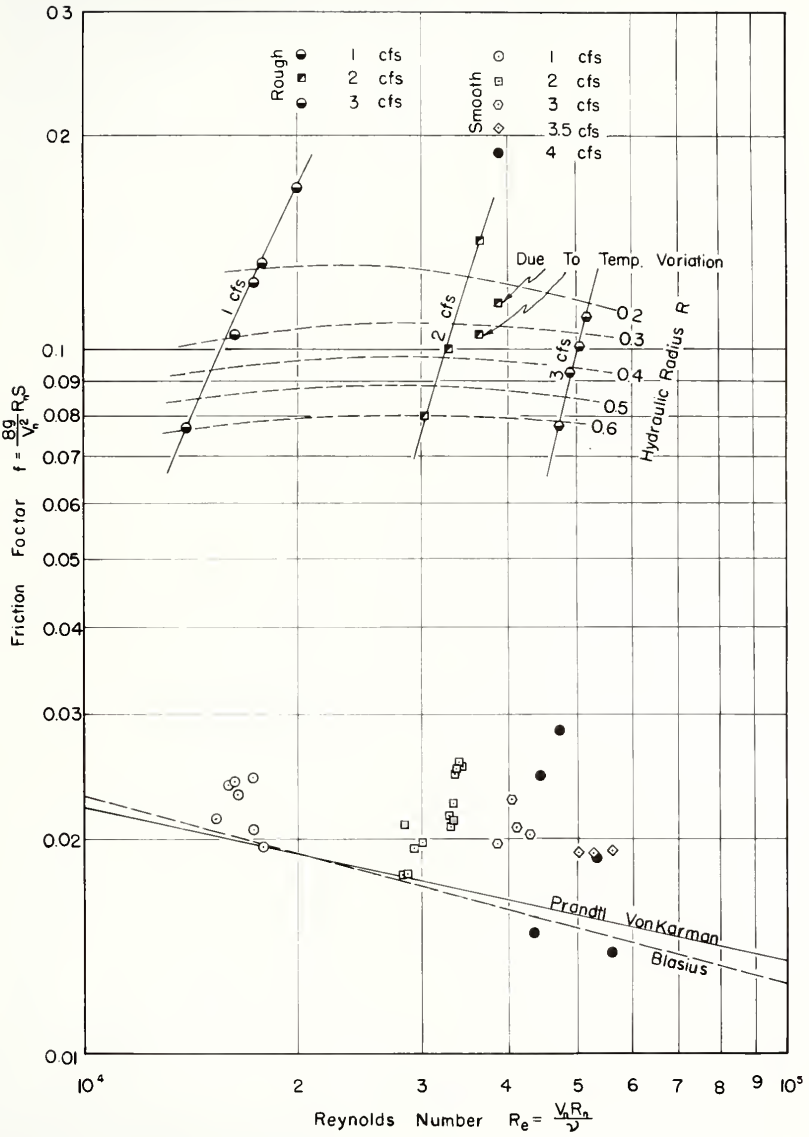


FIGURE 5-13 f – Re RELATION FOR NORMAL DEPTH TESTS

FIGURE 5-14 TESTING FLUME WITH ARTIFICIAL ROUGHNESS.

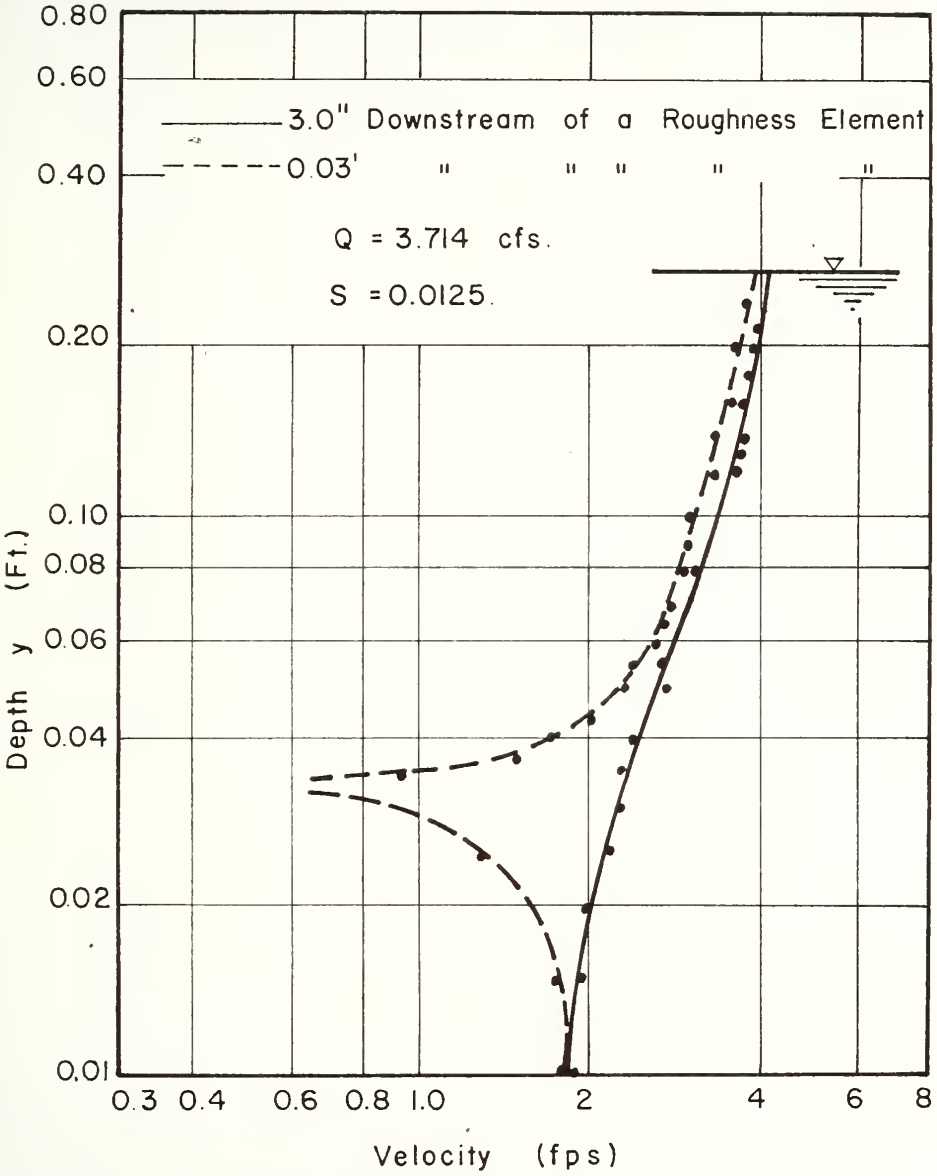


FIG 5-15 EFFECT OF BARS ON VELOCITY

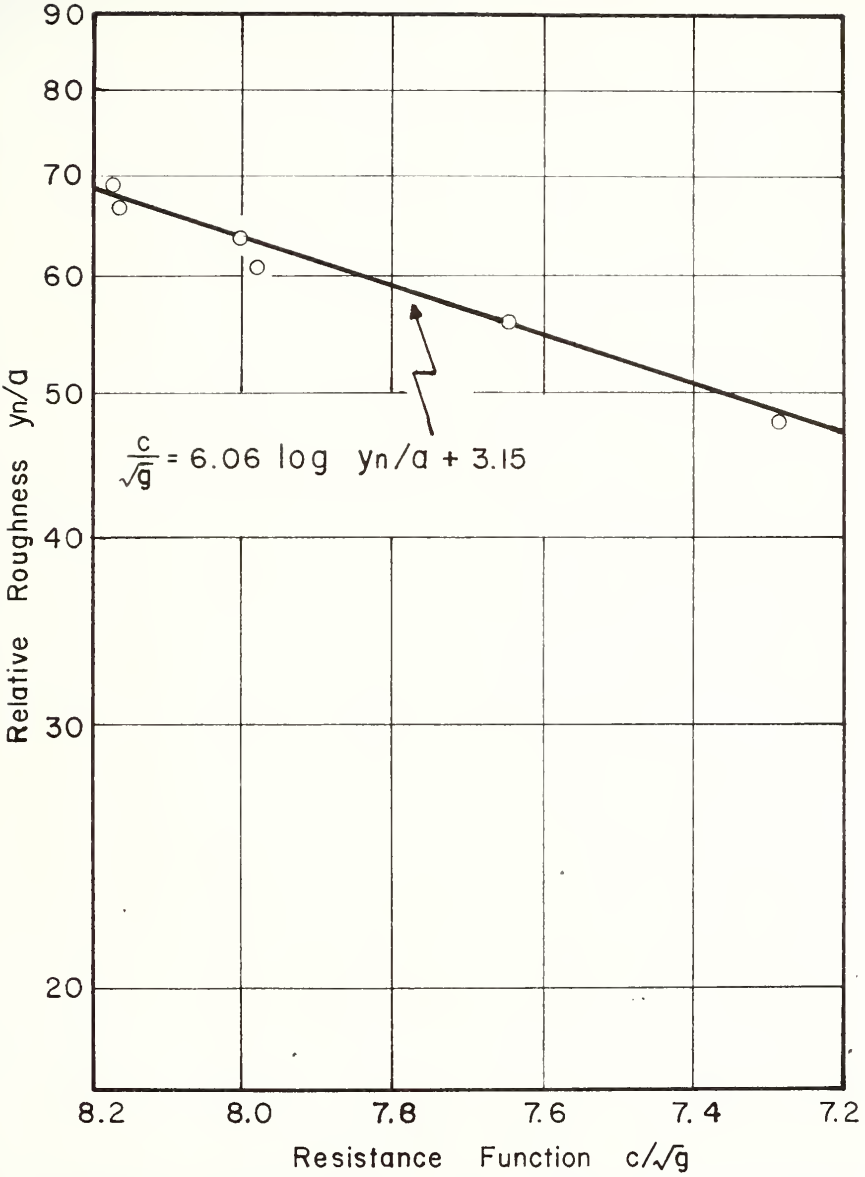


FIG 5-16 VARIATION OF RESISTANCE FUNCTION WITH RELATIVE ROUGHNESS yn/a

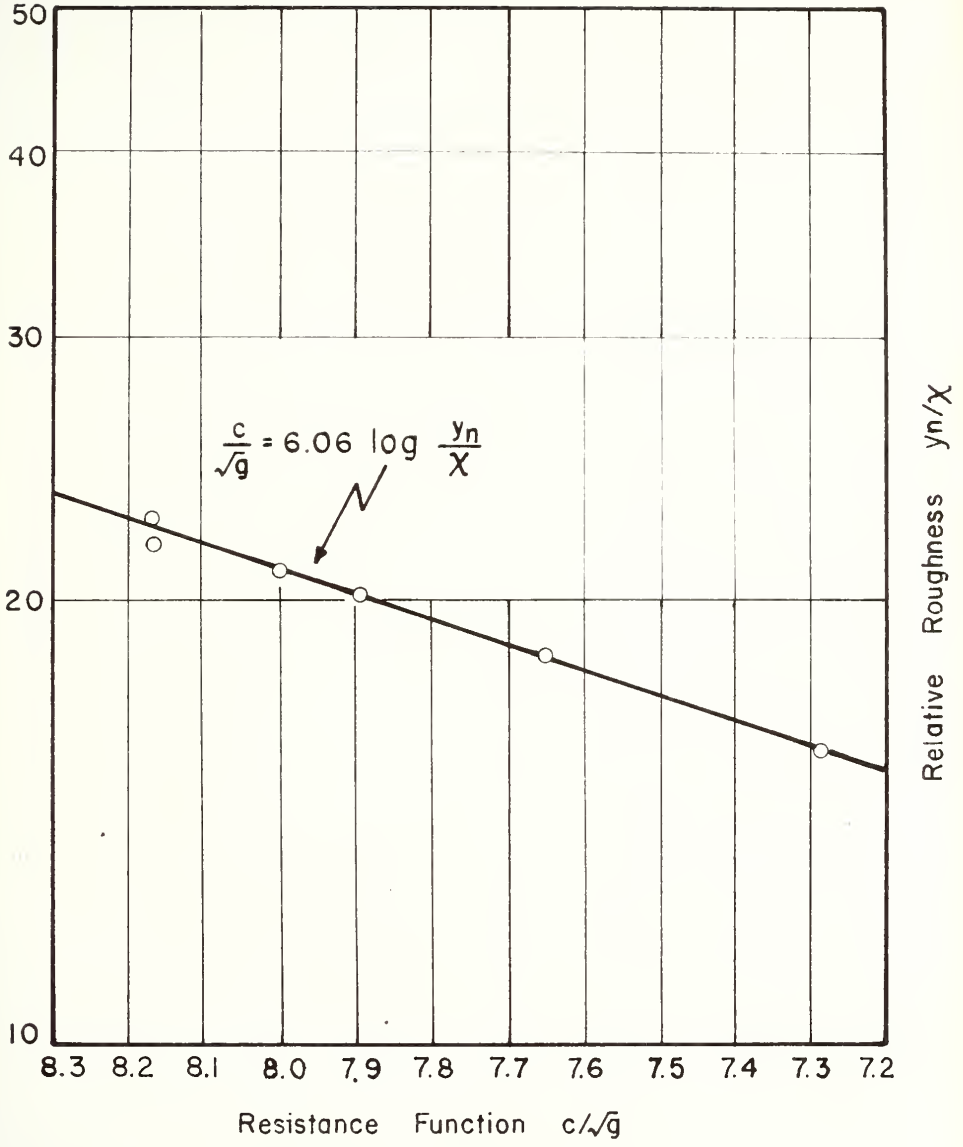


FIG 5-17 VARIATION OF RESISTANCE FUNCTION WITH RELATIVE ROUGHNESS y_n/χ

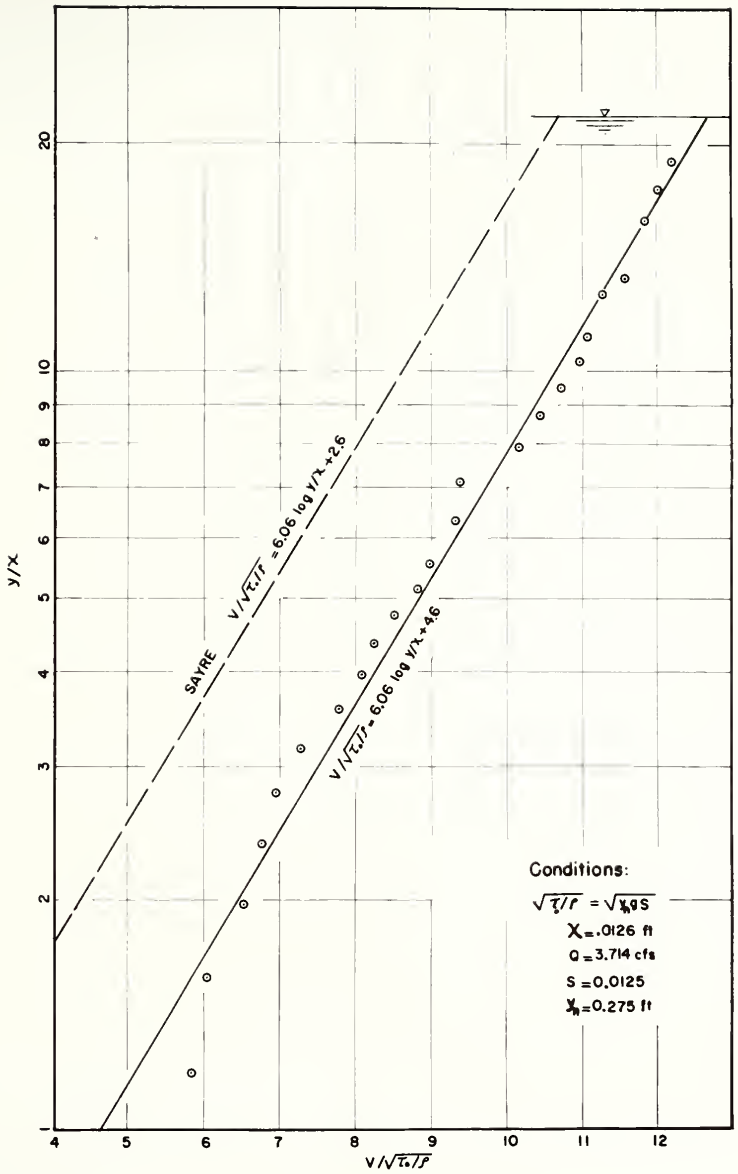


FIGURE 5-18 DIMENSIONLESS VELOCITY PROFILE

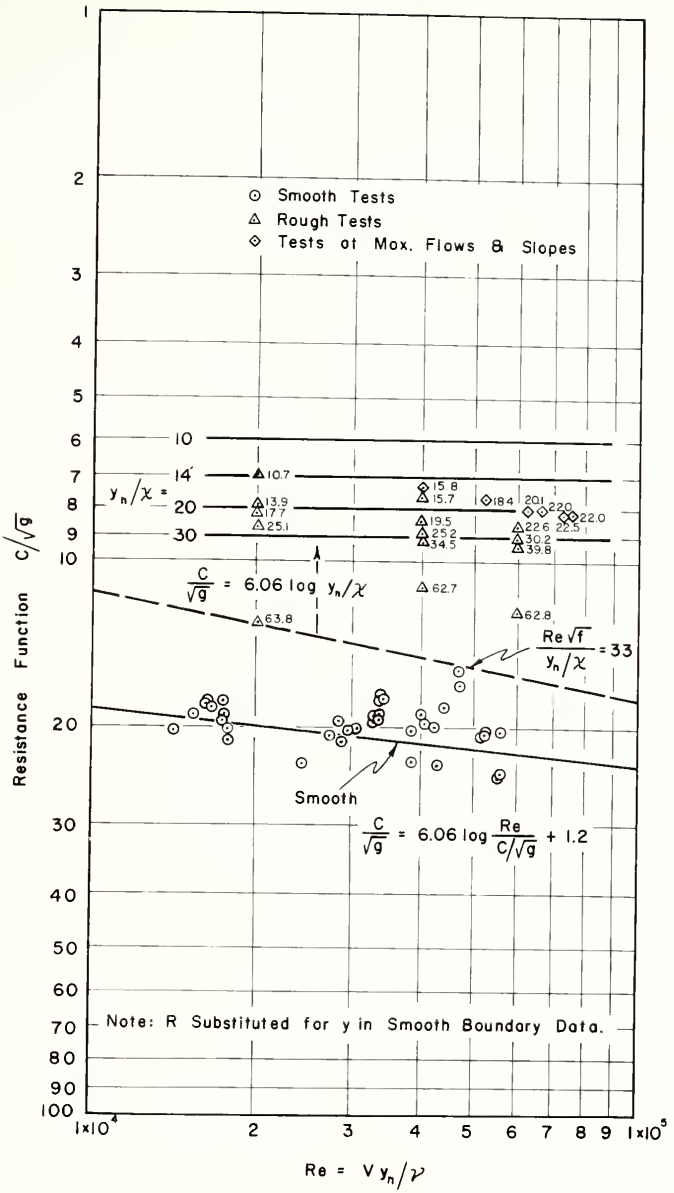


FIGURE 5-19 GENERAL RESISTANCE DIAGRAM FOR UNIFORM FLOW IN OPEN CHANNELS (SAYRE)

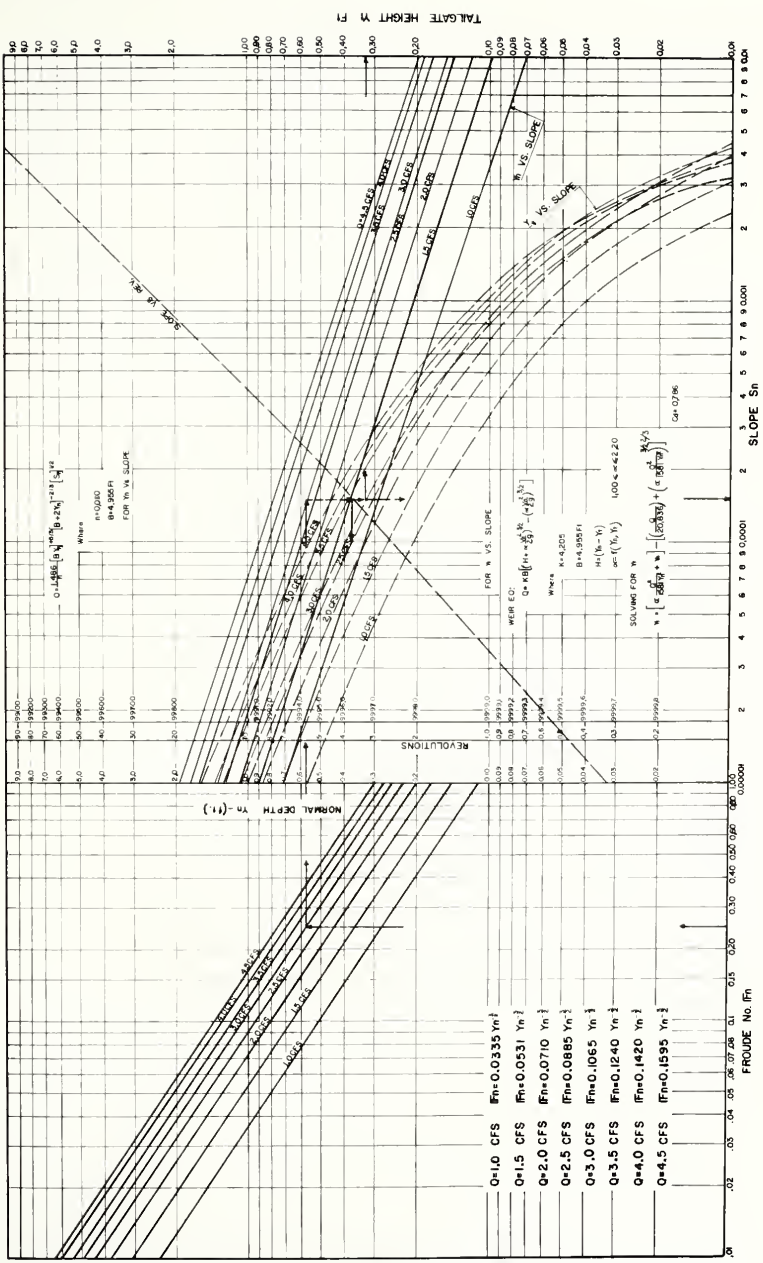


FIGURE 6-1 TESTS SELECTION CURVE — LARGE FLUME — SMOOTH BOUNDARIES

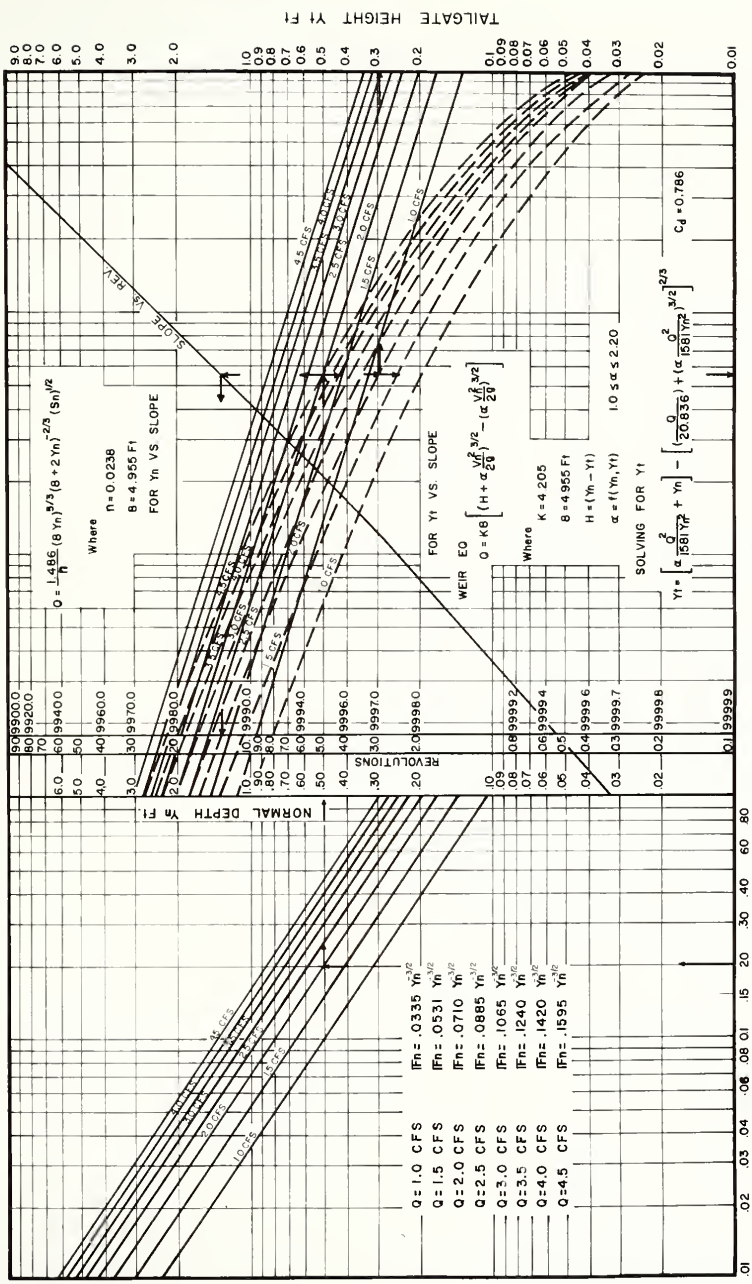
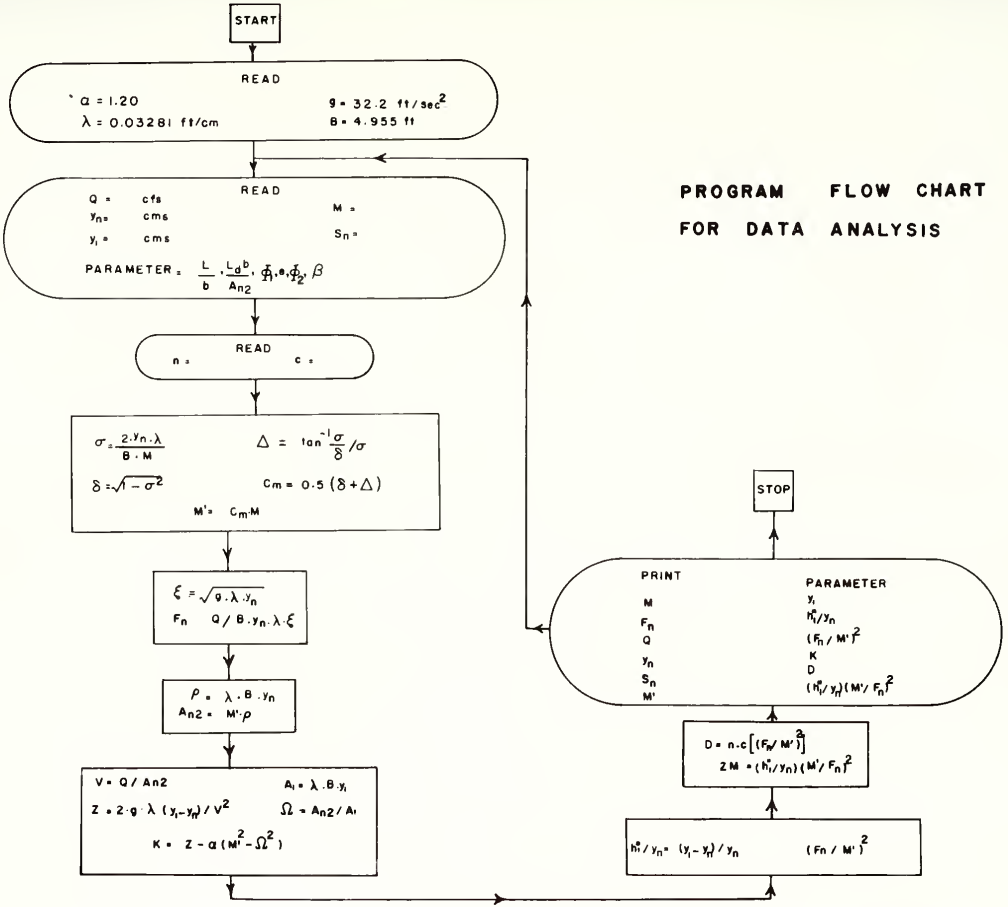


FIGURE 6-2 TESTS SELECTION CURVE — LARGE FLUME — ROUGH BOUNDARIES



PROGRAM FLOW CHART
FOR DATA ANALYSIS

FIG. 6-3

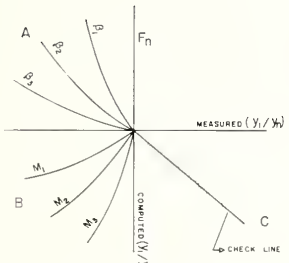


FIGURE 6 - 4

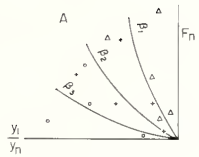


FIGURE 6 - 5

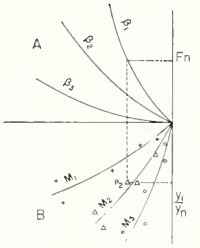


FIGURE 6 - 6

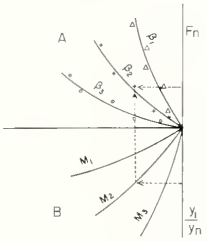


FIGURE 6 - 8

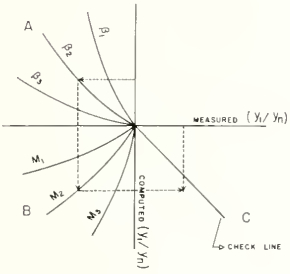


FIGURE 6 - 7

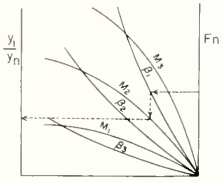


FIGURE 6 - 10

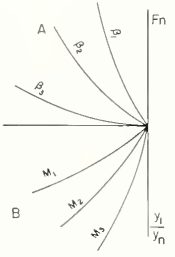


FIGURE 6 - 9

$M_1 = 0.75$ $\beta_1 = 0.0$
$M_2 = 0.5$ $\beta_2 = 0.3$
$M_3 = 0.25$ $\beta_3 = 0.5$

FOUR VARIABLES GRAPHICAL MULTIPLE CORRELATION

$\circ - \beta = 0.5, M = 0.25$

$+ - \beta = 0.3, M = 0.75$

$\triangle - \beta = 0.0, M = 0.5$

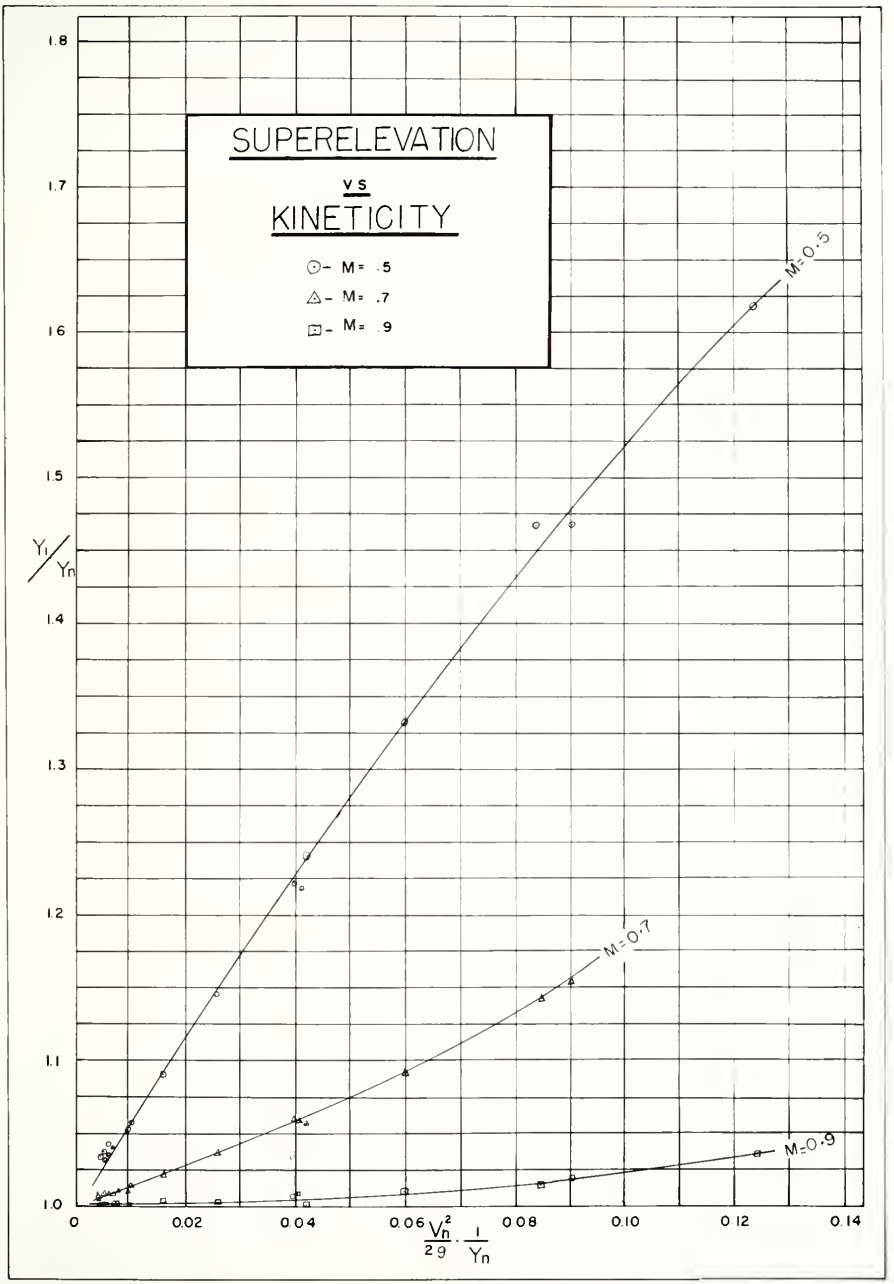

SUPERELEVATION
VS
KINETICITY
⊙ - M = .5
△ - M = .7
□ - M = .9
M=0.5
M=0.7
M=0.9
Y1/Yn
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0
0.02
0.04
0.06
0.08
0.10
0.12
0.14
Vn²/2g · 1/Yn

FIGURE 7-1-1

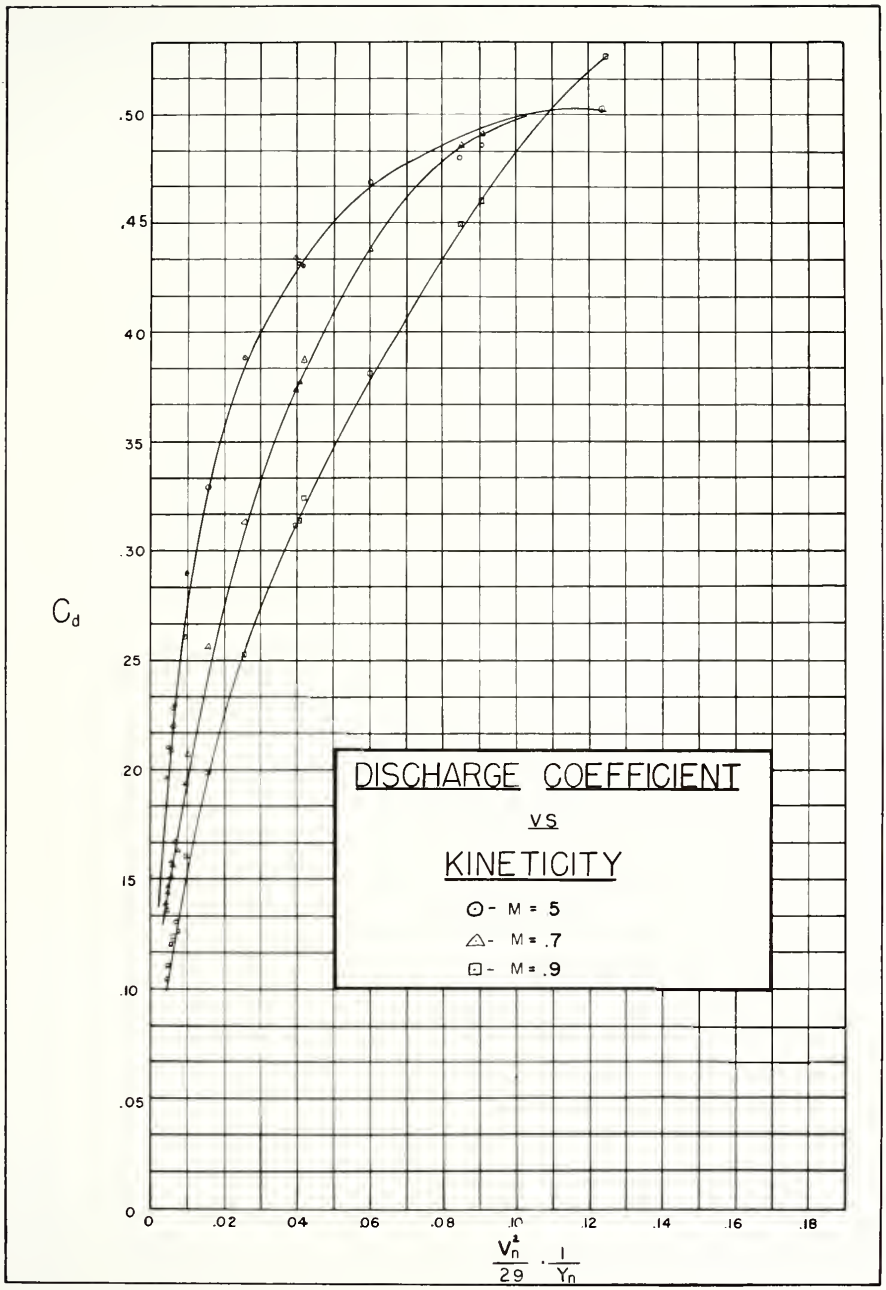

DISCHARGE COEFFICIENT
VS
KINETICITY
⊙- M = 5
△- M = .7
⊡- M = .9
C_d
.50
.45
40
35
.30
25
20
15
.10
.05
0
0
.02
04
06
.08
.10
.12
.14
.16
.18
$\frac{V_n^2}{29} \cdot \frac{1}{Y_n}$

FIGURE 7-1-2

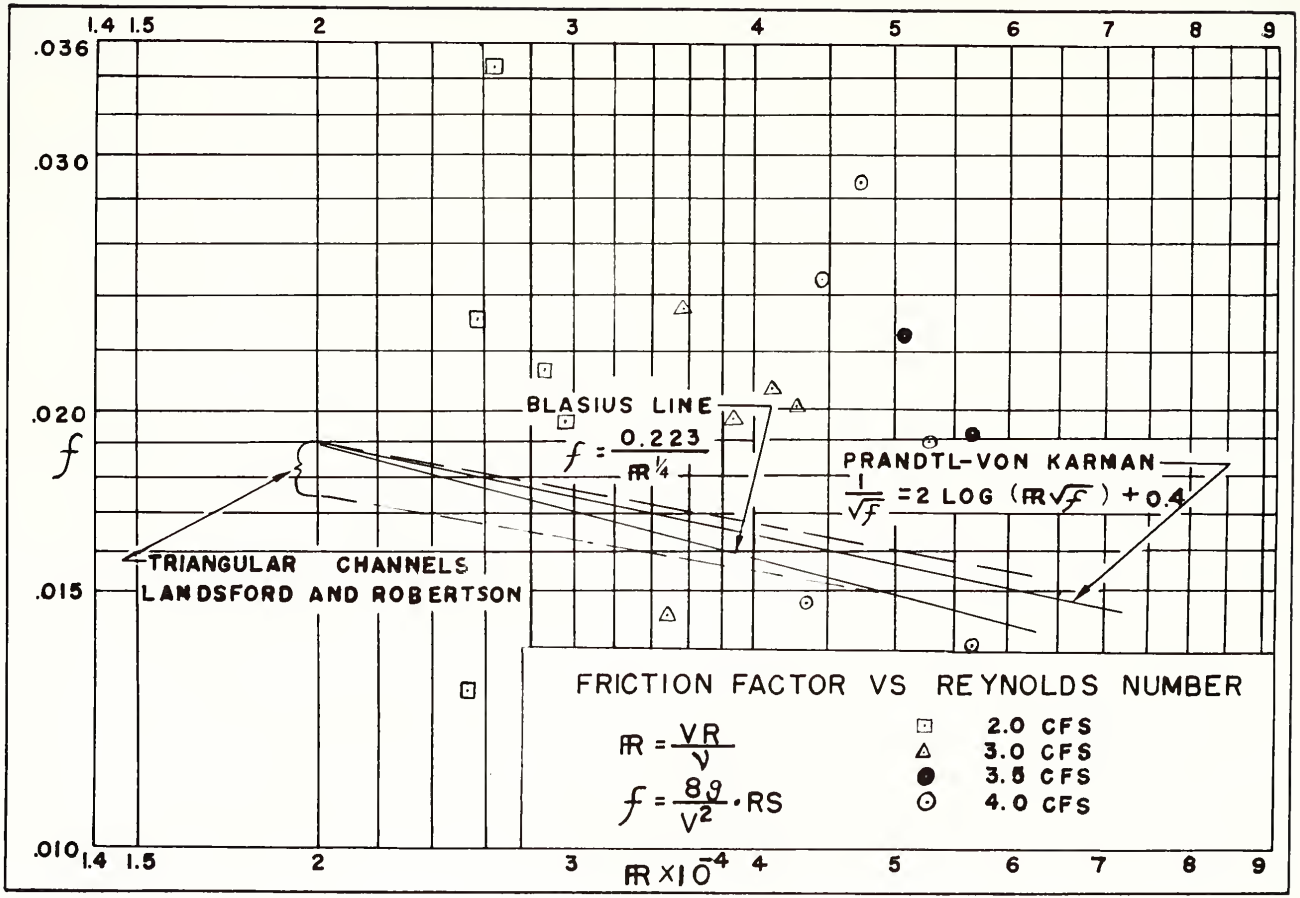

1.4 1.5
2
3
4
5
6
7
8
9
.036
.030
.020
f
.015
.010
BLASIUS LINE
$f = \frac{0.223}{RR^{1/4}}$
PRANDTL-VON KARMAN
$\frac{1}{\sqrt{f}} = 2 \log (RR\sqrt{f}) + 0.4$
TRIANGULAR CHANNELS
LANDSFORD AND ROBERTSON
FRICTION FACTOR VS REYNOLDS NUMBER
$RR = \frac{VR}{\nu}$
$f = \frac{8g}{V^2} \cdot RS$
2.0 CFS
3.0 CFS
3.5 CFS
4.0 CFS
RR X 10⁻⁴

FIGURE 7-1-3

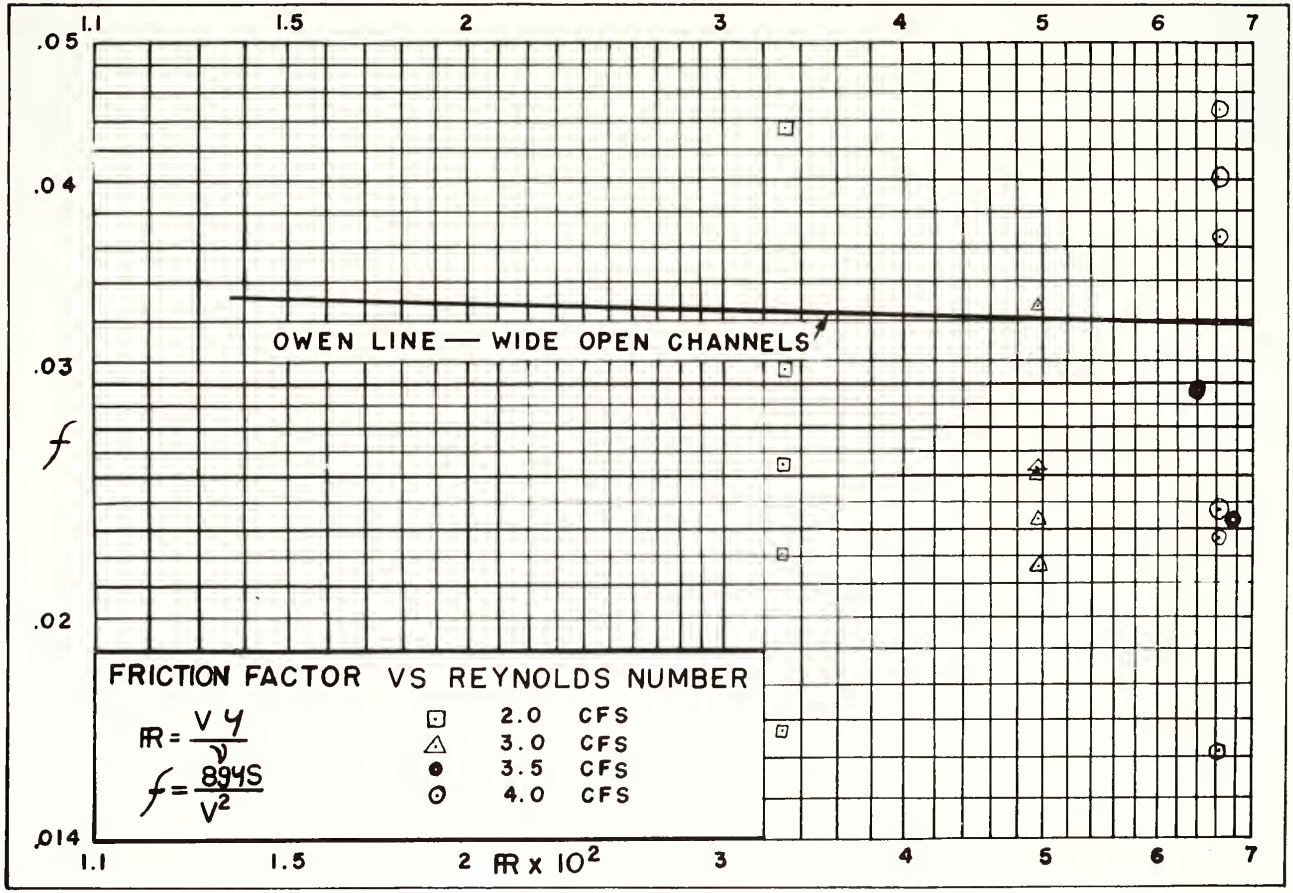

1.1
1.5
2
3
4
5
6
7
.05
.04
.03
f
.02
.014
OWEN LINE — WIDE OPEN CHANNELS
FRICTION FACTOR VS REYNOLDS NUMBER
$RR = \frac{V\,4}{\nu}$
$f = \frac{89\,4S}{V^2}$
2.0 CFS
3.0 CFS
3.5 CFS
4.0 CFS
RR x 10^2

FIGURE 7-1-4

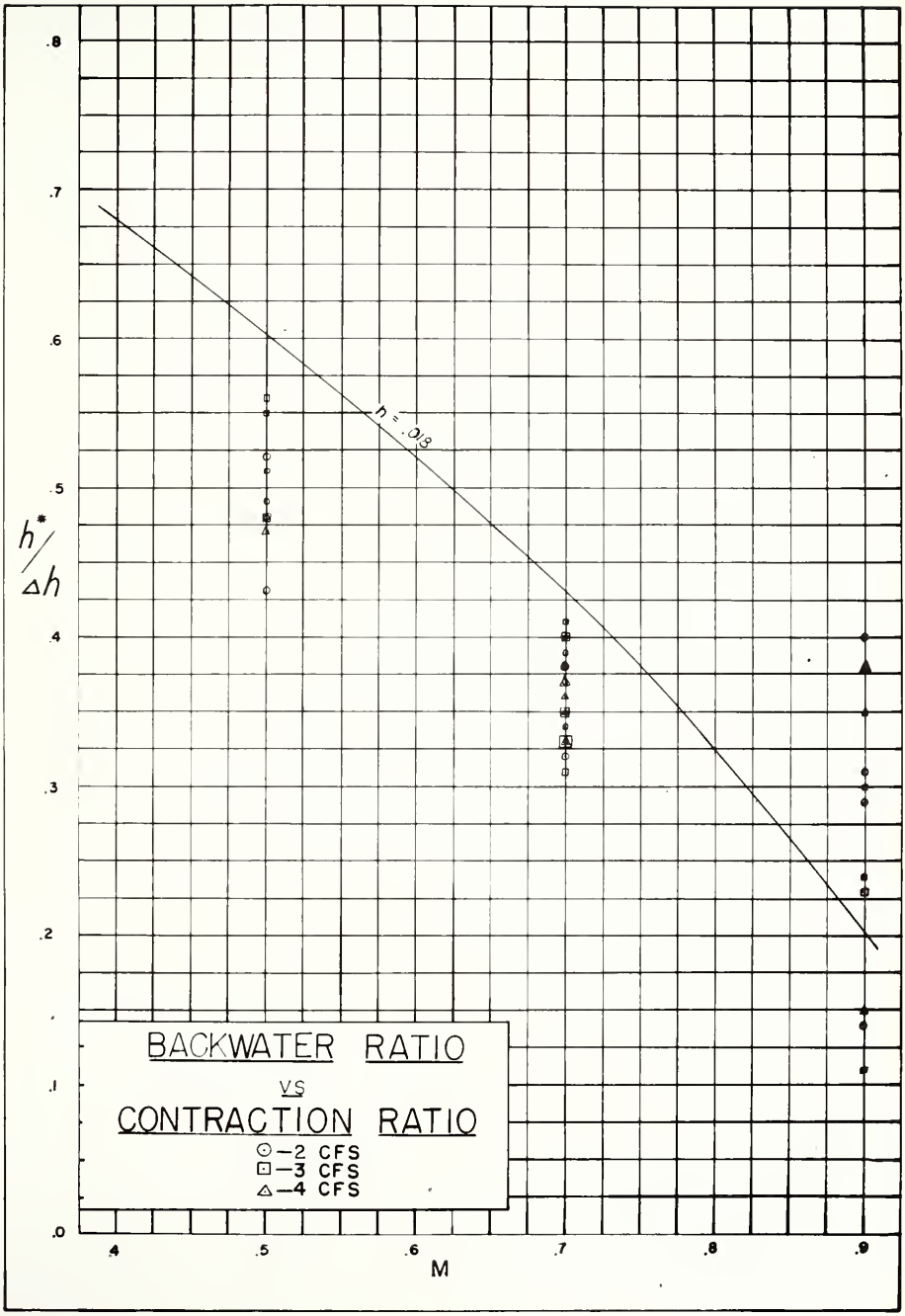

.8
.7
.6
.5
.4
.3
.2
.1
.0
h*/Δh
h = .018
.4
.5
.6
.7
.8
.9
M
BACKWATER RATIO
VS
CONTRACTION RATIO
⊙ —2 CFS
⊡ —3 CFS
△ —4 CFS

FIGURE 7-1-5

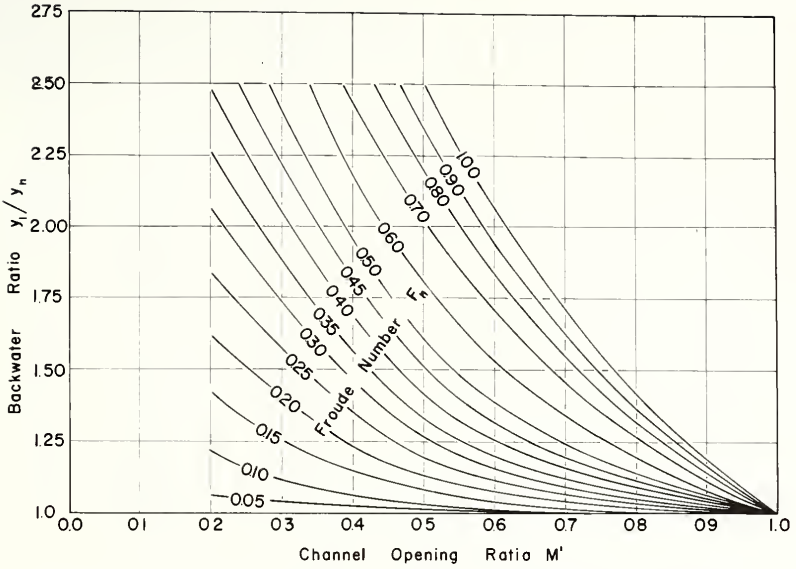


FIGURE 7-1-6 — BACKWATER RATIO VS CHANNEL OPENING RATIO L/b =0 SEMI-CIRC. SMOOTH CHANNEL

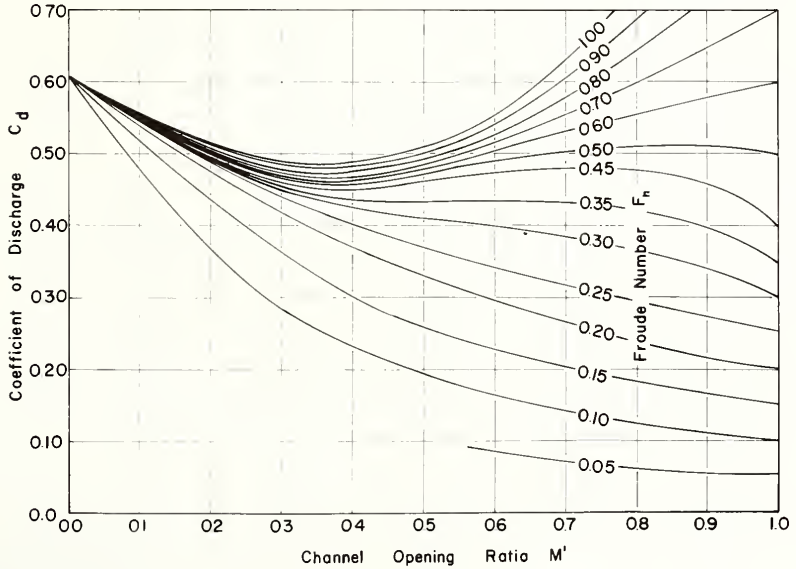


FIGURE 7-1-7 DISCHARGE COEF. VS CHANNEL OPENING RATIO L/b =0 SEMI-CIRC. SMOOTH CHANNEL

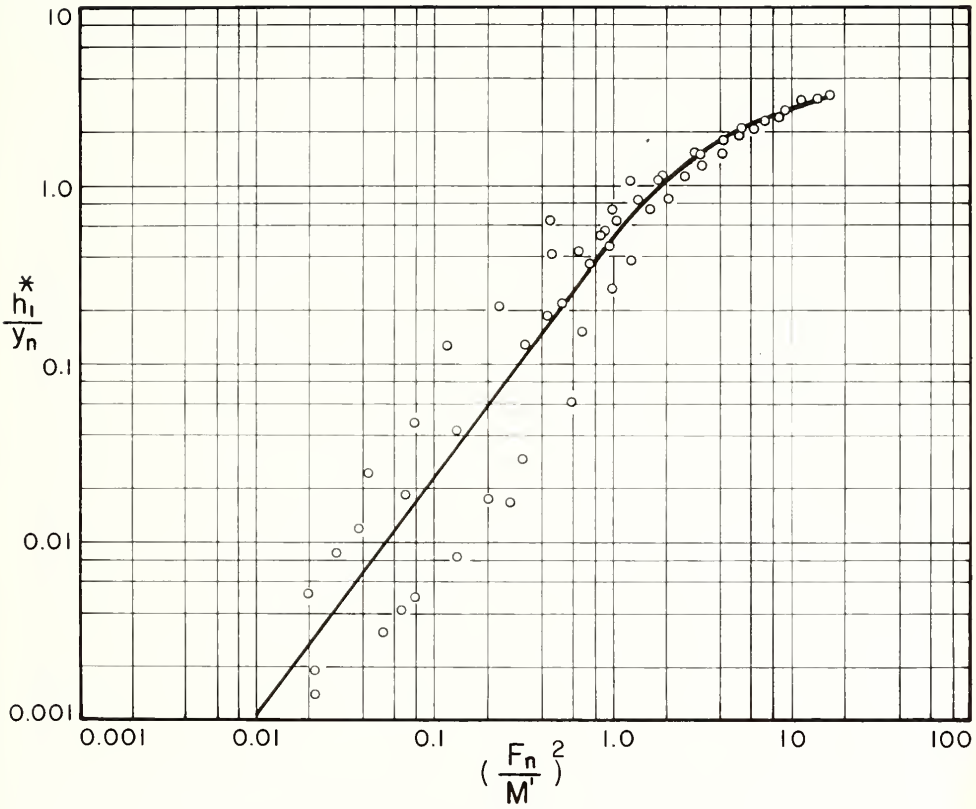


FIGURE 7-1-8 BACKWATER RATIO FOR GEOMETRY I_a, SMOOTH BOUNDARY $\frac{L}{b}$ = 0.0

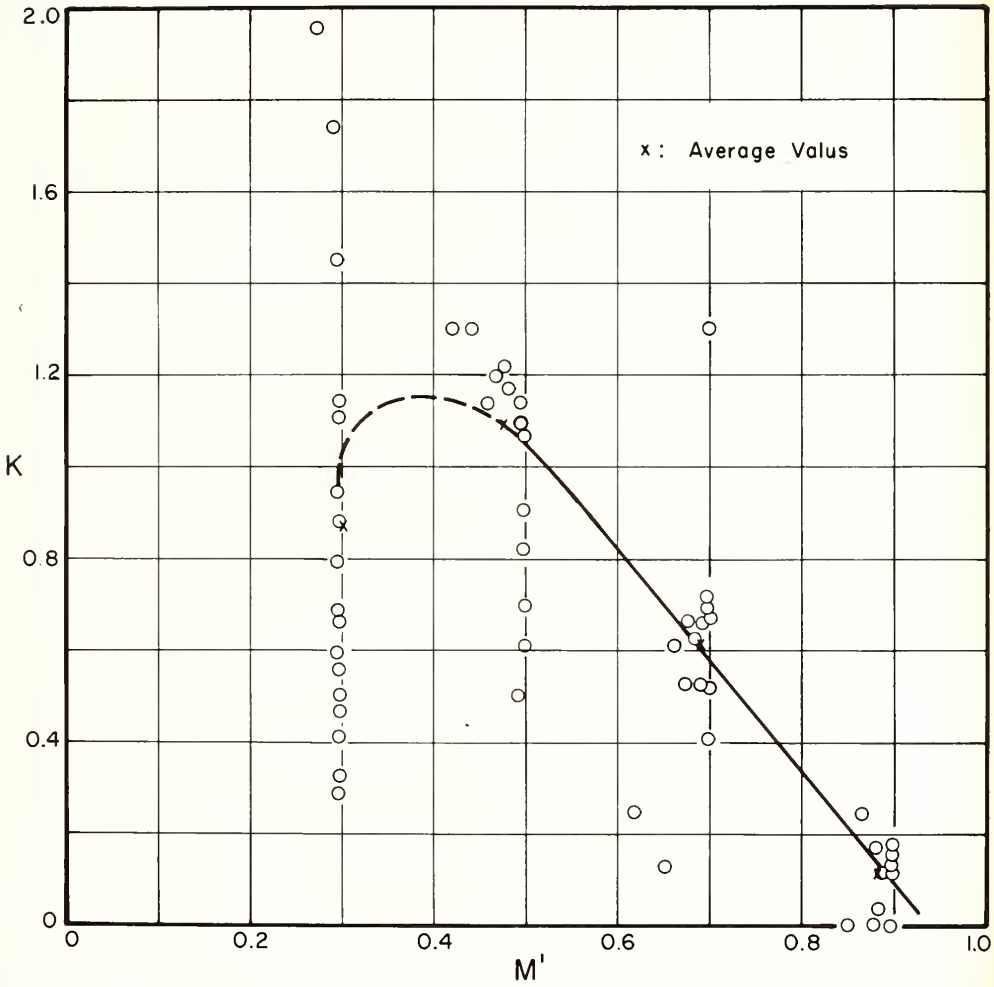


FIGURE 7-1-9 HEAD LOSS COEFFICIENT, GEOMETRY I_a
SMOOTH BOUNDARY $\frac{L}{b} = 0.0$

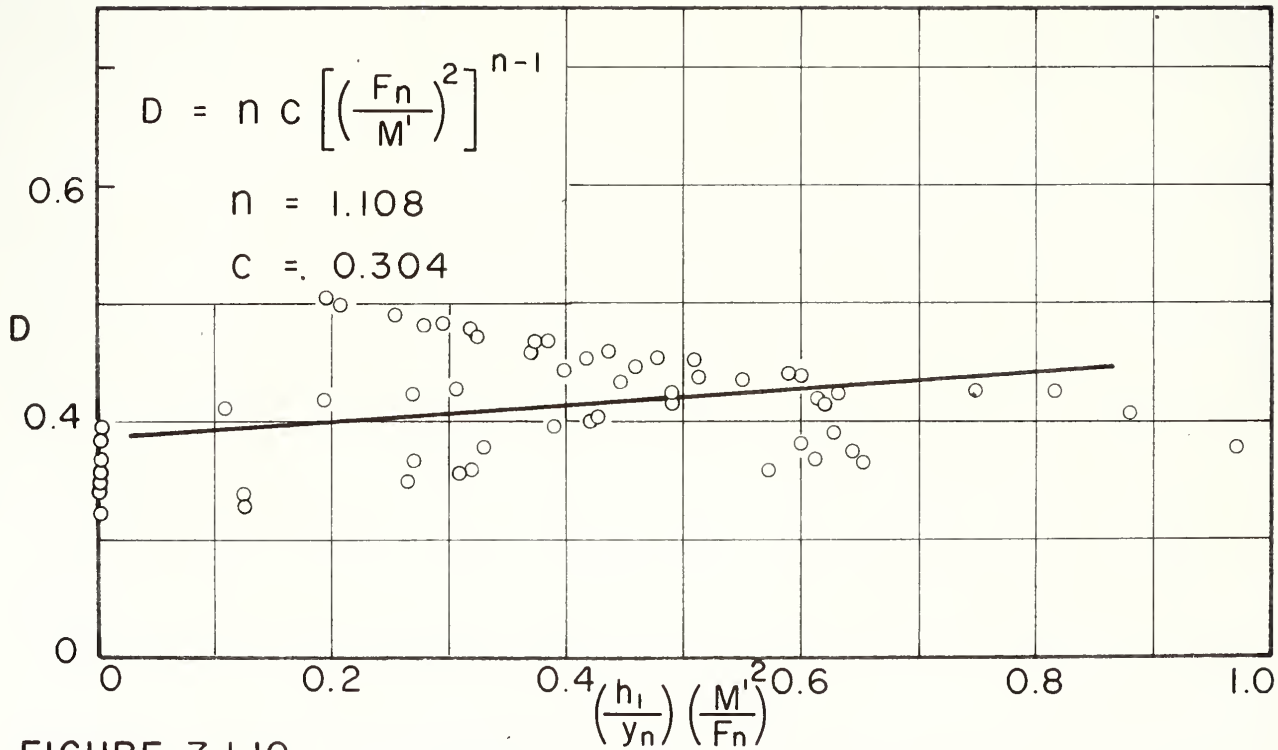


FIGURE 7-1-10 BACKWATER RATIO COEFFICIENT, GEOMETRY I_a, SMOOTH BOUNDARY $\frac{L}{b} = 0.0$

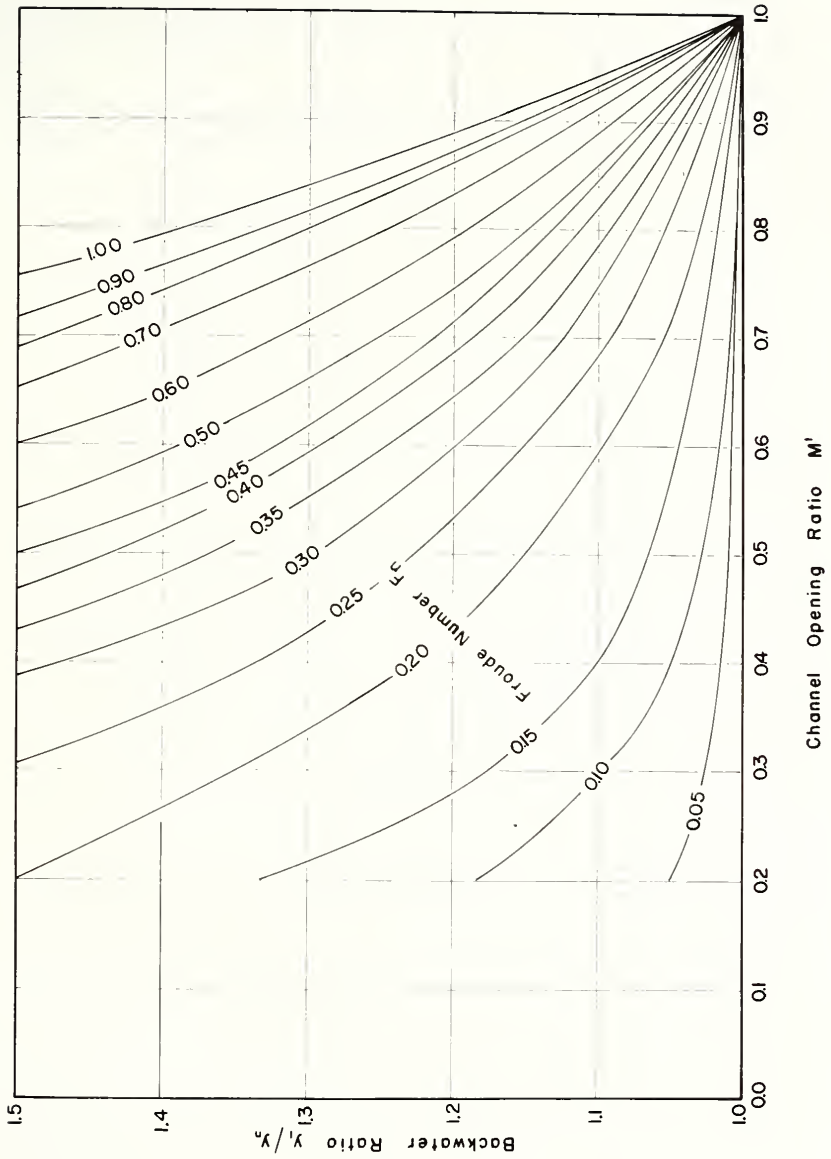


FIGURE 7-2-1a BACKWATER RATIO VS CHANNEL OPENING RATIO L/b=0 SEMI-CIRC. ROUGH CHANNEL $y_1/y_n \leq 1.50$

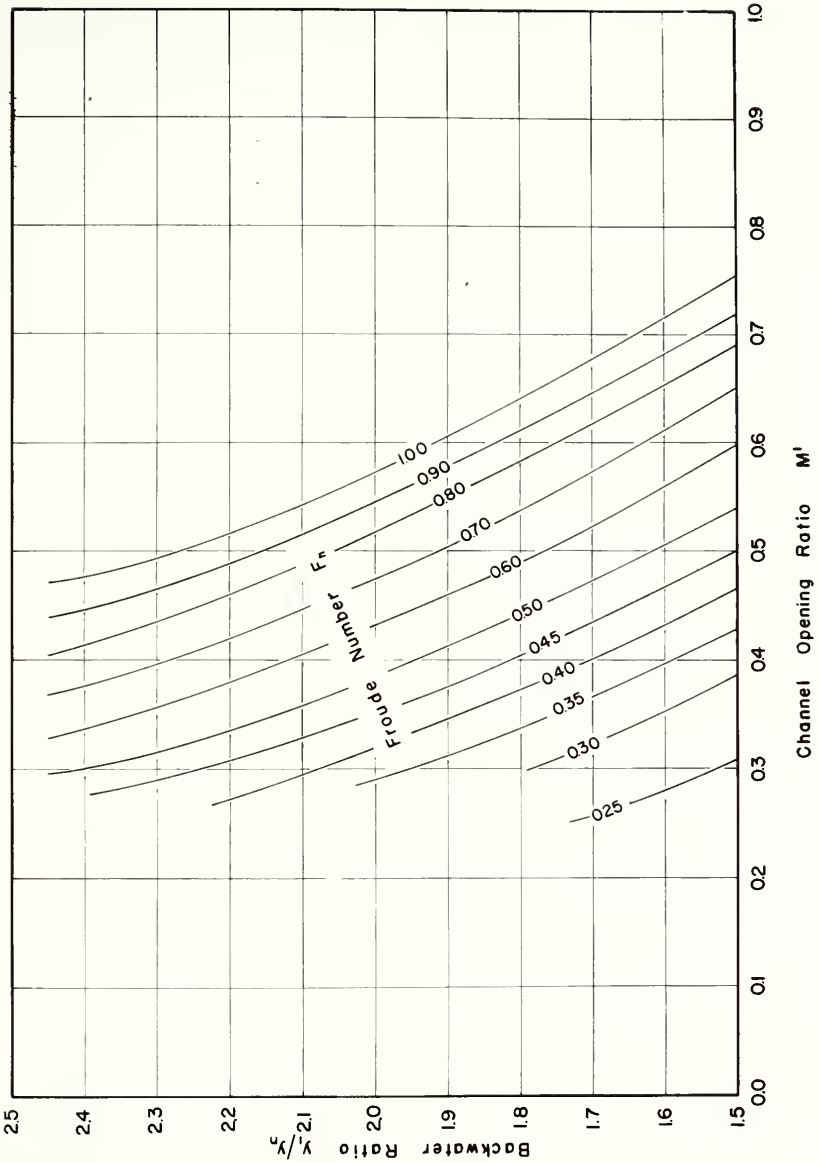


FIGURE 7-2-1b BACKWATER RATIO VS CHANNEL OPENING RATIO L/b=0 SEMI-CIRC. ROUGH CHANNEL $1.50 \leq y_1/y_n \leq 2.50$

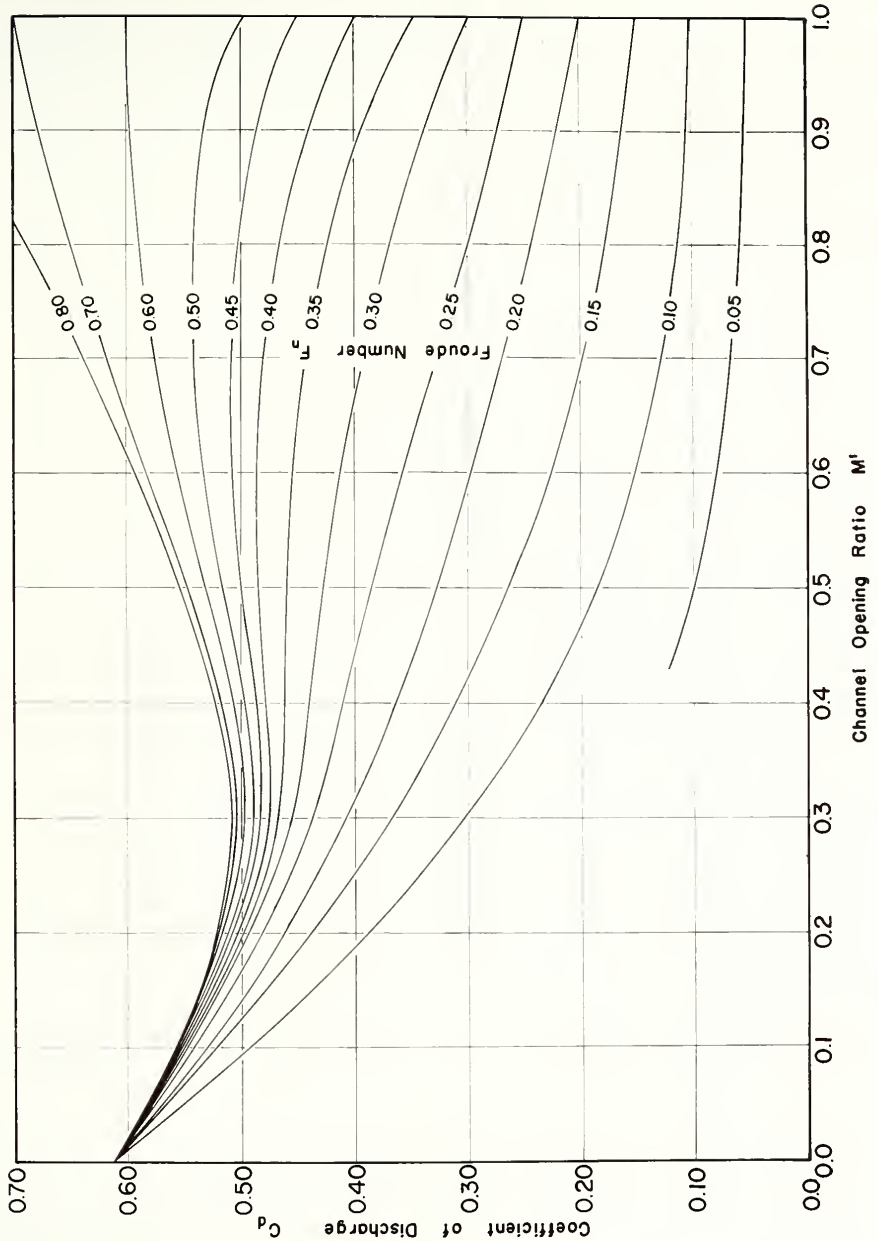


FIGURE 7-2-2 DISCHARGE COEF. VS CHANNEL OPENING RATIO L/b=0 SEMI-CIRC. ROUGH CHANNEL

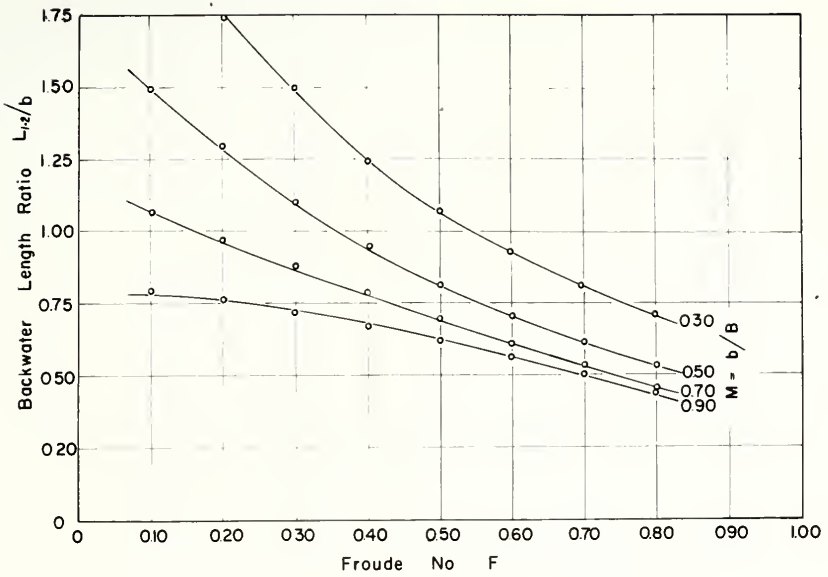


FIGURE 7-2-3a LENGTH TO MAXIMUM BACKWATER

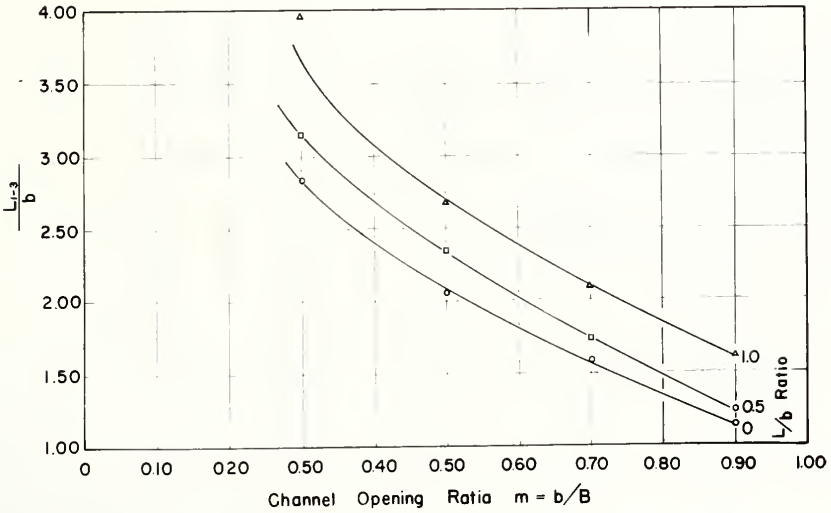


FIGURE 7-2-3b LENGTH OF SURFACE PROFILE BETWEEN y_1 & y_3

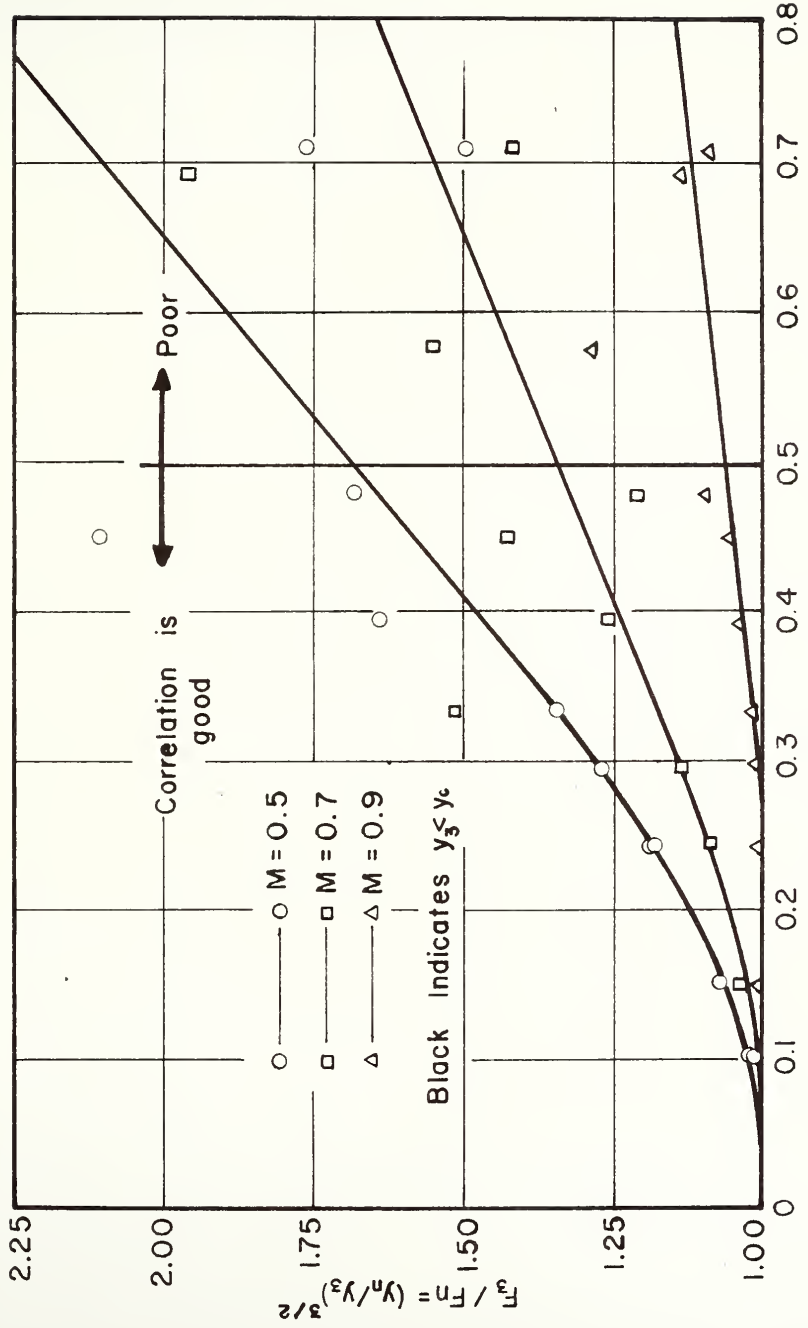


FIG 7-2-4 CORRELATION CURVE OF F_3

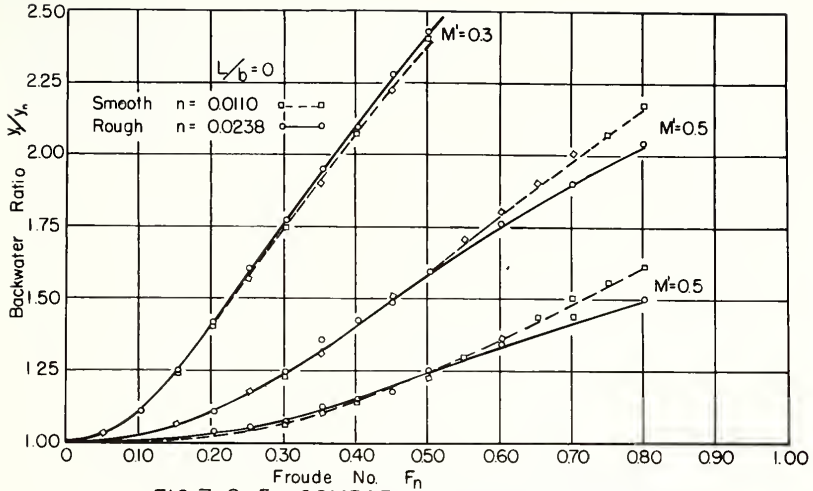


FIG. 7-2-5a COMPARISON BETWEEN BACKWATER RATIOS IN SMOOTH AND ROUGH CHANNELS

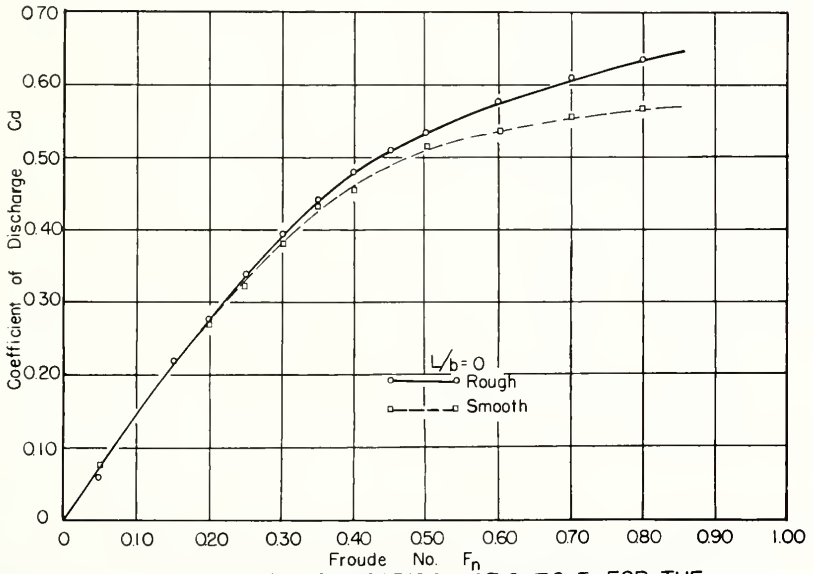


FIG 7-2-5b COMPARISON OF Cd TO F_n FOR THE TWO ROUGHNESS CONDITIONS M'=0.7

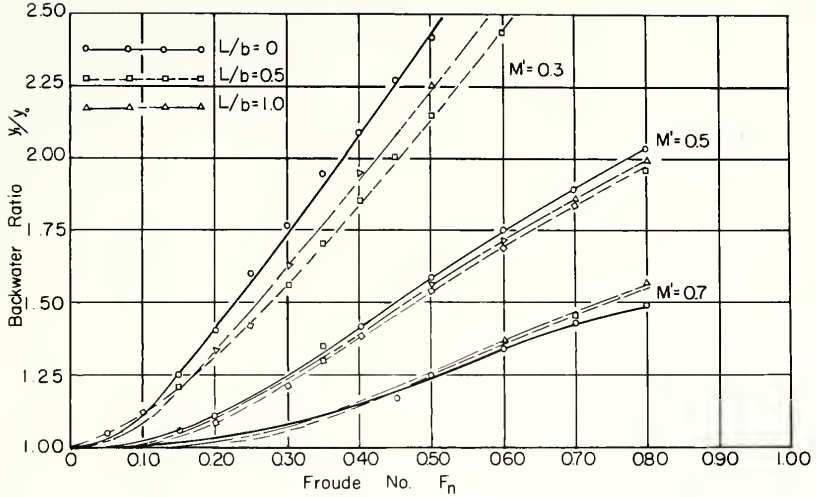


FIG. 7-2-6a COMPARISON BETWEEN BACKWATER RATIOS FOR BRIDGE LENGTHS - ROUGH CHANNEL

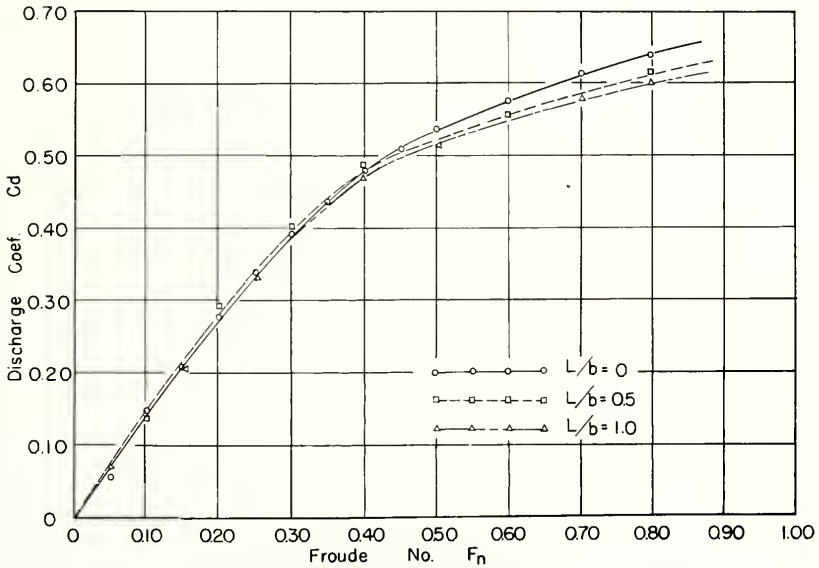


FIG. 7-2-6b COMPARISON BETWEEN DISCHARGE COEFFICIENTS FOR BRIDGE LENGTHS - ROUGH CHANNEL - M' = 0.7

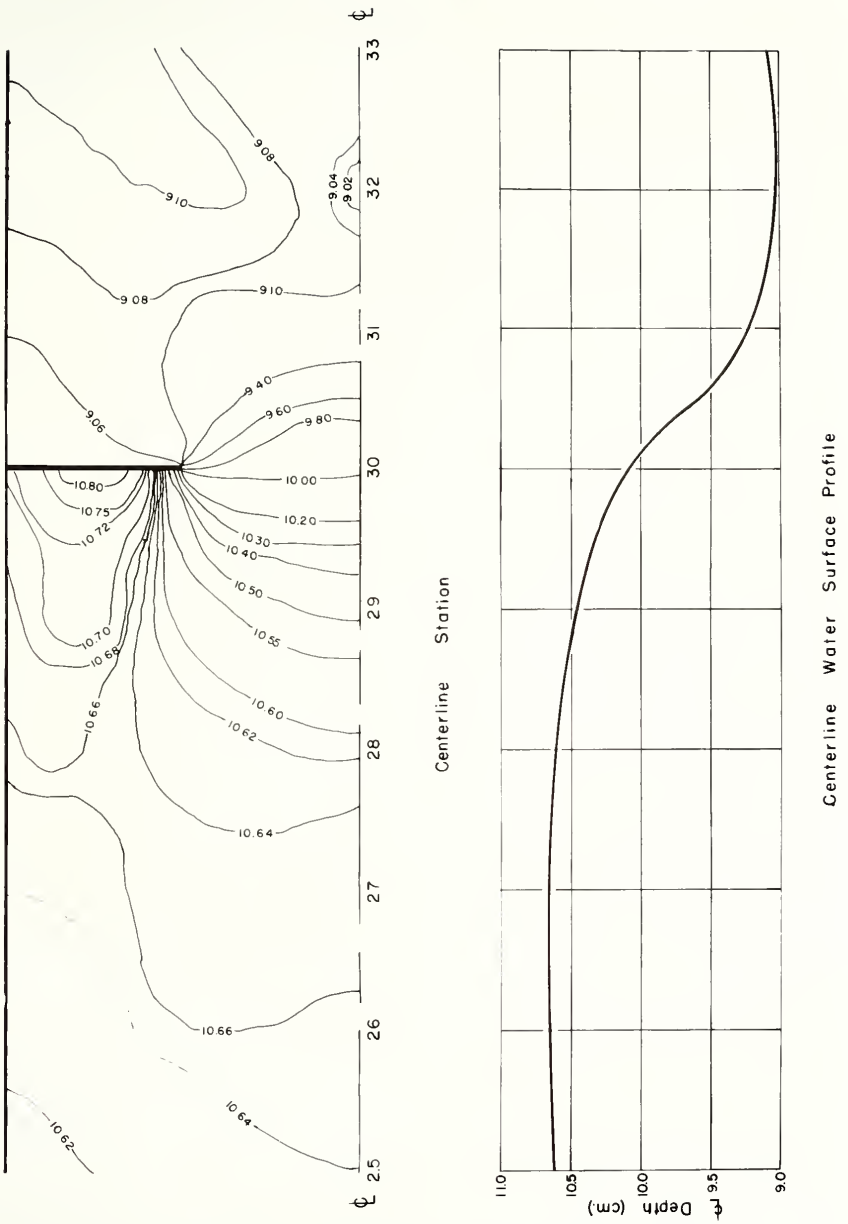


FIGURE 7-2-7 SURFACE TOPOGRAPHY Q = 1 CFS,
S = 0.000584, M = 0.5, L/b = 0

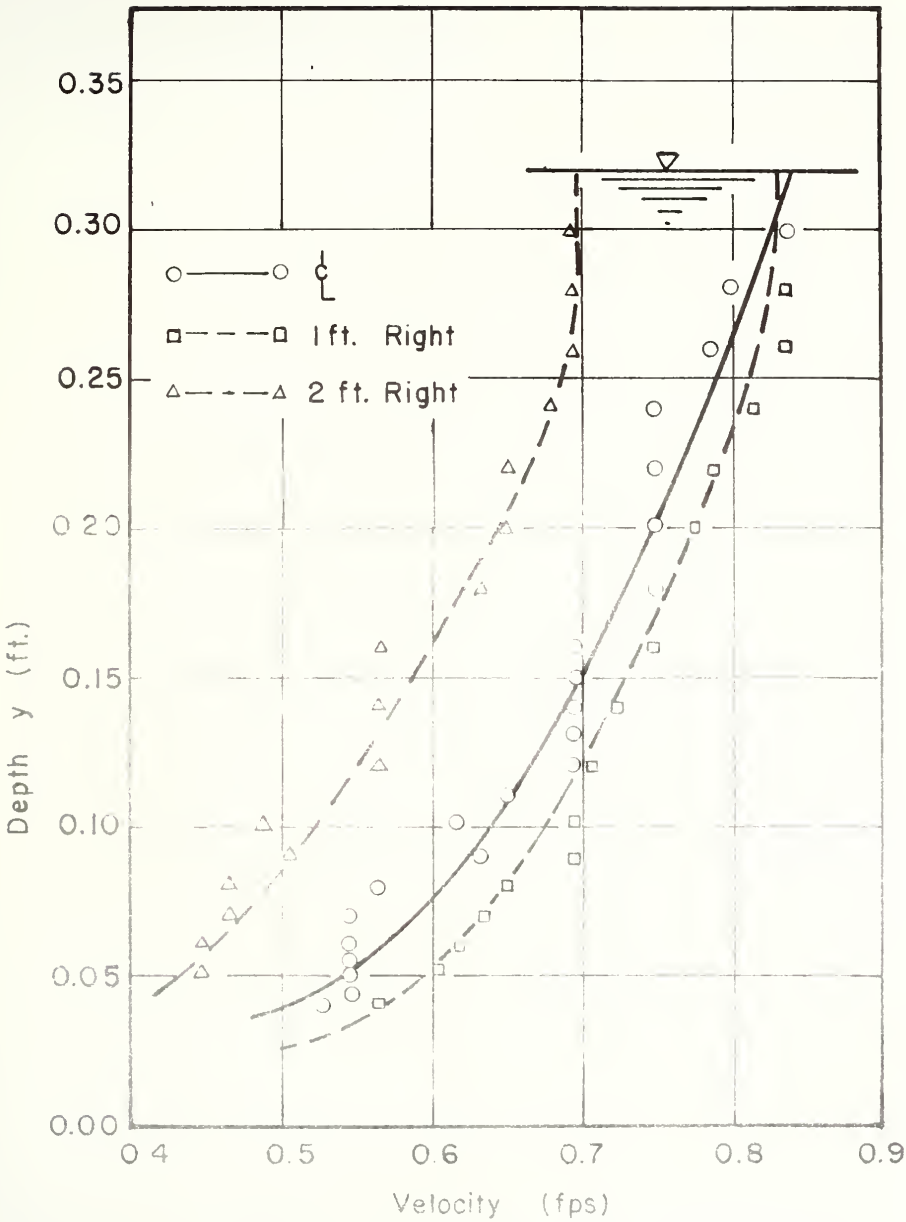


FIG 7-2-8 VELOCITY PROFILES AT MAXIMUM BACKWATER Q = 1CFS, S = 0.000584, M = 0.5, L/b = 3

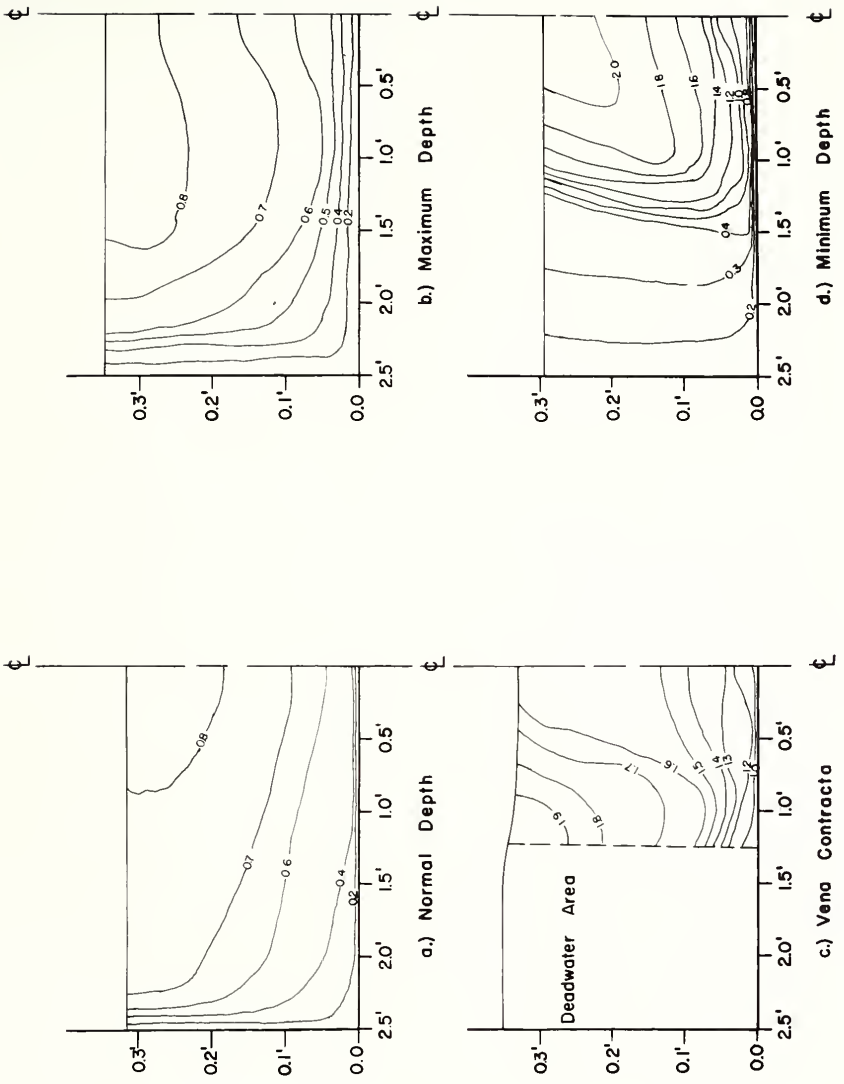


FIG. 7-2-9 ISOVEL DIAGRAMS IN FPS Q=1CFS, S=0.0000584, M=0.5, L/b=0

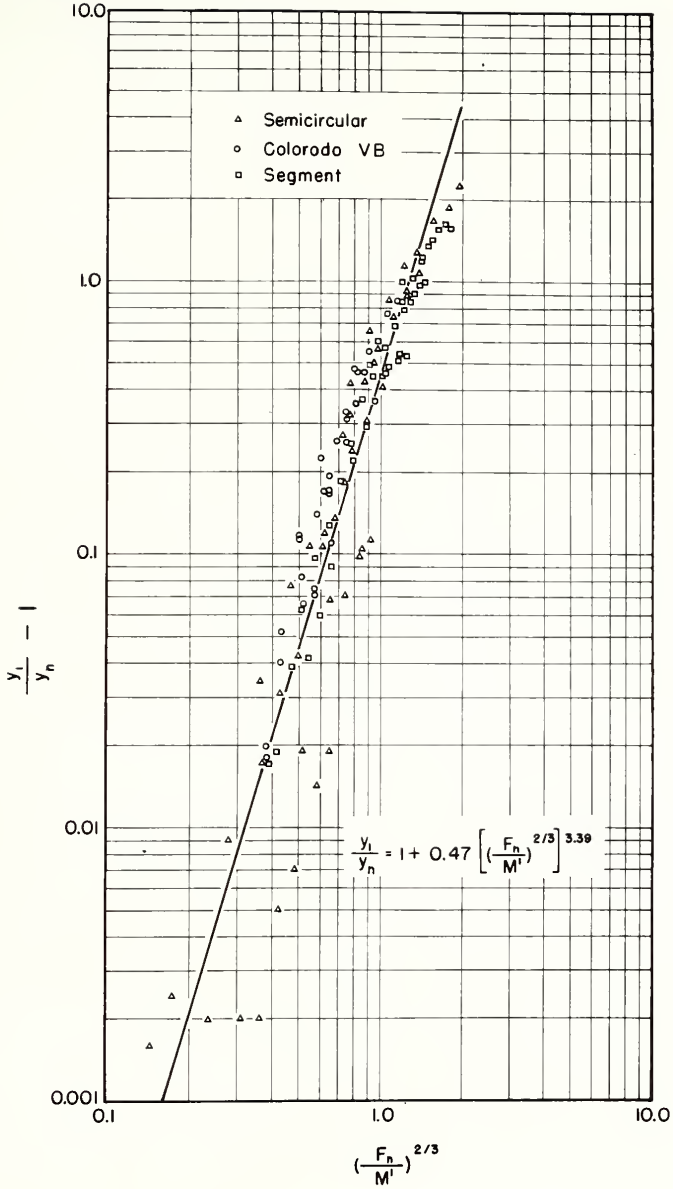


FIGURE 7-2-10 GENERALIZED BACKWATER RATIO

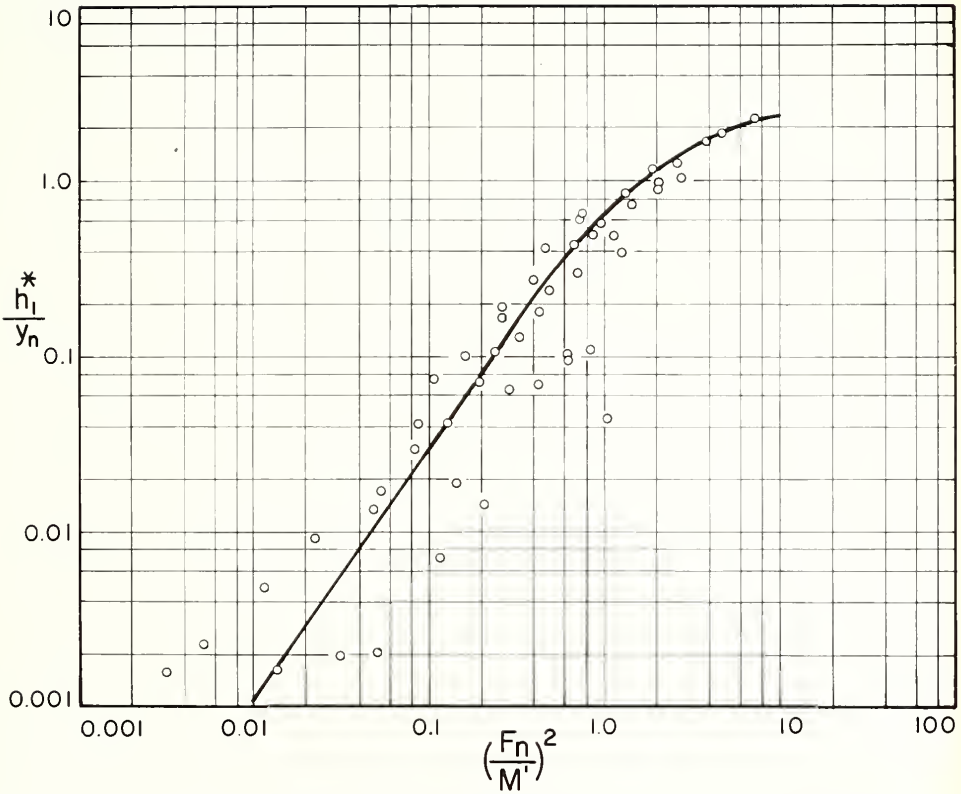


FIGURE 7-2-11 BACKWATER RATIO FOR GEOMETRY I_a, ROUGH BOUNDARY $\frac{L}{b} = 0.0$

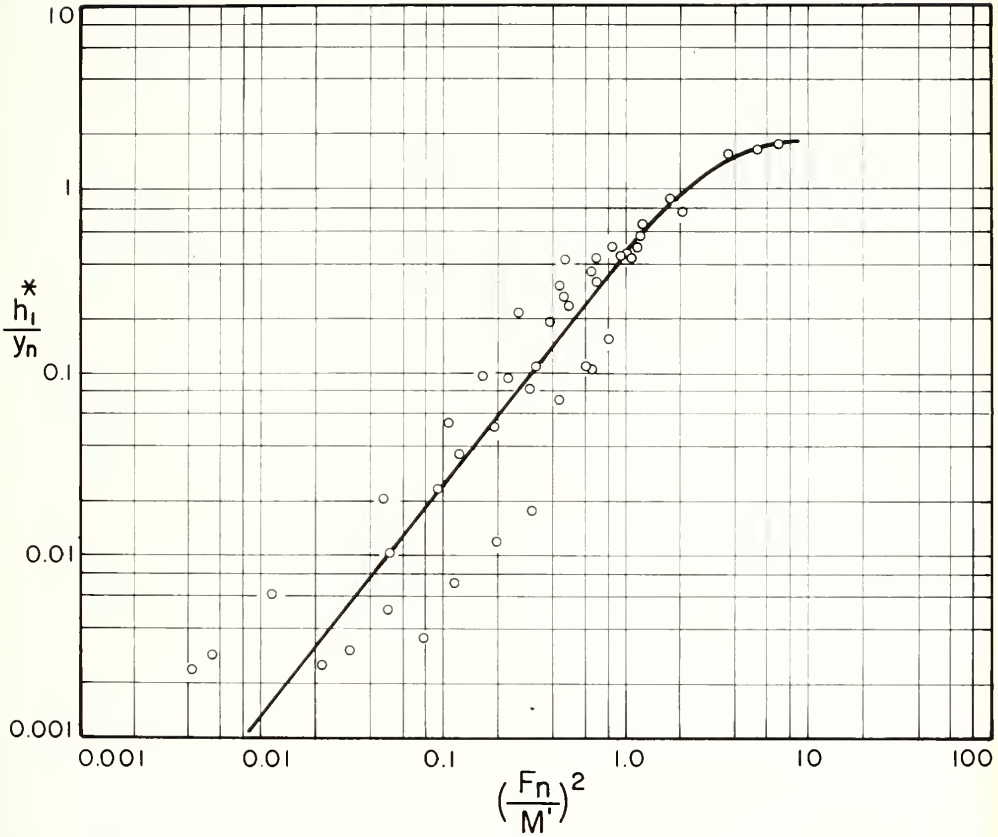


FIGURE 7-2-12 BACKWATER RATIO FOR GEOMETRY I_b, ROUGH BOUNDARY $\frac{L}{b} = 0.5$

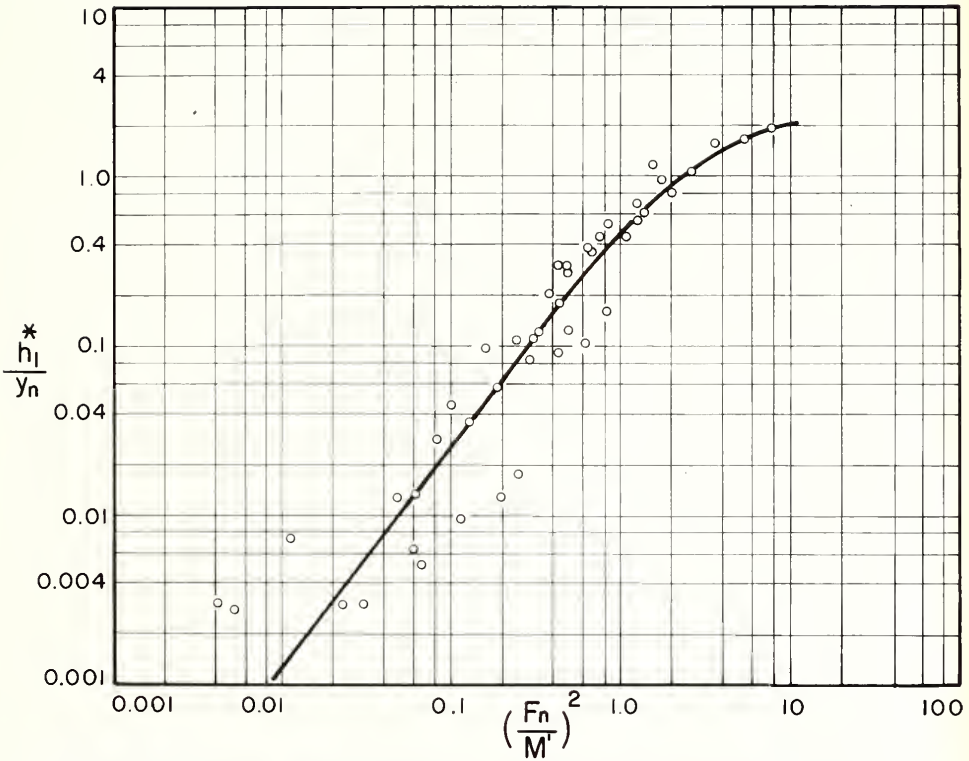


FIGURE 7-2-13 BACKWATER RATIO FOR GEOMETRY I_b
ROUGH BOUNDARY $\frac{L}{b} = 1.0$

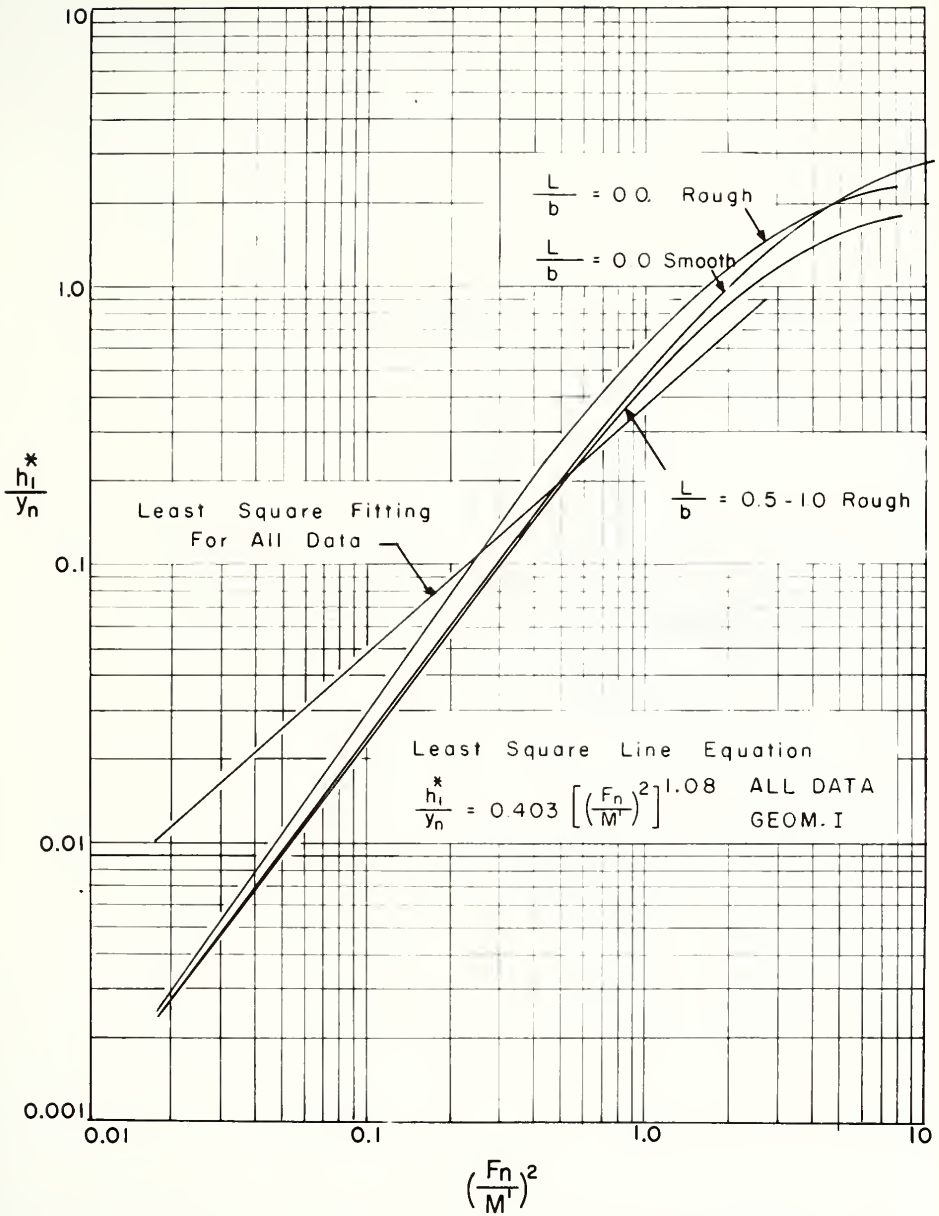


FIGURE 7-2-14 SUMMARY OF BACKWATER RATIO, GEOMETRY I, ROUGH & SMOOTH BOUNDARIES

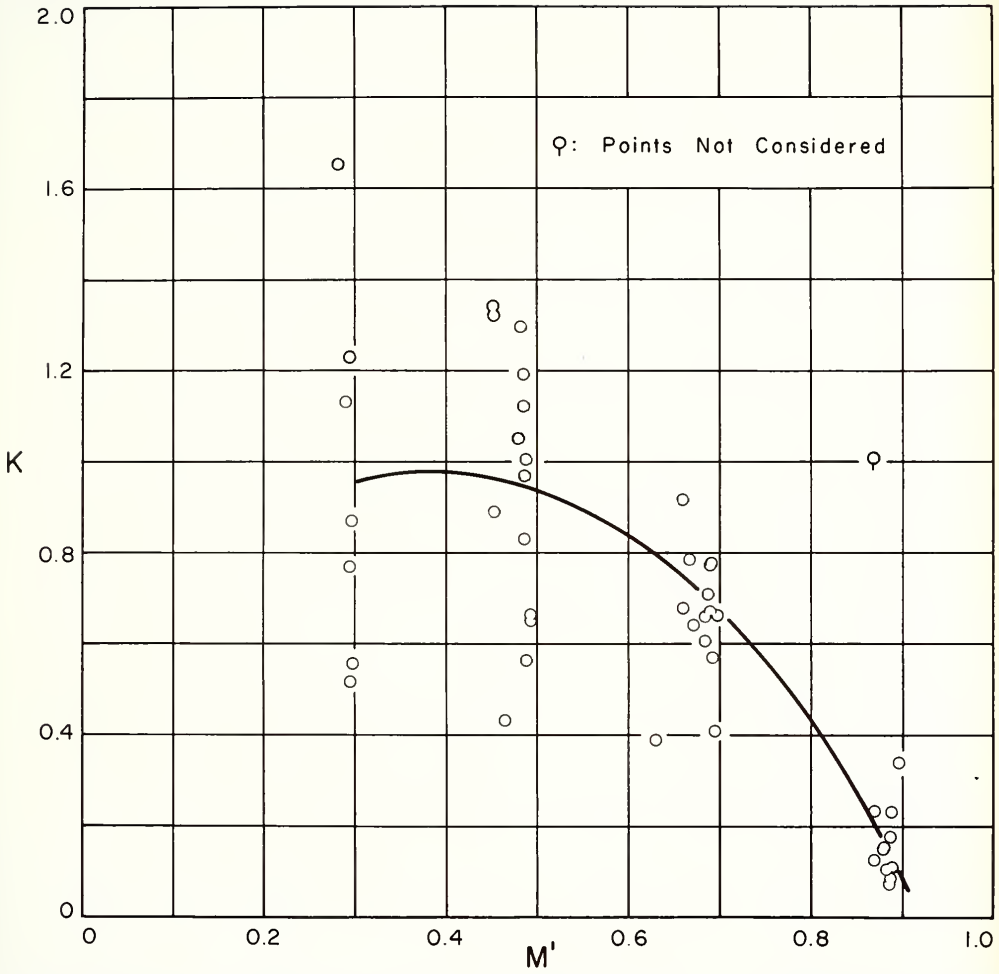


FIGURE 7-2-15 HEAD LOSS COEFFICIENT, GEOMETRY I_a
ROUGH BOUNDARY, $\frac{L}{B} = 0.00$

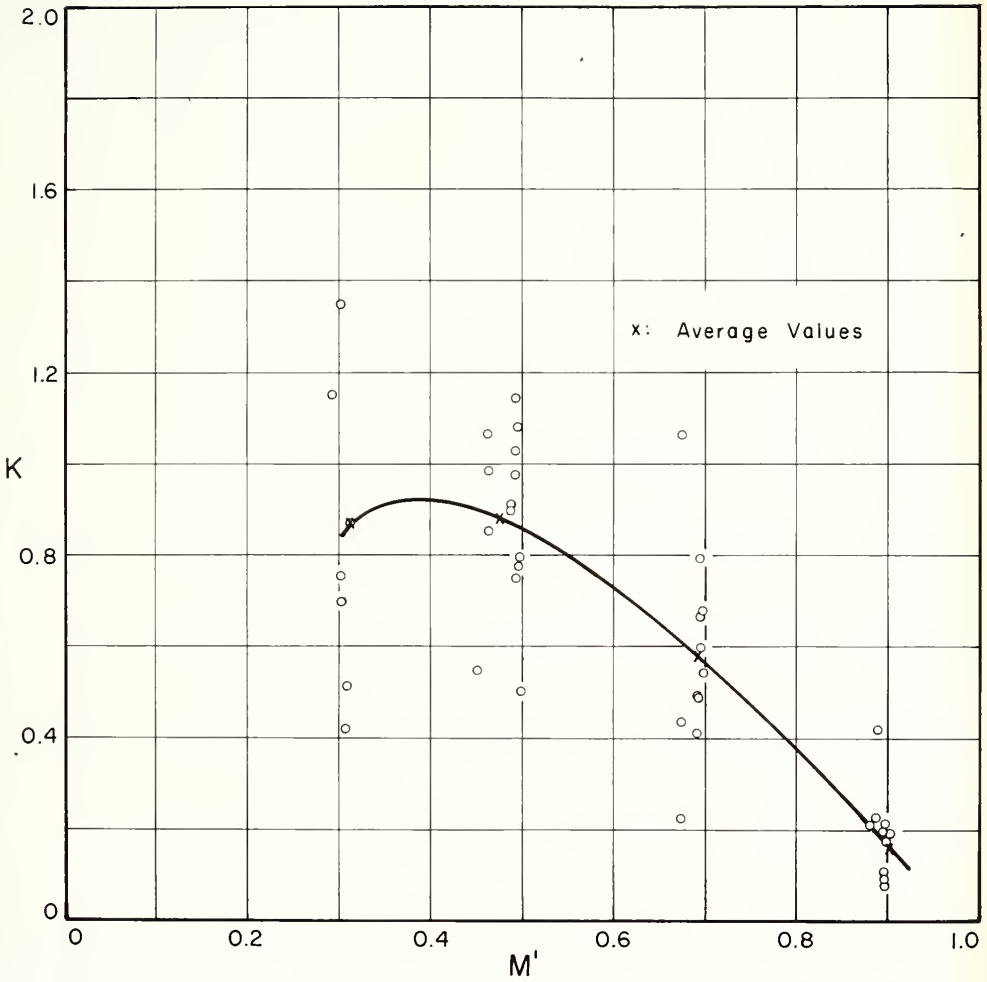


FIGURE 7-2-16 HEAD LOSS COEFFICIENT, GEOMETRY I_b
ROUGH BOUNDARY $\frac{L}{b} = 0.5$

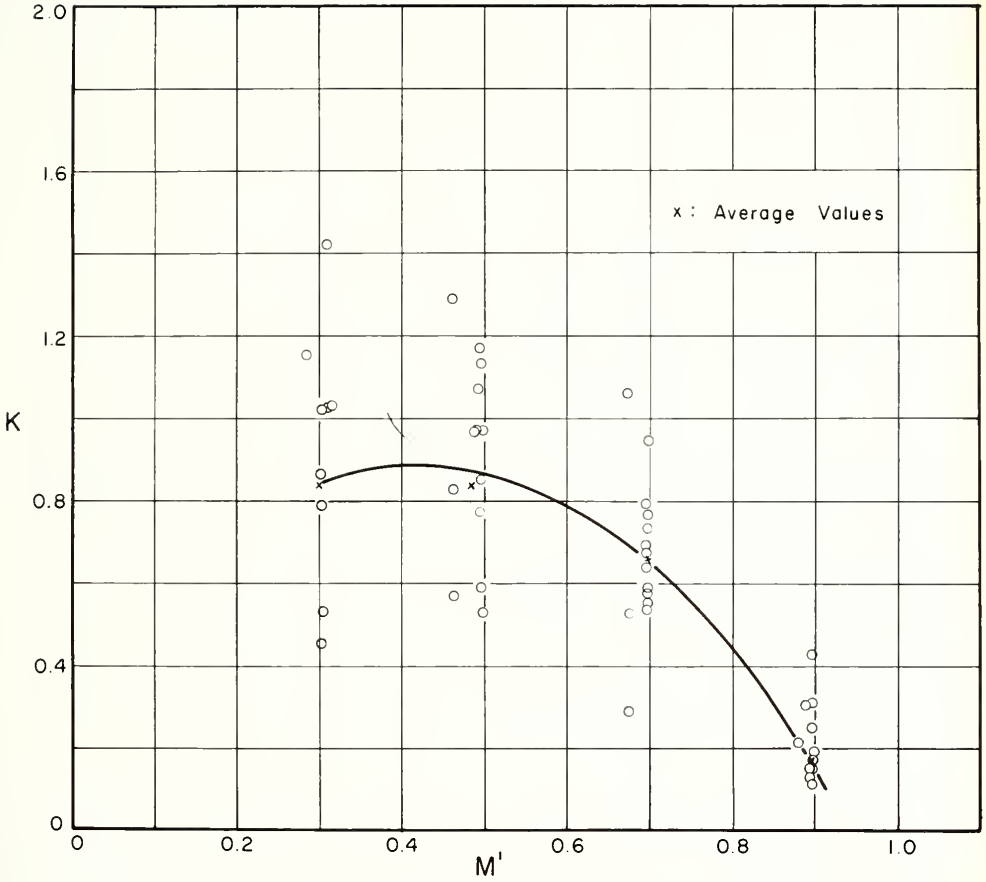


FIGURE 7-2-17 HEAD LOSS COEFFICIENT, GEOMETRY I_b

ROUGH BOUNDARY $\frac{L}{b}$ = 1.0

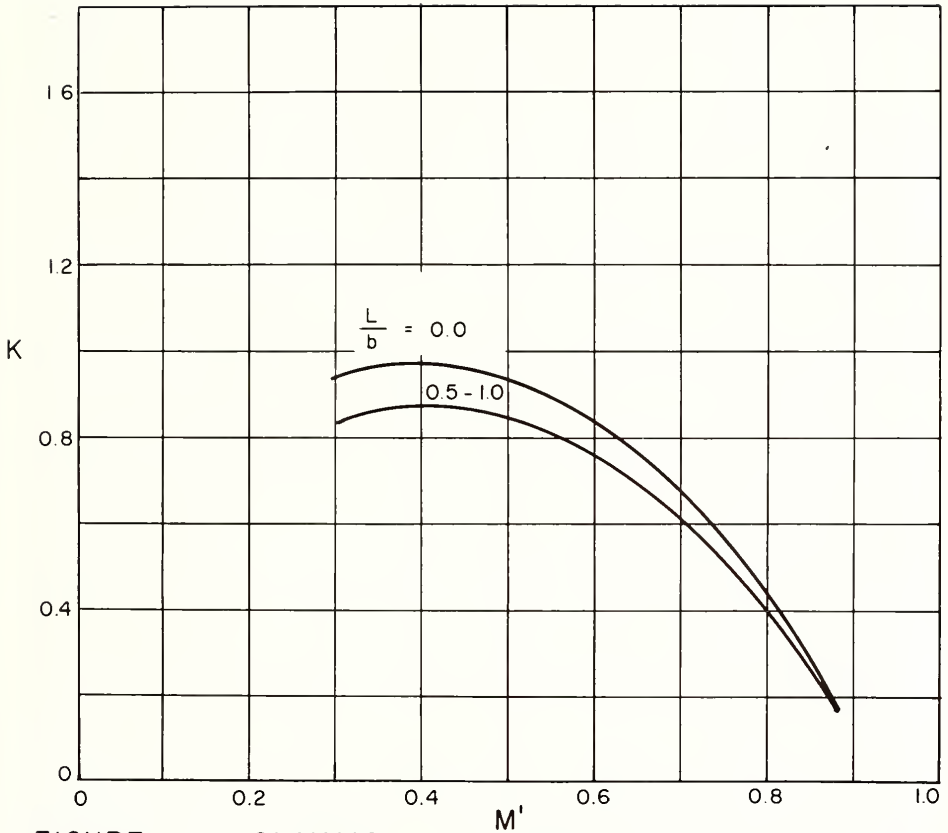


FIGURE 7-2-18 SUMMARY OF HEAD LOSS COEFFICIENTS GEOMETRY Ia & Ib, ROUGH BOUNDARY

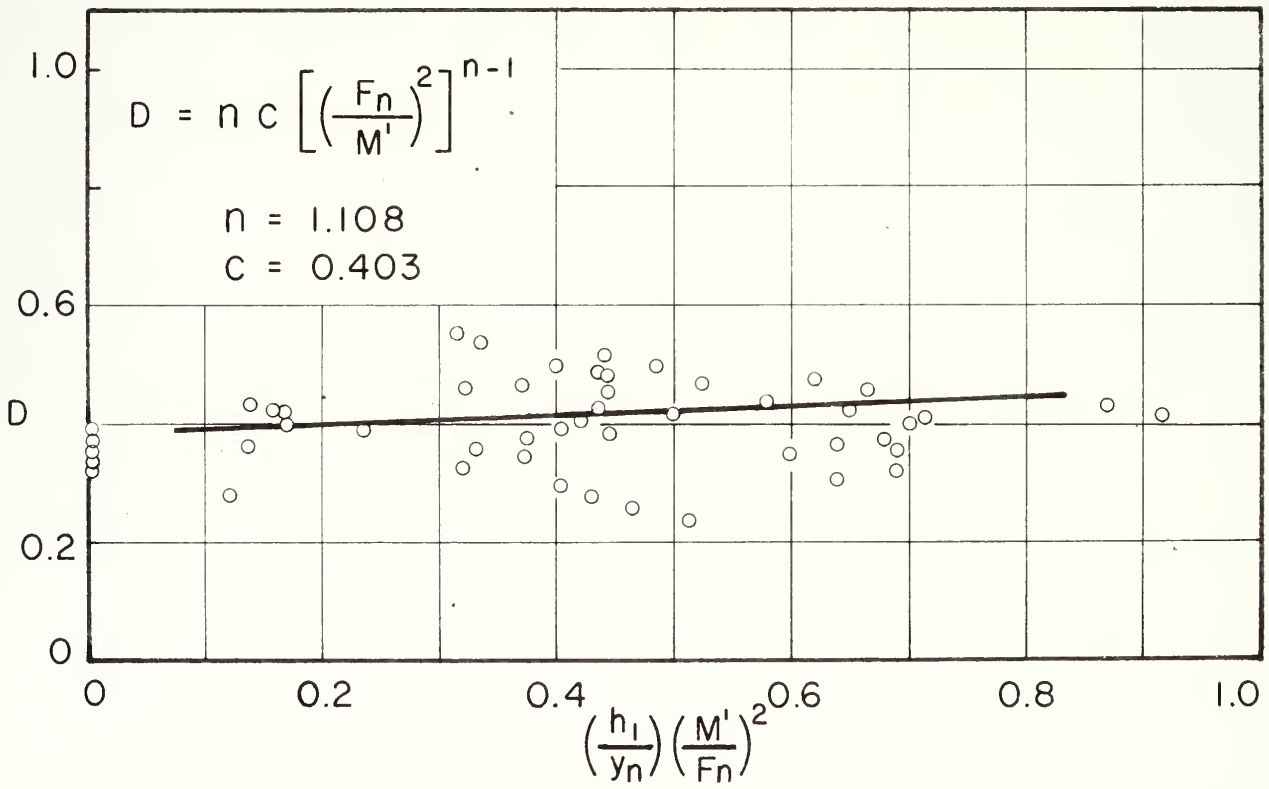


FIGURE 7-2-19 BACKWATER RATIO COEFFICIENT, GEOMETRY Ia
ROUGH BOUNDARY $\frac{L}{b} = 0.00$

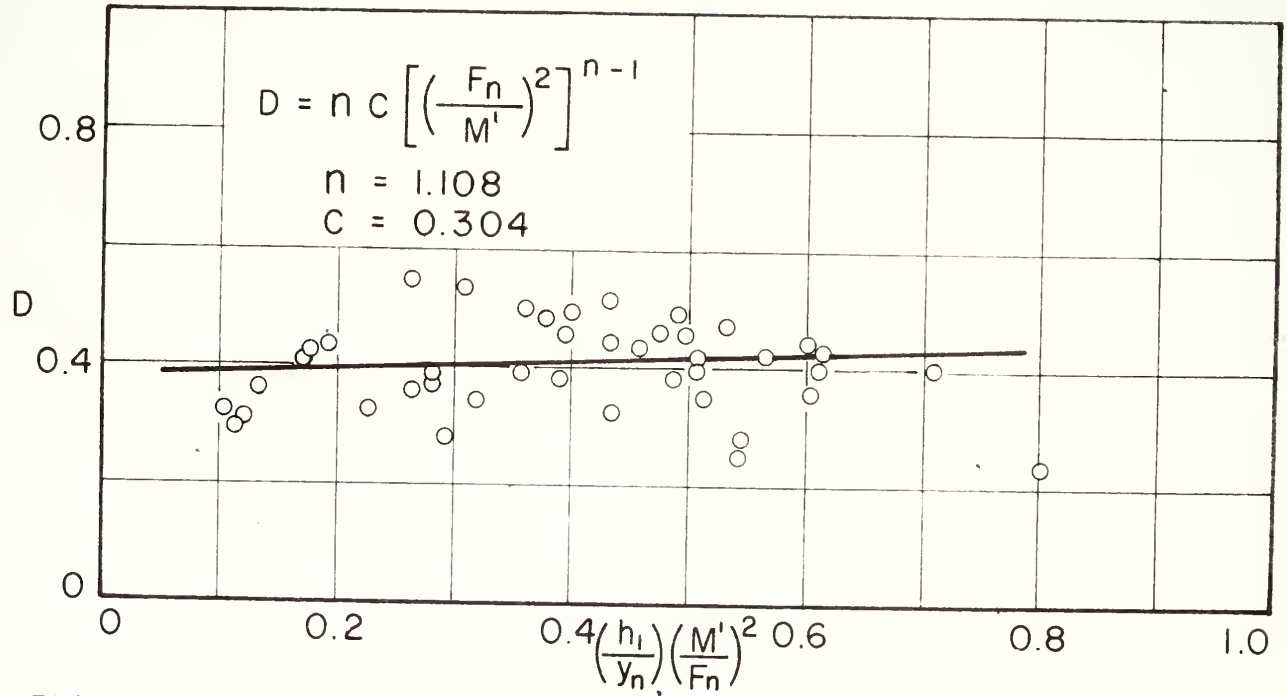


FIGURE 7-2-20 BACKWATER RATIO COEFFICIENT, GEOMETRY I_b, ROUGH BOUNDARY $\frac{L}{b} = 0.5$

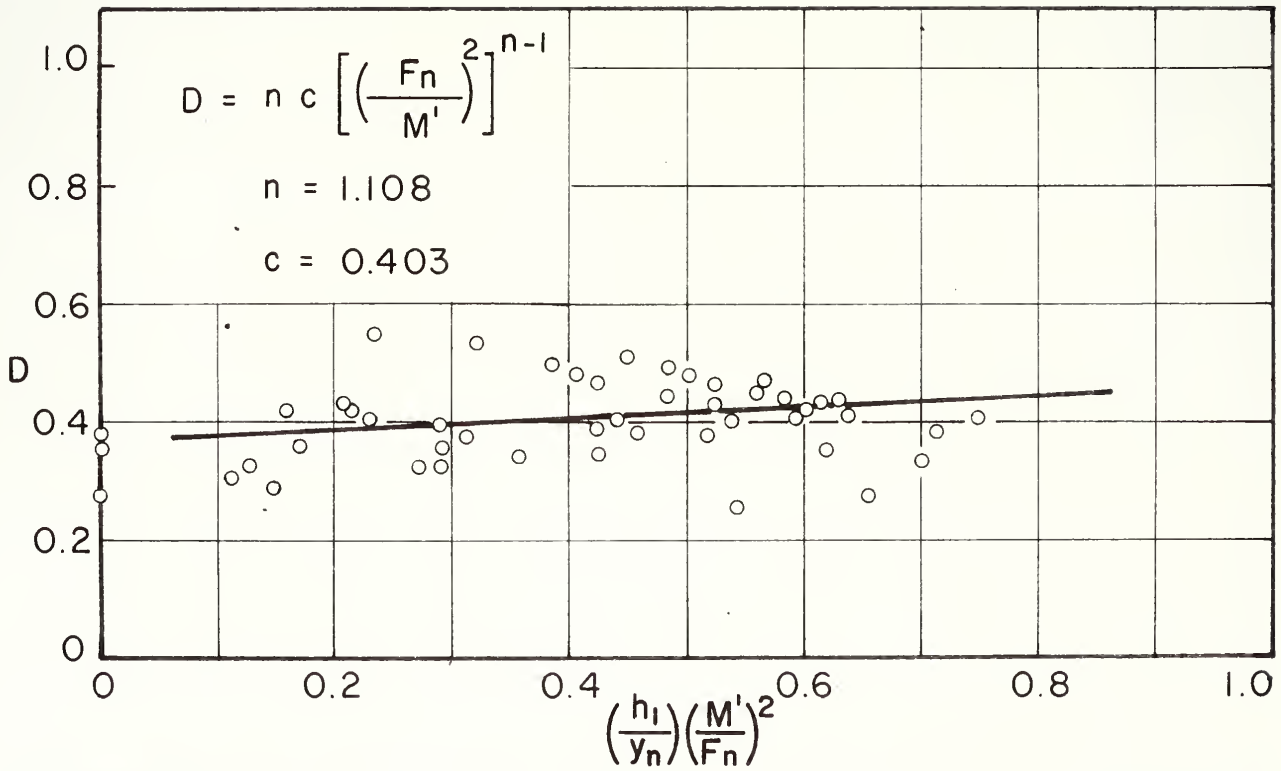
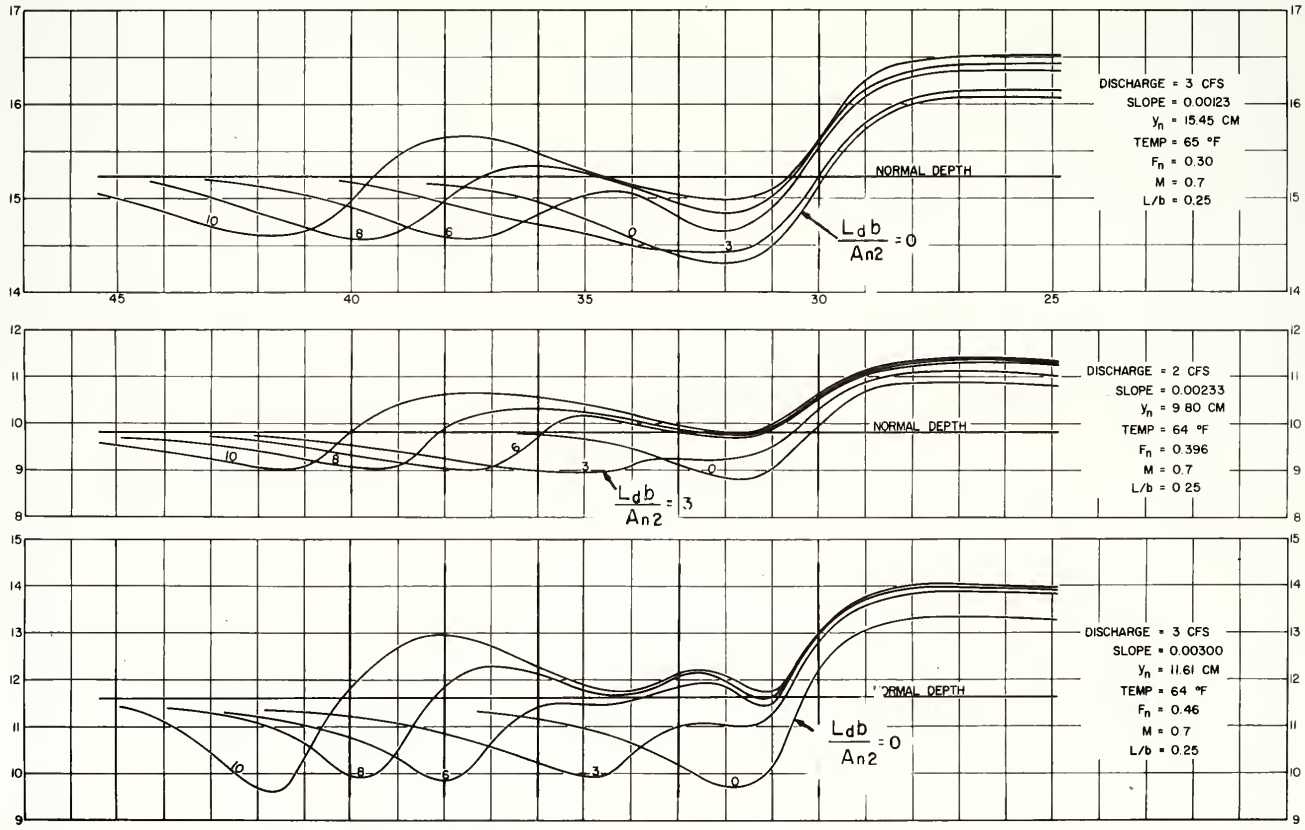


FIGURE 7-2-21 BACKWATER RATIO COEFFICIENT, GEOMETRY I_b
ROUGH BOUNDARY $\frac{L}{b} = 1.0$



MEASURED WATER SURFACE PROFILES ALONG THE CENTERLINE FOR THREE DIMENSIONAL DUAL PARALLEL ARCH BRIDGE MODELS

FIG. 7-3-0

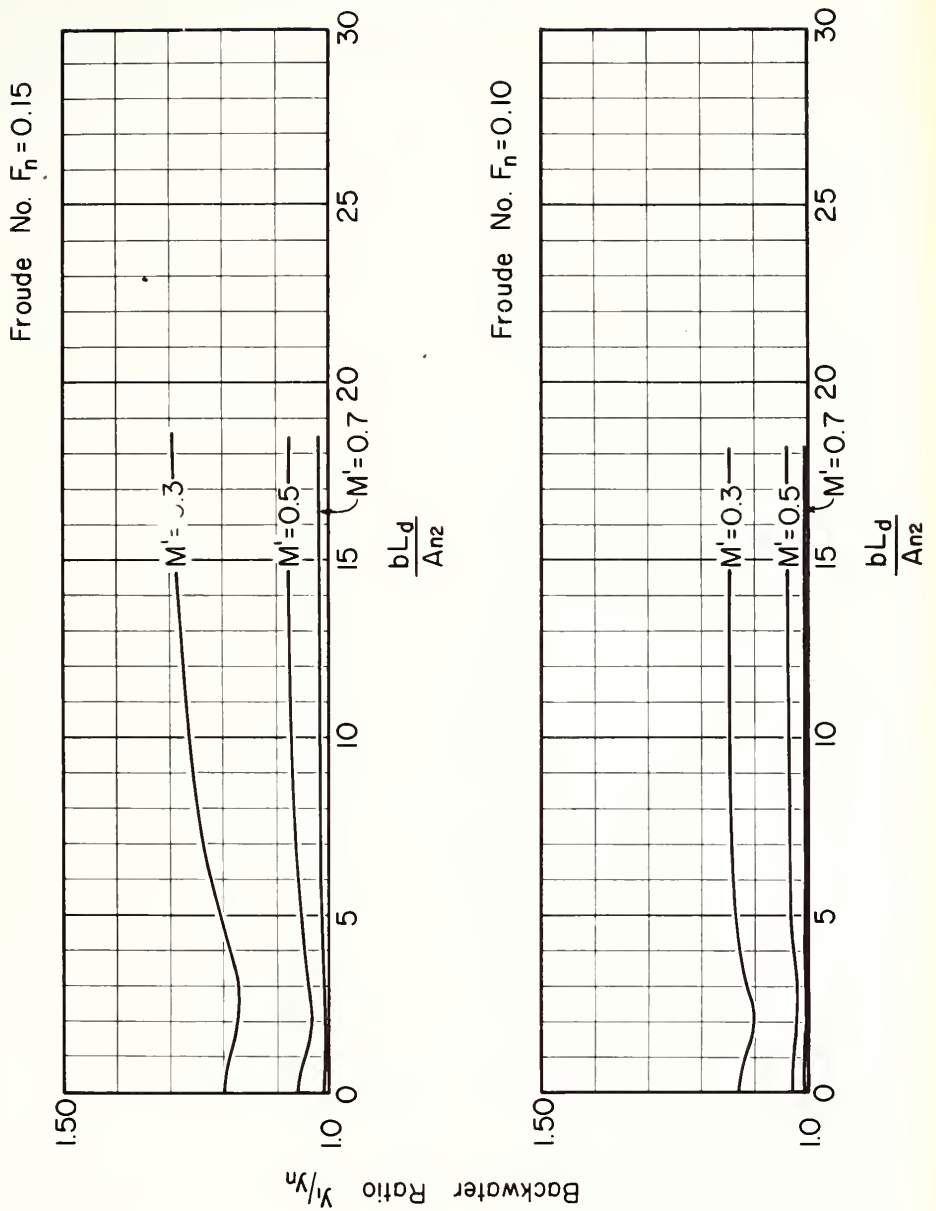


FIG. 7-3-1 BACKWATER RATIO FOR DUAL PARALLEL BRIDGES F_n=0.10, AND 0.15

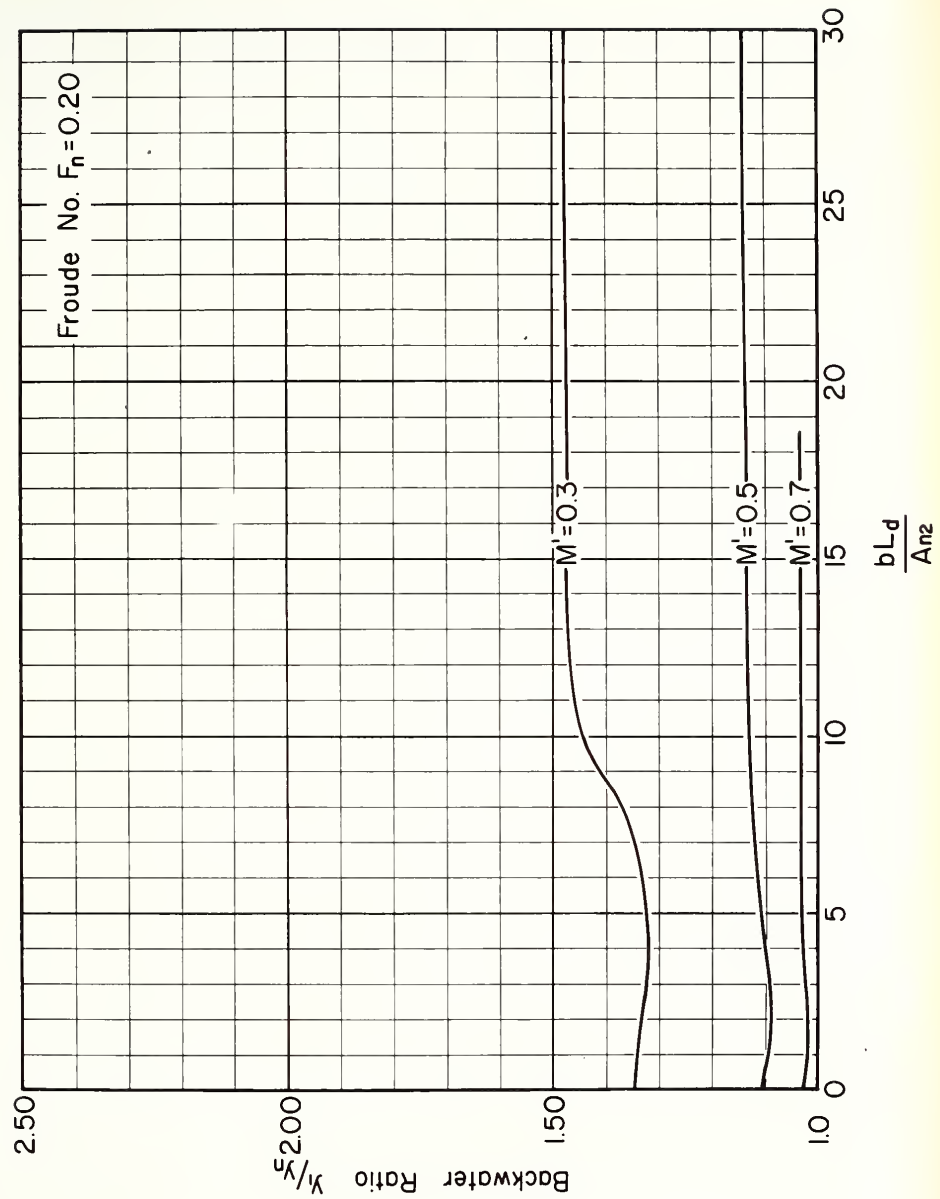


FIG. 7-3-2 BACKWATER RATIO FOR DUAL PARALLEL BRIDGES

F_n = 0.20

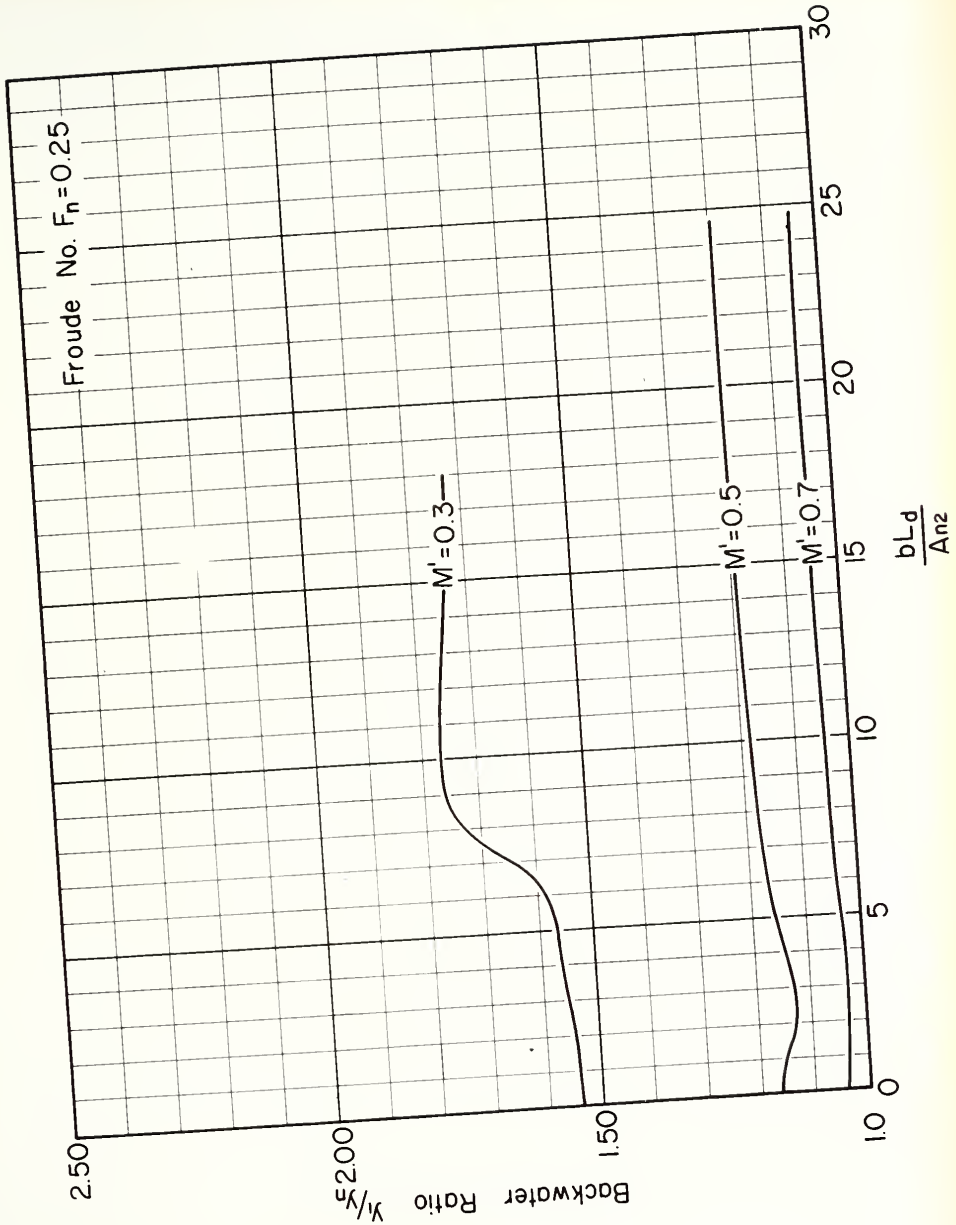


FIG.7-3-3 BACKWATER RATIO FOR DUAL PARALLEL BRIDGES

F_n=0.25

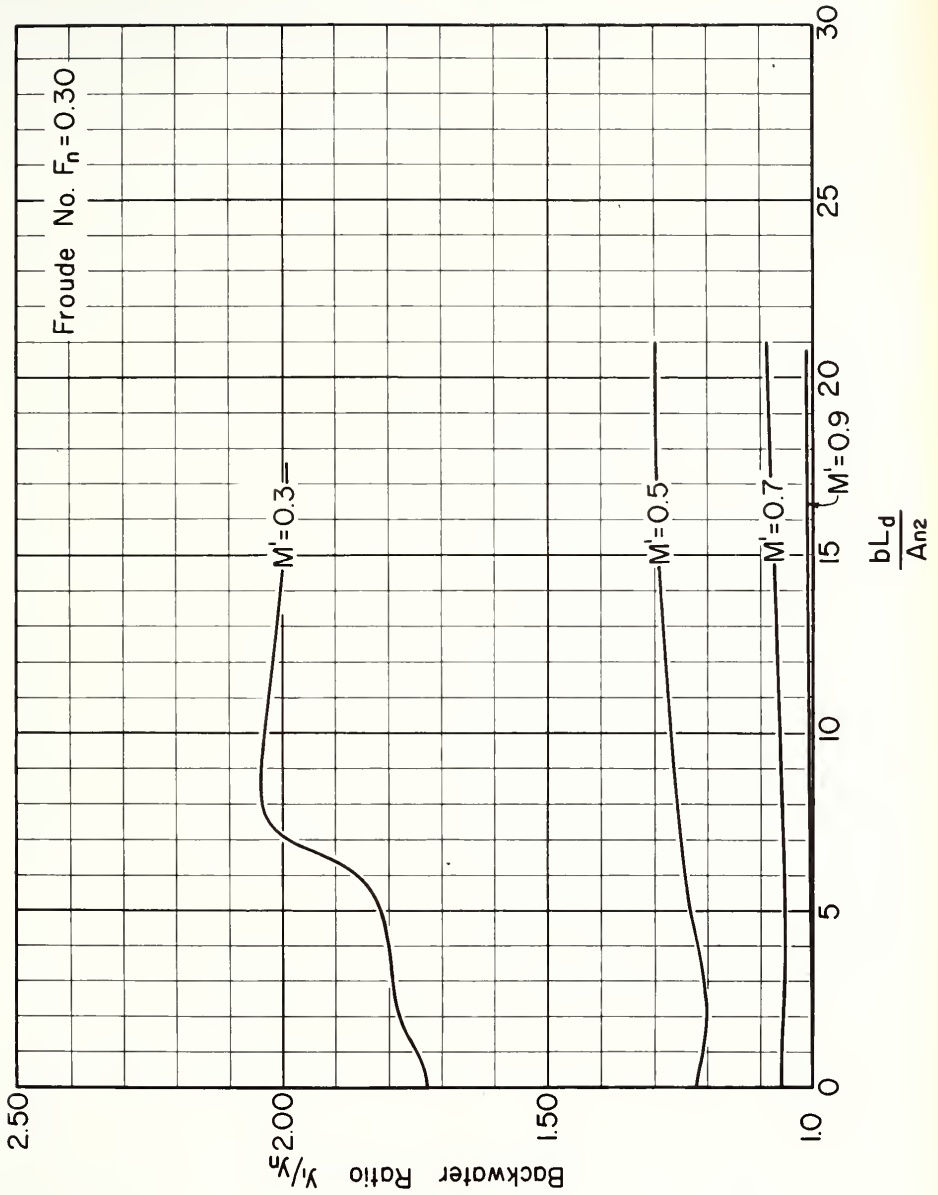


FIG. 7-3-4 BACKWATER RATIO FOR DUAL PARALLEL BRIDGES

F_n = 0.30

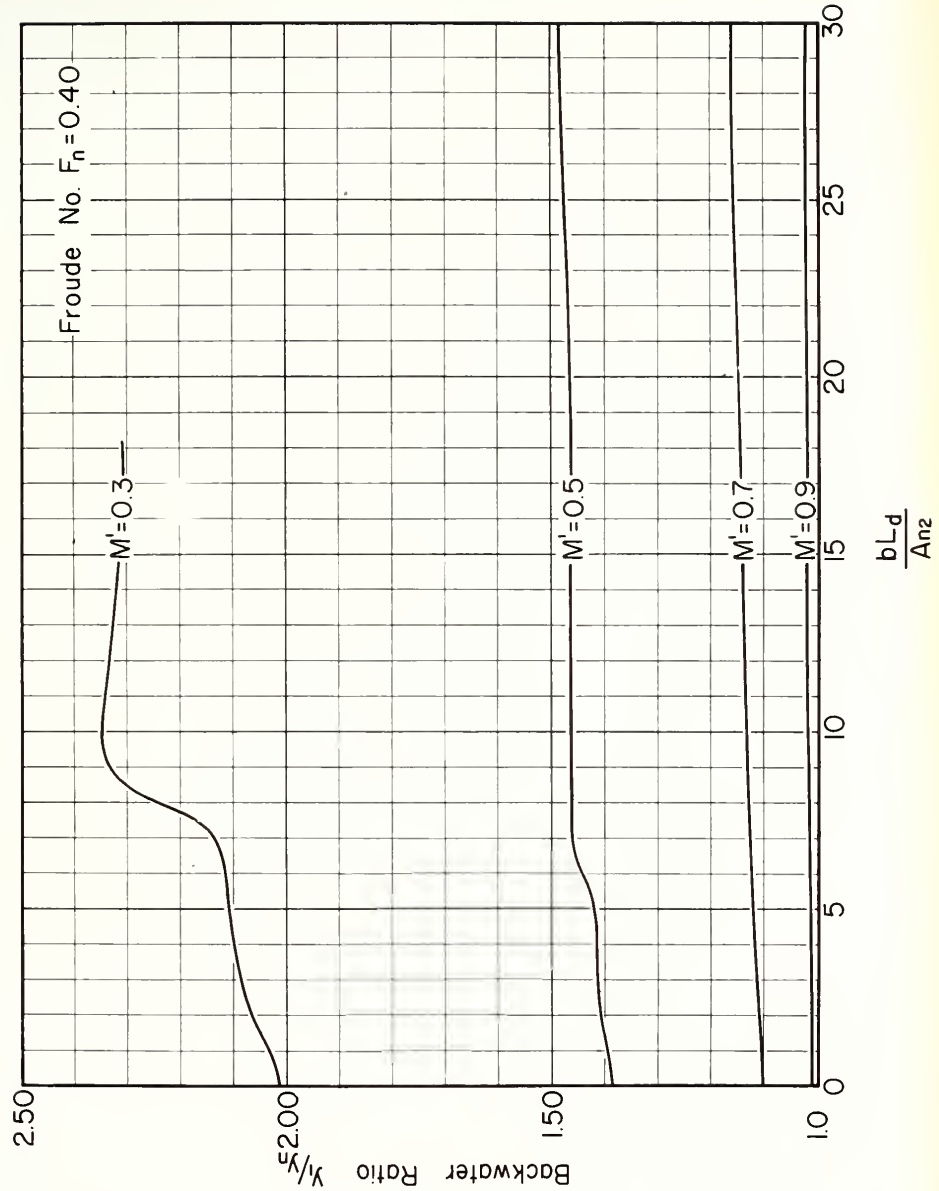


FIG. 7-3-5 BACKWATER RATIO FOR DUAL PARALLEL BRIDGES

F_n = 0.40

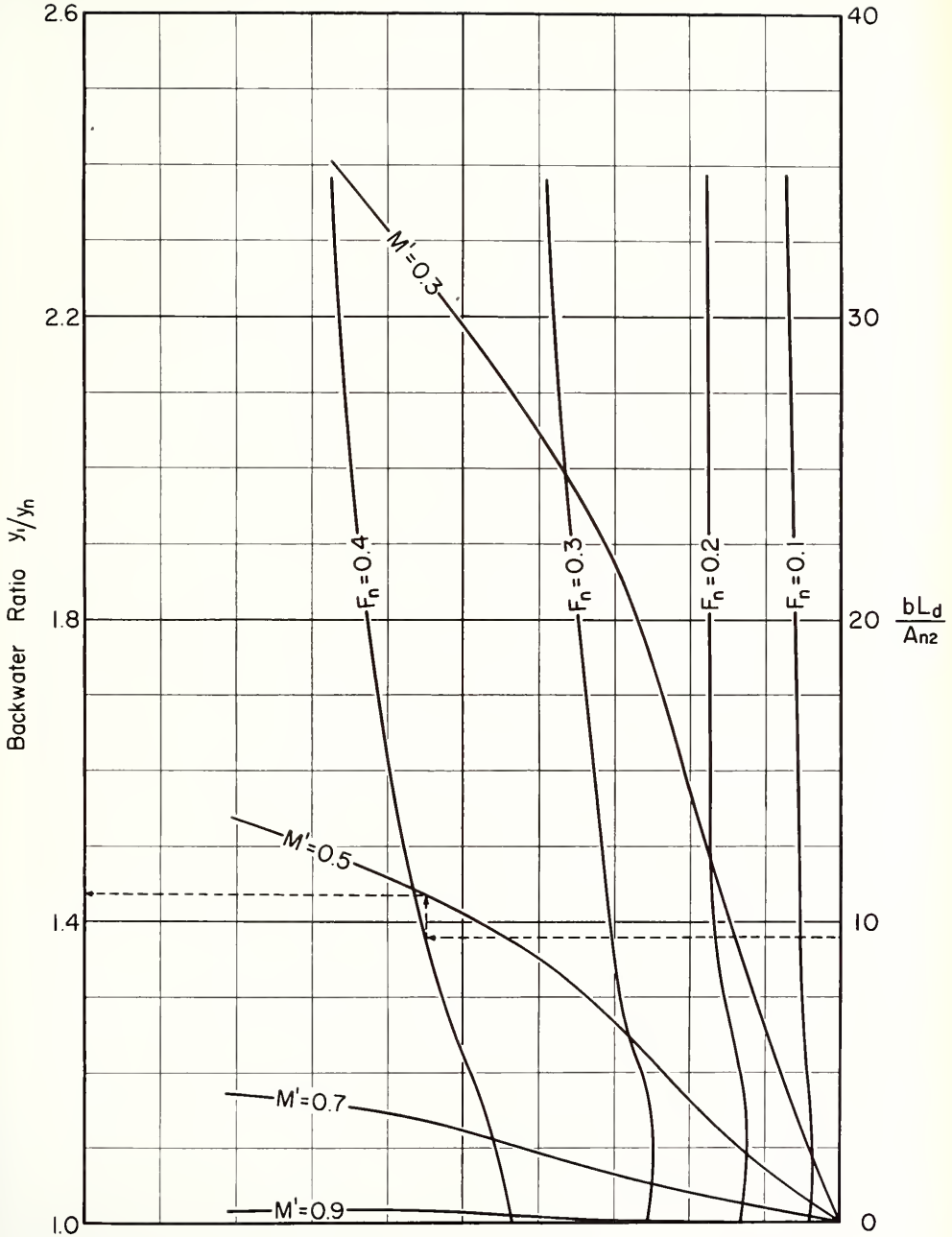
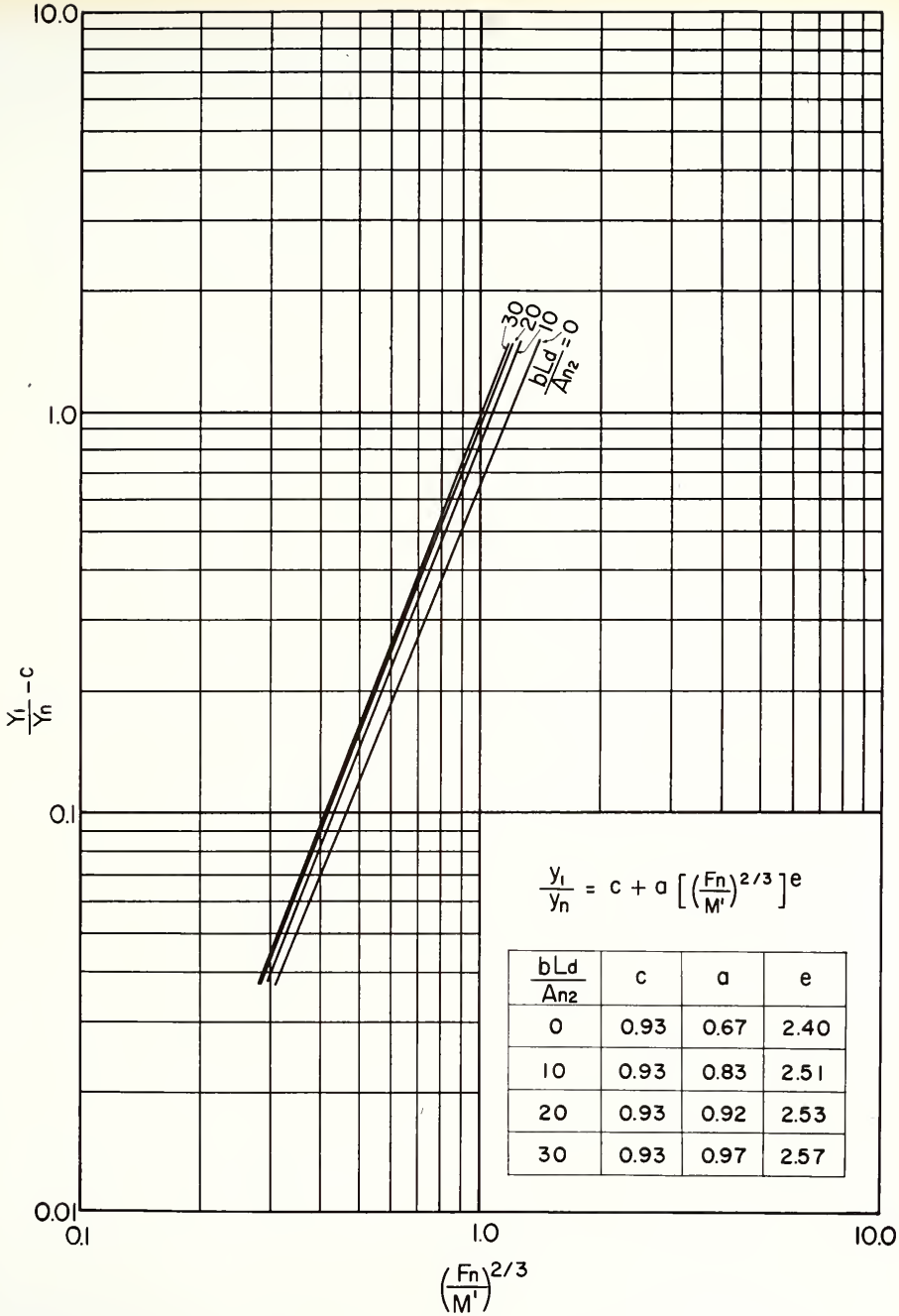


FIG. 7-3-6 BACKWATER RATIO FOR DUAL PARALLEL BRIDGES



$\frac{bLd}{An_2}$	c	a	e
0	0.93	0.67	2.40
10	0.93	0.83	2.51
20	0.93	0.92	2.53
30	0.93	0.97	2.57

FIG. 7-3-7 - GENERALIZED BACKWATER RATIO FOR DUAL PARALLEL BRIDGES

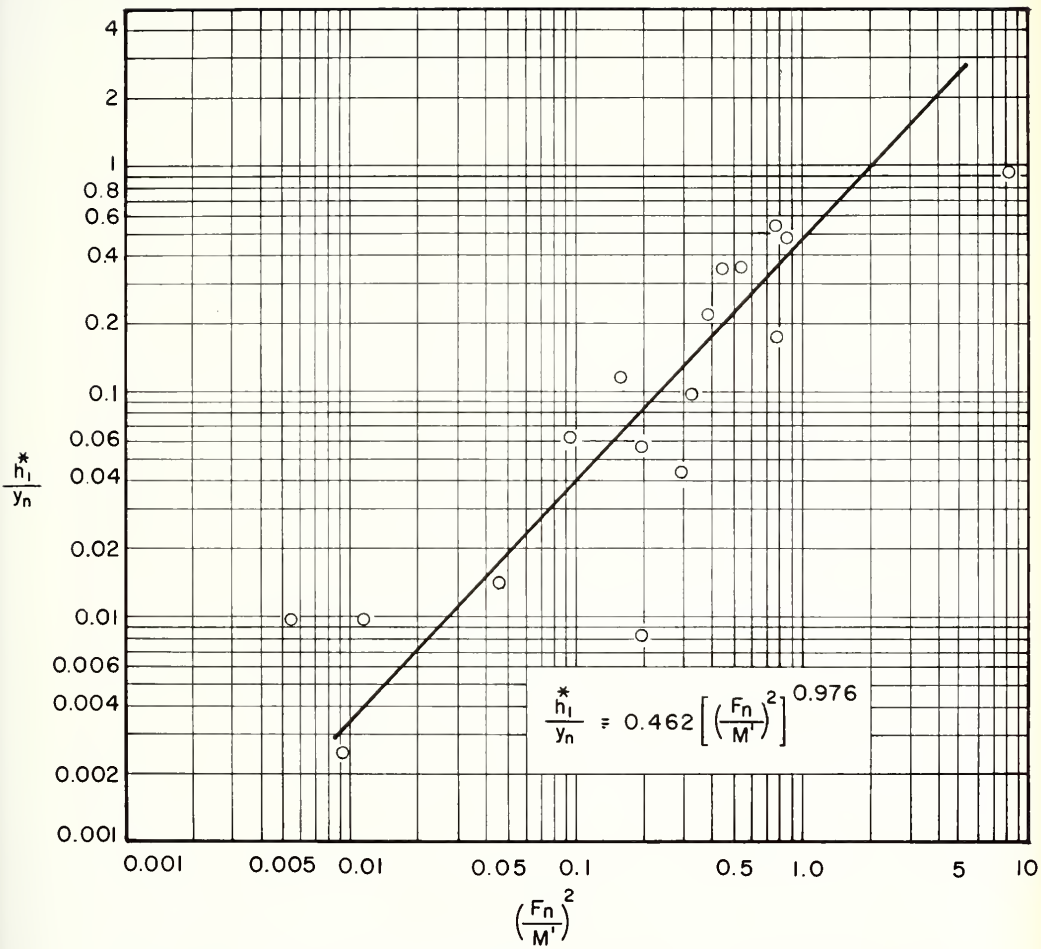


FIGURE 7-3-8 BACKWATER RATIO, GEOMETRY II

ROUGH BOUNDARY $\frac{L_{db}}{An2} = 0.00$

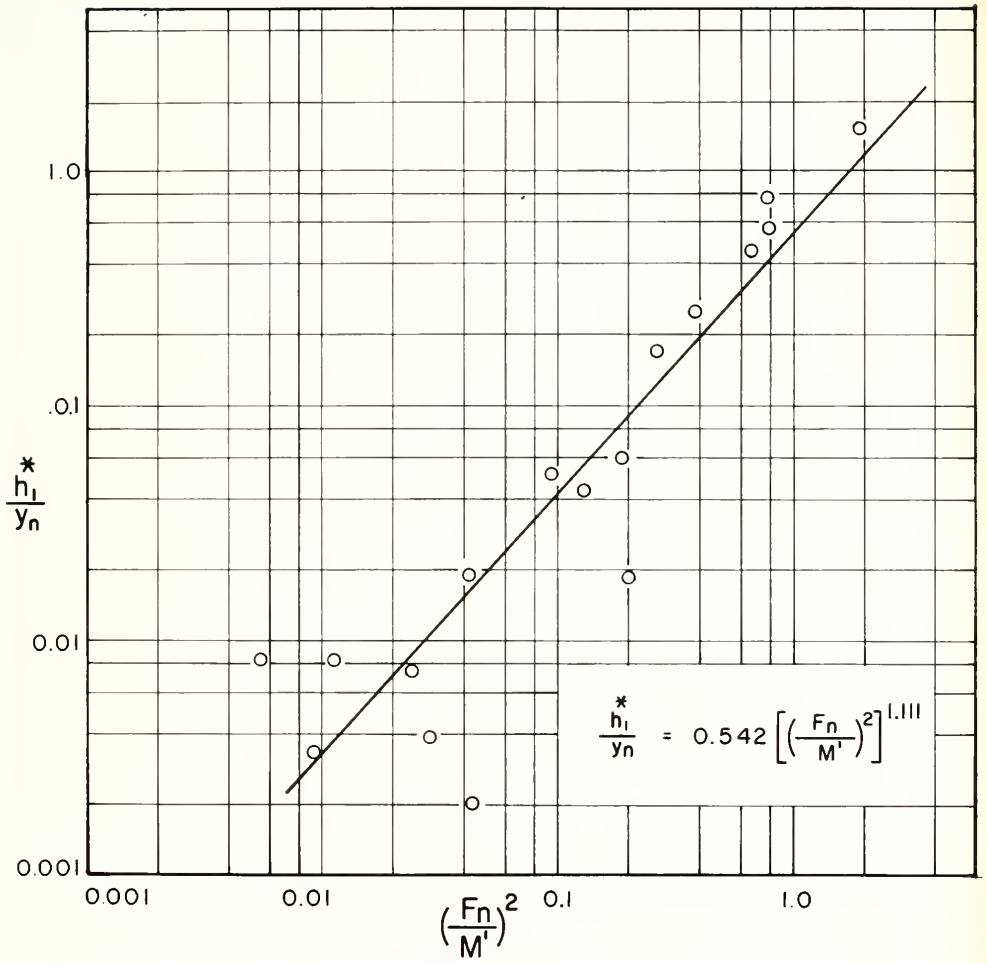


FIGURE 7-3-9 BACKWATER RATIO FOR GEOMETRY II ROUGH BOUNDARY $0 < \frac{L_d b}{An2} \leq 7.5$

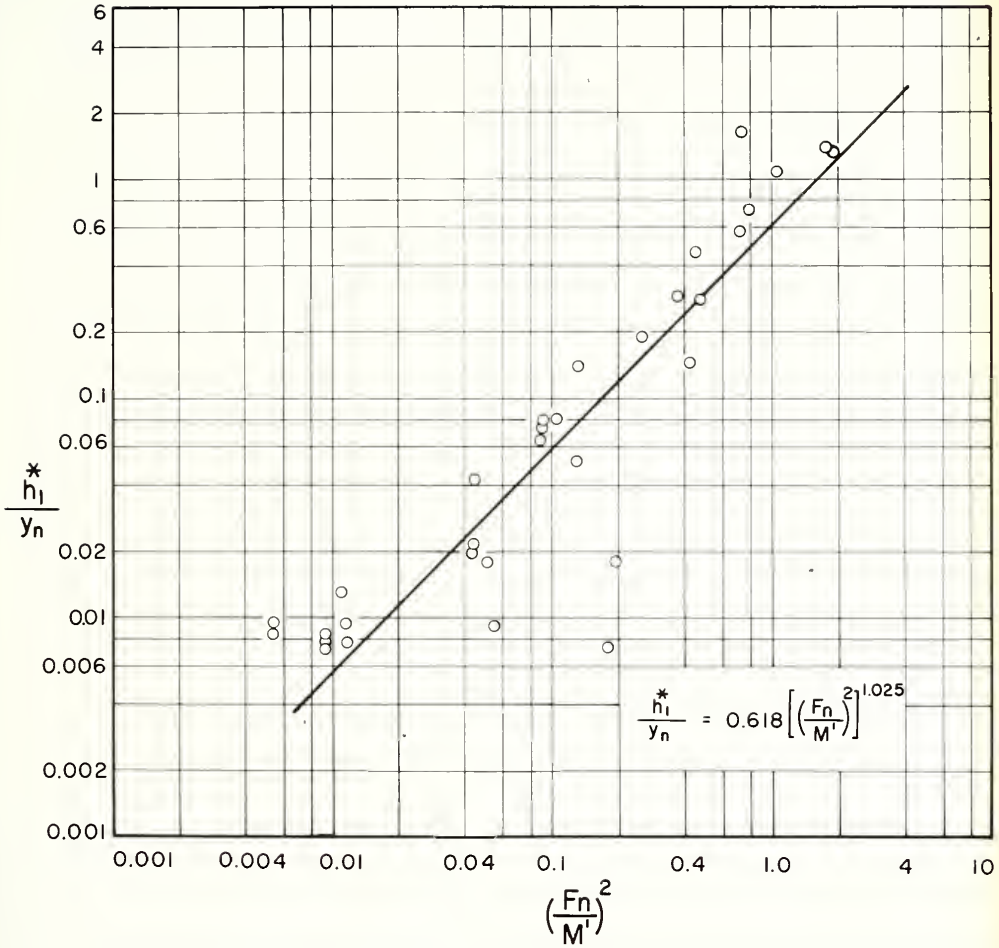


FIGURE 7-3-10 BACKWATER RATIO, GEOMETRY II

ROUGH BOUNDARY $\frac{Ldb}{An2}$ = 7.5 - 15

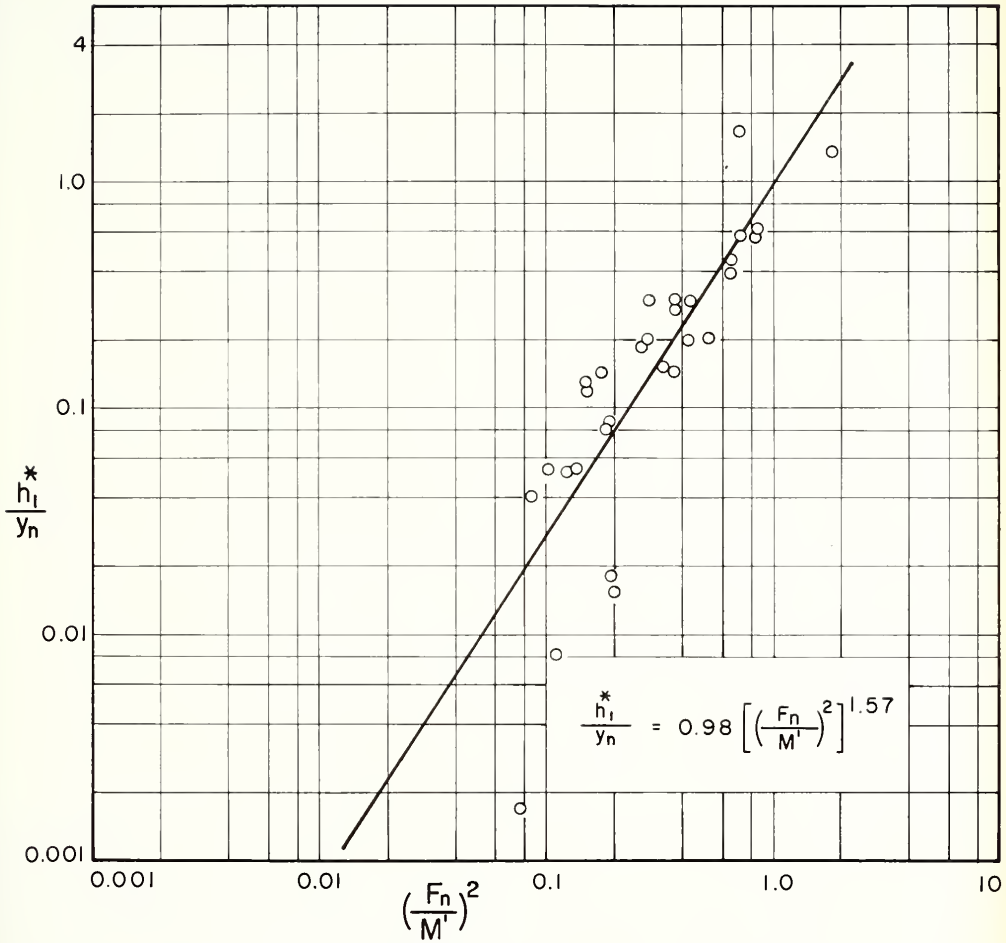


FIGURE 7-3-11 BACKWATER RATIO, GEOMETRY II

ROUGH BOUNDARY $\frac{L_d b}{A_{n2}}$ = 15 - 25

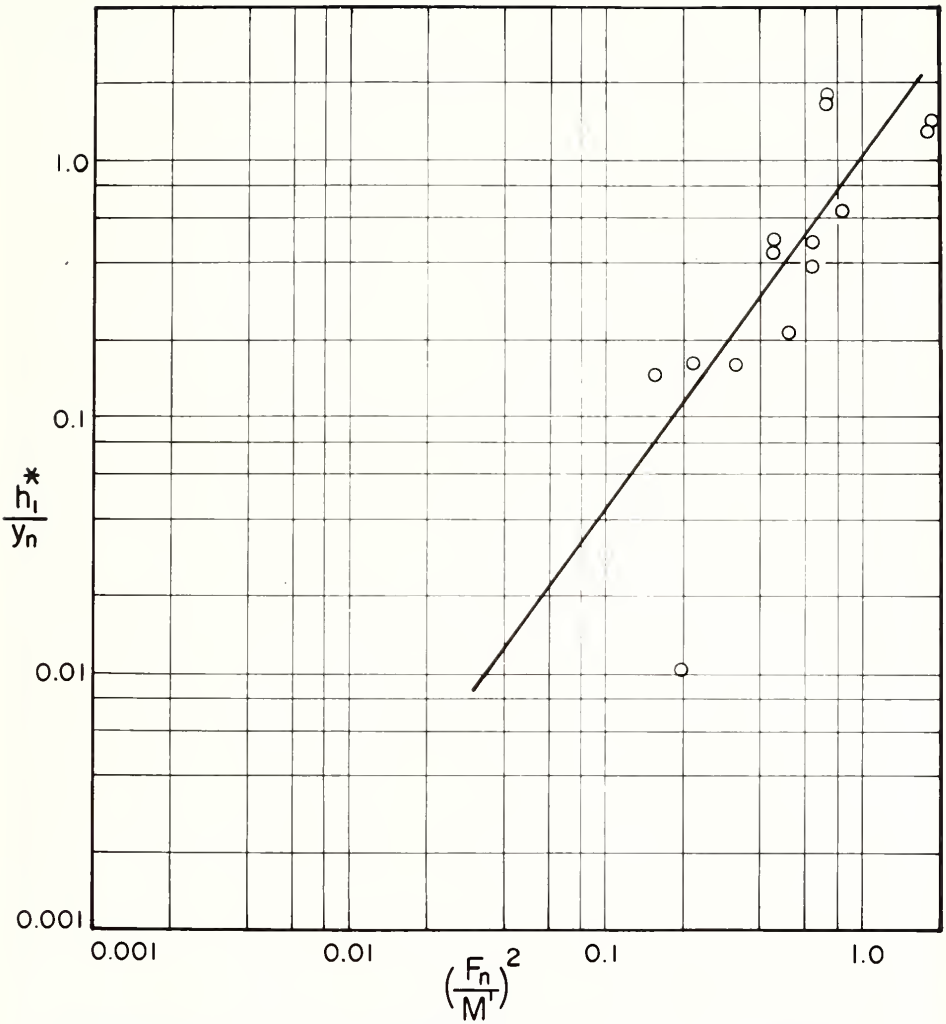


FIGURE 7-3-12 BACKWATER RATIO, GEOMETRY II
ROUGH BOUNDARY $\frac{L_{db}}{A_{n2}}$ = 25-30

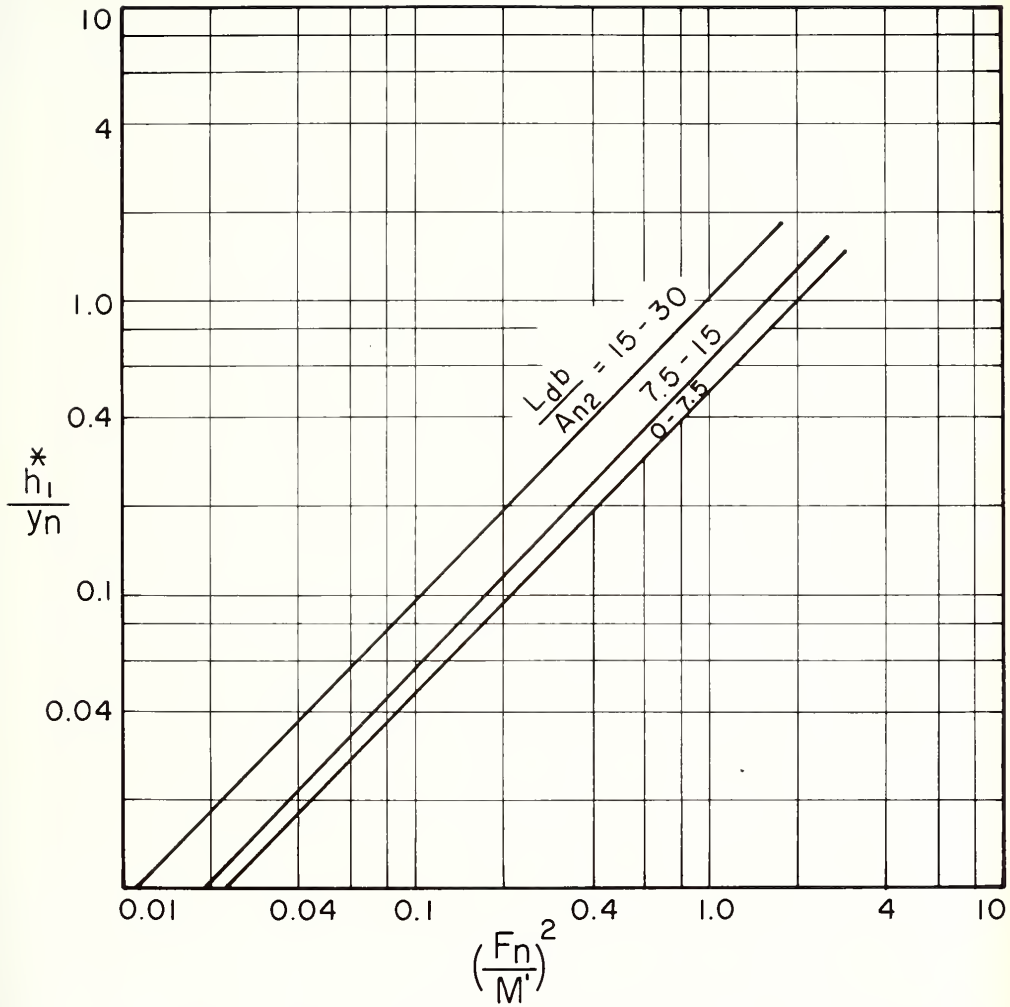


FIGURE 7-3-13 SUMMARY OF BACKWATER RATIO, GEOMETRY II ROUGH BOUNDARY

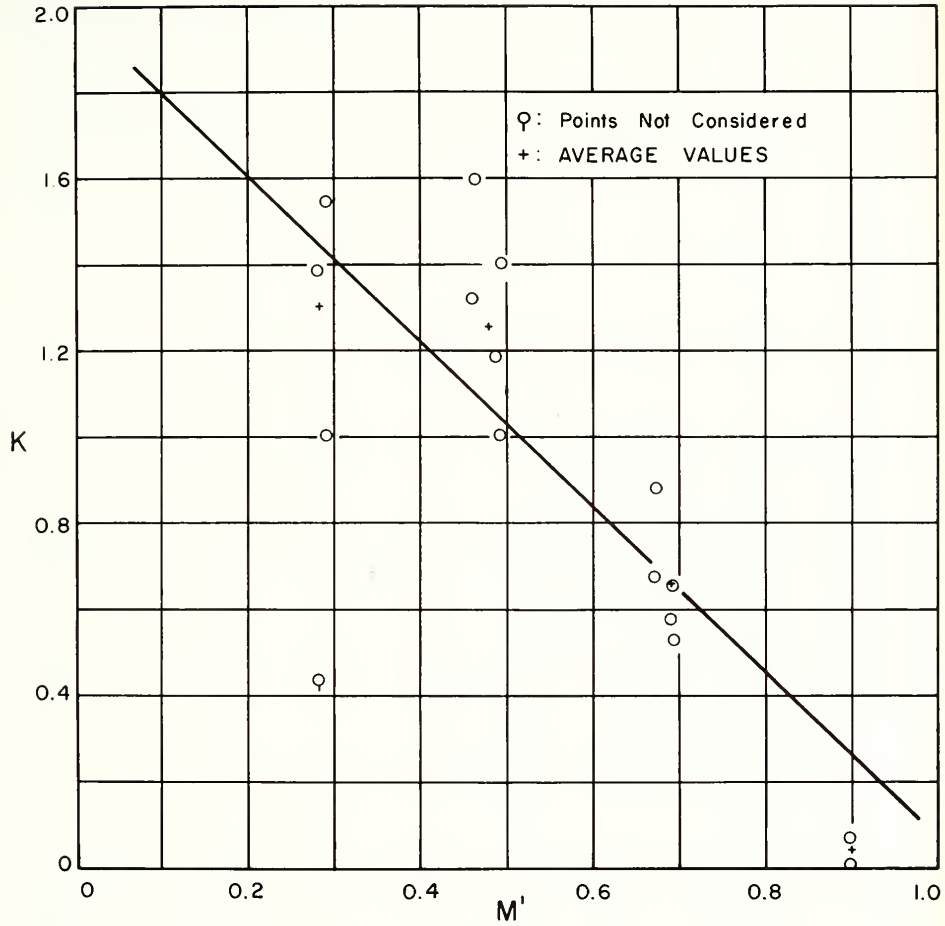


FIGURE 7-3-14 HEAD LOSS COEFFICIENT, GEOMETRY II

ROUGH BOUNDARY $\frac{L_d b}{An_2} = 0.00$

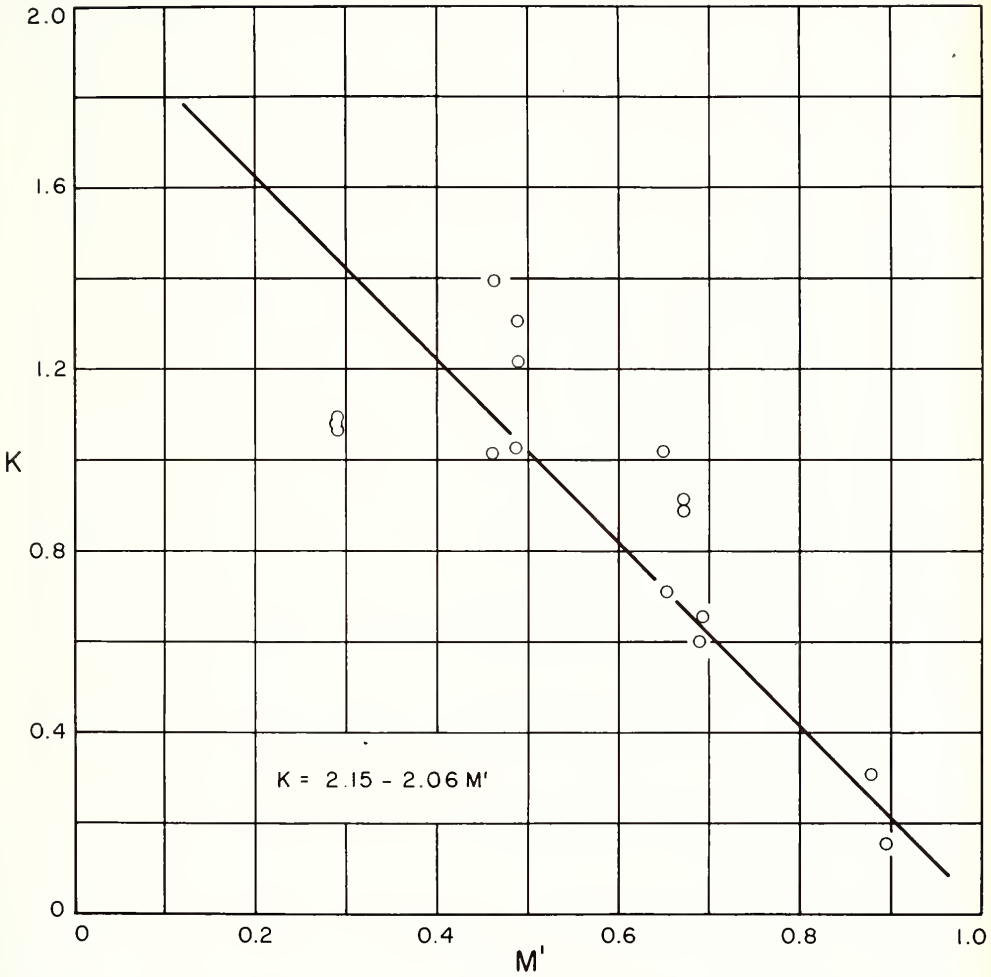


FIGURE 7-3-15 HEAD LOSS COEFFICIENT, GEOMETRY II

ROUGH BOUNDARY $\frac{L_d b}{A_{n2}} > 0 \leq 7.5$

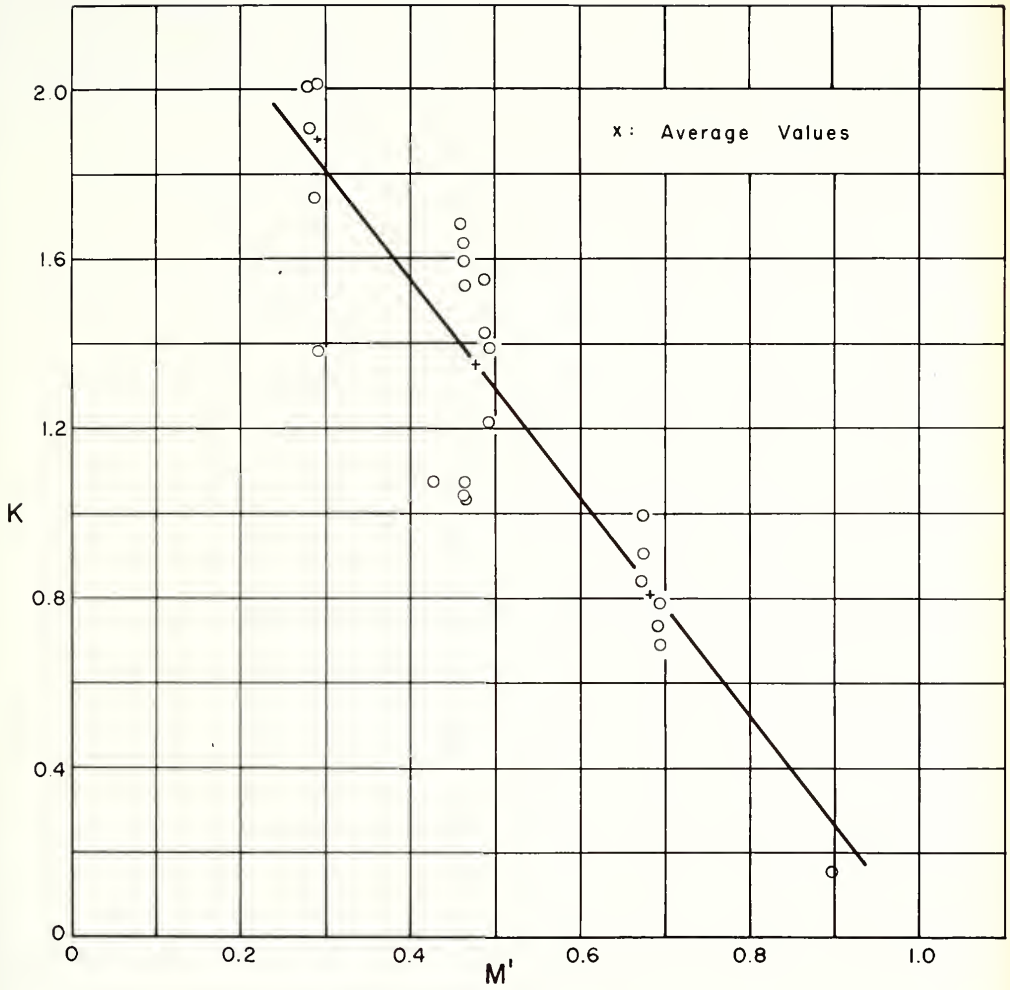


FIGURE 7-3-16 HEAD LOSS COEFFICIENT, GEOMETRY II
ROUGH BOUNDARY $\frac{L_d b}{A_{n2}}$ = 7.5 - 15

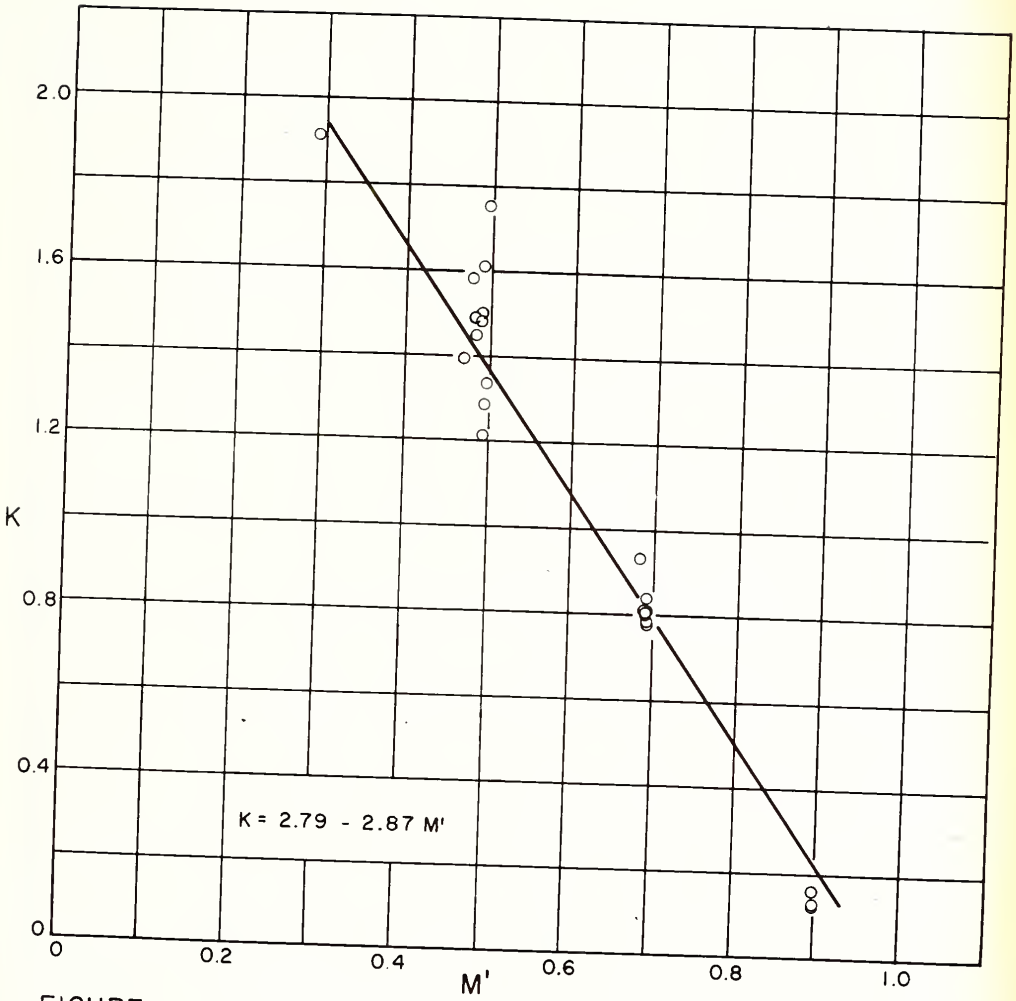


FIGURE 7-3-17 HEAD LOSS COEFFICIENT, GEOMETRY II
ROUGH BOUNDARY $\frac{Ldb}{An2}$ = 15 - 25

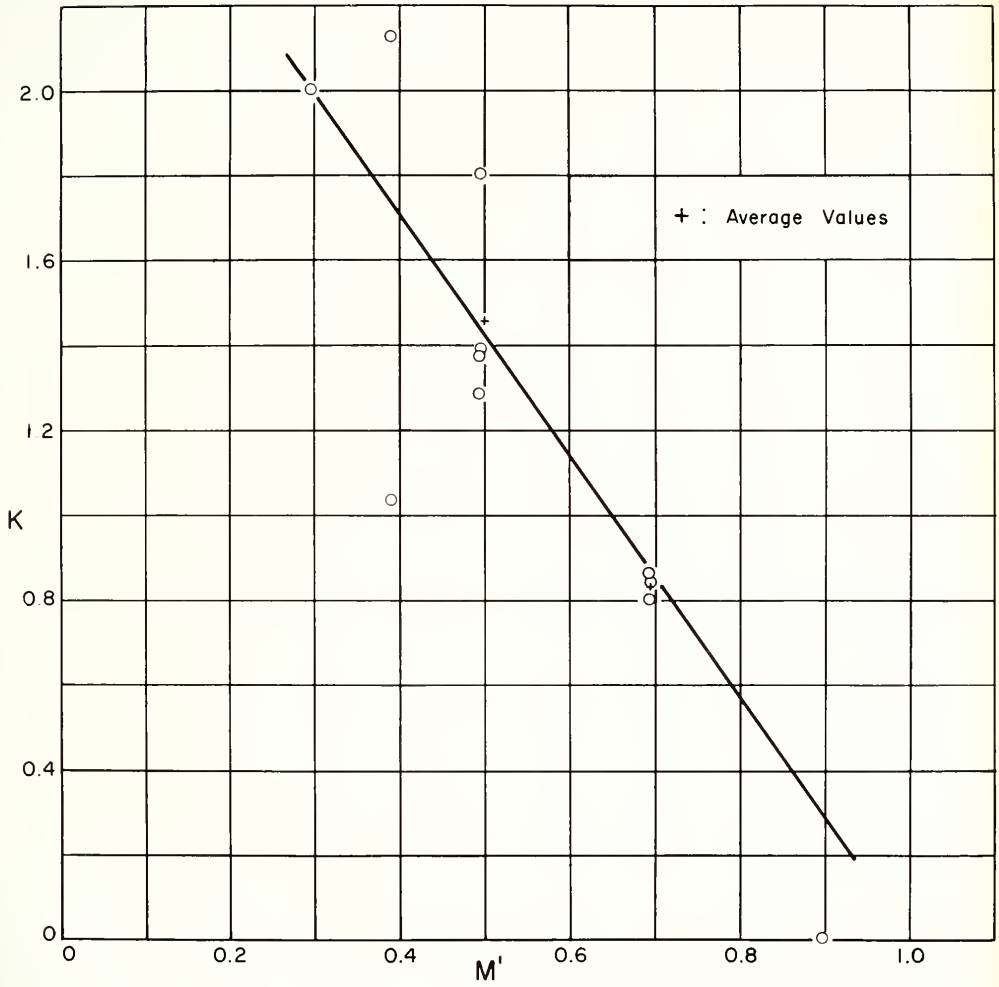


FIGURE 7-3-18 HEAD LOSS COEFFICIENT, GEOMETRY II

ROUGH BOUNDARY $\frac{L_d b}{A_{n2}}$ = 25 - 30

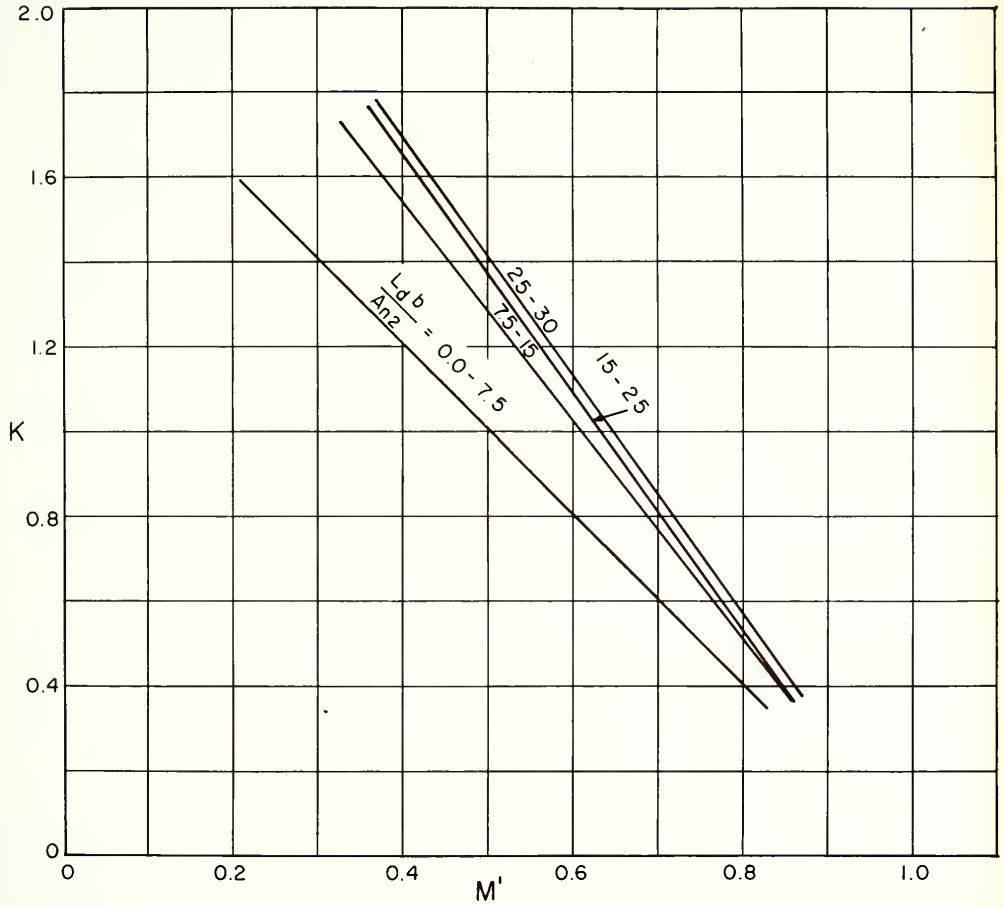


FIGURE 7-3-19 SUMMARY OF HEAD LOSS COEFFICIENTS, GEOMETRY II, ROUGH BOUNDARIES

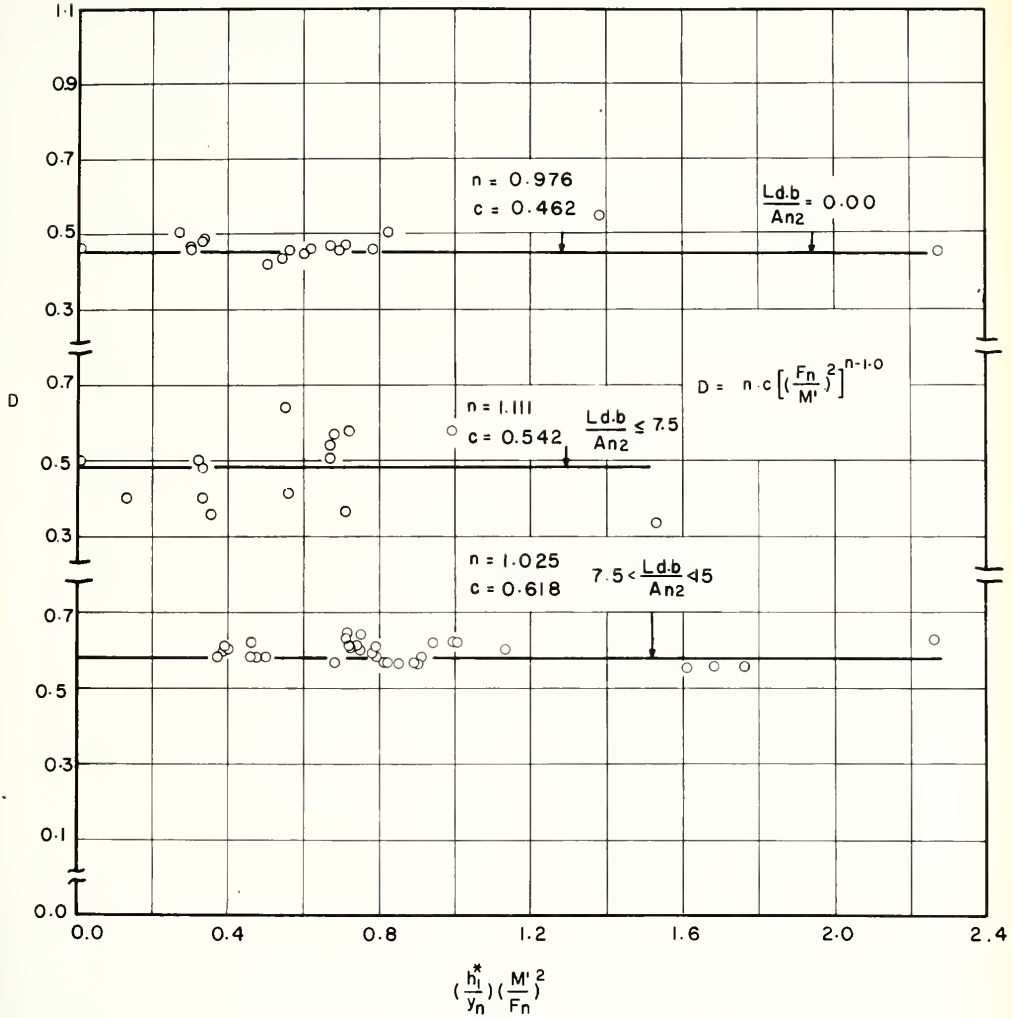


FIGURE 7-3-20 BACKWATER RATIO COEFICIENT GEOMETRY II

ROUGH BOUNDARY

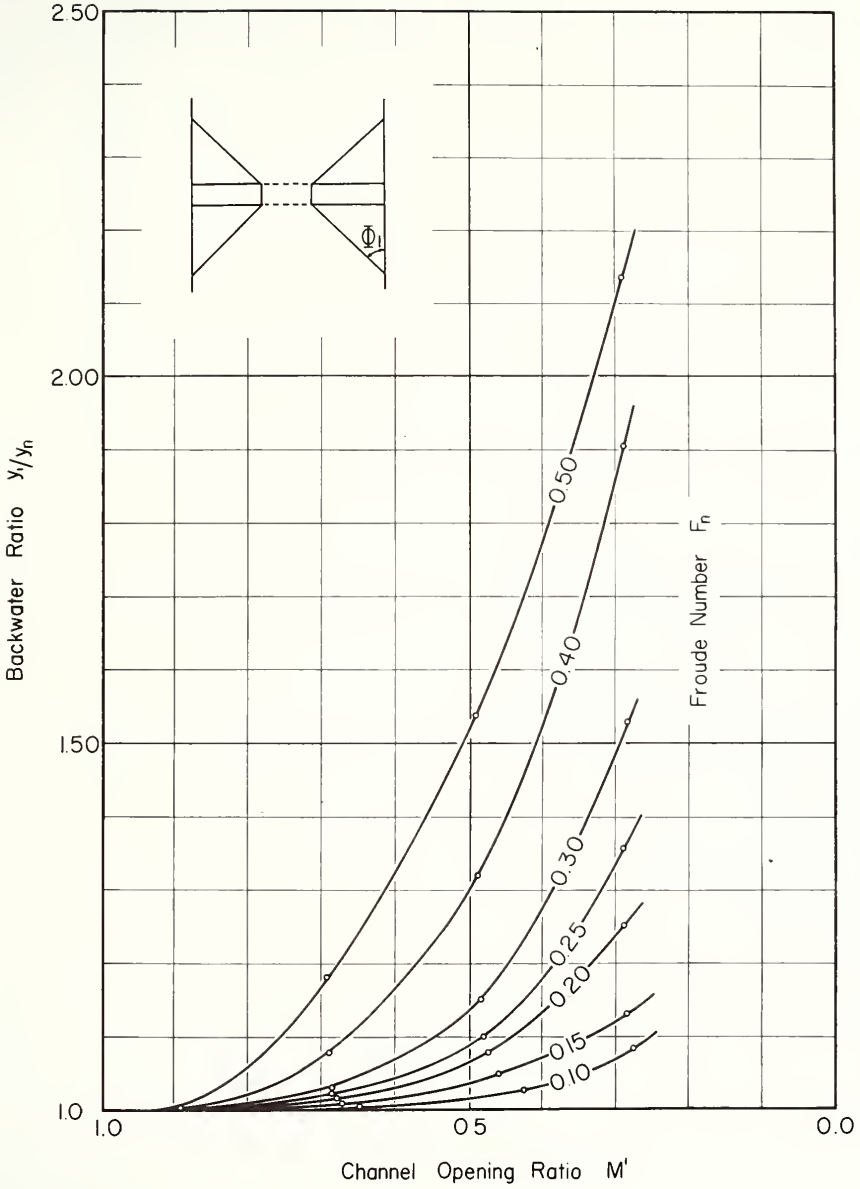


FIG. 7-4-1 BACKWATER RATIO FOR ARCH BRIDGES WITH WINGWALLS $\Phi_1 = 30°$

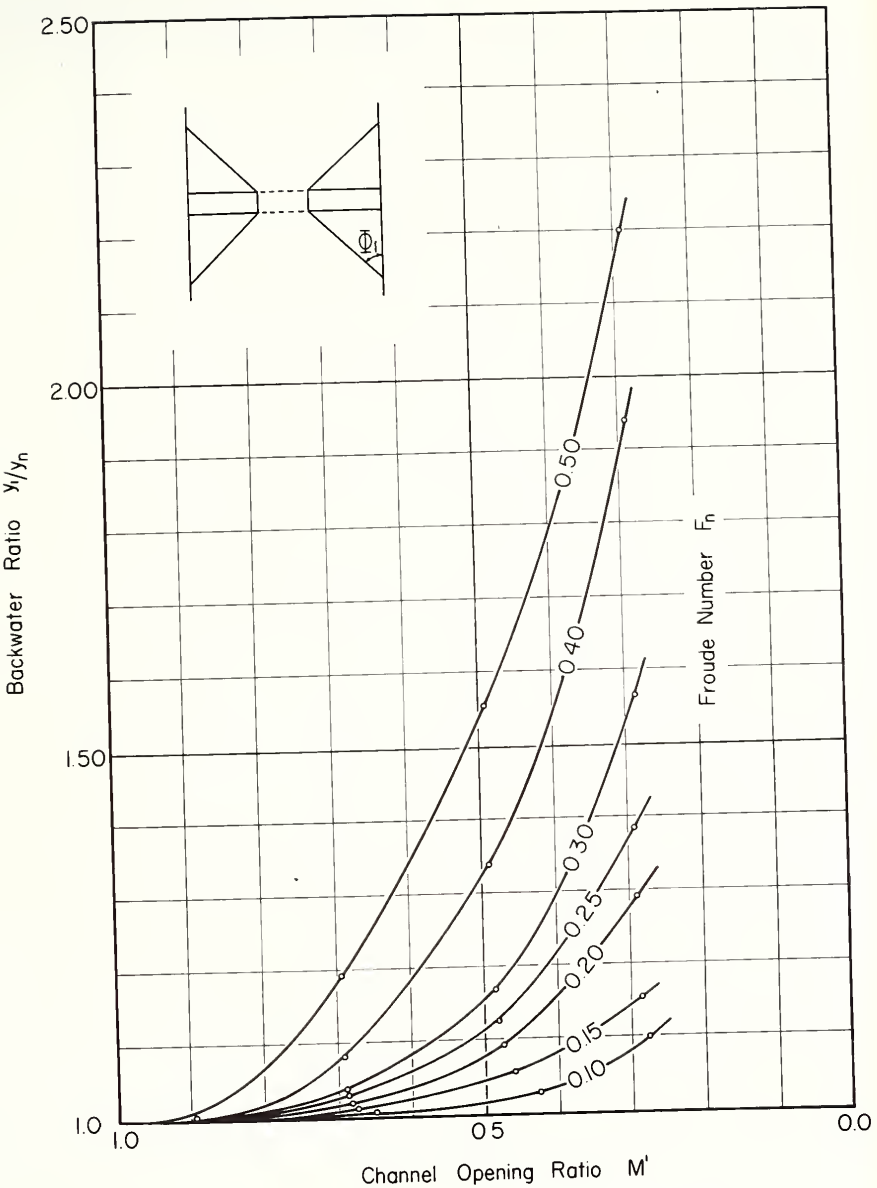


FIG. 7-4-2 BACKWATER RATIO FOR ARCH BRIDGES WITH WINGWALLS $\Phi_1 = 45°$

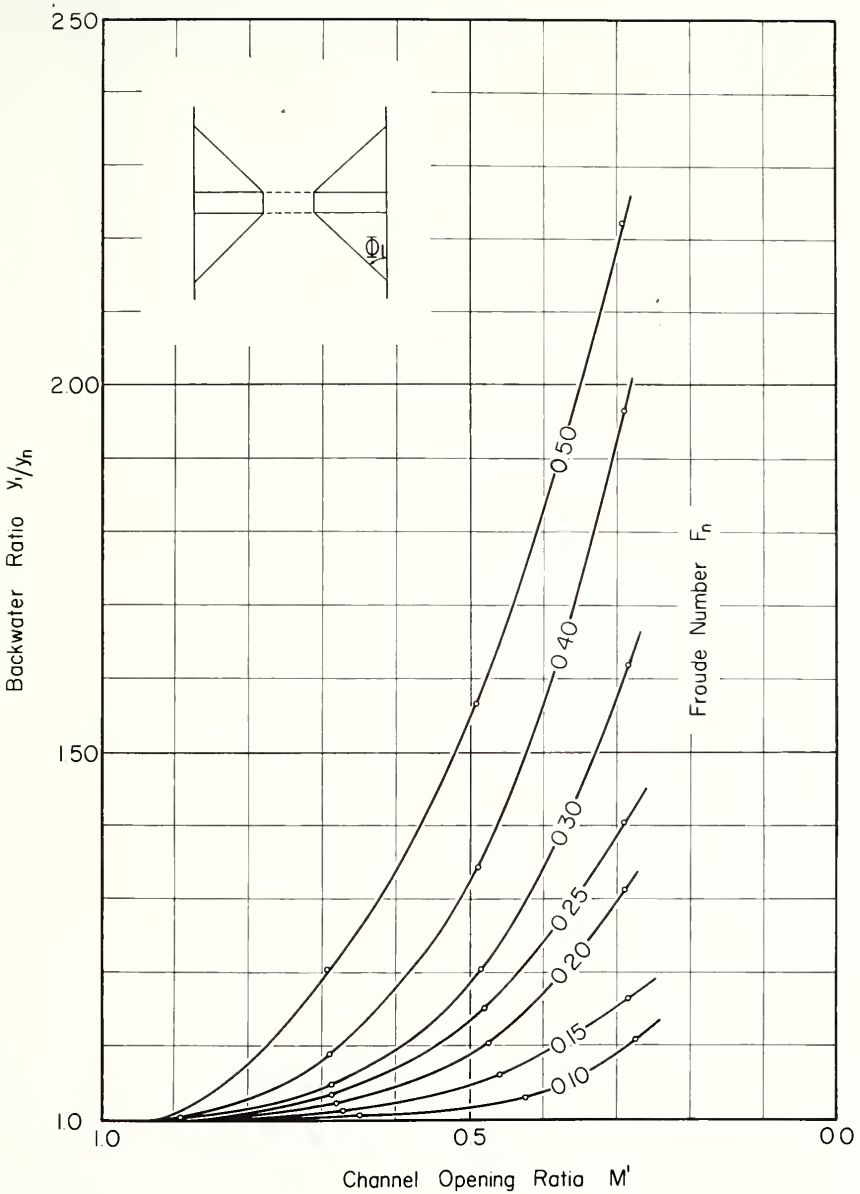


FIG. 7-4-3 BACKWATER RATIO FOR ARCH BRIDGES WITH WINGWALLS $\Phi_1=60°$

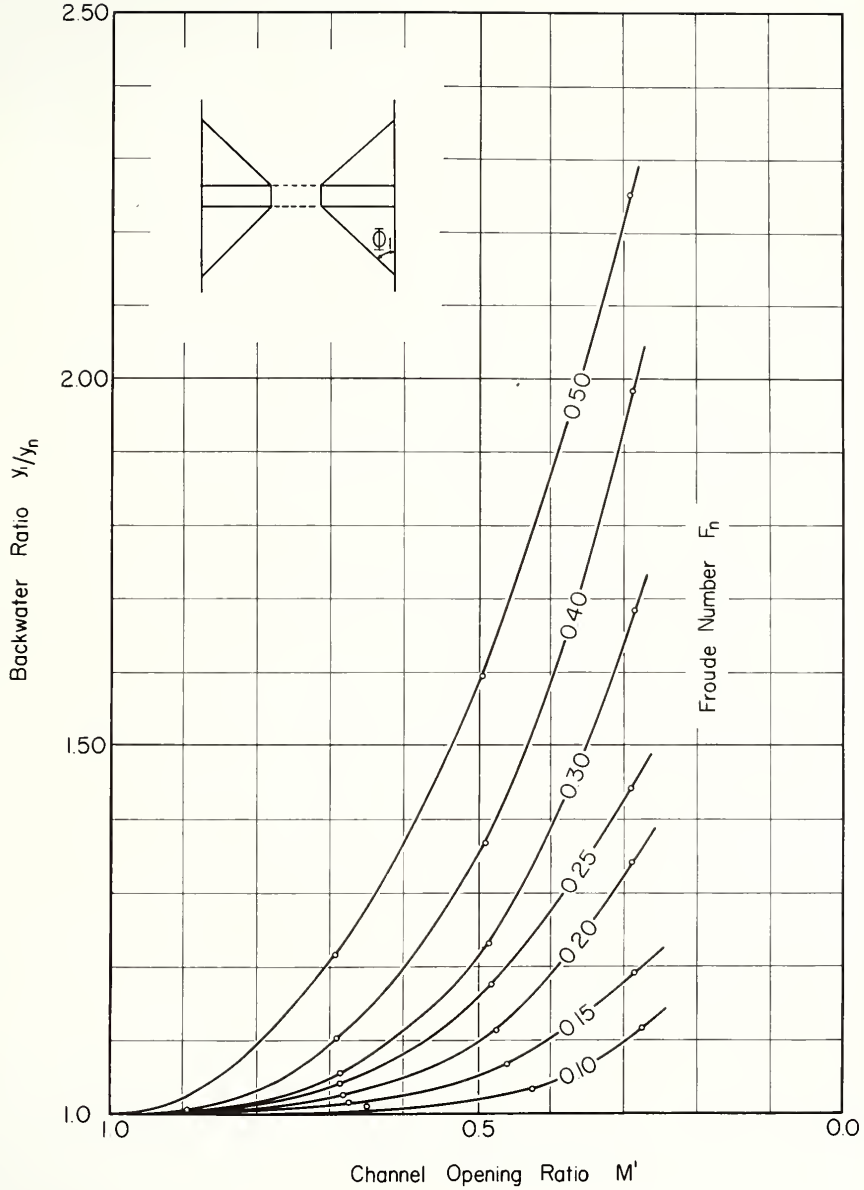


FIG. 7-4-4 BACKWATER RATIO FOR ARCH BRIDGES WITH WINGWALLS $\Phi_1 = 90°$

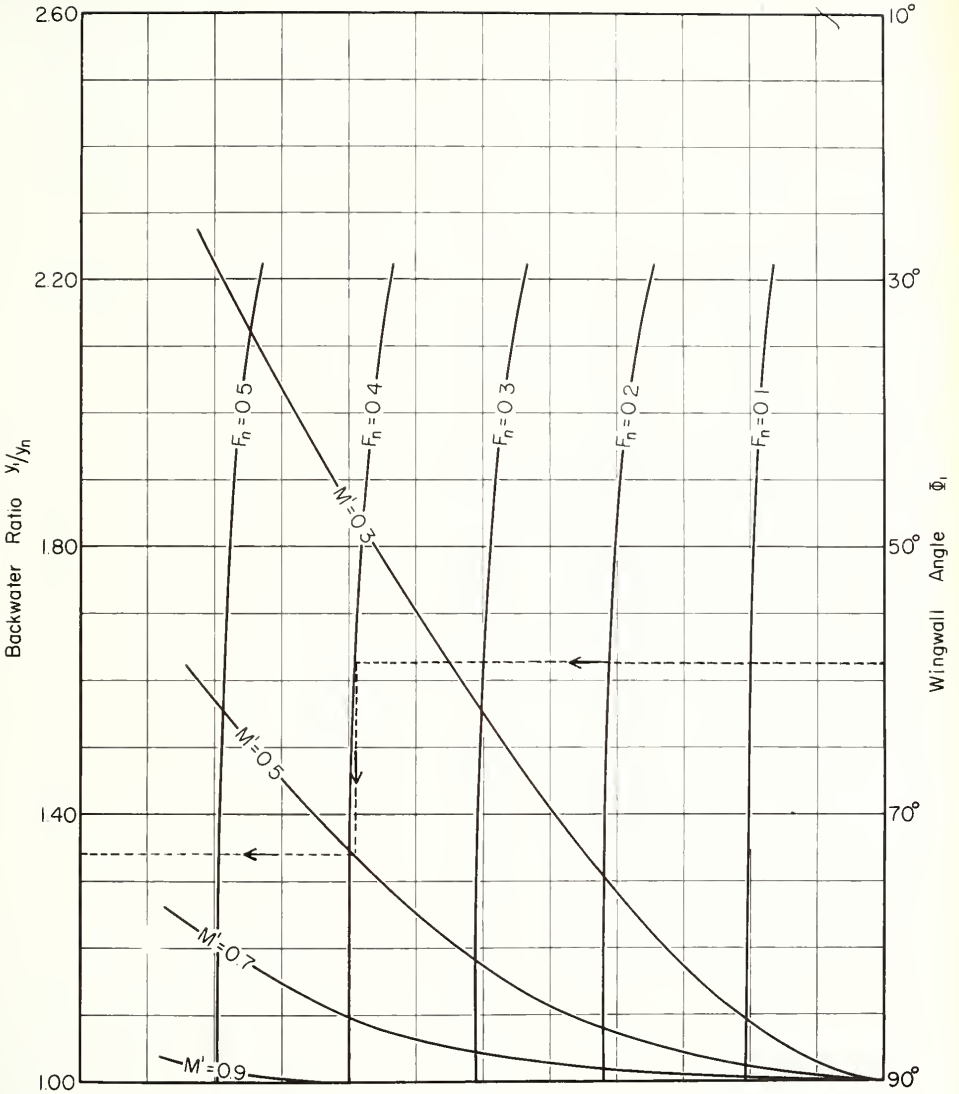
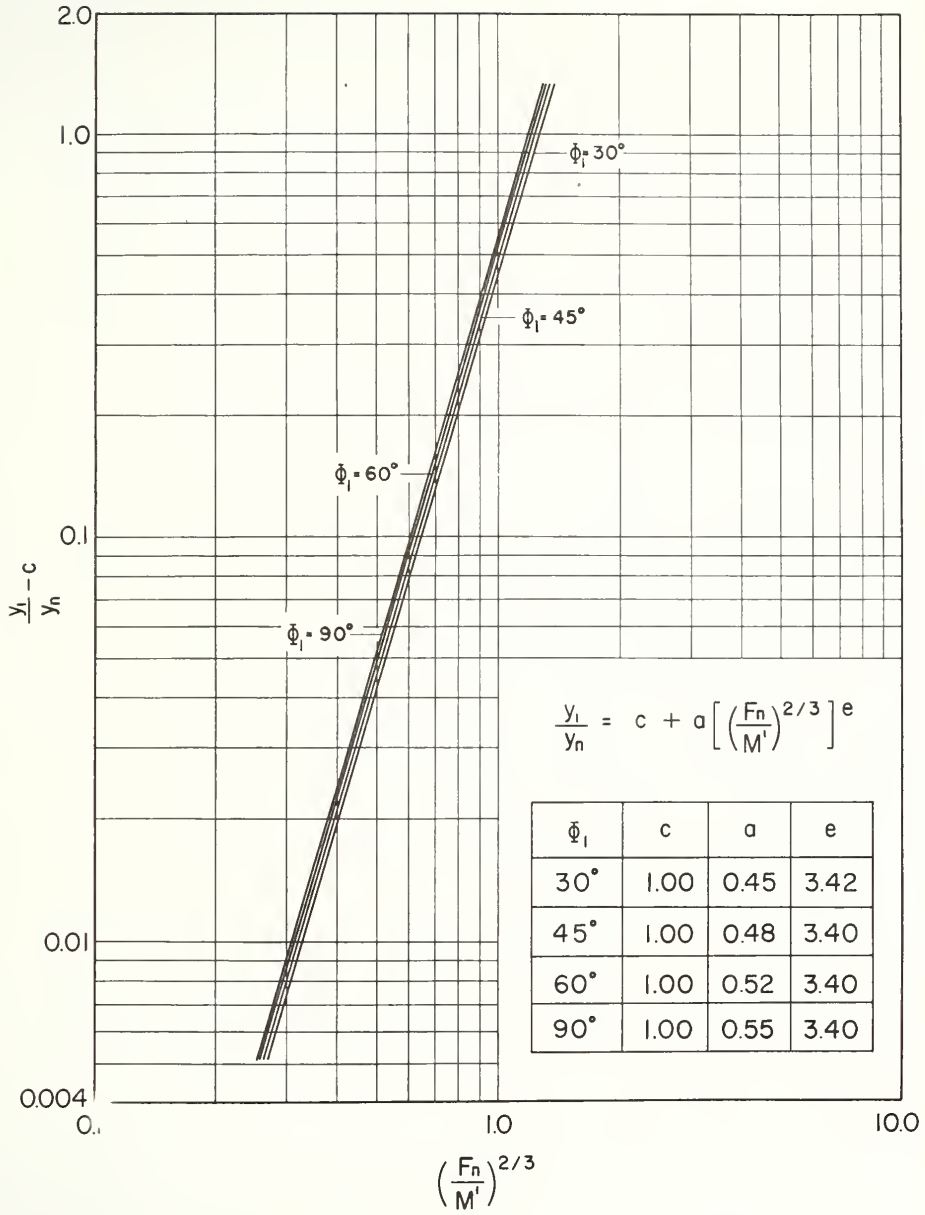


FIG. 7-4-5 BACKWATER RATIO FOR ARCH BRIDGES WITH WINGWALLS



Φ_1	c	a	e
30°	1.00	0.45	3.42
45°	1.00	0.48	3.40
60°	1.00	0.52	3.40
90°	1.00	0.55	3.40

FIG. 7-4-6 - GENERALIZED BACKWATER RATIO FOR ARCH BRIDGES WITH WINGWALLS

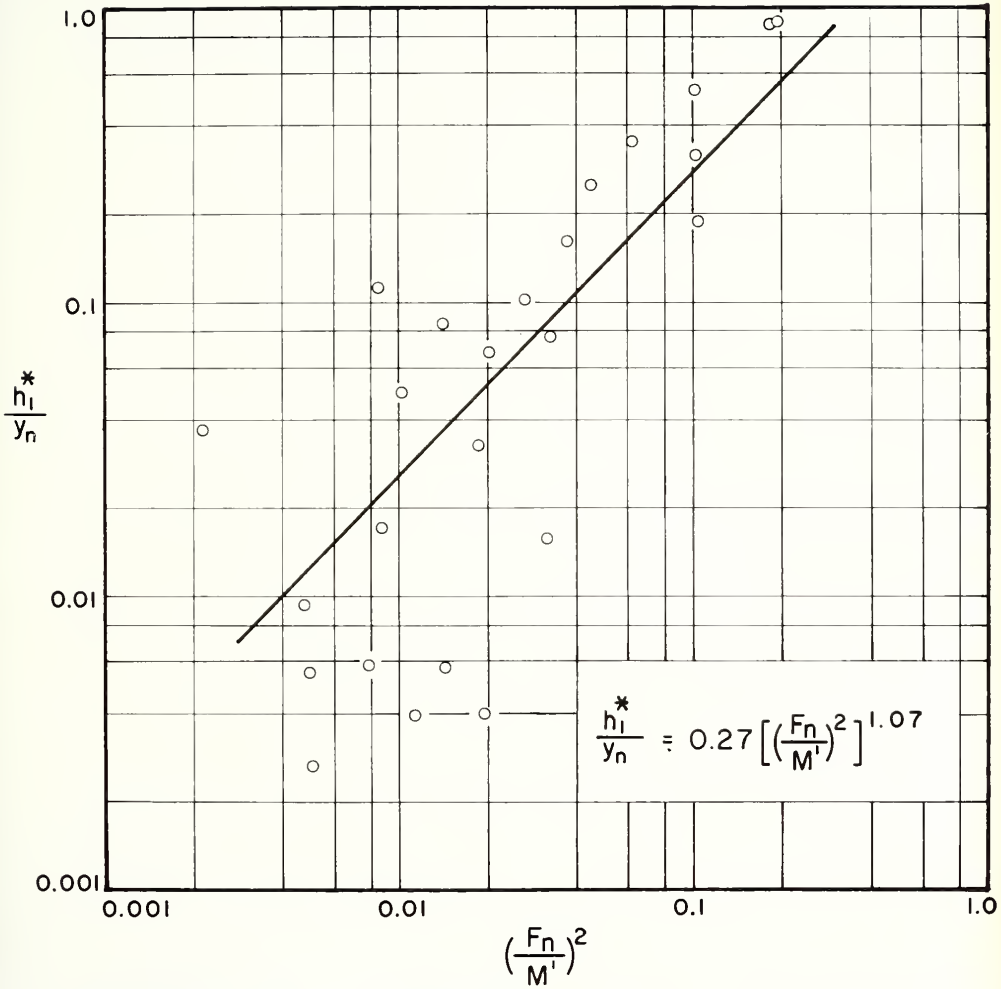


FIGURE 7-4-7 BACKWATER RATIO, GEOMETRY III ROUGH BOUNDARY $\Phi_1 = 30°$

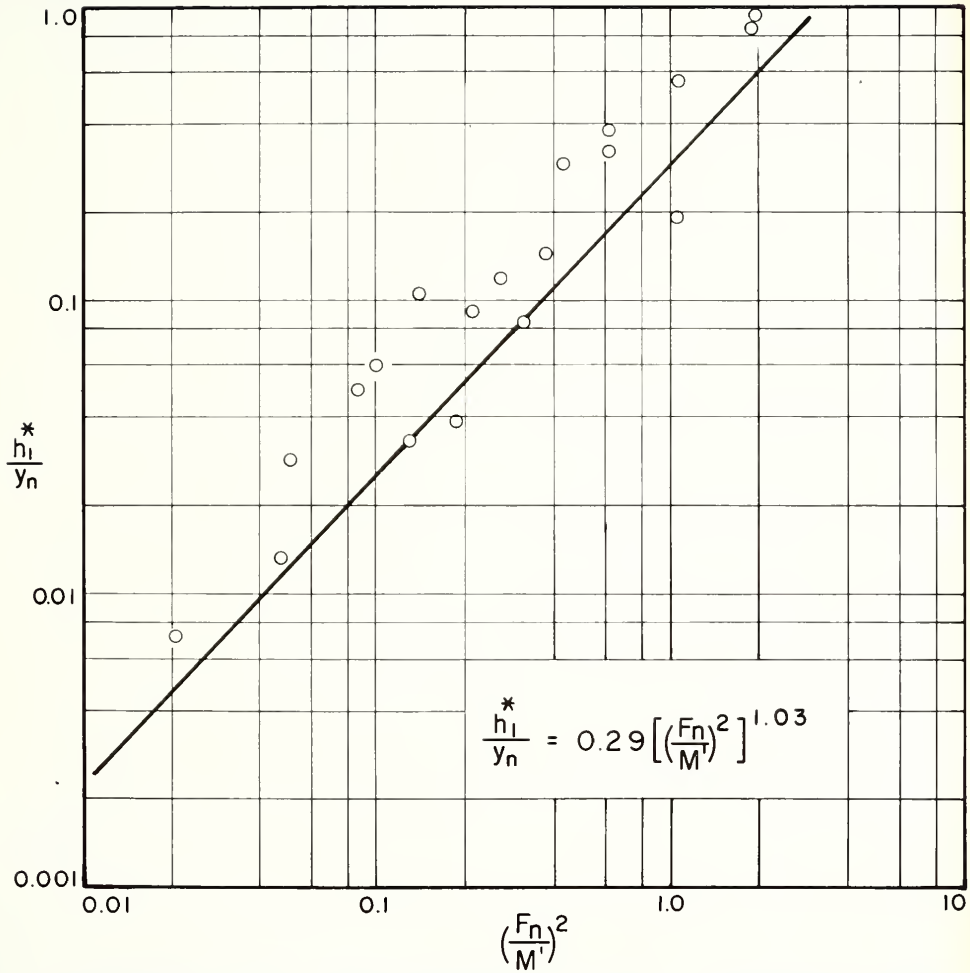


FIGURE 7-4-8 BACKWATER RATIO, GEOMETRY III

ROUGH BOUNDARY $\Phi_1 = 45°$

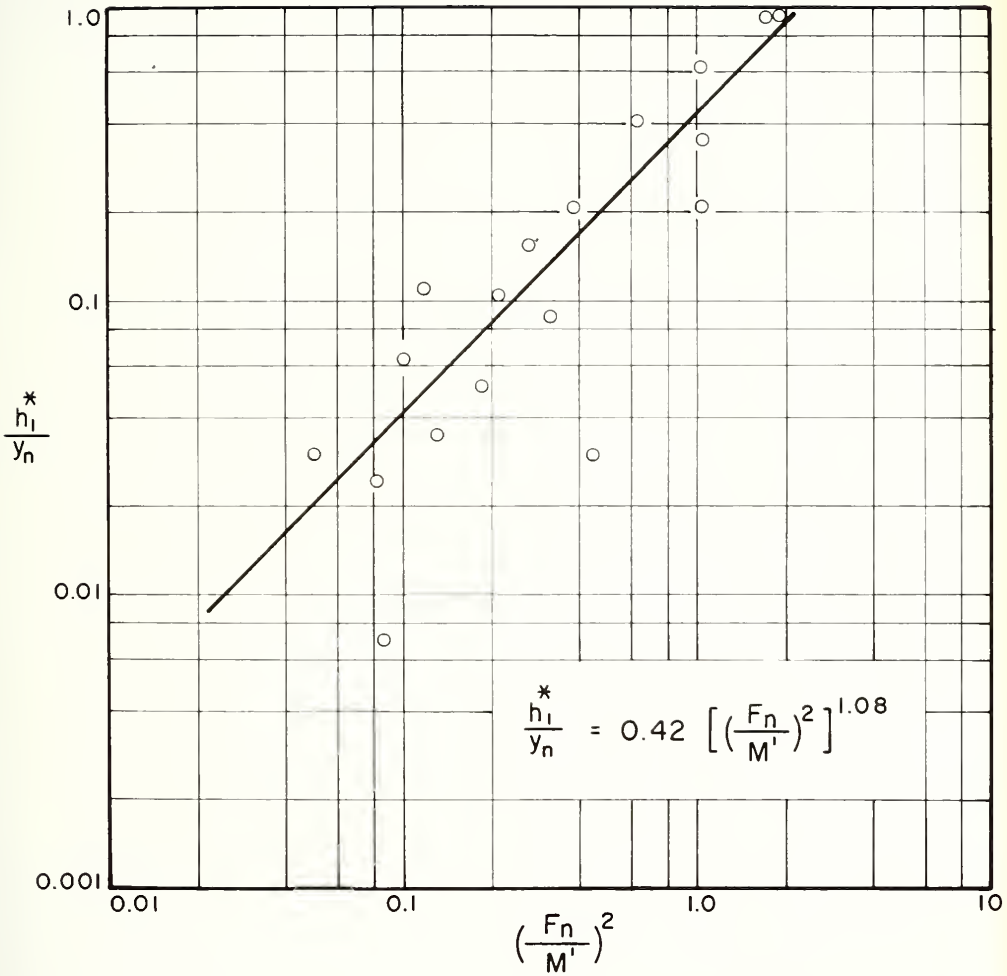


FIGURE 7-4-9 BACKWATER RATIO, GEOMETRY III
ROUGH BOUNDARY $\Phi_1 = 60°$

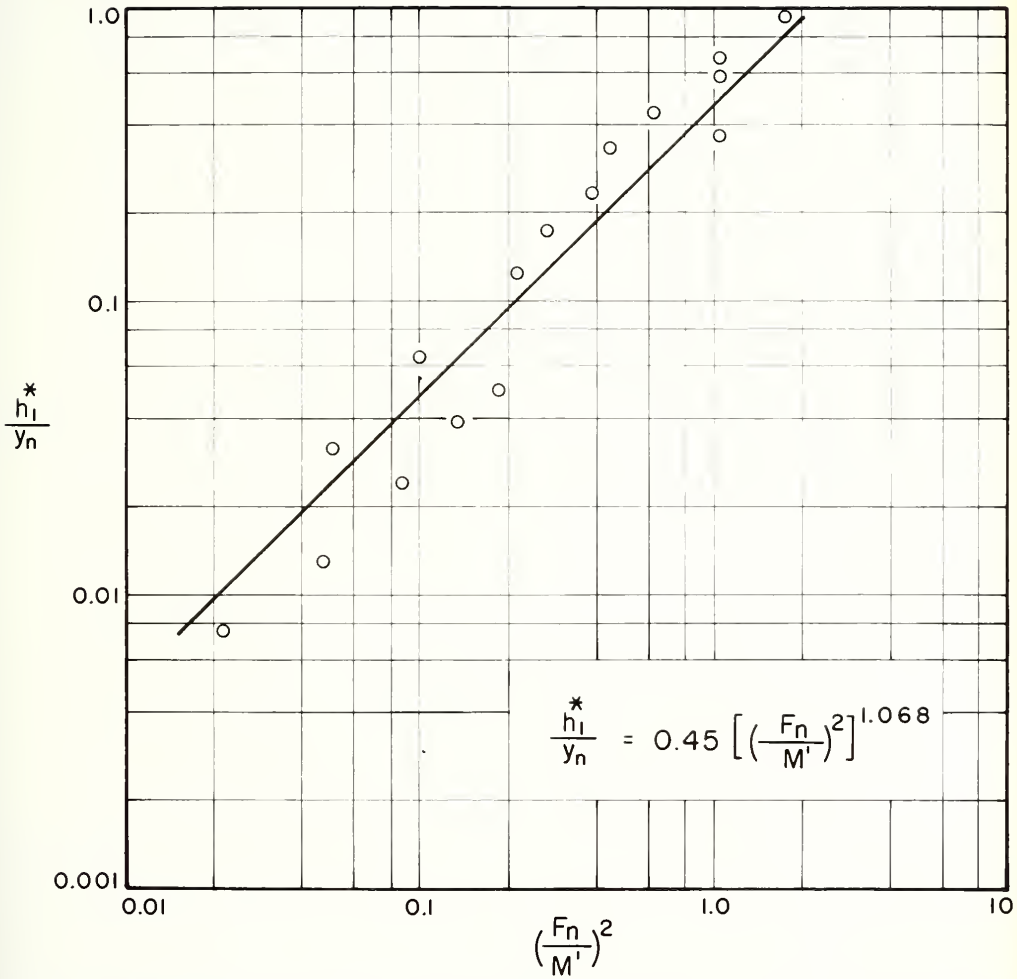


FIGURE 7-4-10 BACKWATER RATIO, GEOMETRY III ROUGH BOUNDARY $\Phi_1 = 90°$

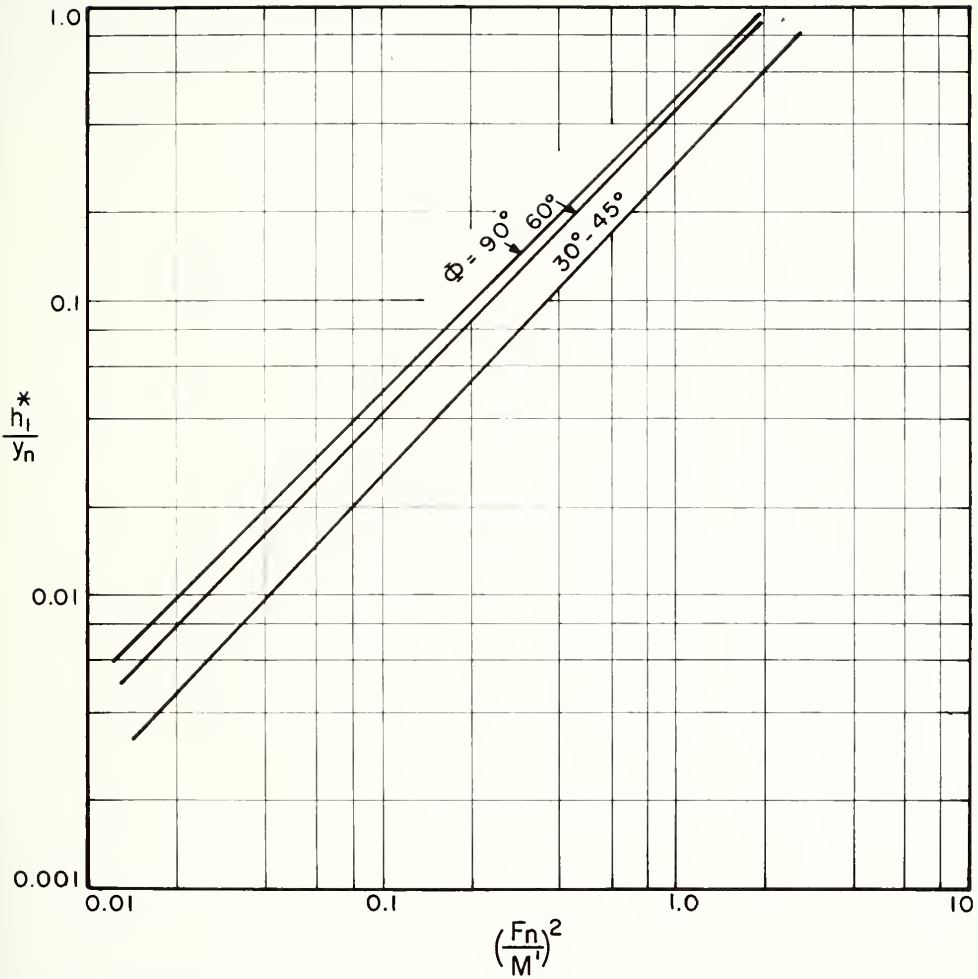


FIGURE 7-4-11 SUMMARY OF BACKWATER RATIO, GEOMETRY III, ROUGH BOUNDARY

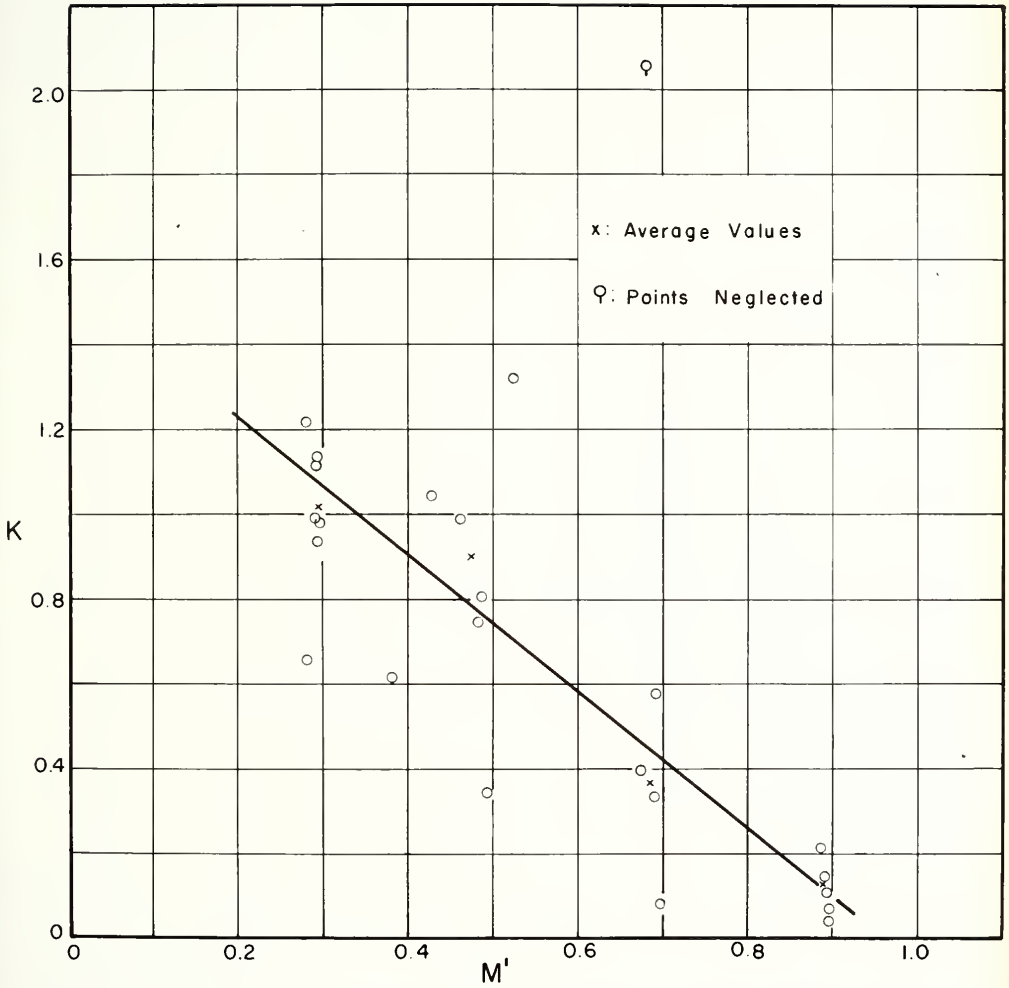


FIGURE 7-4-12 HEAD LOSS COEFFICIENT, GEOMETRY III ROUGH BOUNDARY $\Phi_1 = 30°$

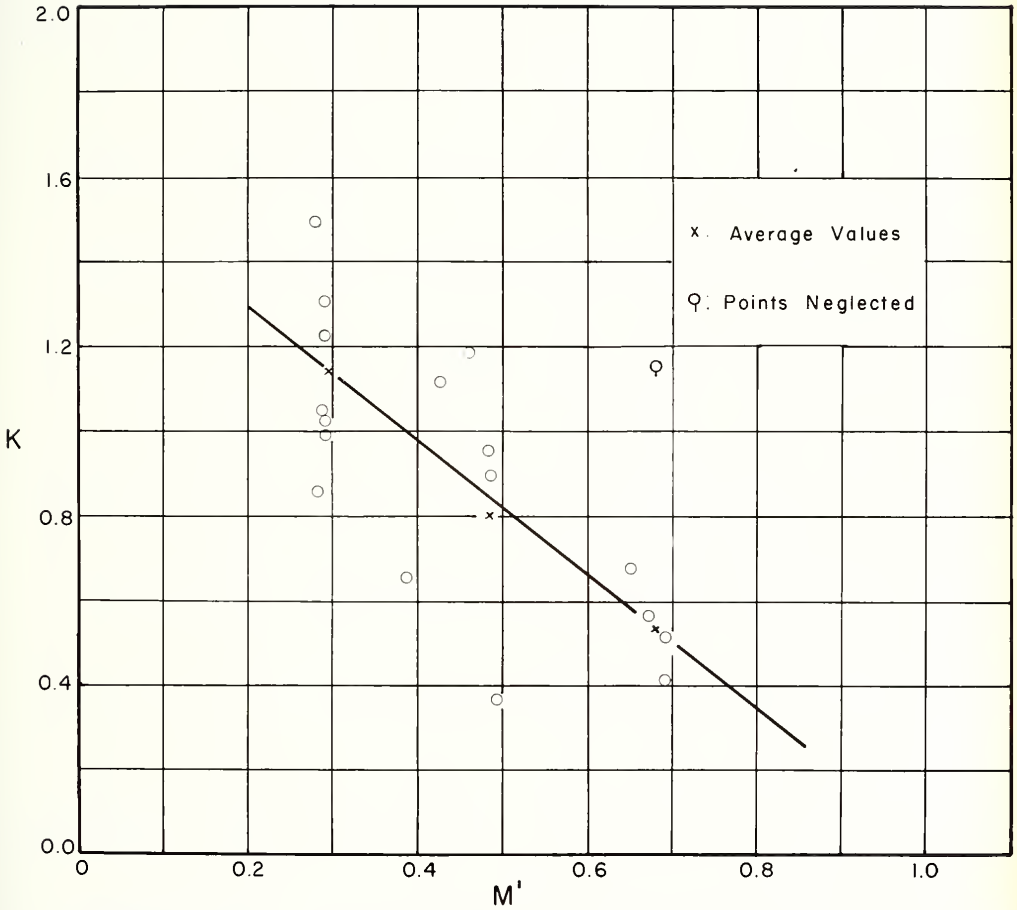


FIGURE 7-4-13 HEAD LOSS COEFFICIENT, GEMETRY III ROUGH BOUNDARY $\Phi_1 = 45°$

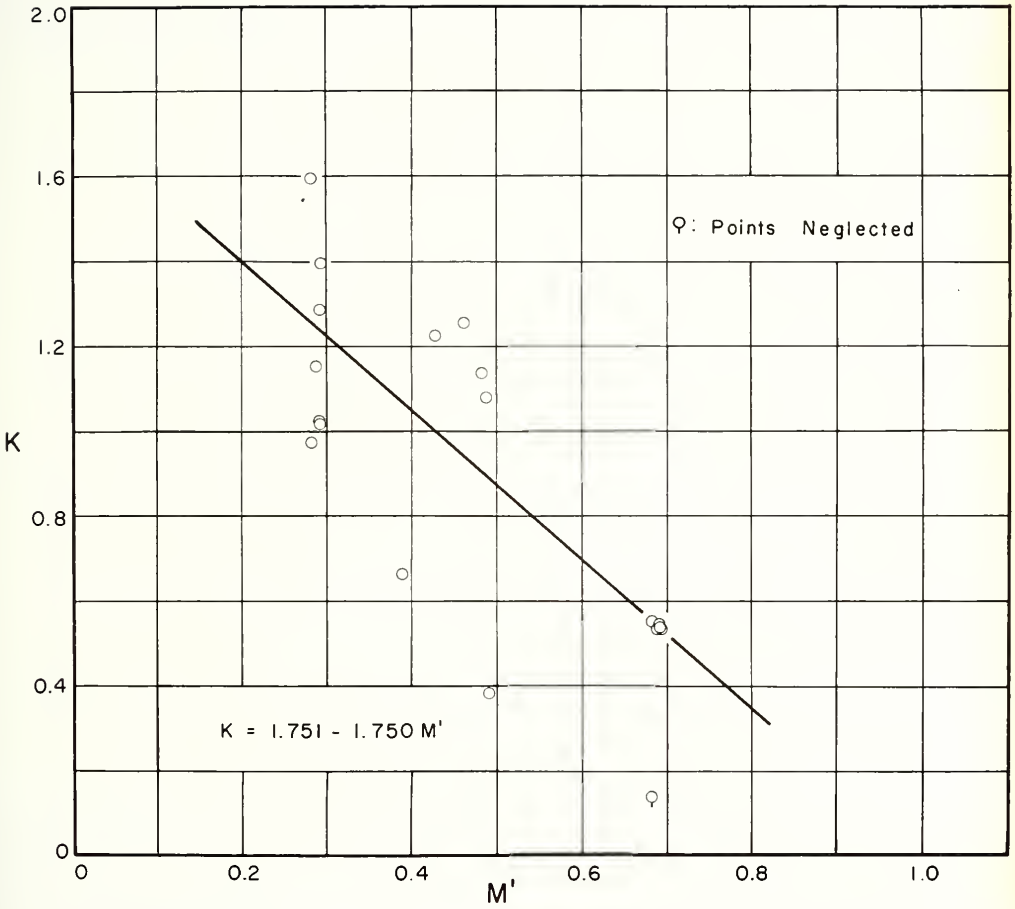


FIGURE 7-4-14 HEAD LOSS COEFFICIENT, GEOMETRY III
ROUGH BOUNDARY $\Phi_1 = 60°$

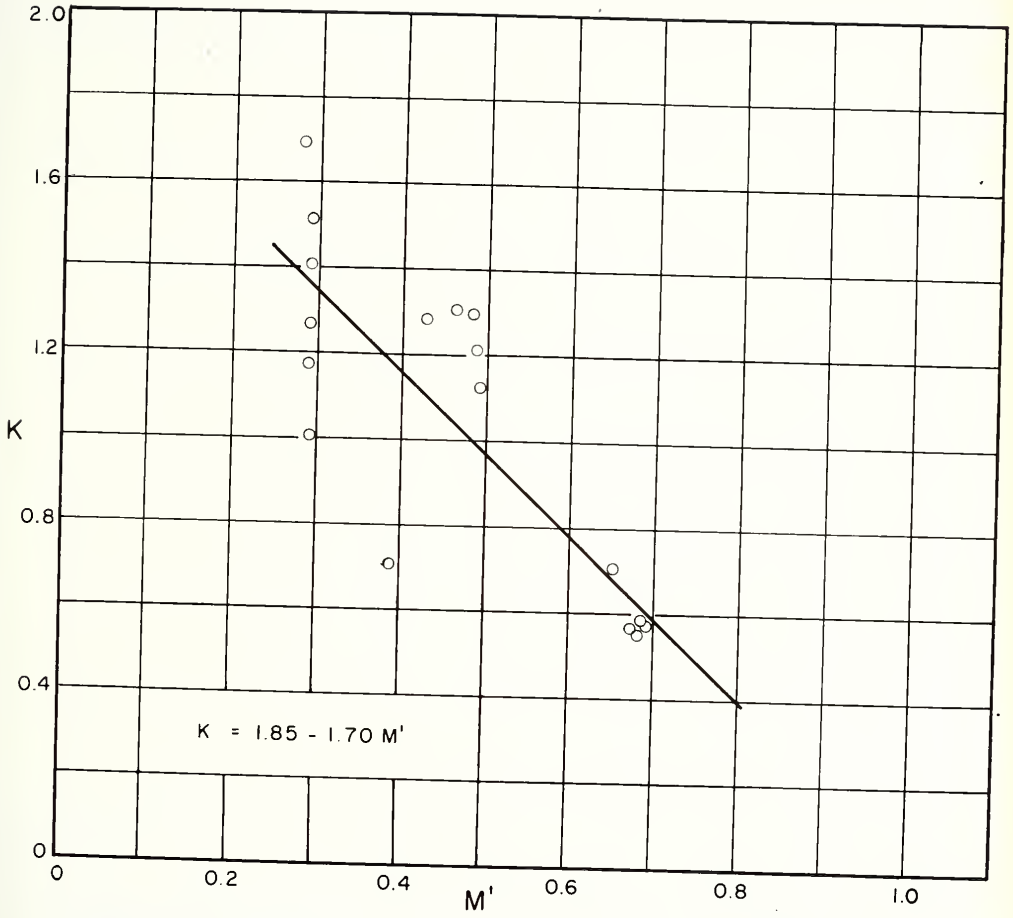


FIGURE 7-4-15 HEAD LOSS COEFFICIENT, GEOMETRY III
ROUGH BOUNDARY $\Phi_1 = 90°$

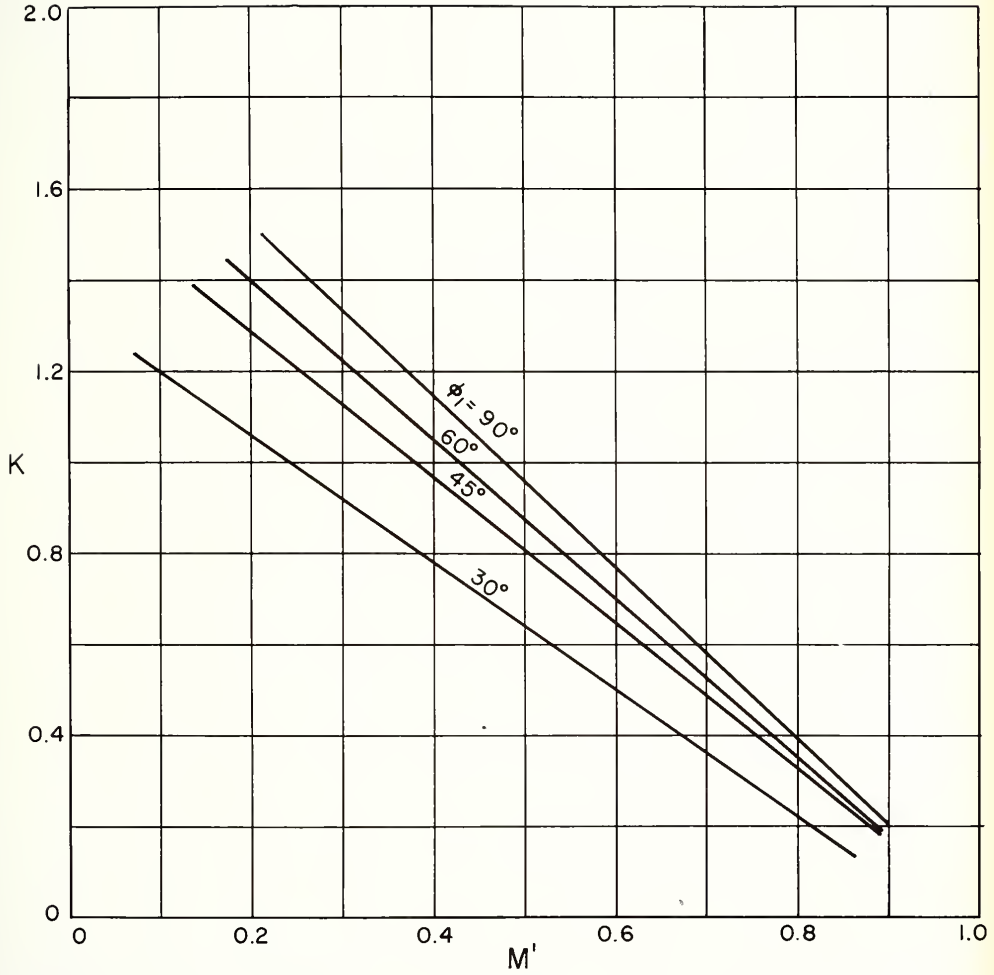


FIGURE 7-4-16 SUMMARY OF HEAD LOSS COEFFICIENTS
GEOMETRY III, ROUGH BOUNDARIES

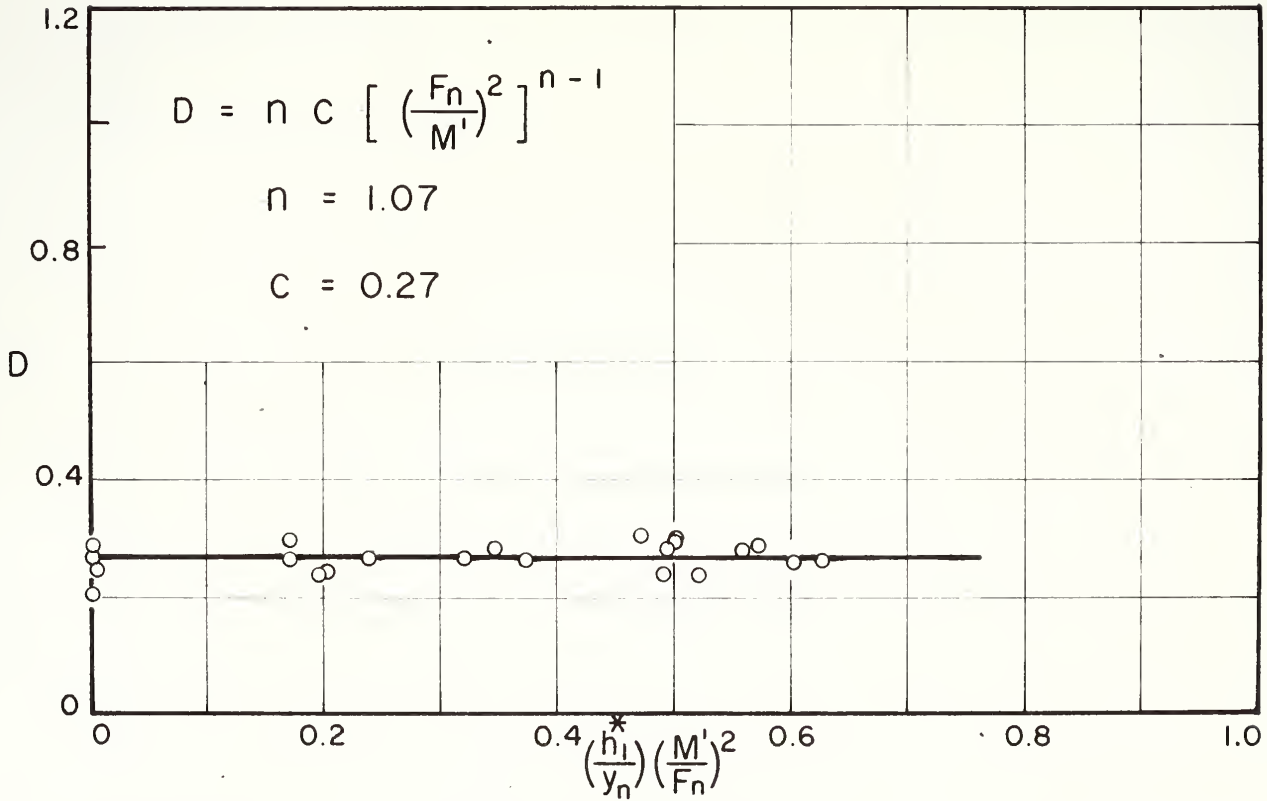


FIGURE 7-4-17 BACKWATER RATIO COEFFICIENT, GEOMETRY III, ROUGH BOUNDARY $\Phi_1 = 30°$

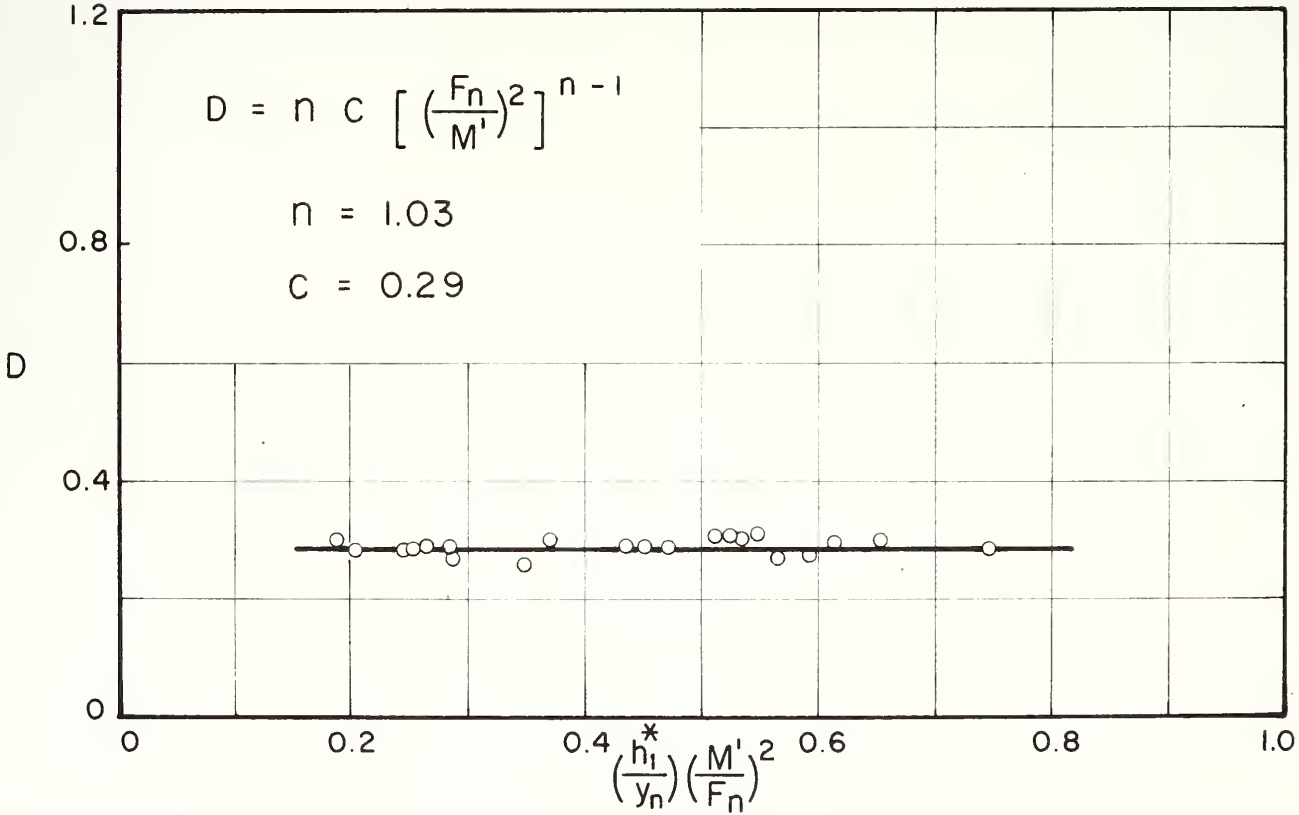


FIGURE 7-4-18 BACKWATER RATIO COEFFICIENT, GEOMETRY III ROUGH BOUNDARY $\Phi_1 = 45°$

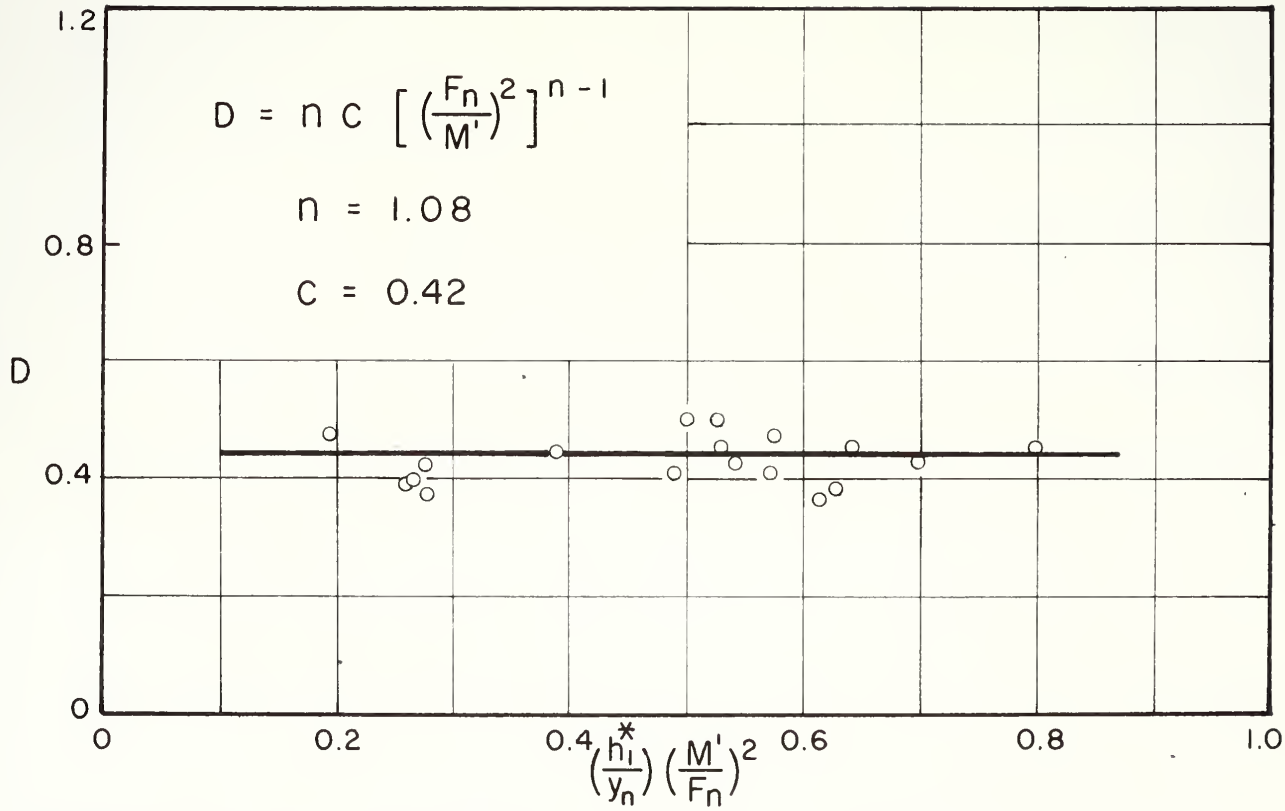


FIGURE 7-4-19 BACKWATER RATIO COEFFICIENT, GEOMETRY III, ROUGH BOUNDARY $\Phi_1 = 60°$

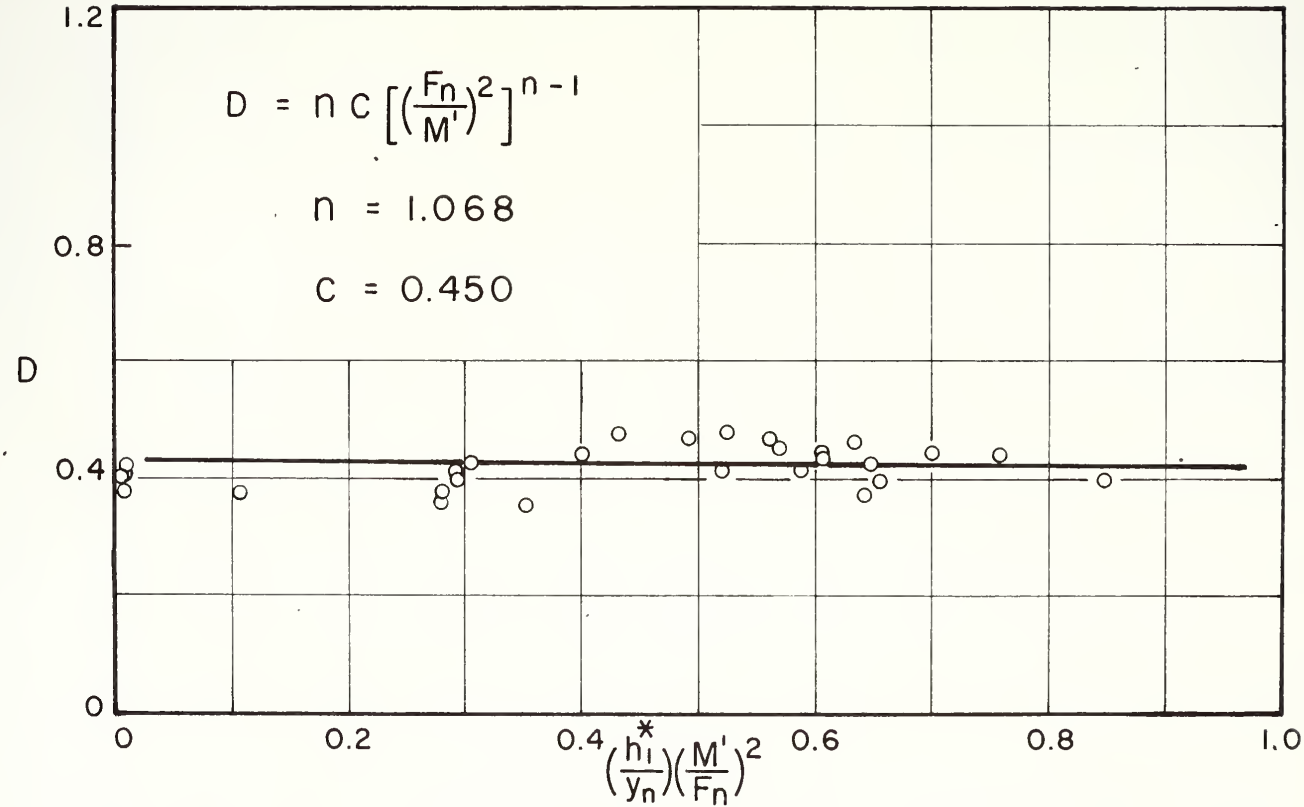


FIGURE 7-4-20 BACKWATER RATIO COEFFICIENT, GEOMETRY III, ROUGH BOUNDARY $\Phi_1 = 90°$

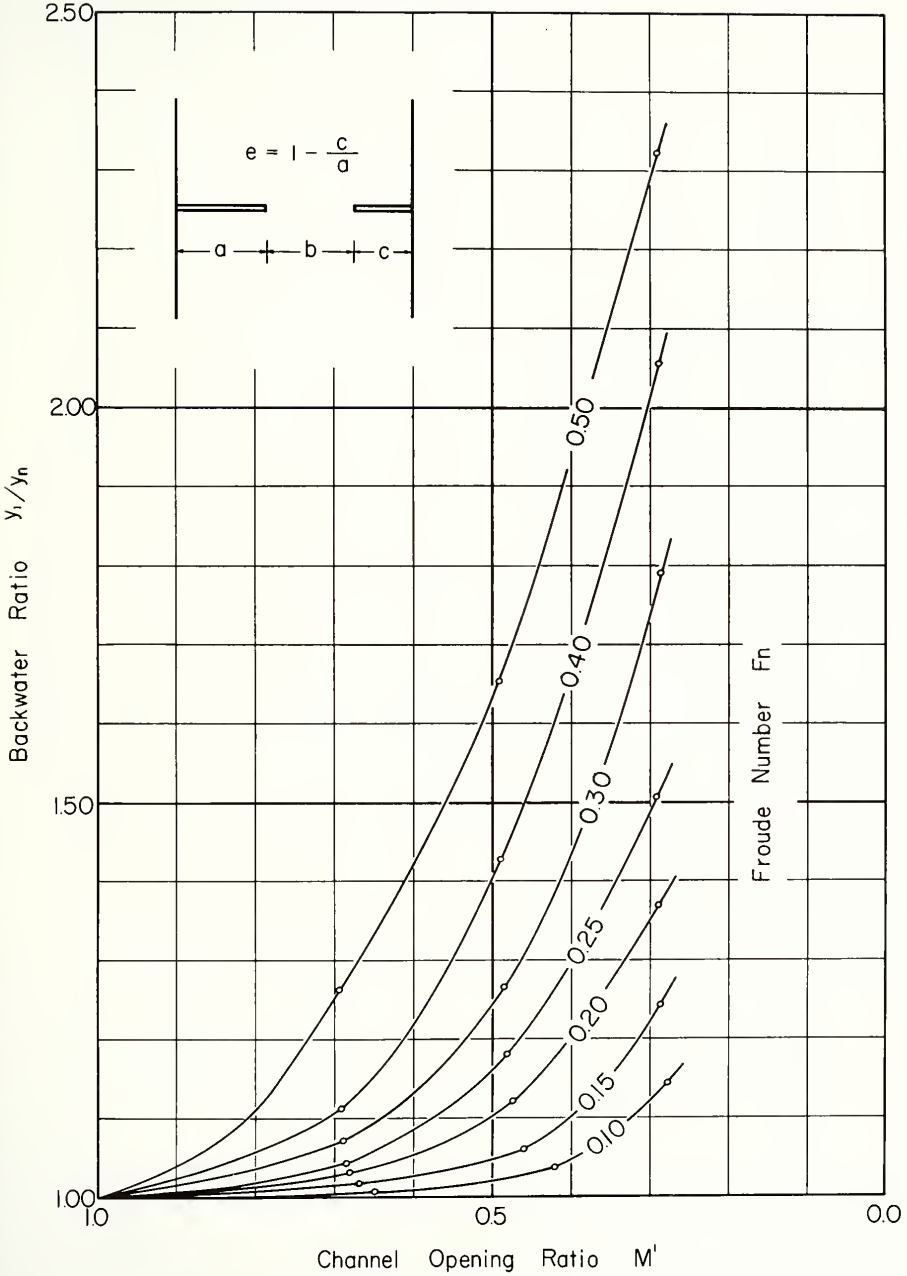


FIG. 7-5-1 BACKWATER RATIO FOR ECCENTRIC ARCH BRIDGES

e = 0

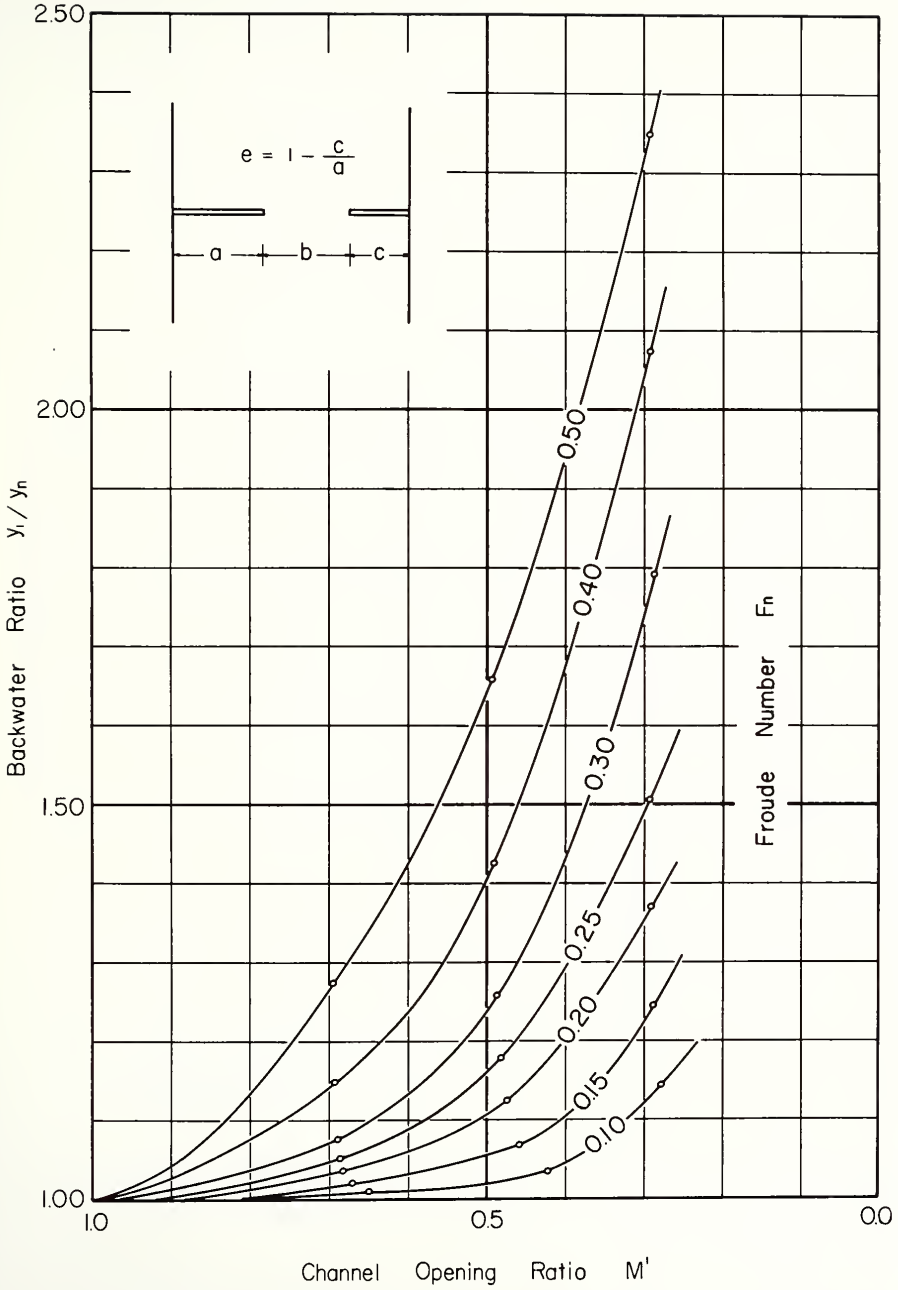


FIG. 7-5-2 - BACKWATER RATIO FOR ECCENTRIC ARCH BRIDGES

e = .80

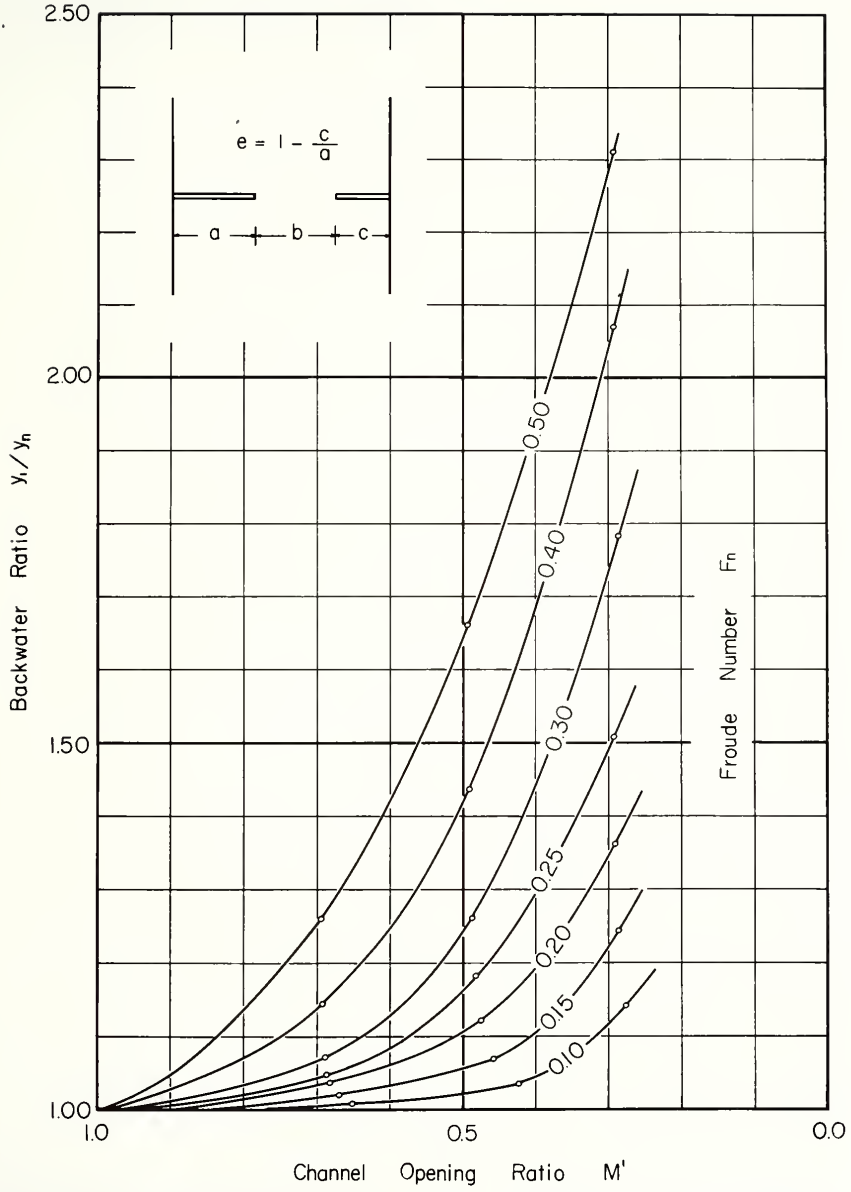


FIG. 7-5-3 - BACKWATER RATIO FOR ECCENTRIC ARCH BRIDGES

e = .85

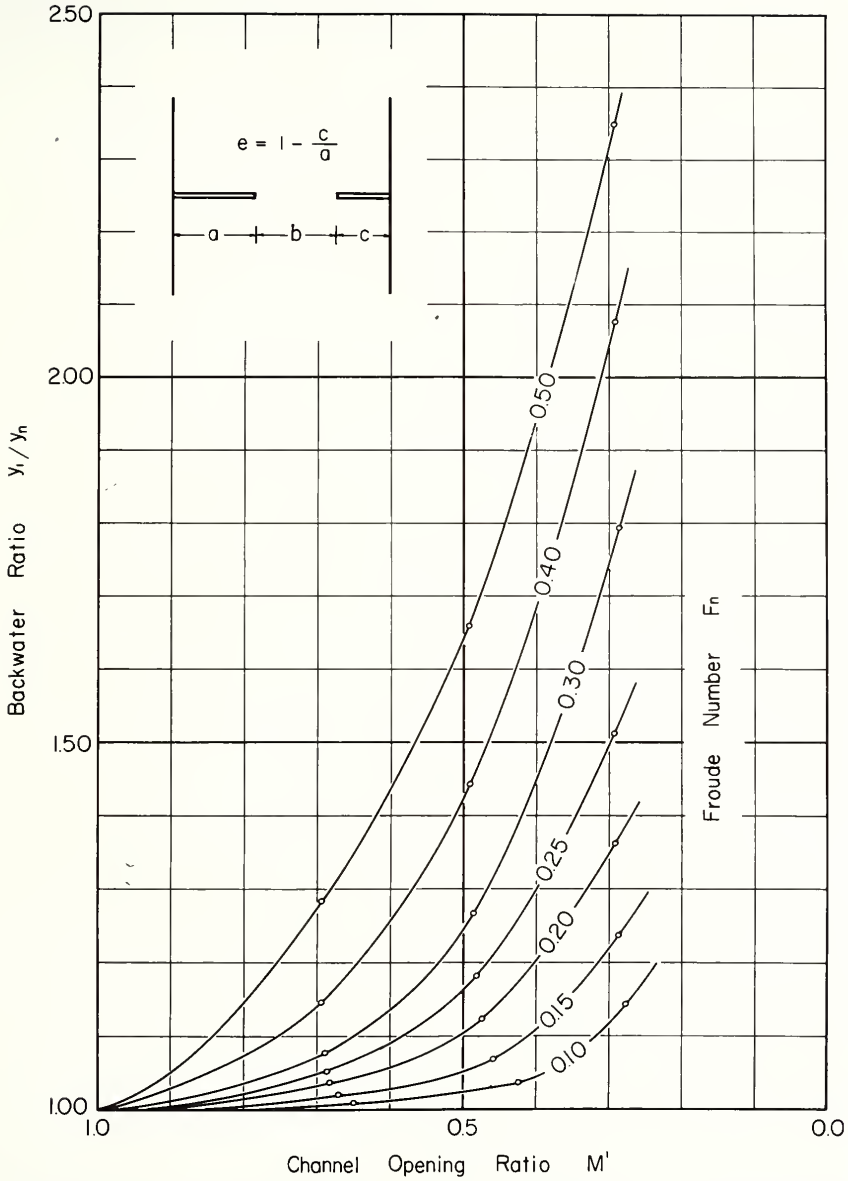


FIG. 7-5-4 BACKWATER RATIO FOR ECCENTRIC ARCH BRIDGES

e = .90

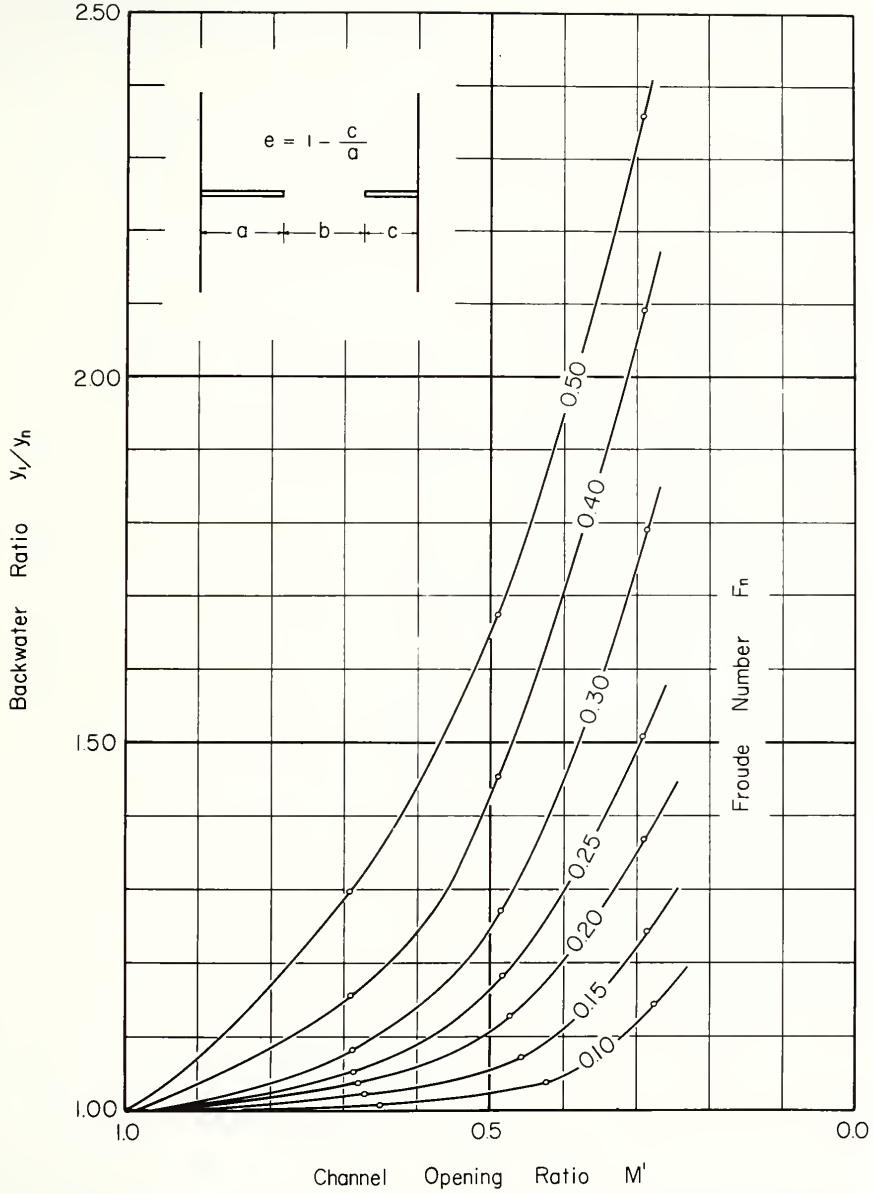


FIG. 7-5-5 - BACKWATER RATIO FOR ECCENTRIC ARCH BRIDGES

e = .95

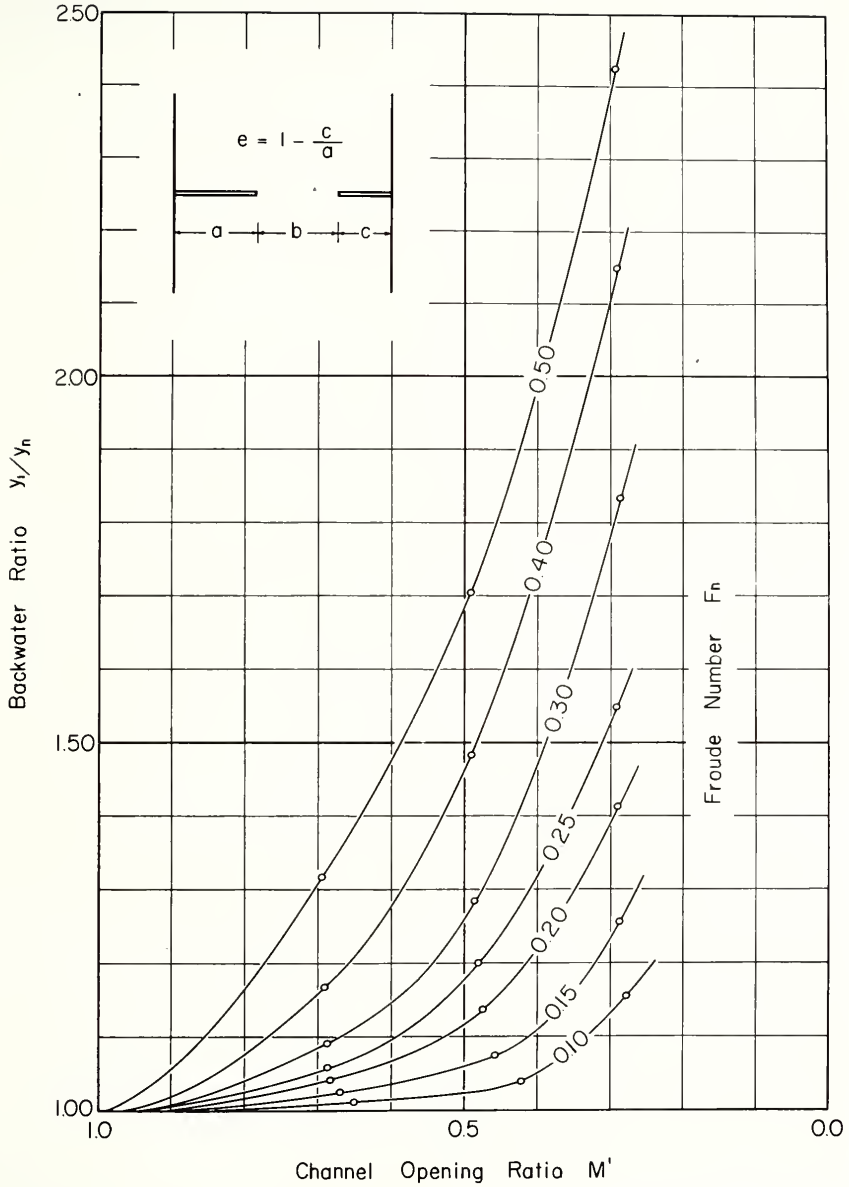


FIG. 7-5-6 - BACKWATER RATIO FOR ECCENTRIC ARCH BRIDGES

e = 1.00

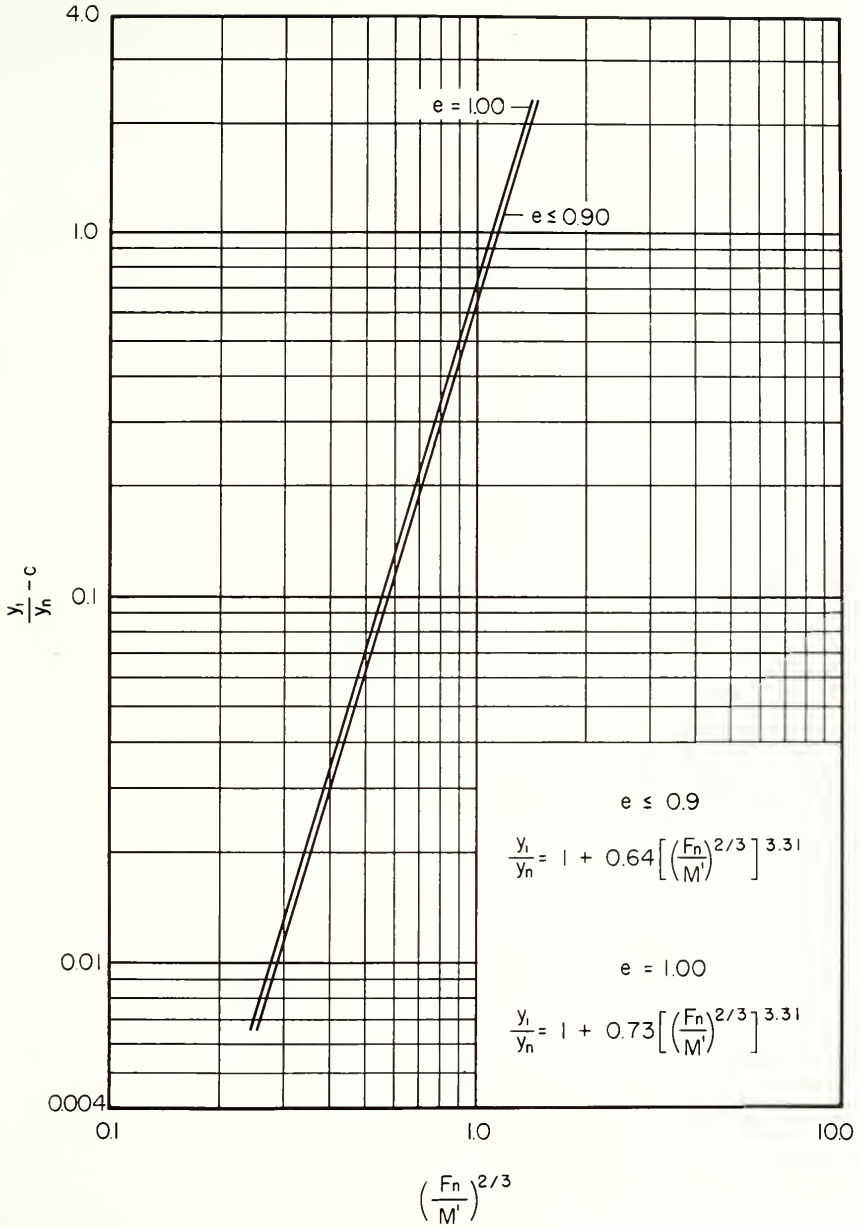


FIG. 7-5-7 - GENERALIZED BACKWATER RATIO FOR ECCENTRIC ARCH BRIDGE

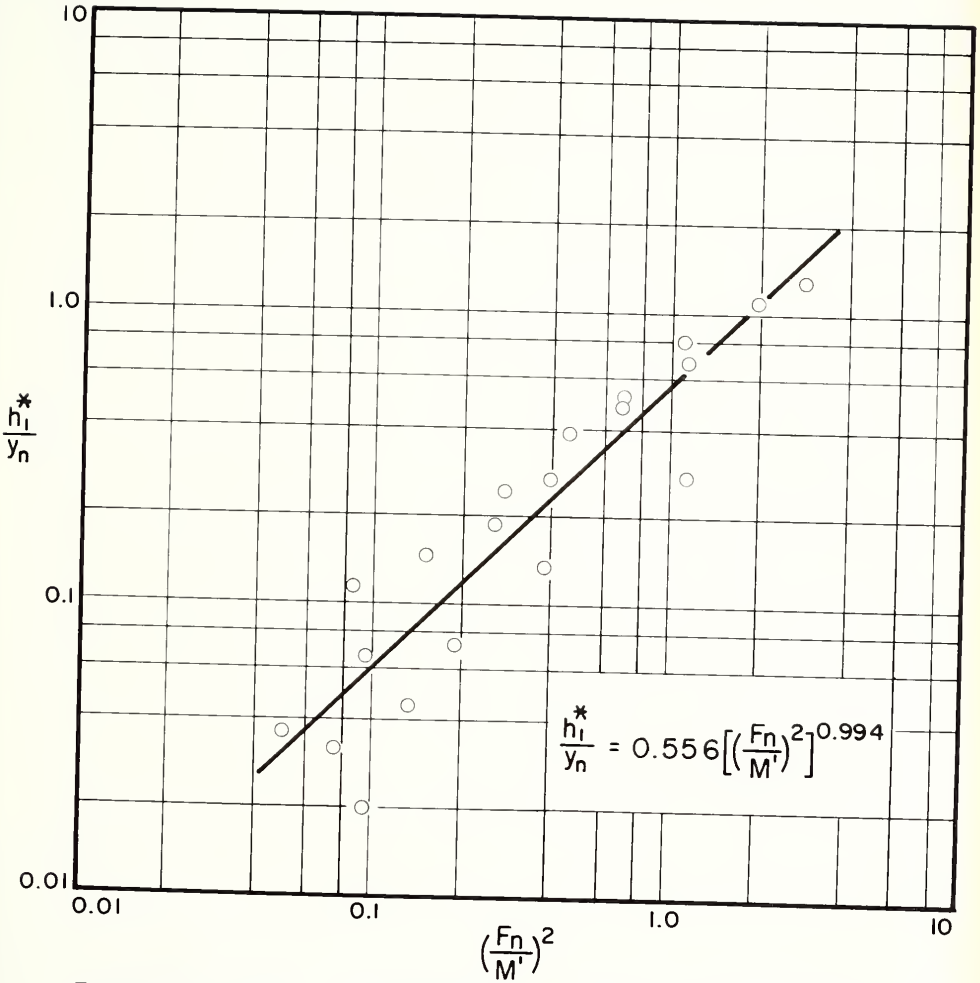


FIGURE 7-5-8 BACKWATER RATIO, GEOMETRY IV
ROUGH BOUNDARY e = 0.0

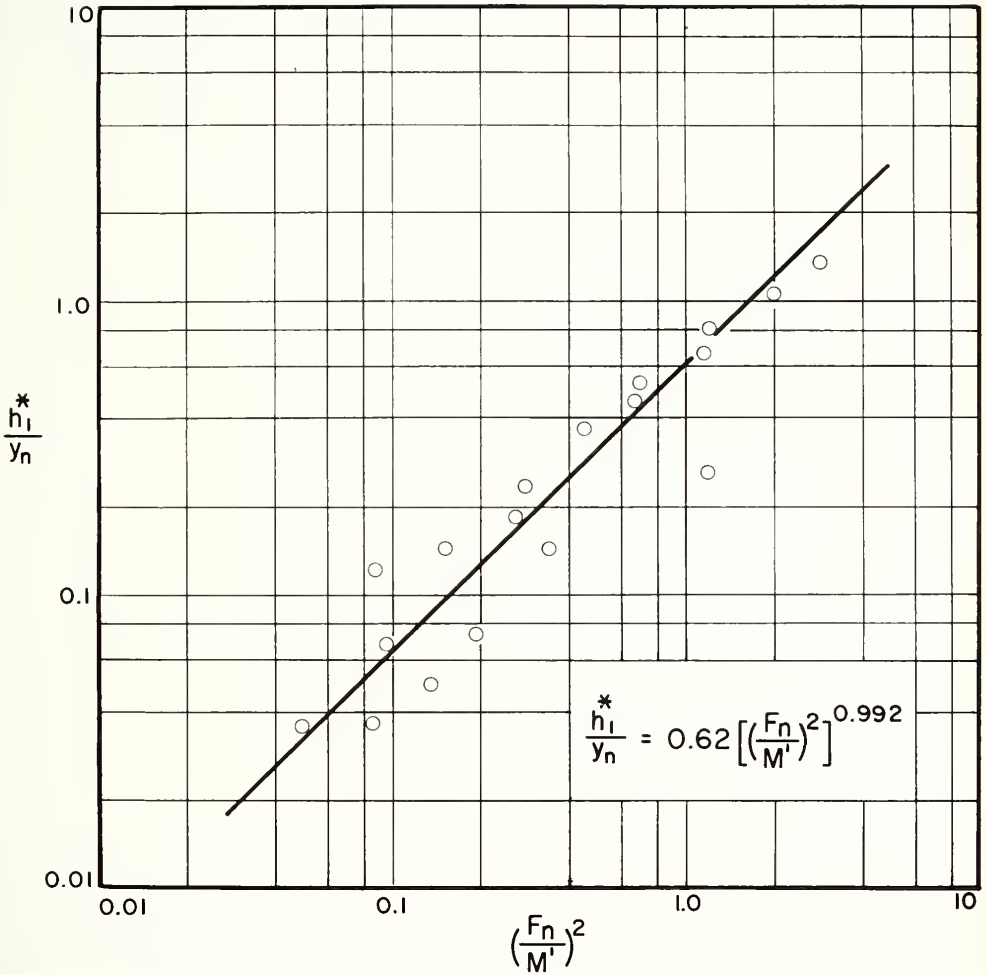


FIGURE 7-5-9 BACKWATER RATIO, GEOMETRY IV

ROUGH BOUNDARY e = 0.8

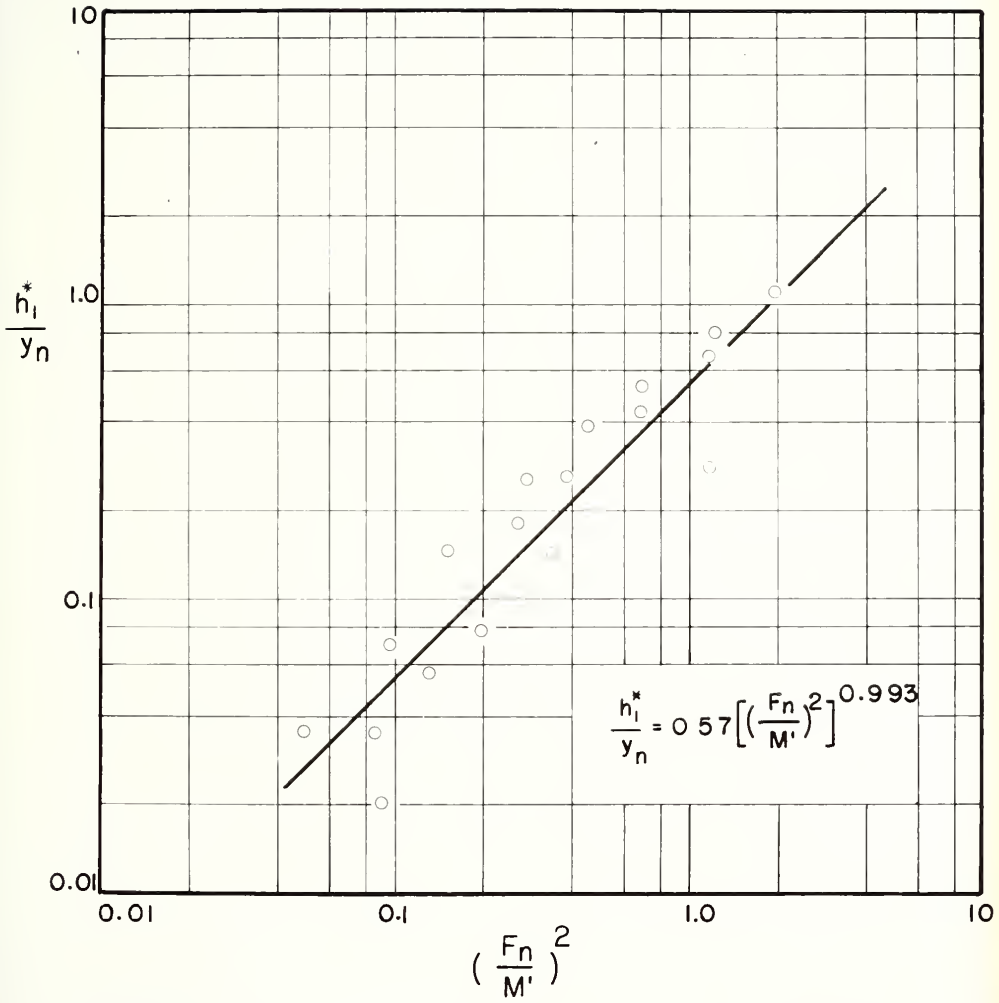


FIGURE 7-5-10 BACKWATER RATIO GEOMETRY IV

ROUGH BOUNDARY e = 0.85

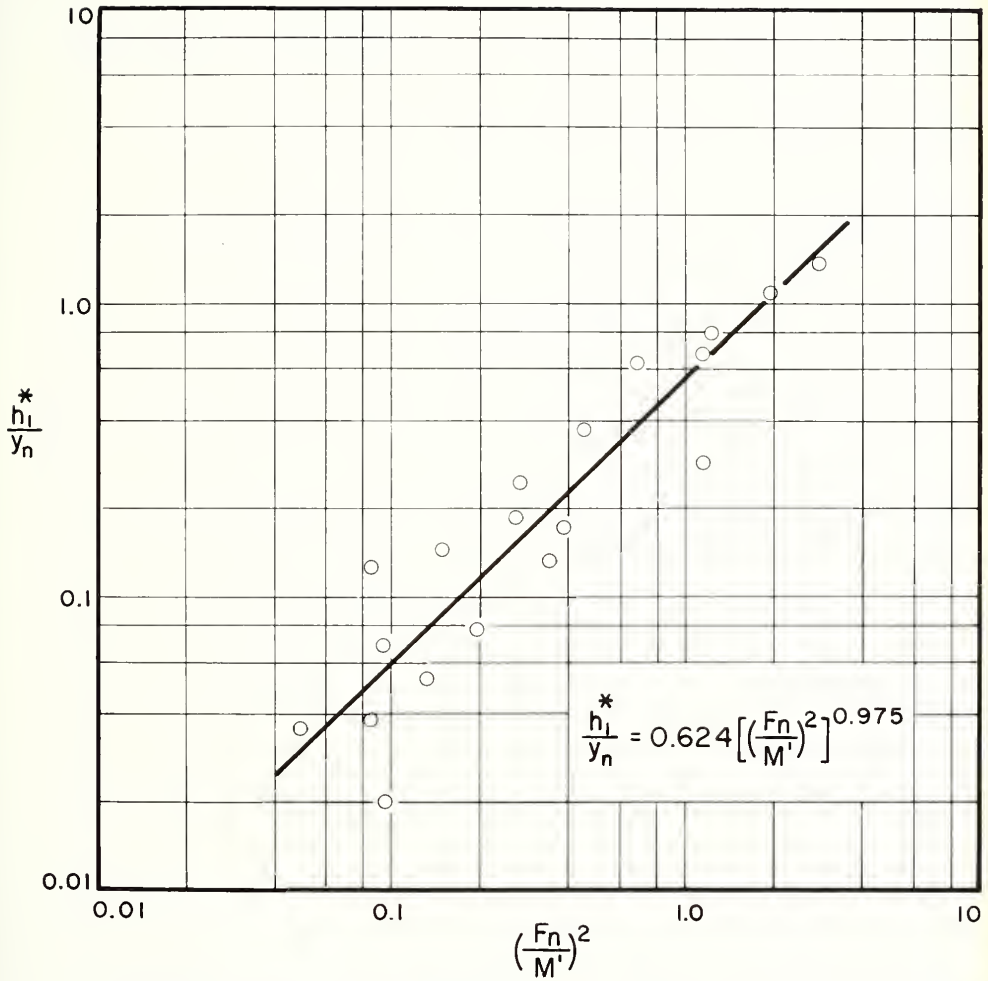


FIGURE 7-5-11 BACKWATER RATIO, GEOMETRY IV

ROUGH BOUNDARY e = 0.9

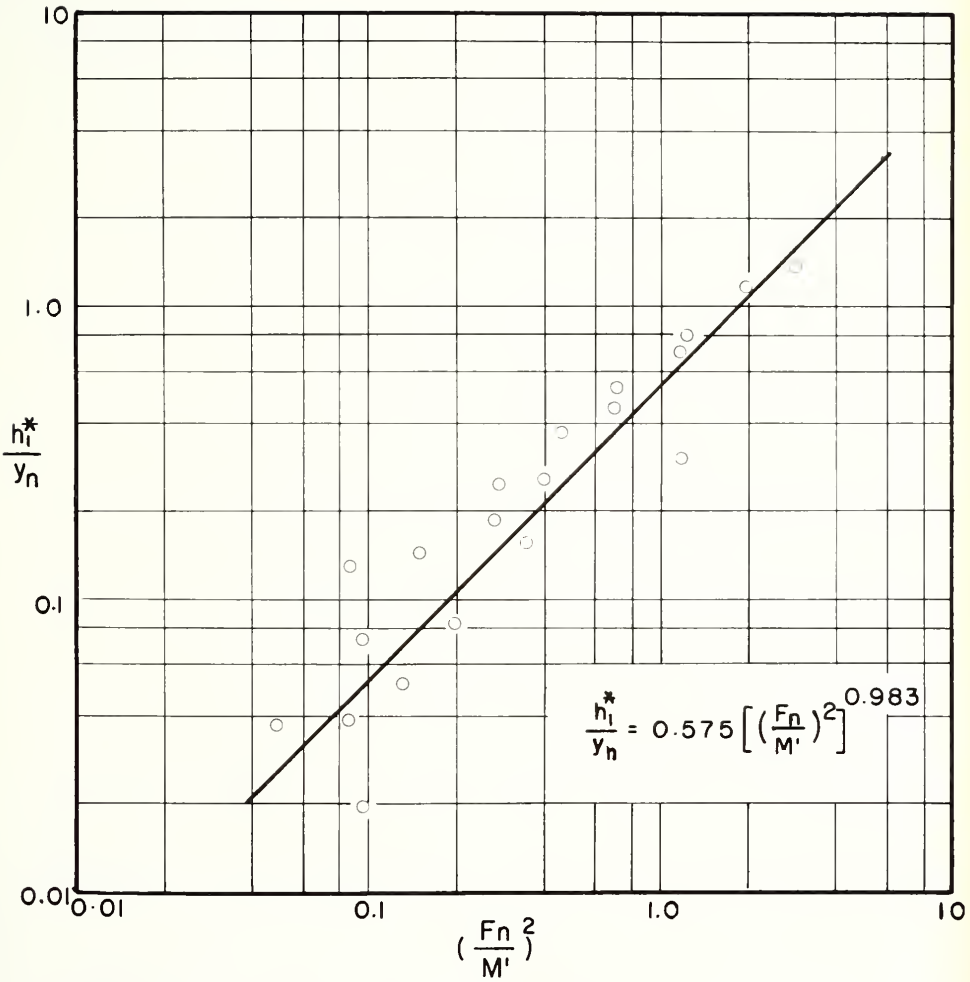


FIGURE 7-5-12 BACKWATER RATIO GEOMETRY IV

ROUGH BOUNDARY e = 0.95

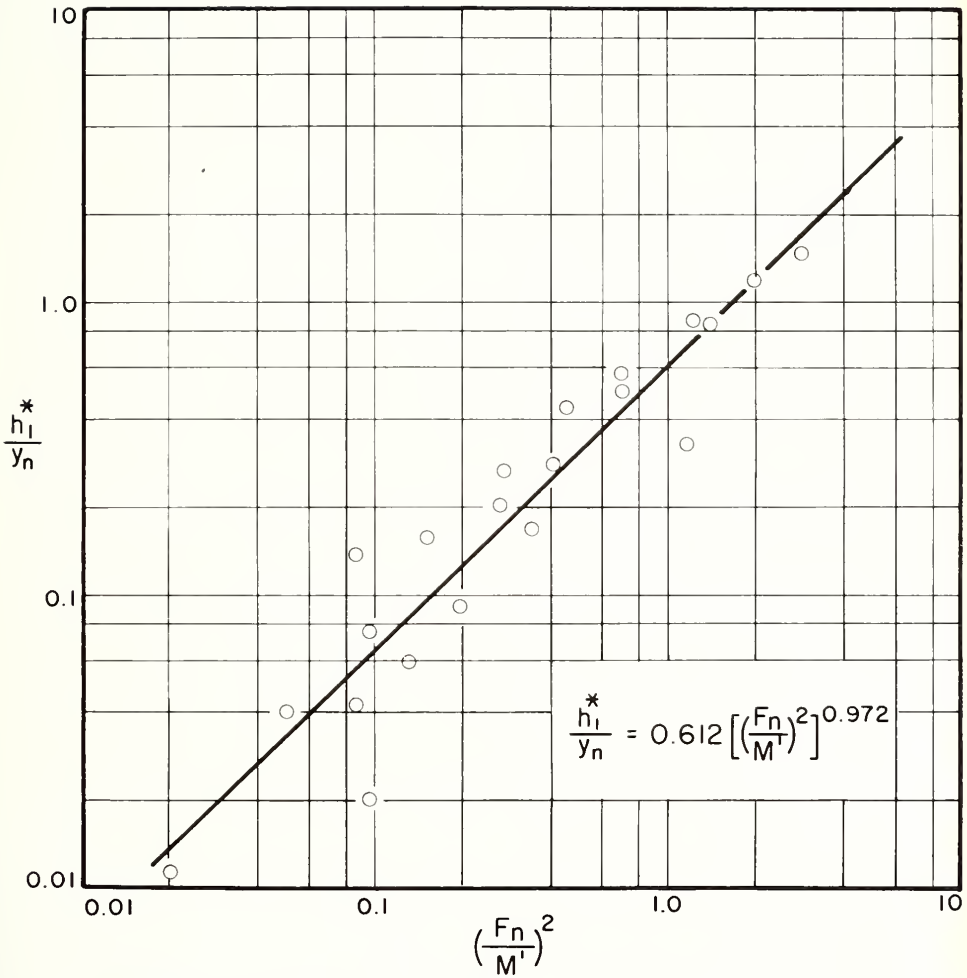


FIGURE 7-5-13 BACKWATER RATIO, GEOMETRY IV
ROUGH BOUNDARY e = 1.0

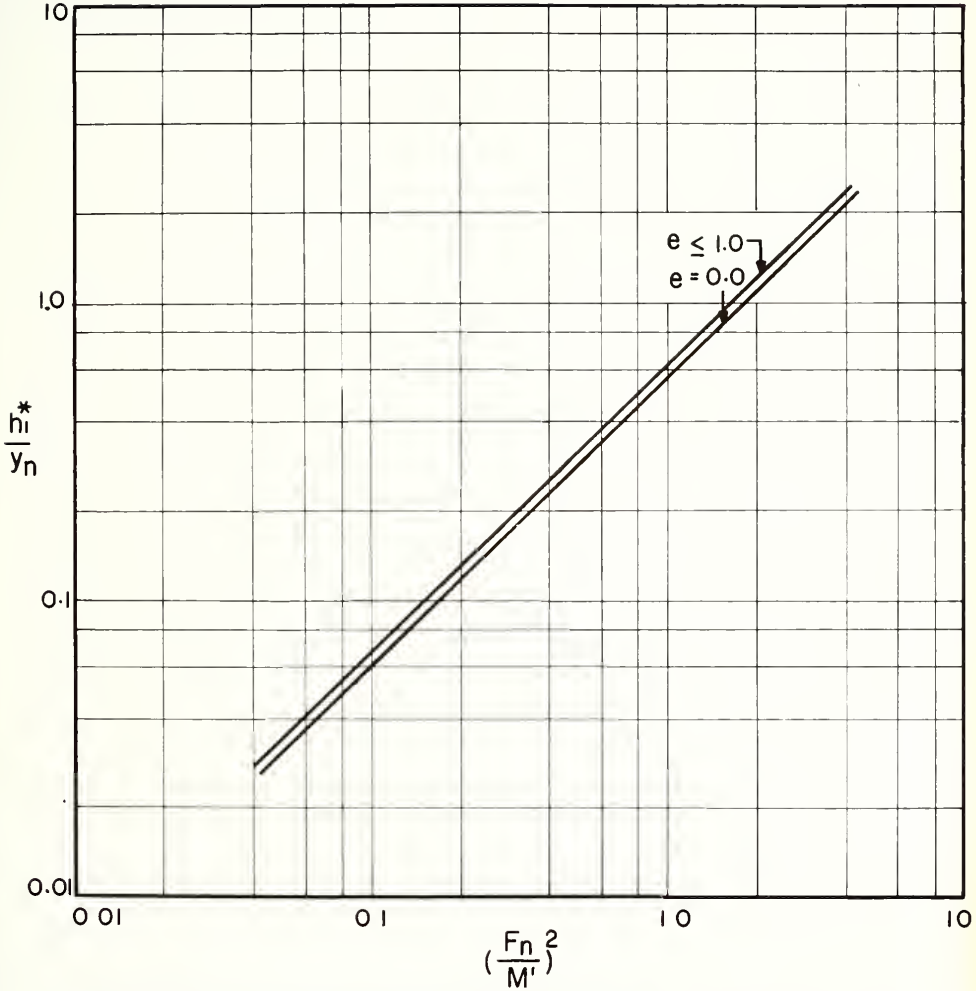


FIGURE 7-5-14 SUMMARY OF BACKWATER RATIO

GEOMETRY IV ROUGH BOUNDARY

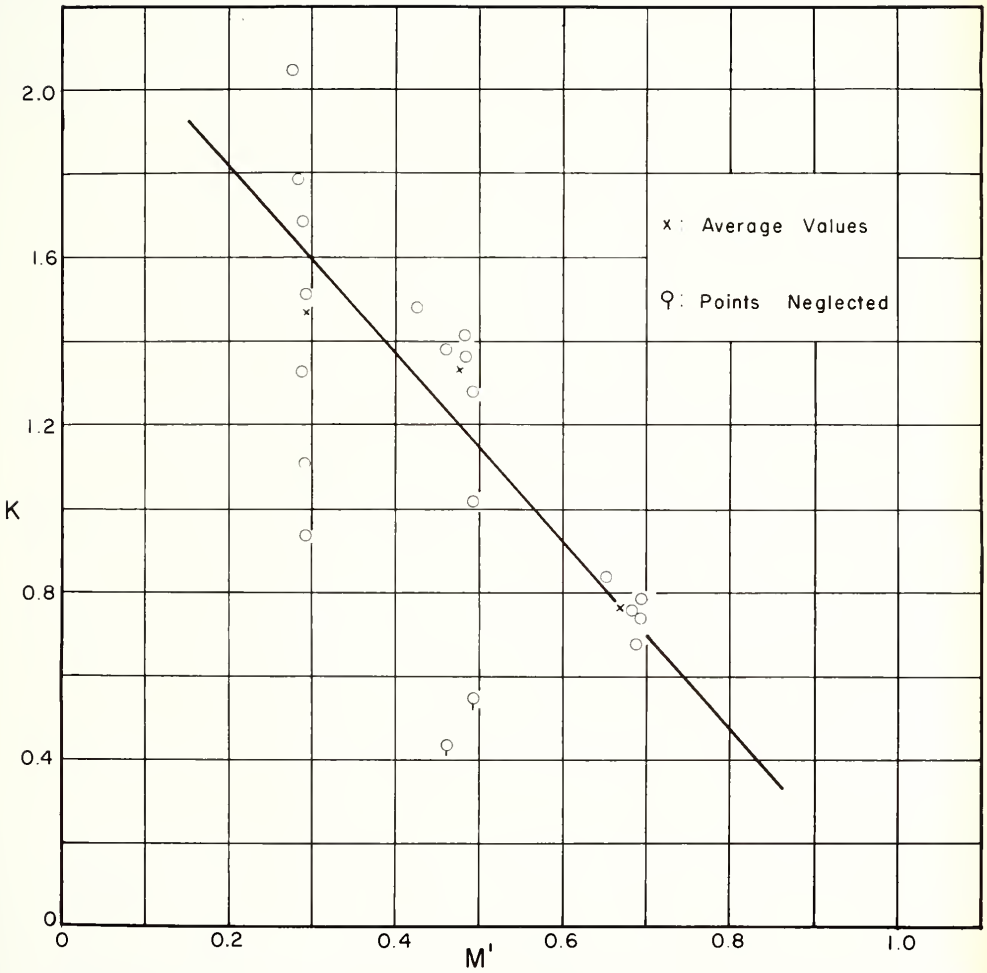


FIGURE 7-5-15 HEAD LOSS COEFFICIENT, GEOMETRY IV
ROUGH BOUNDARY e = 0.00

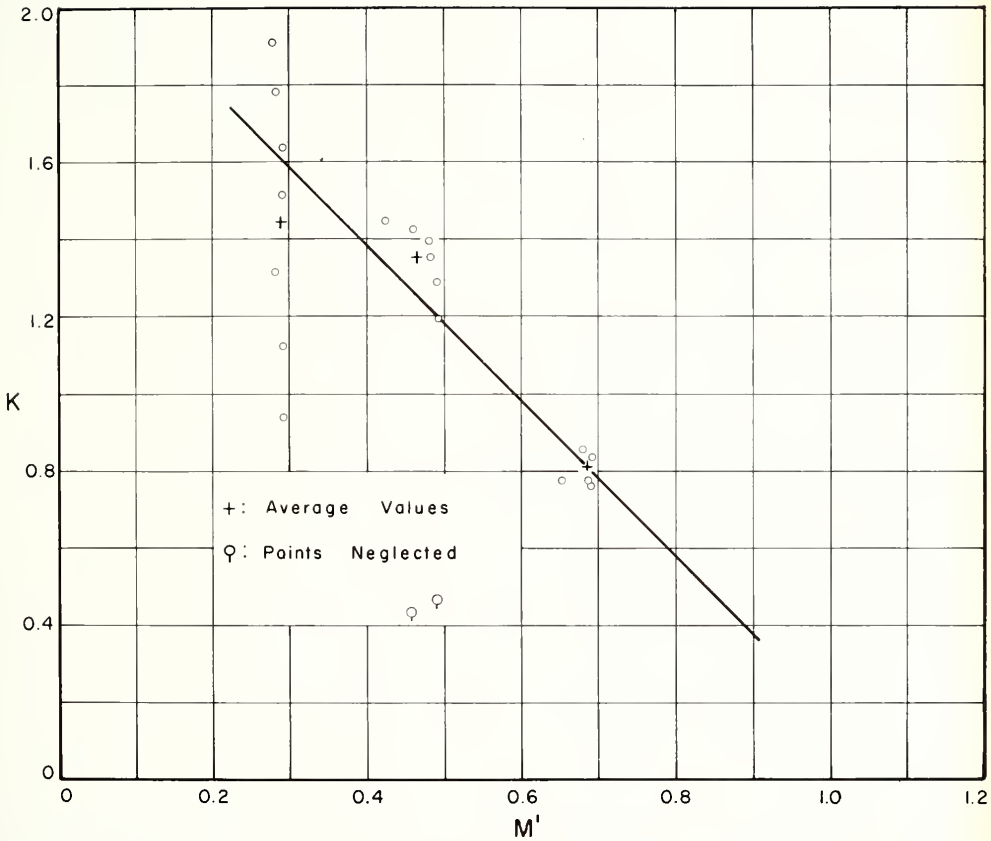


FIGURE 7-5-16 HEAD LOSS COEFFICIENT, GEOMETRY IV
ROUGH BOUNDARY e =0·8

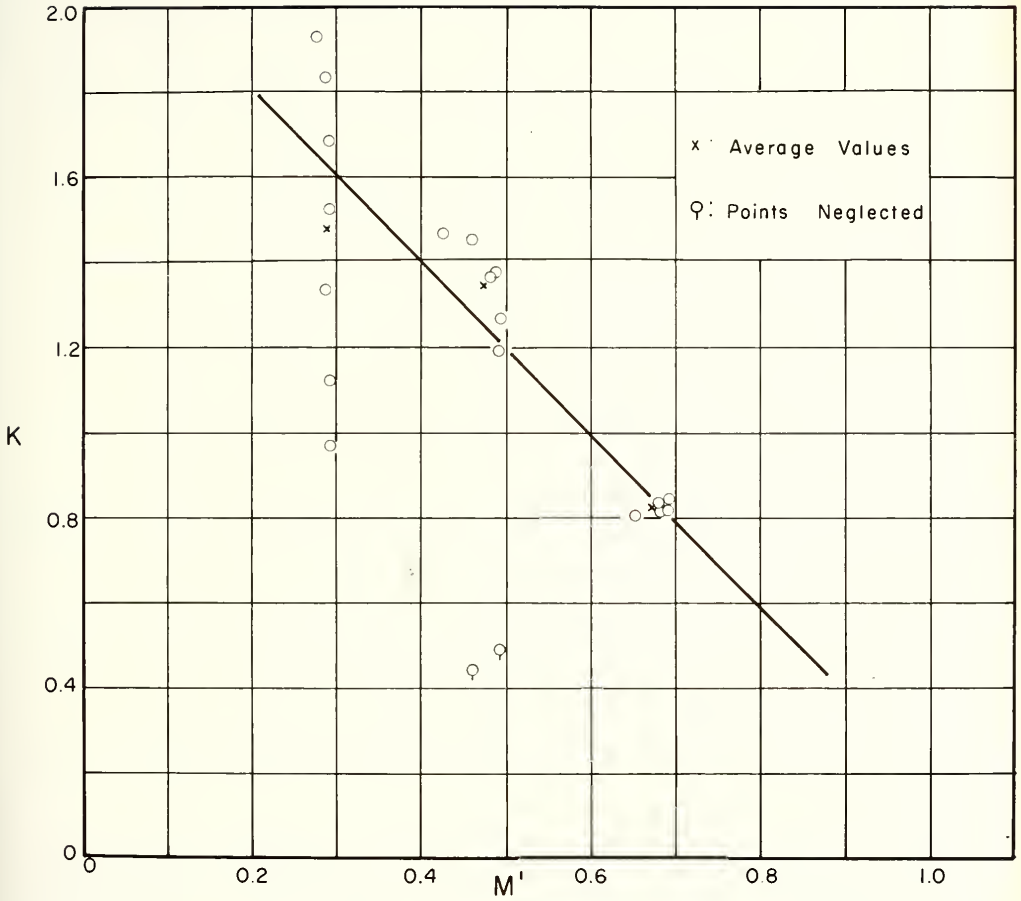


FIGURE 7-5-17 HEAD LOSS COEFFICIENT, GEOMETRY IV
ROUGH BOUNDARY e = 0.85

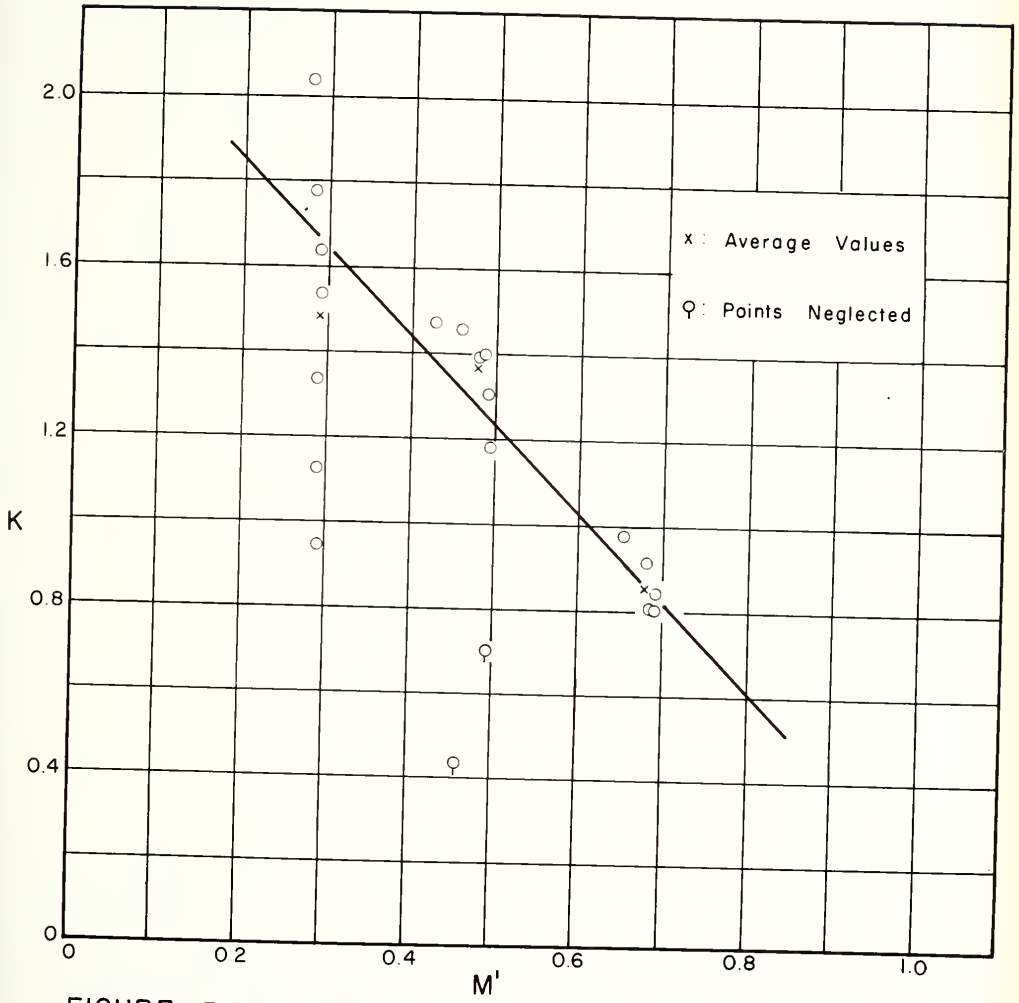


FIGURE 7-5-18 HEAD LOSS COEFFICIENT, GEOMETRY IV
ROUGH BOUNDARY e = 0.9

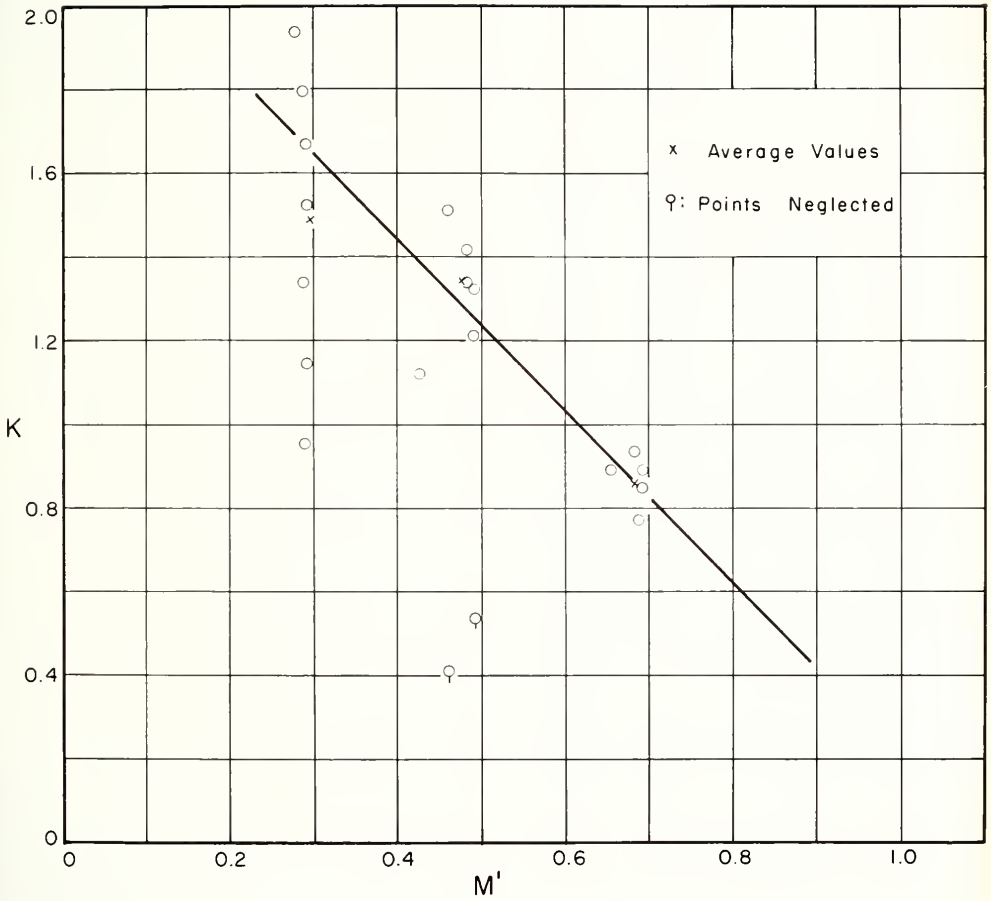


FIGURE 7-5-19 HEAD LOSS COEFFICIENT, GEOMETRY IV
ROUGH BOUNDARY e = 0.95

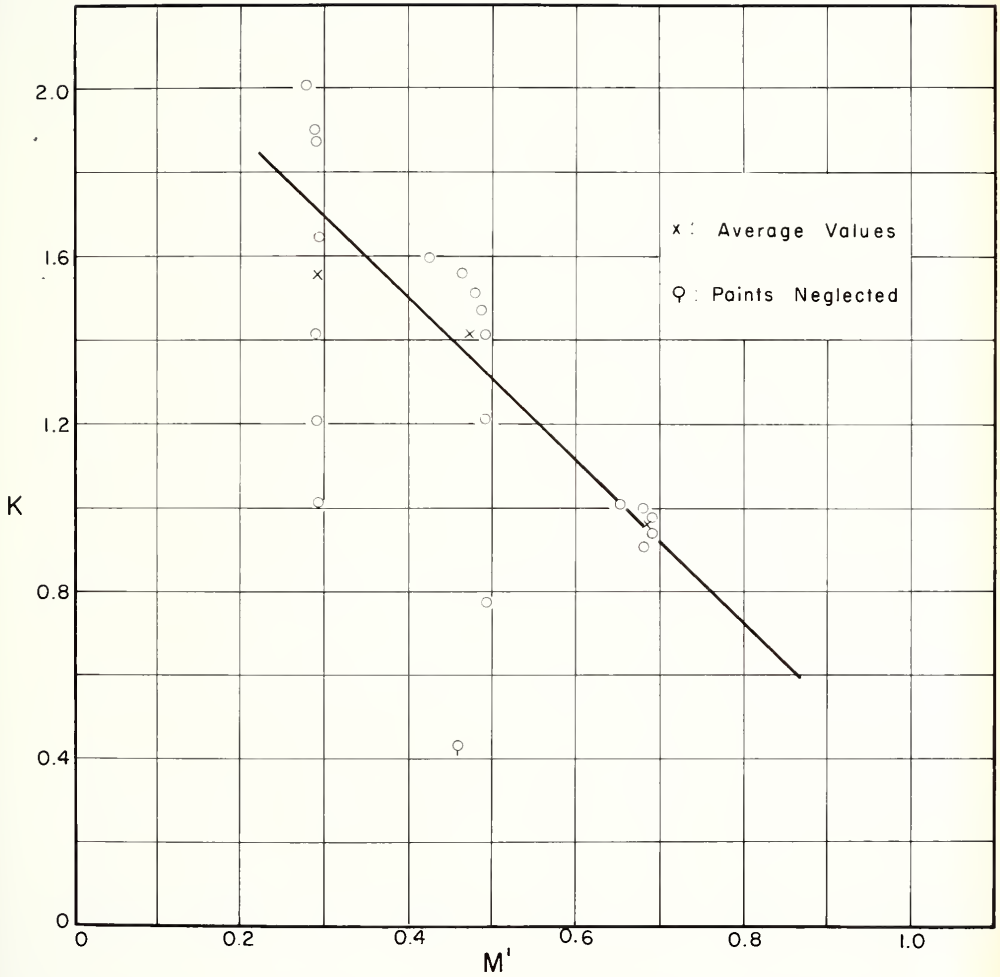


FIGURE 7-5-20 HEAD LOSS COEFFICIENT, GEOMETRY IV
ROUGH BOUNDARY e = 1.0

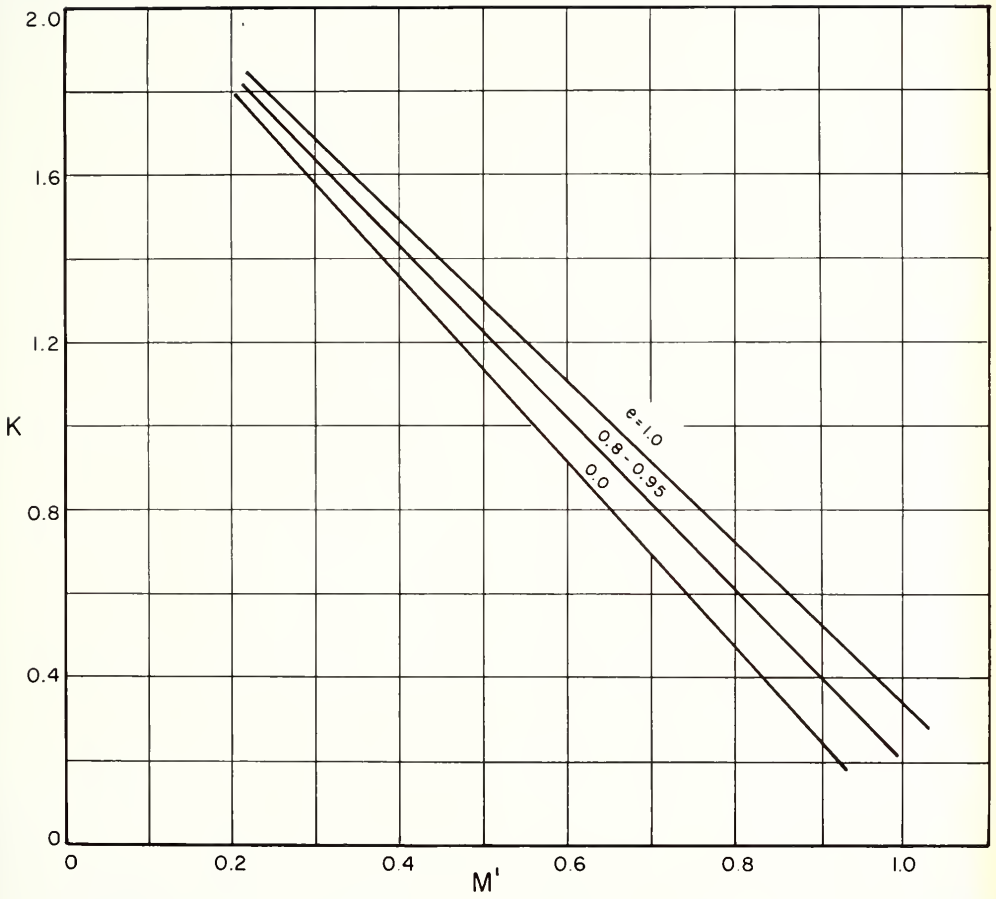


FIGURE 7-5-21 SUMMARY OF HEAD LOSS COEFFICIENTS
GEOMETRY IV ROUGH BOUNDARY

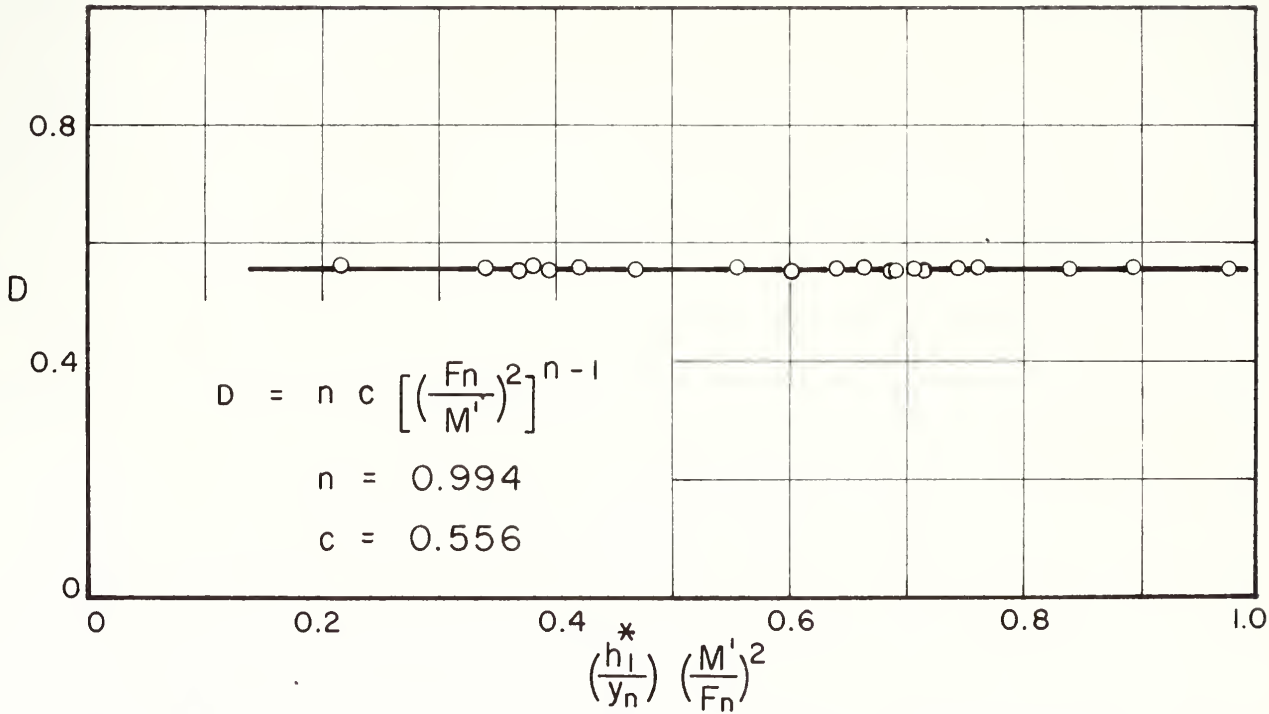


FIGURE 7-5-22 BACKWATER RATIO COEFFICIENT, GEOMETRY IV ROUGH BOUNDARY e = 0.0

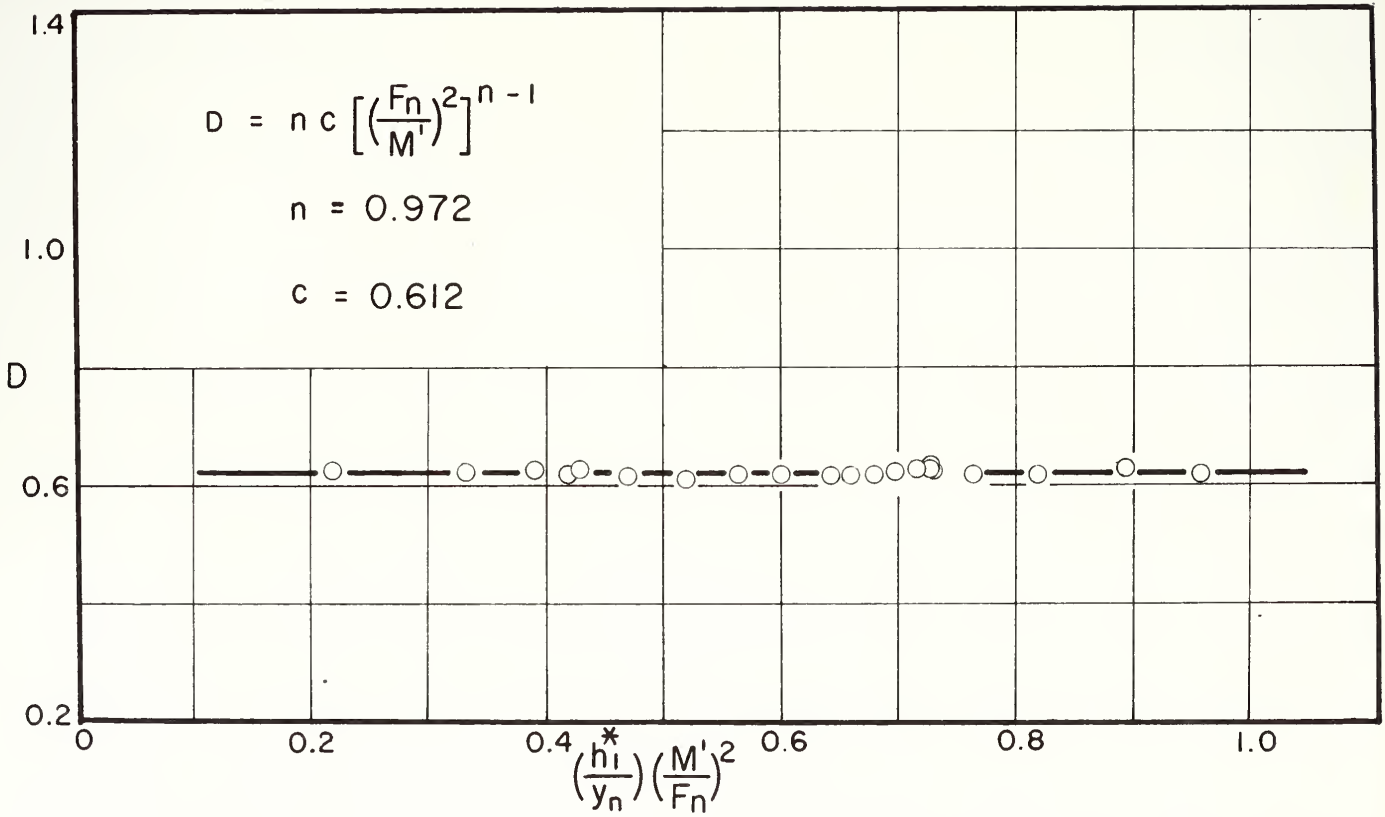


FIGURE 7-5-23 BACKWATER RATIO COEFFICIENT, GEOMETRY IV ROUGH BOUNDARY e = 0.8

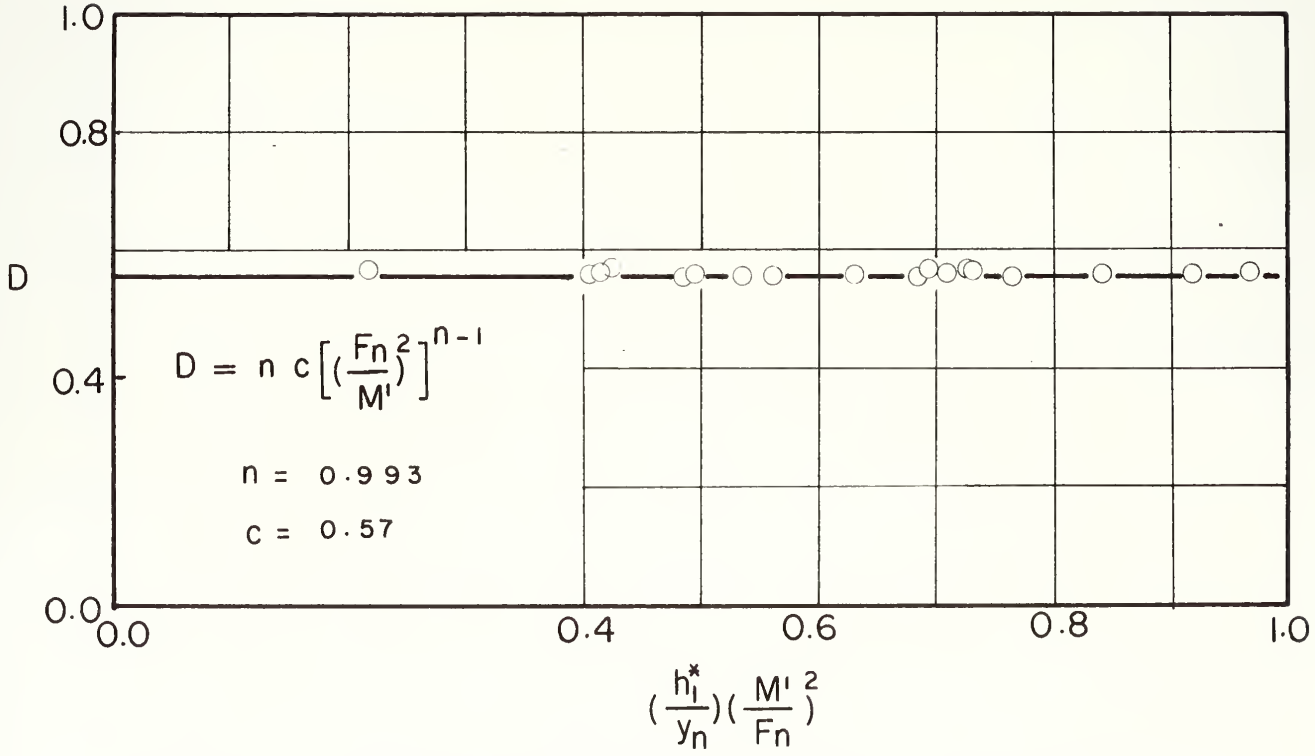


FIGURE 7-5-24 BACKWATER RATIO COEFFICIENT

GEOMETRY IV ROUGH BOUNDARY e = 0.85

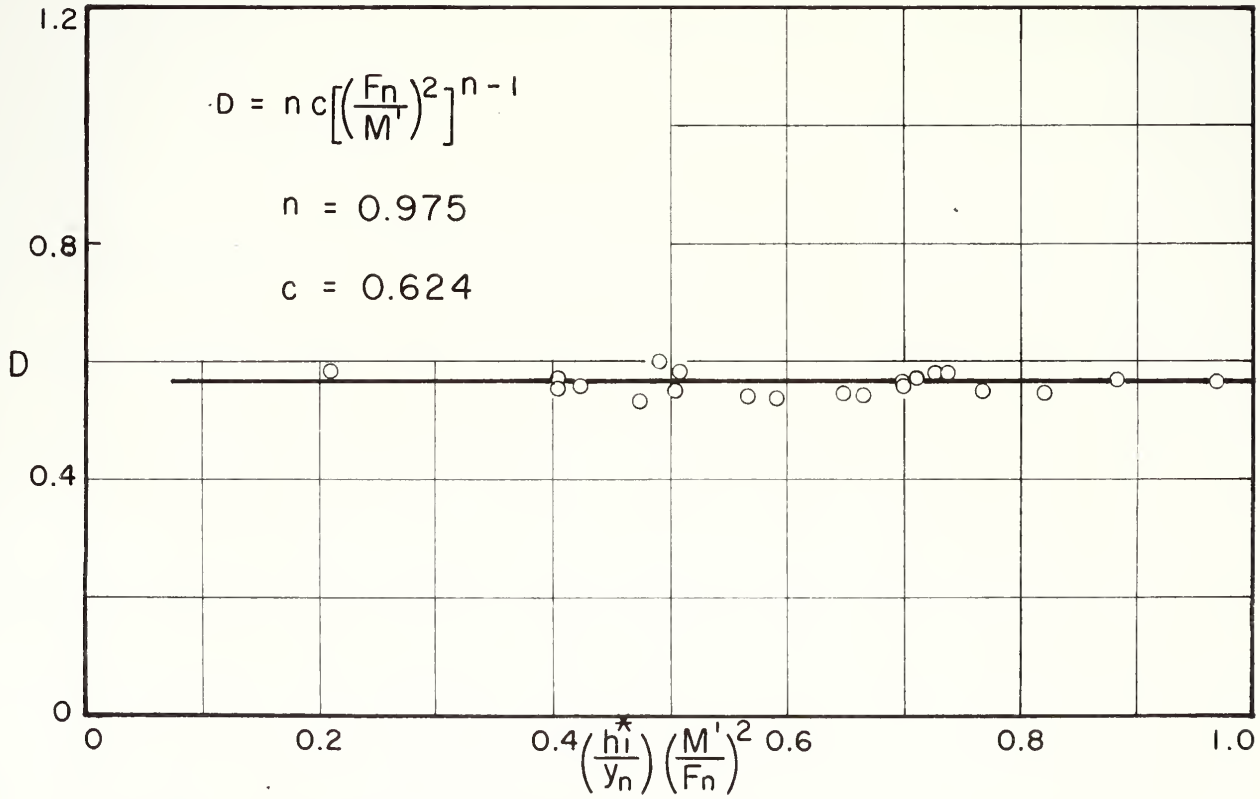


FIGURE 7-5-25 BACKWATER RATIO COEFFICIENT, GEOMETRY IV ROUGH BOUNDARY e = 0.9

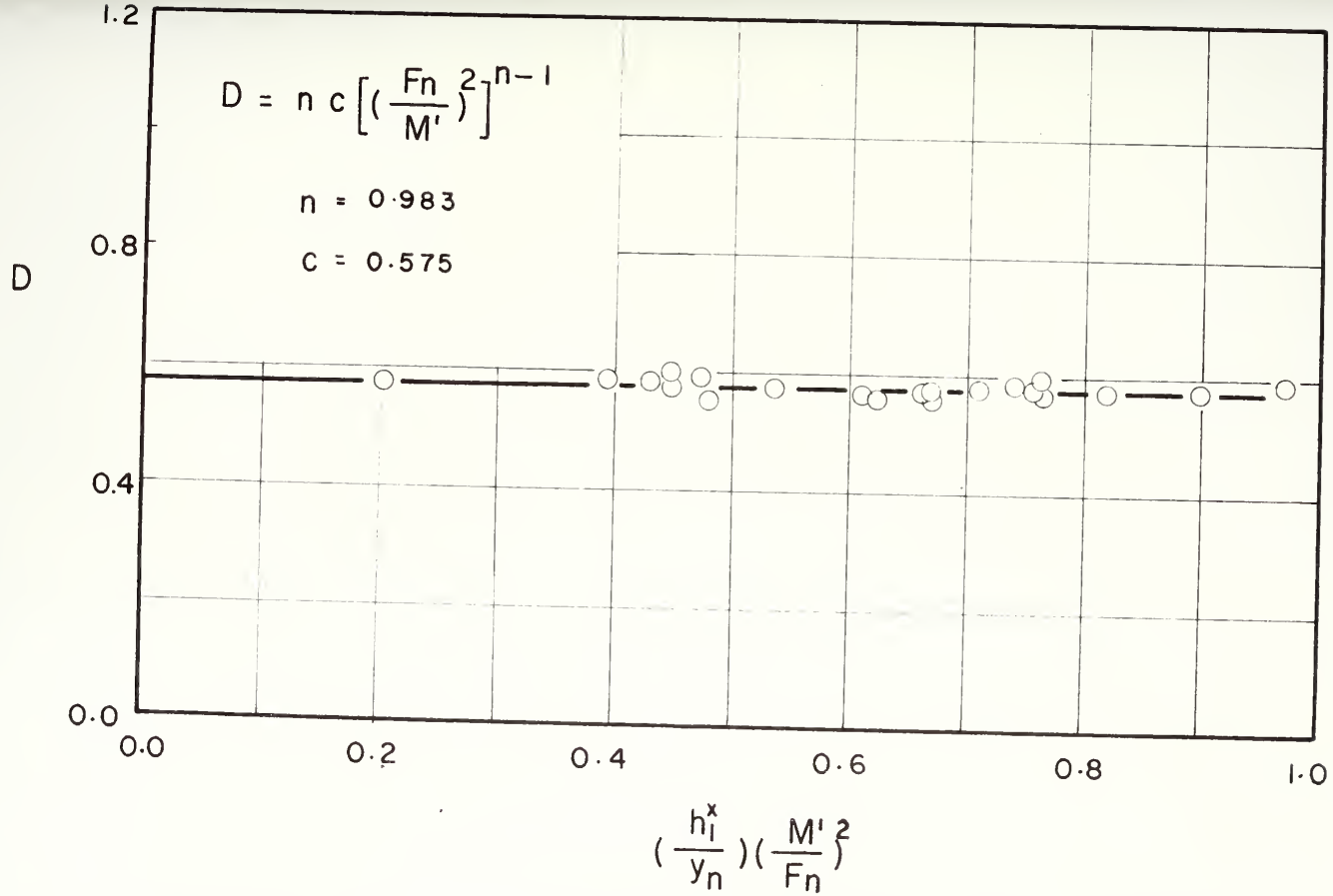


FIGURE 7-5-26 BACKWATER RATIO COEFFICIENT

GEOMETRY IV ROUGH BOUNDARY e = 0.95

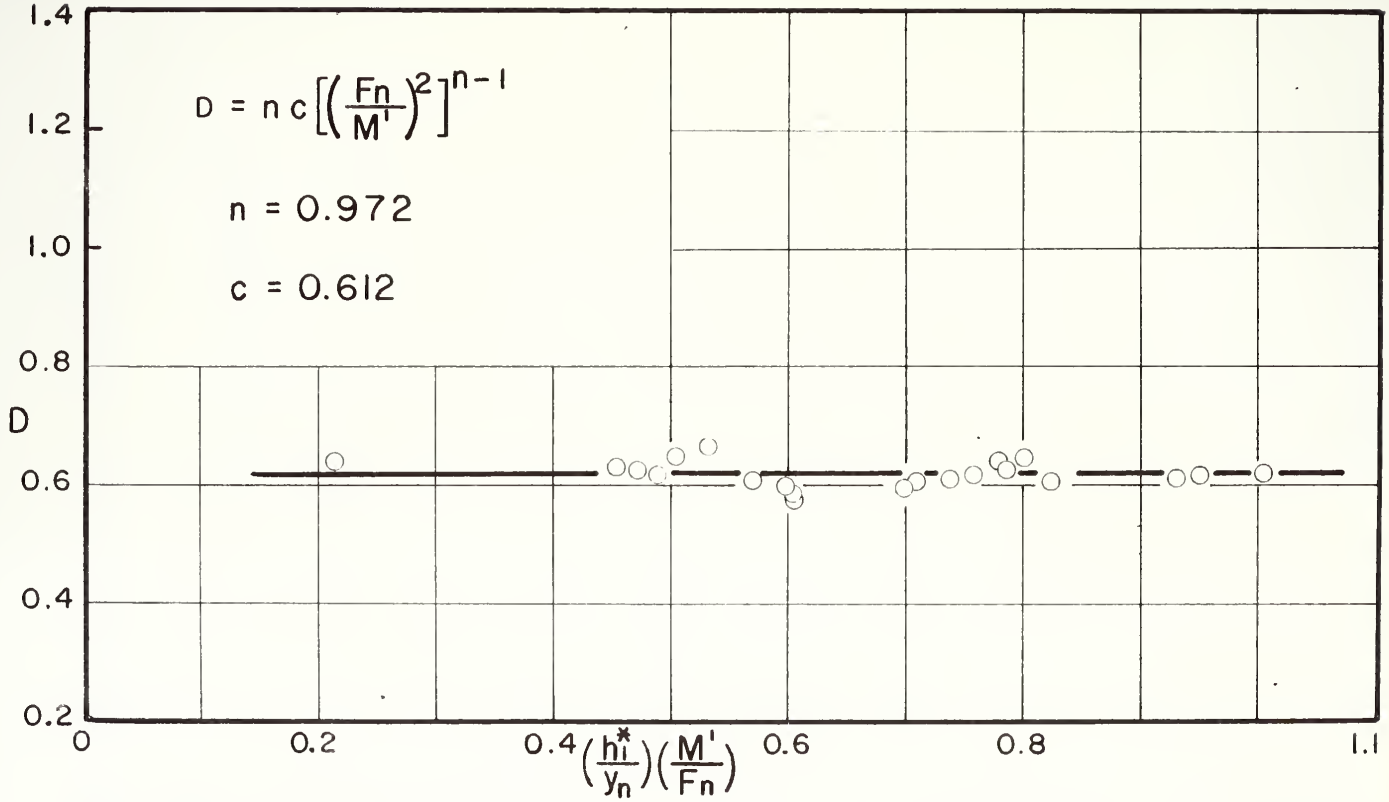


FIGURE 7-5-27 BACKWATER RATIO COEFFICIENT GEOMETRY IV ROUGH BOUNDARY e = 1.0

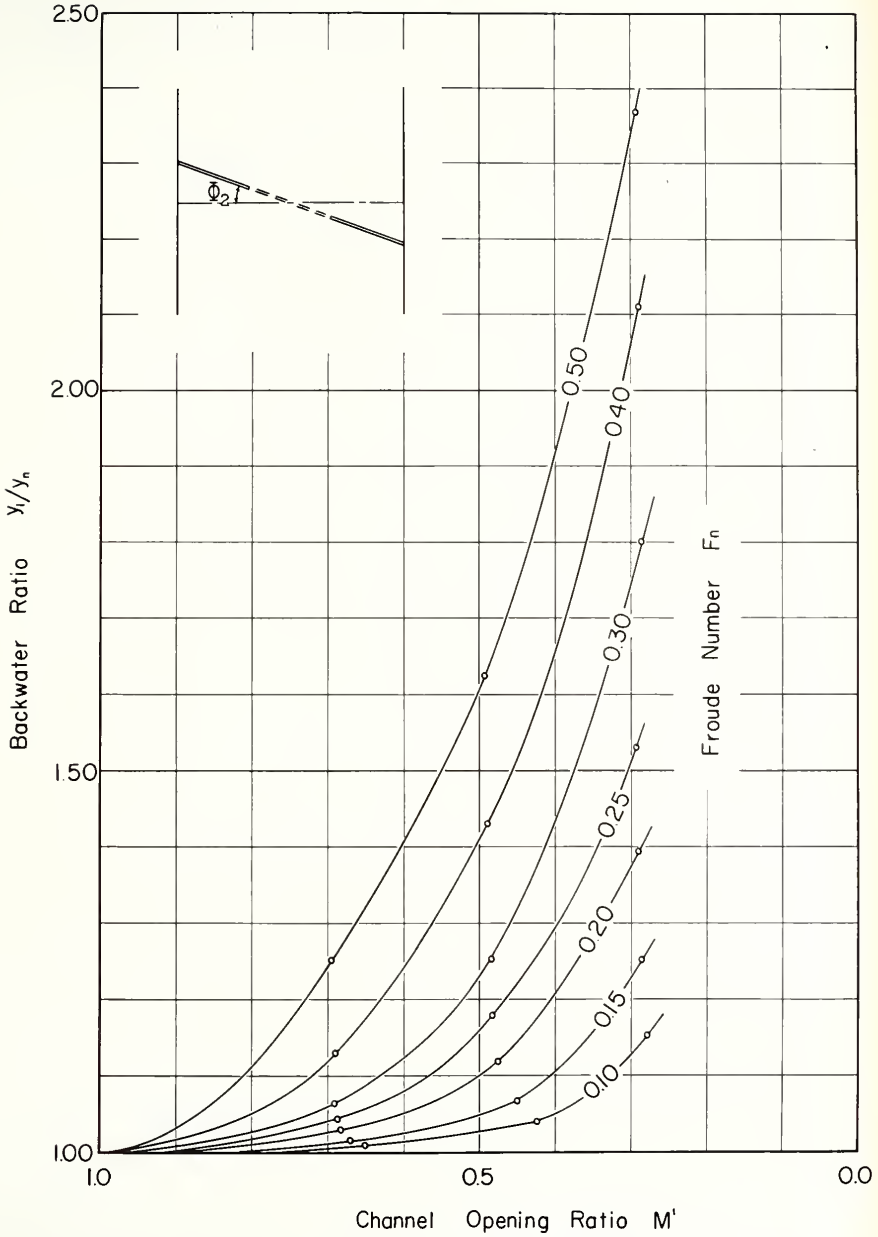


FIG. 7-6-1 -BACKWATER RATIO FOR SKEW ARCH BRIDGES
$\Phi_2 = 0°$

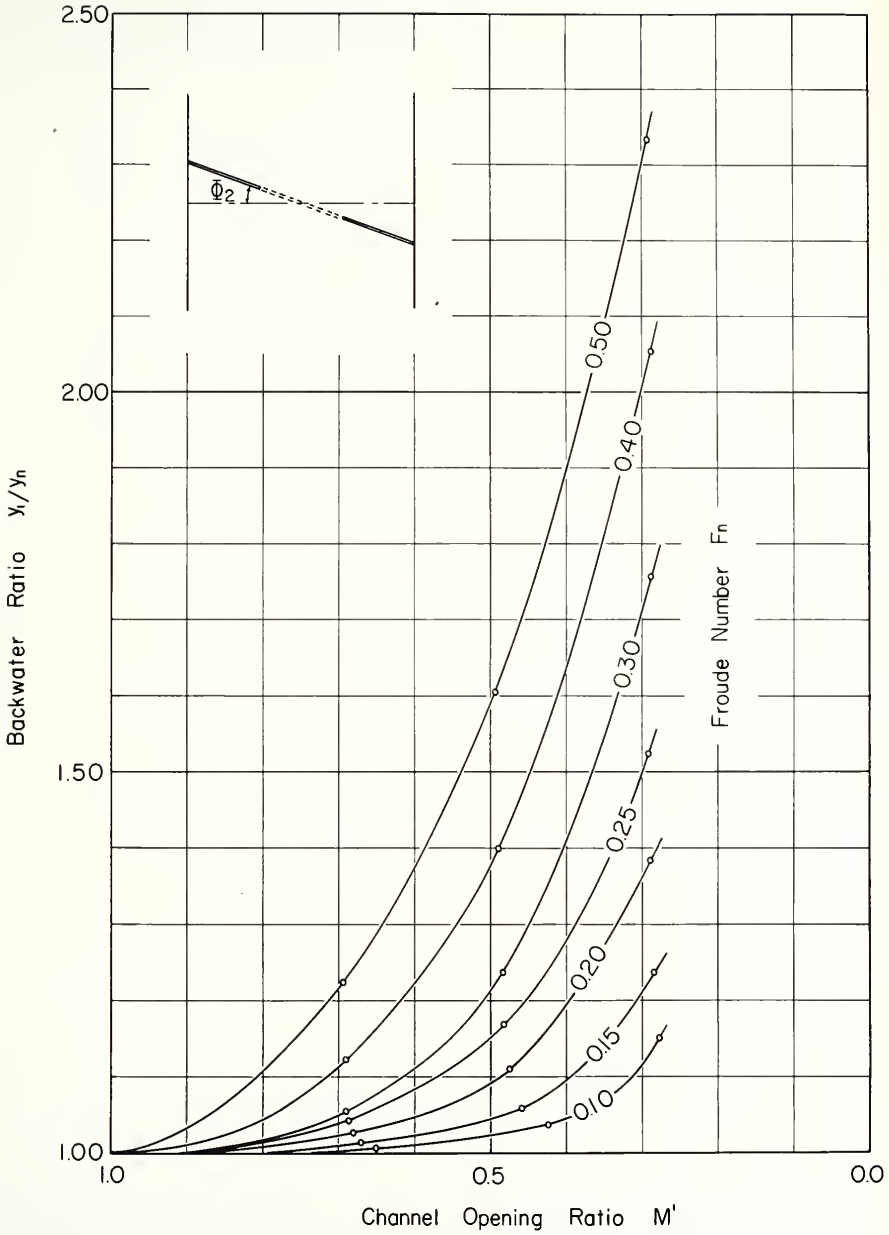


FIG. 7-6-2 -BACKWATER RATIO FOR SKEW ARCH BRIDGES

$\Phi_2 = 15°$

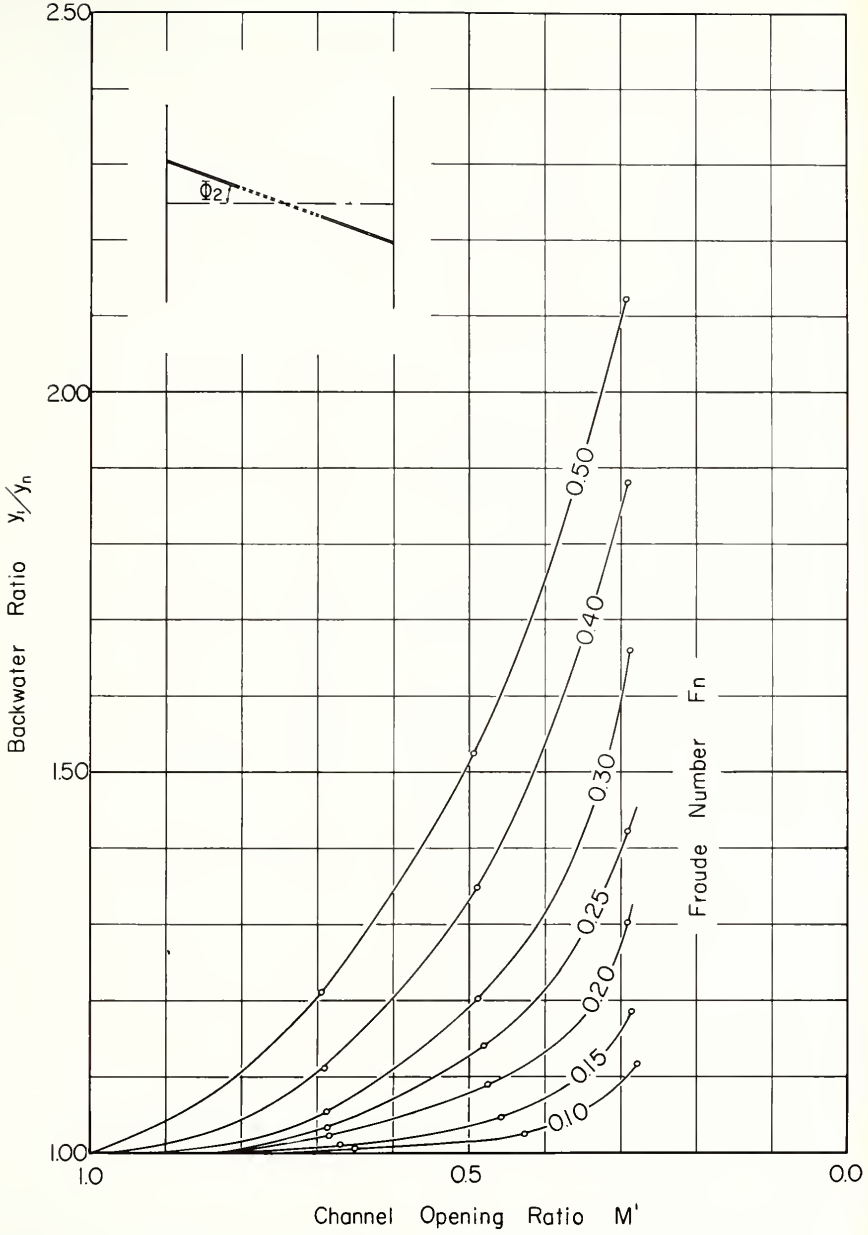


FIG. 7-6-3 -BACKWATER RATIO FOR SKEW ARCH BRIDGES

$\Phi_2 = 30°$

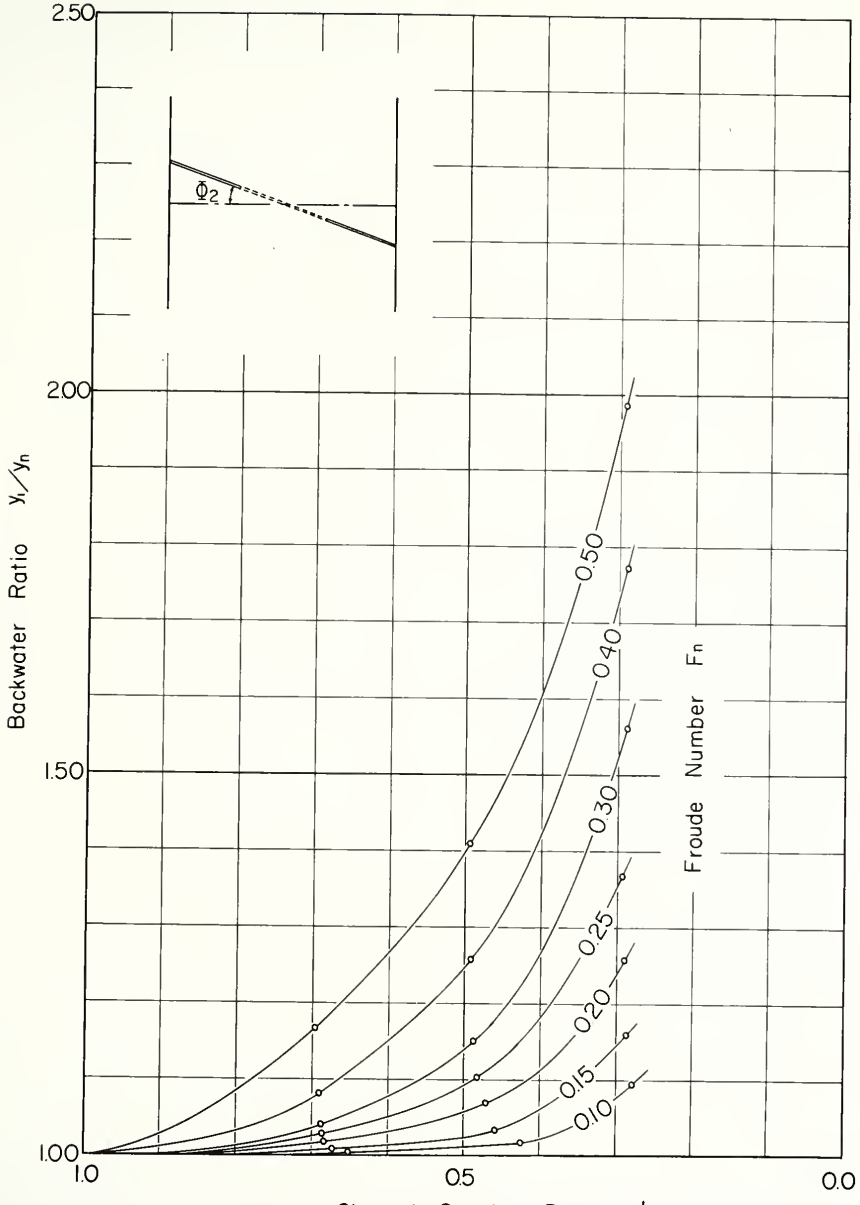


FIG. 7-6-4-BACKWATER RATIO FOR SKEW ARCH BRIDGES

$\Phi_2 = 45°$

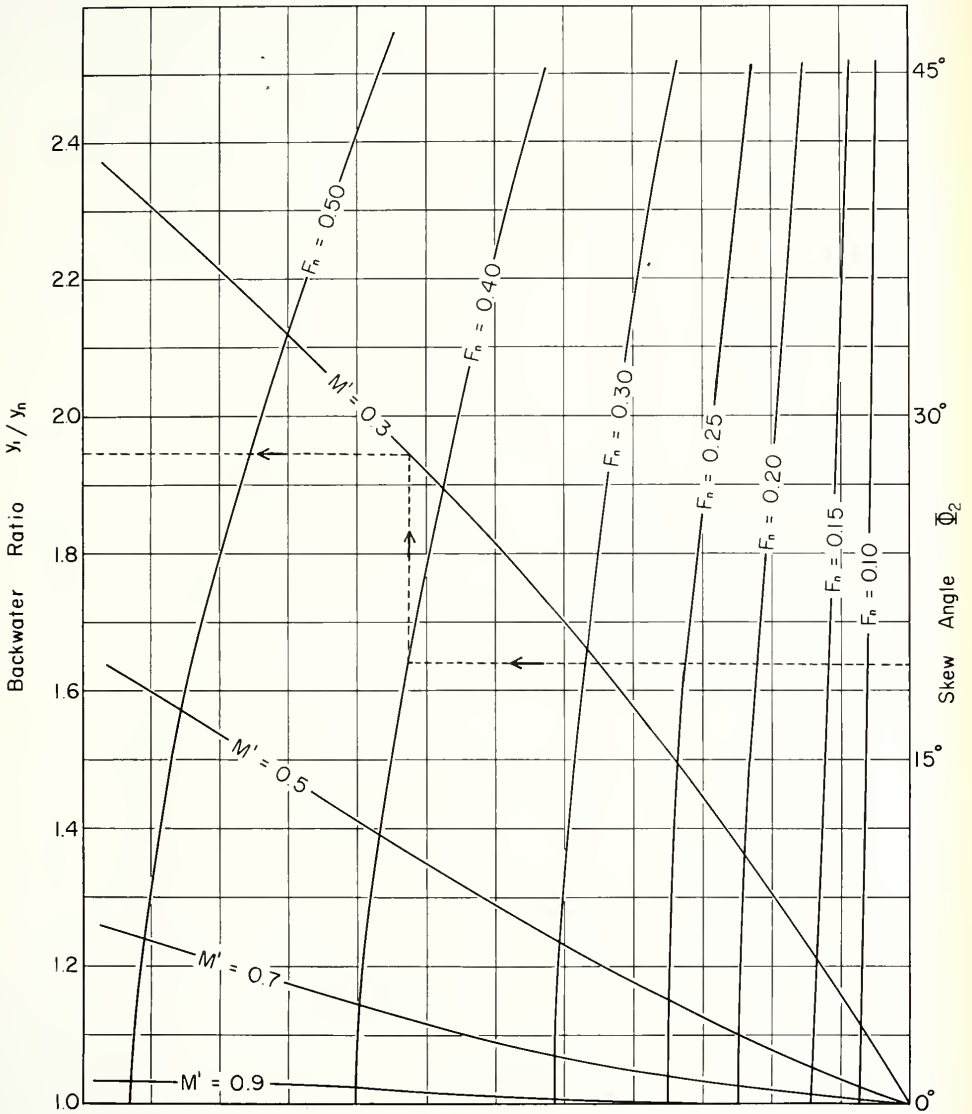
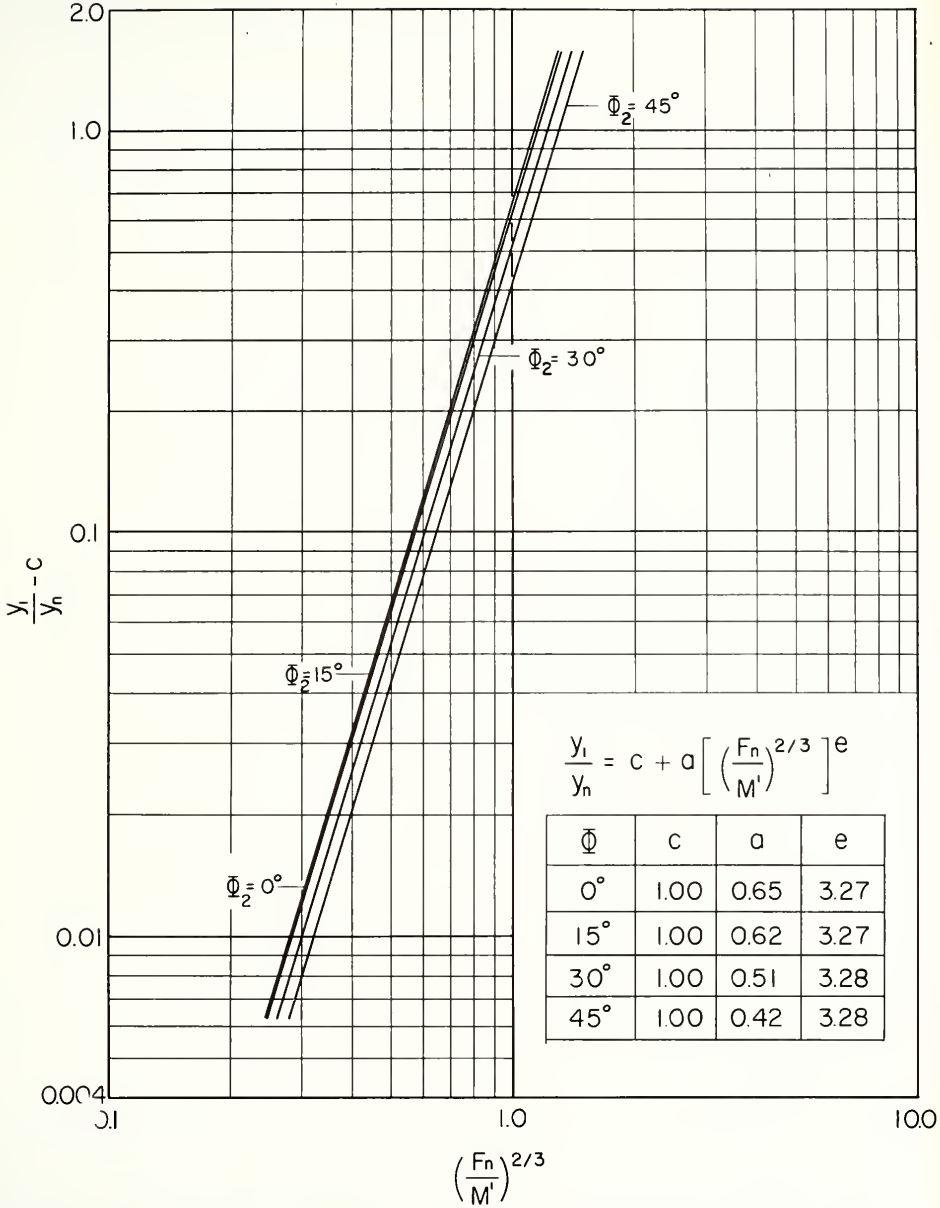


FIG. 7-6-5 - BACKWATER RATIO FOR SKEW ARCH BRIDGE



Φ	c	a	e
0°	1.00	0.65	3.27
15°	1.00	0.62	3.27
30°	1.00	0.51	3.28
45°	1.00	0.42	3.28

FIG. 7-6-6 - GENERALIZED BACKWATER RATIO FOR SKEW ARCH BRIDGE

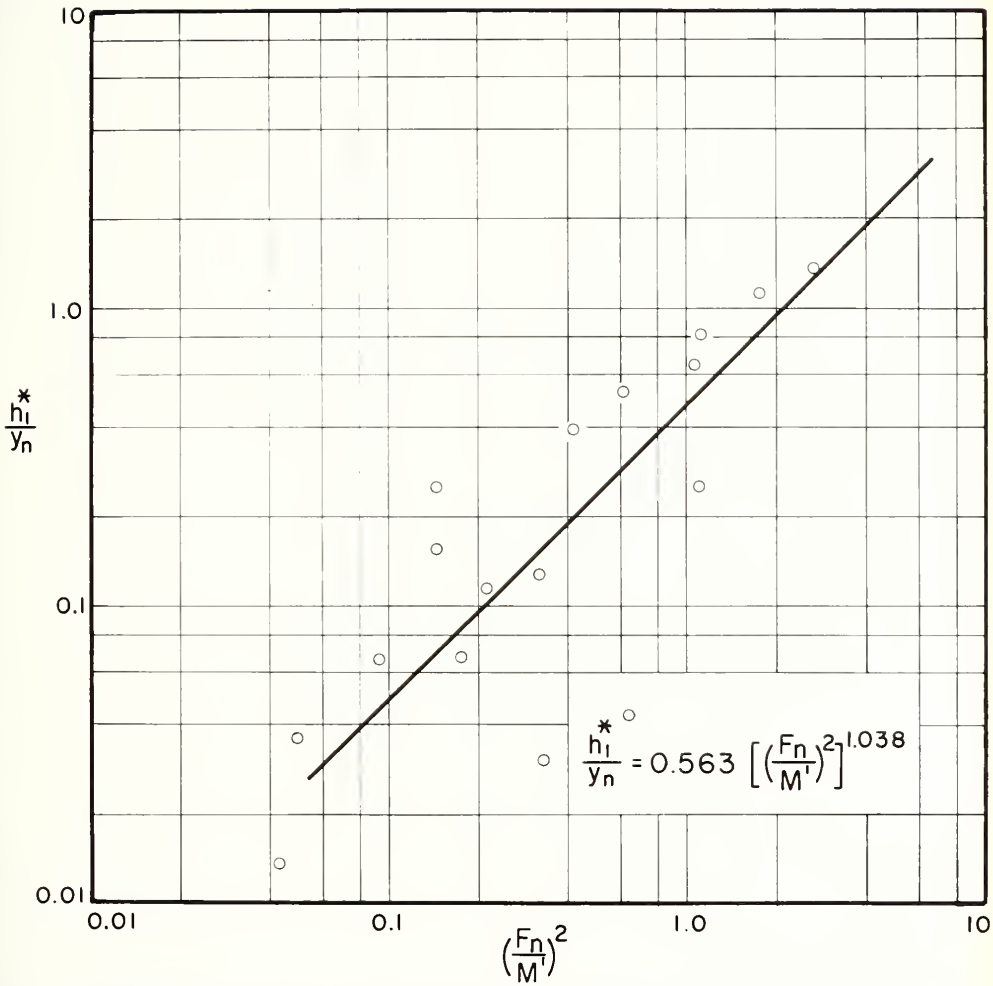


FIGURE 7-6-7 BACKWATER RATIO, GEOMETRY V_a

ROUGH BOUNDARY $\Phi_2 = 0.00$

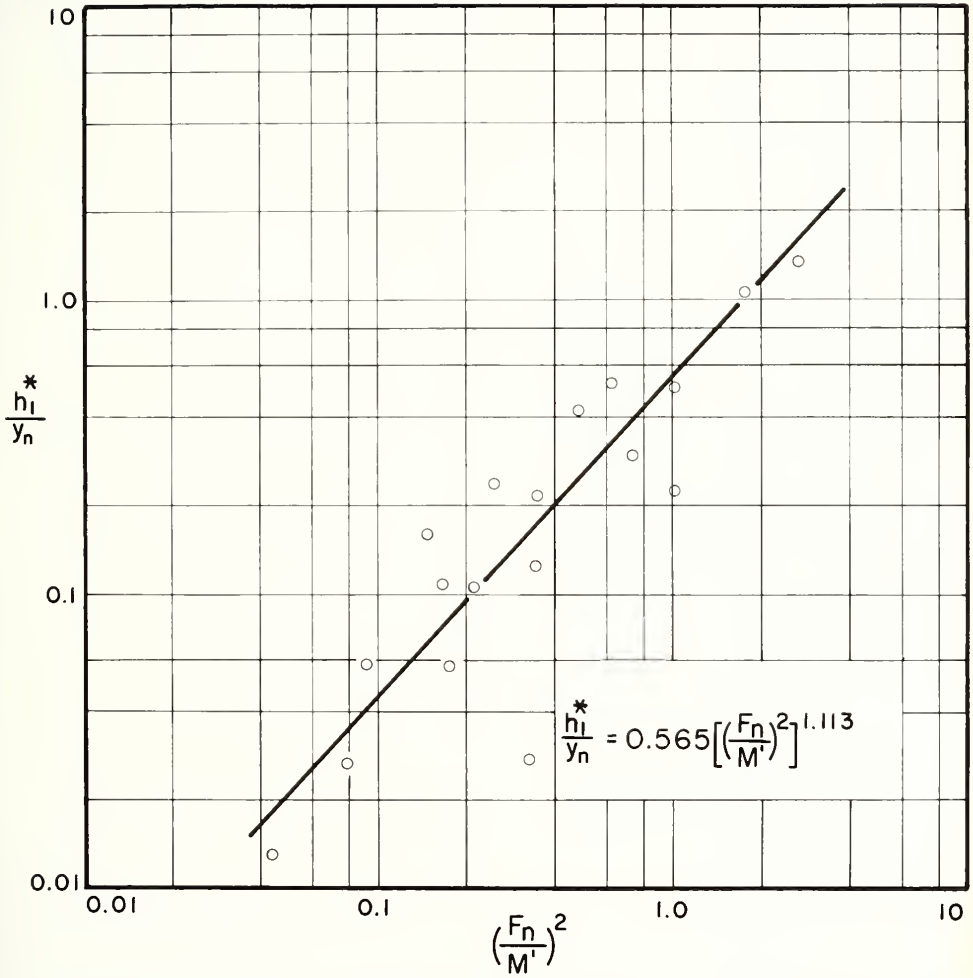


FIGURE 7-6-8 BACKWATER RATIO, GEOMETRY V_a
ROUGH BOUNDARY $\Phi_2 = 15°$

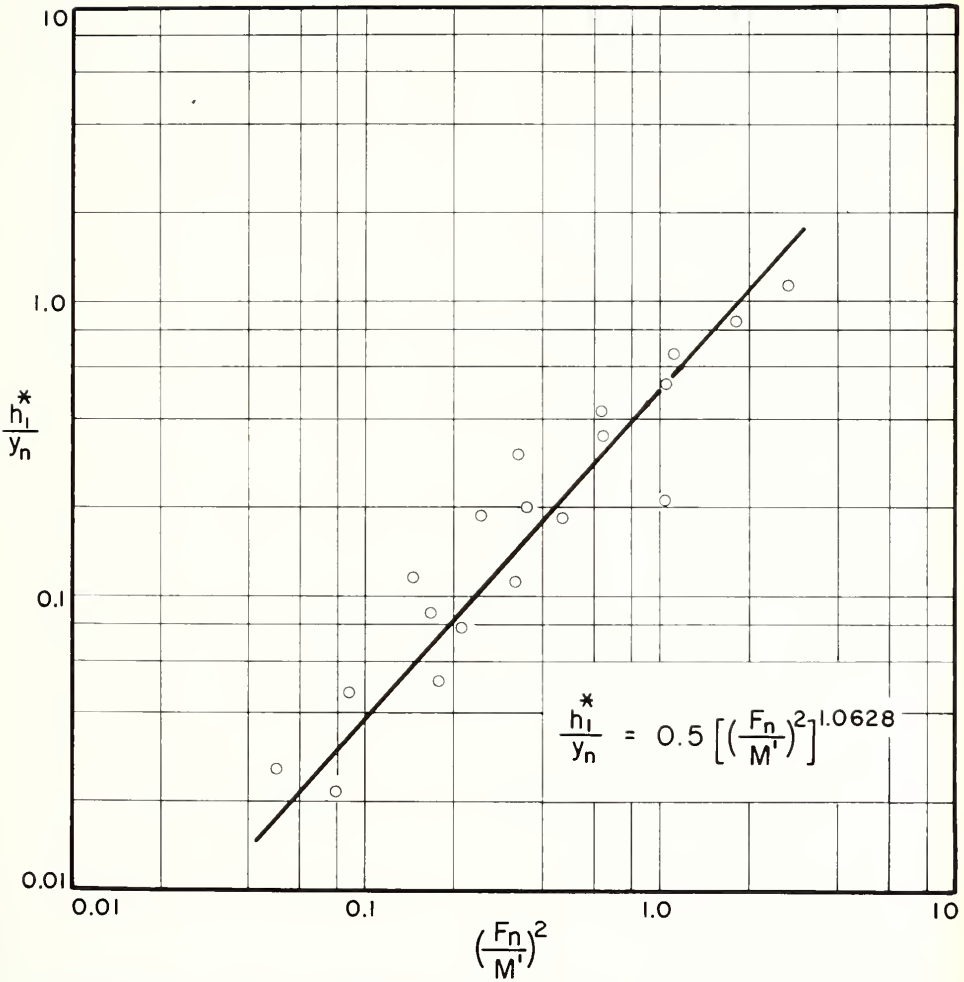


FIGURE 7-6-9 BACKWATER RATIO, GEOMETRY V_a

ROUGH BOUNDARY $\Phi_2 = 30°$

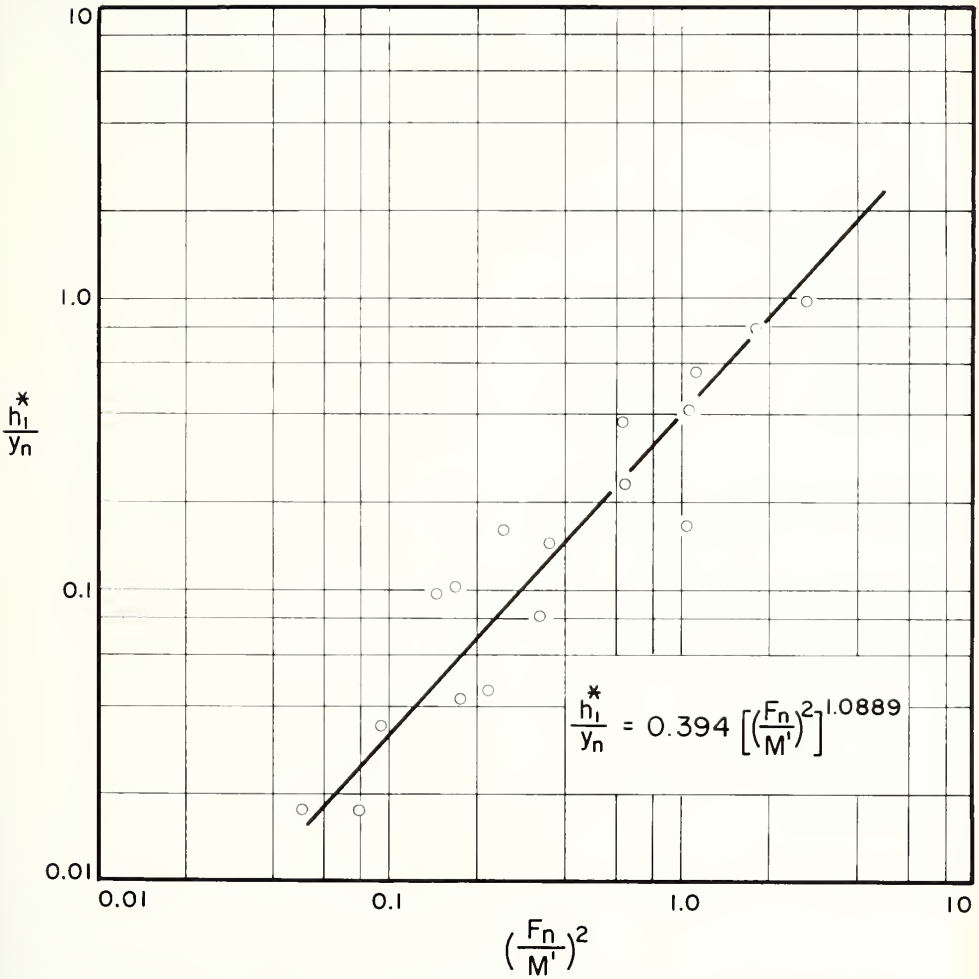


FIGURE 7-6-10 BACKWATER RATIO, GEOMETRY V_a

ROUGH BOUNDARY $\Phi_2 = 45°$

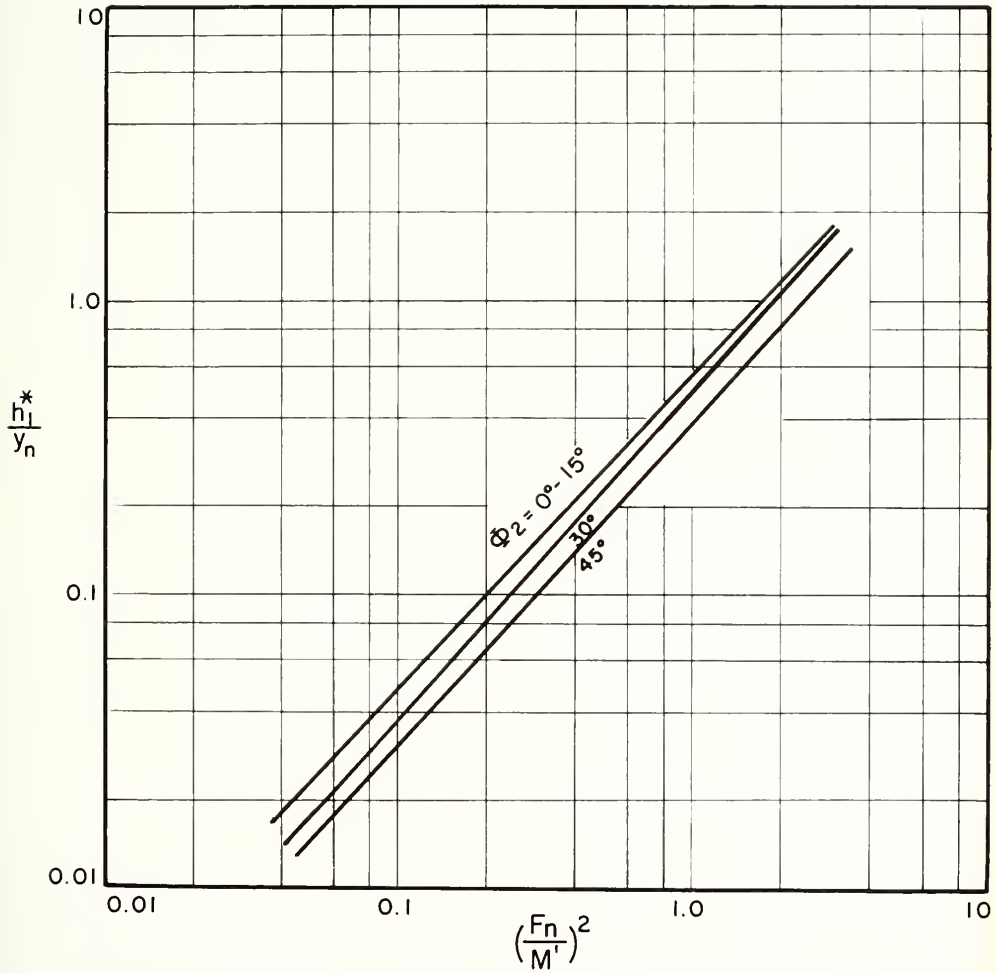


FIGURE 7-6-11 SUMMARY OF BACKWATER RATIO GEOMETRY V_a ROUGH BOUNDARY

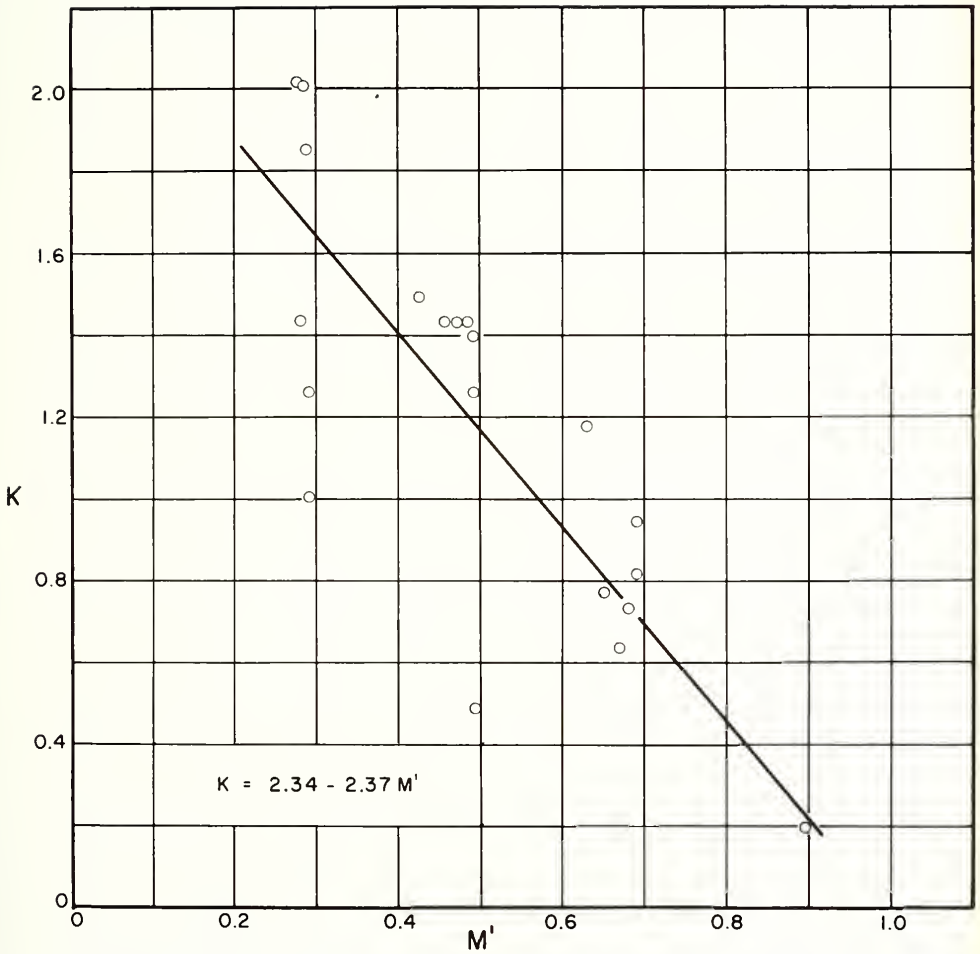


FIGURE 7-6-12 HEAD LOSS COEFFICIENT, GEOMETRY V_a
ROUGH BOUNDARY $\Phi_2 = 0.0°$

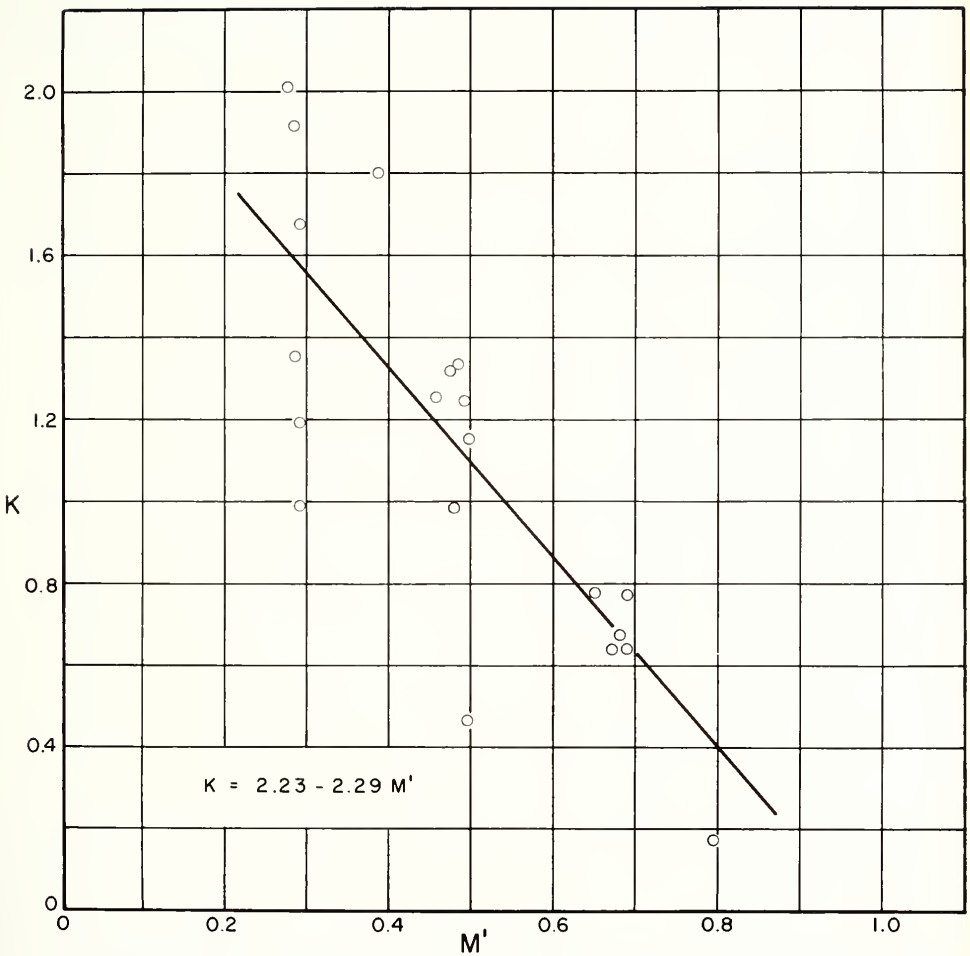


FIGURE 7-6-13 HEAD LOSS COEFFICIENT, GEOMETRY V_a
ROUGH BOUNDARY $\Phi_2 = 15°$

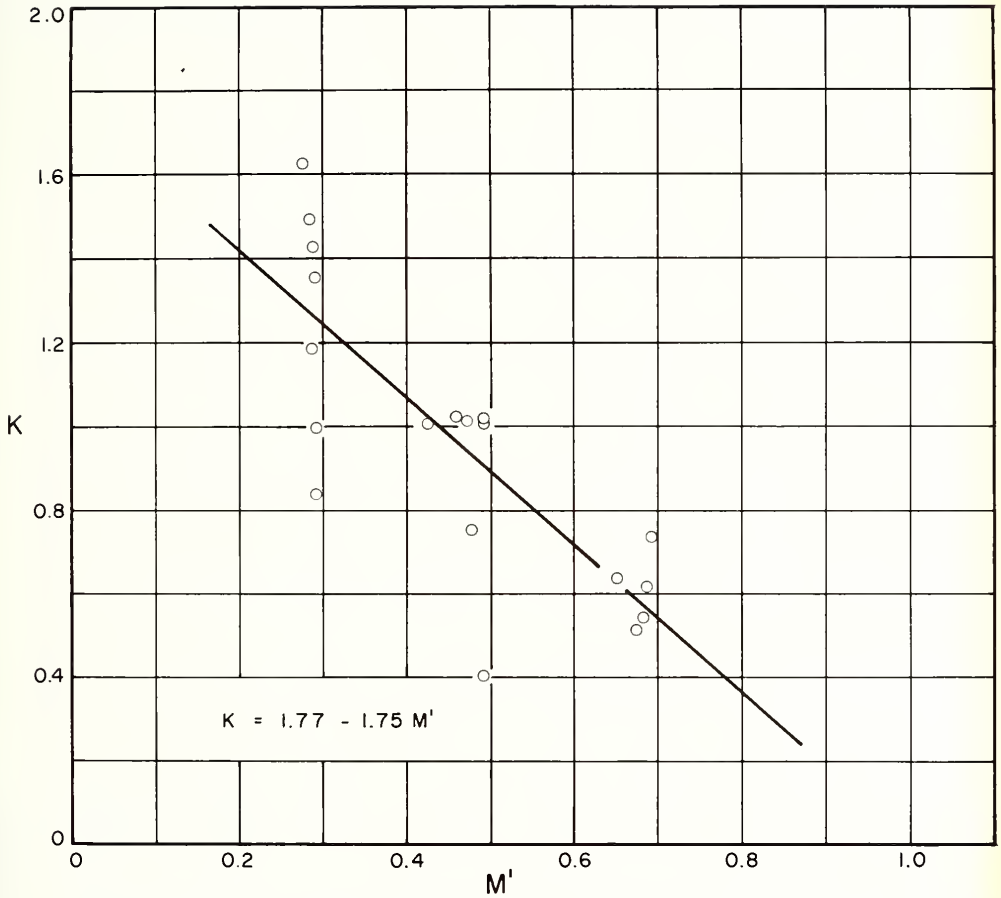


FIGURE 7-6-14 HEAD LOSS COEFFICIENT, GEOMETRY V_a
ROUGH BOUNDARY $\Phi_2 = 30°$

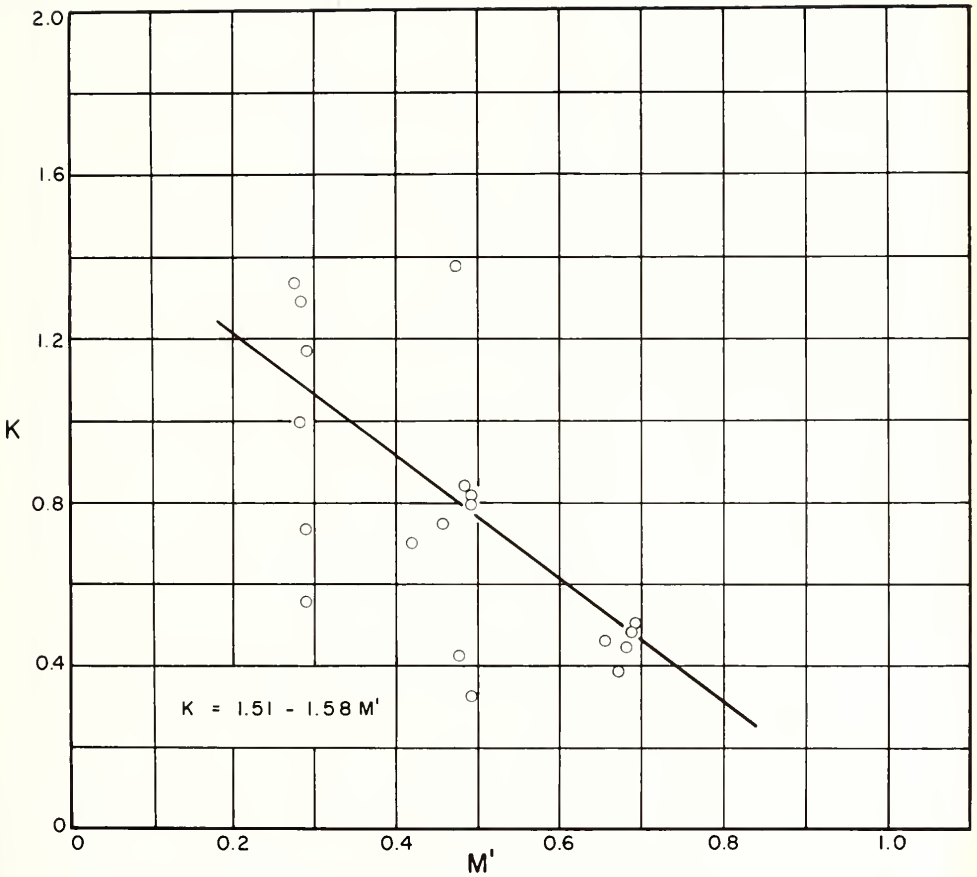


FIGURE 7-6-15 HEAD LOSS COEFFICIENT, GEOMETRY V_a
ROUGH BOUNDARY $\Phi_2 = 45°$

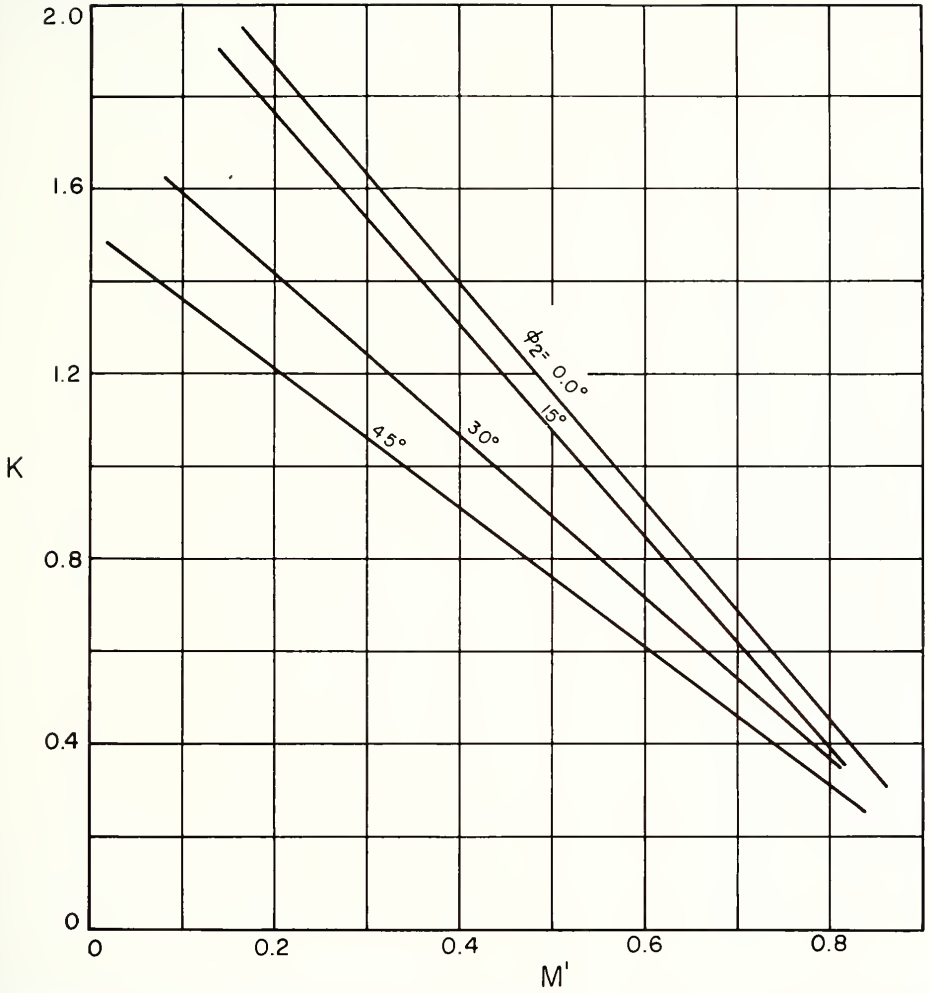


FIGURE 7-6-16 SUMMARY OF HEAD LOSS COEFFICIENTS GEOMETRY V_a. ROUGH BOUNDARIES

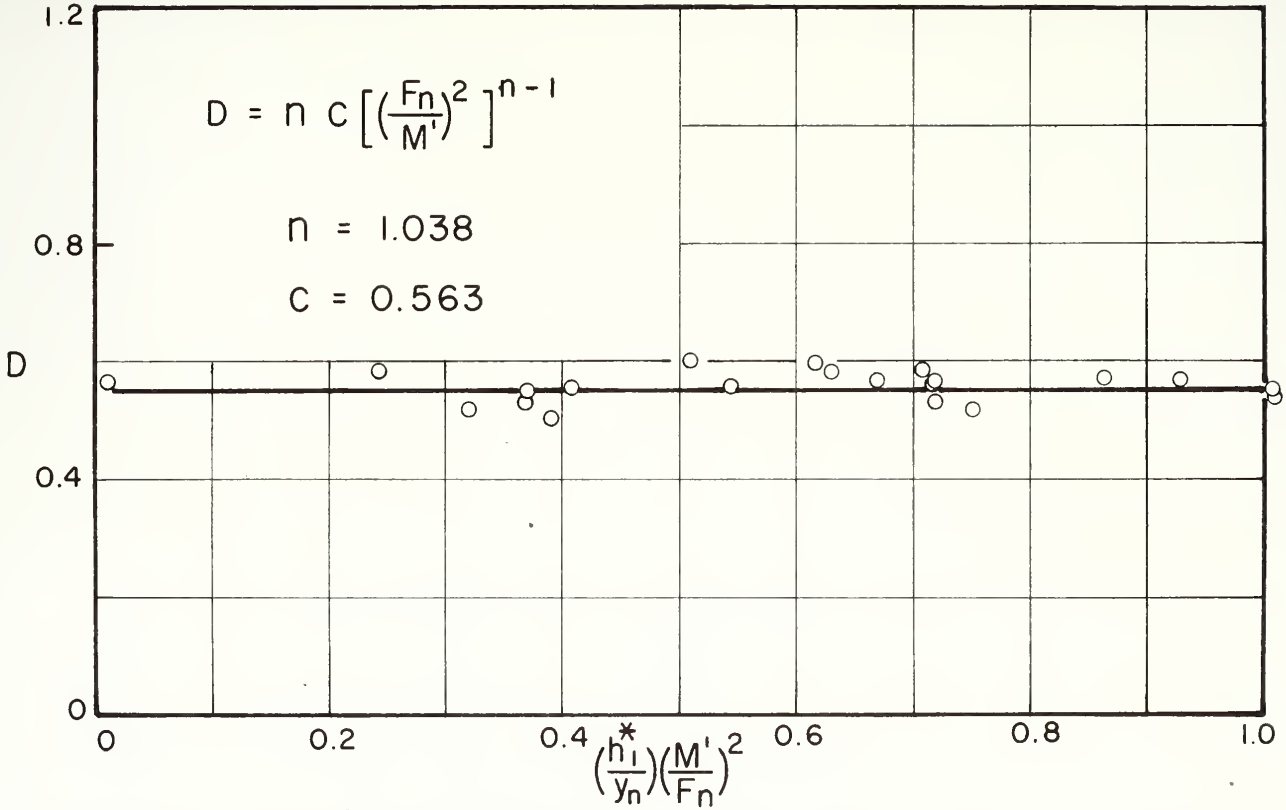


FIGURE 7-6-17 BACKWATER RATIO COEFFICIENT, GEOMETRY V_a ROUGH BOUNDARY $\Phi_2 = 0.0$

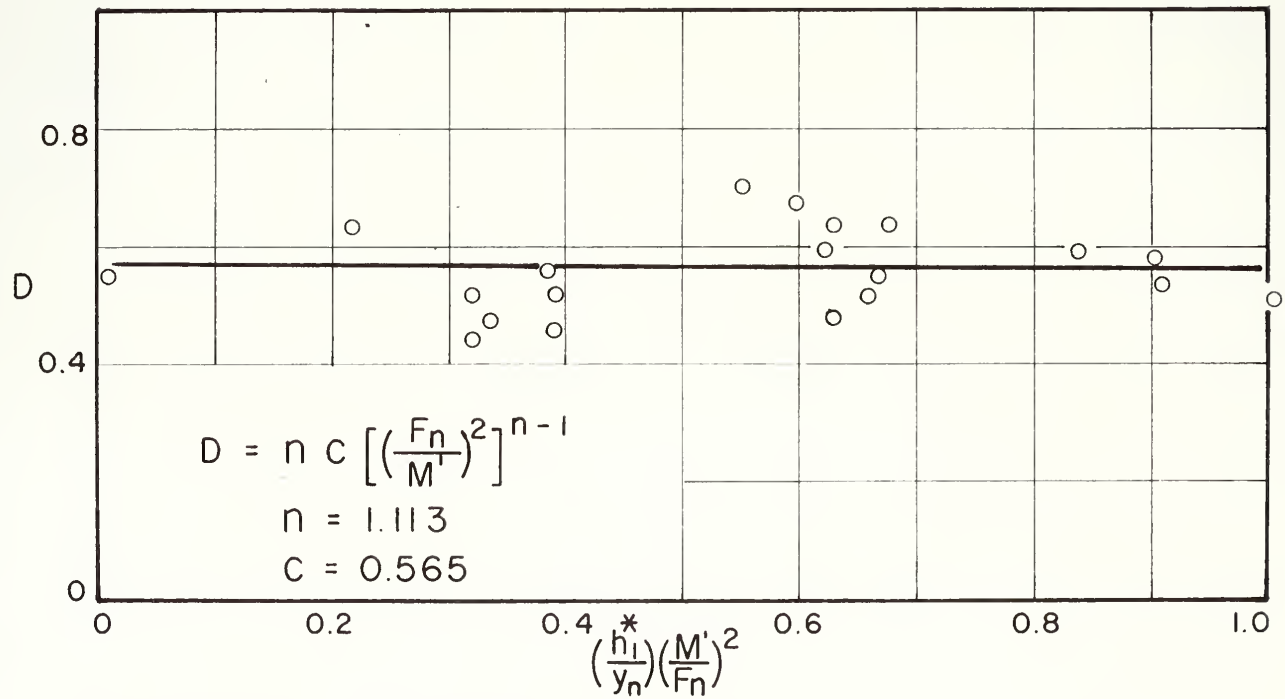


FIGURE 7-6-18 BACKWATER RATIO COEFFICIENT, GEOMETRY ∇_a ROUGH BOUNDARY $\Phi_2 = 15°$

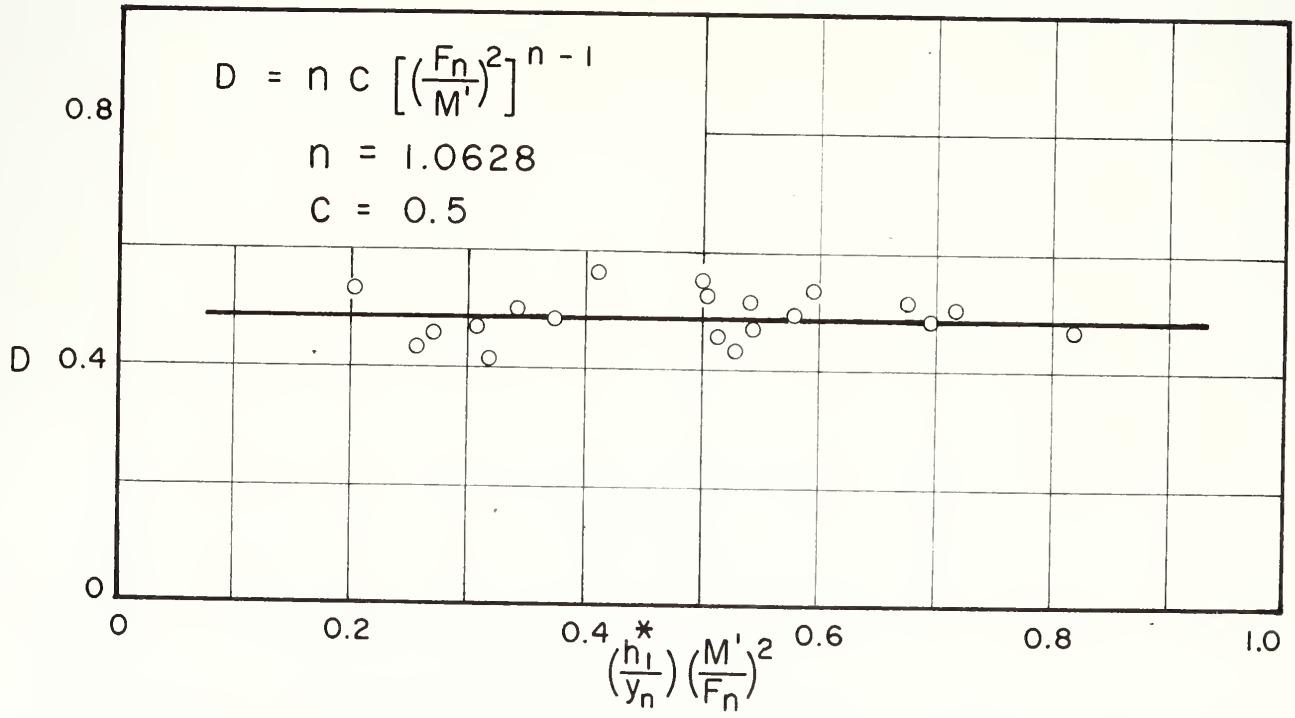


FIGURE 7-6-19 BACKWATER RATIO COEFFICIENT, GEOMETRY V_a ROUGH BOUNDARY $\Phi_2 = 30°$

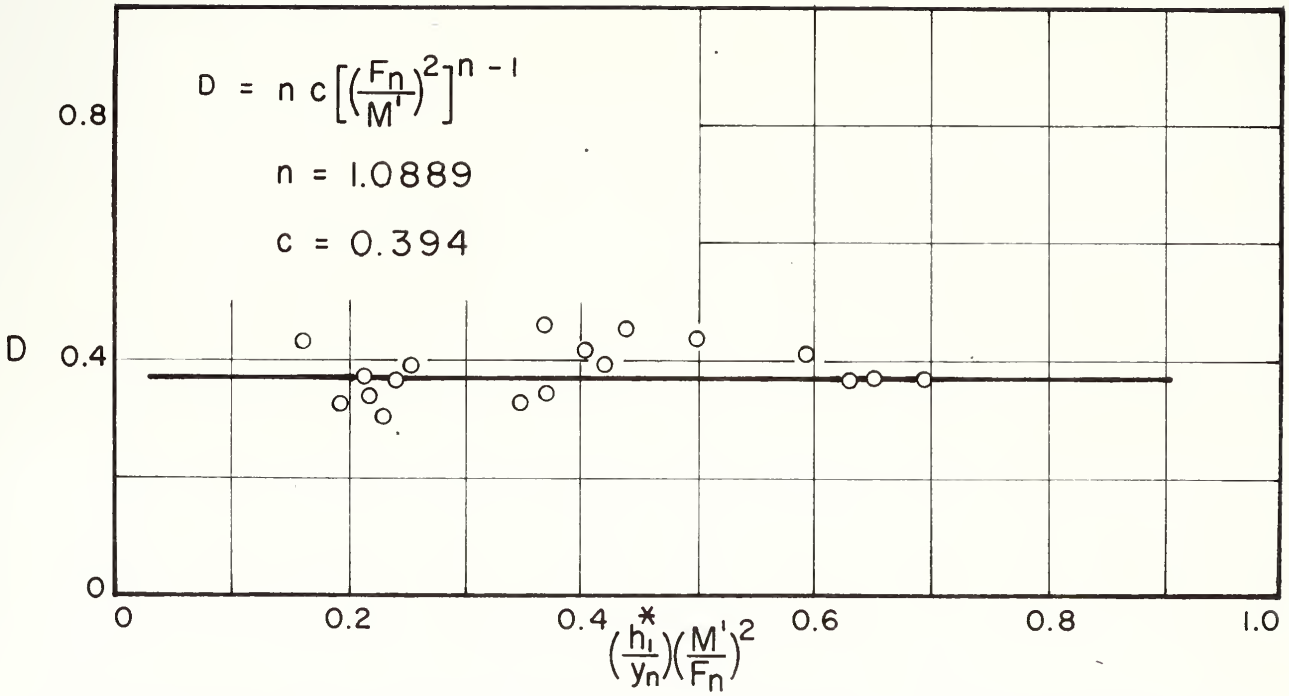


FIGURE 7-6-20 BACKWATER RATIO COEFFICIENT, GEOMETRY ∇_a ROUGH BOUNDARY $\Phi_2 = 45°$

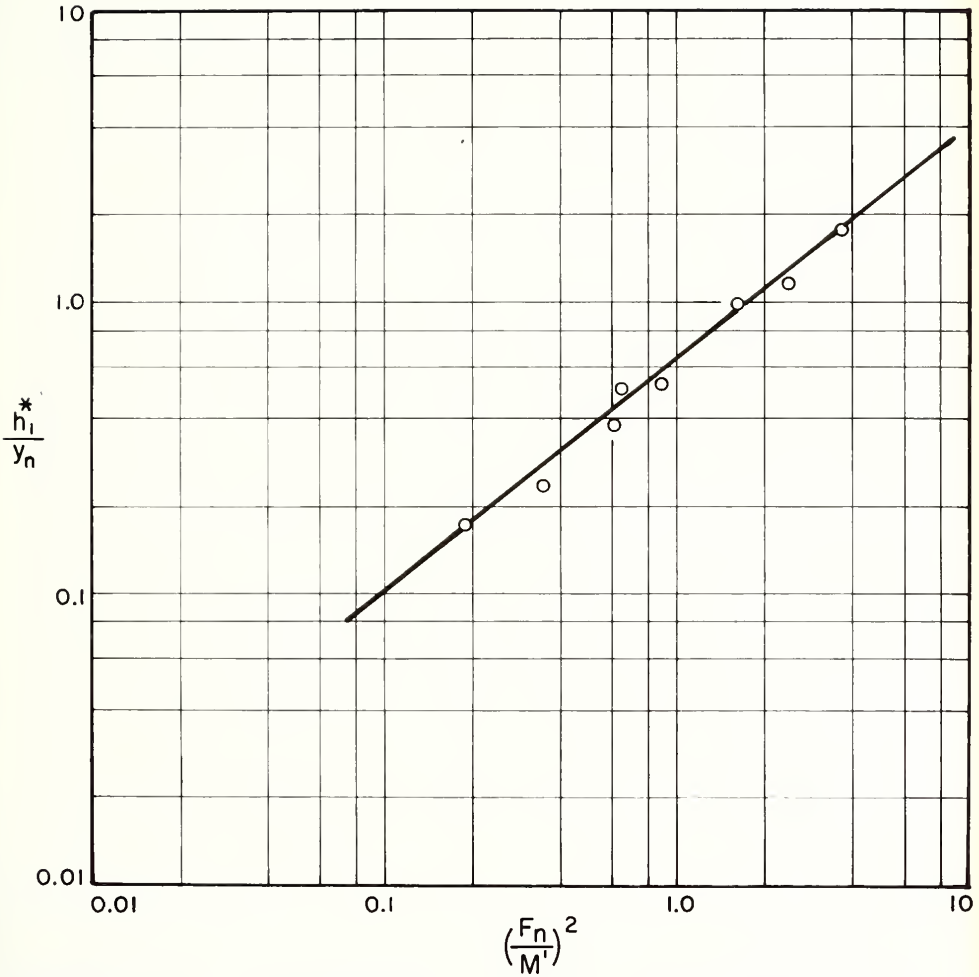


FIGURE 7-7-1 BACKWATER RATIO, GEOMETRY V_b

ROUGH BOUNDARY $\Phi_2 = 15°$

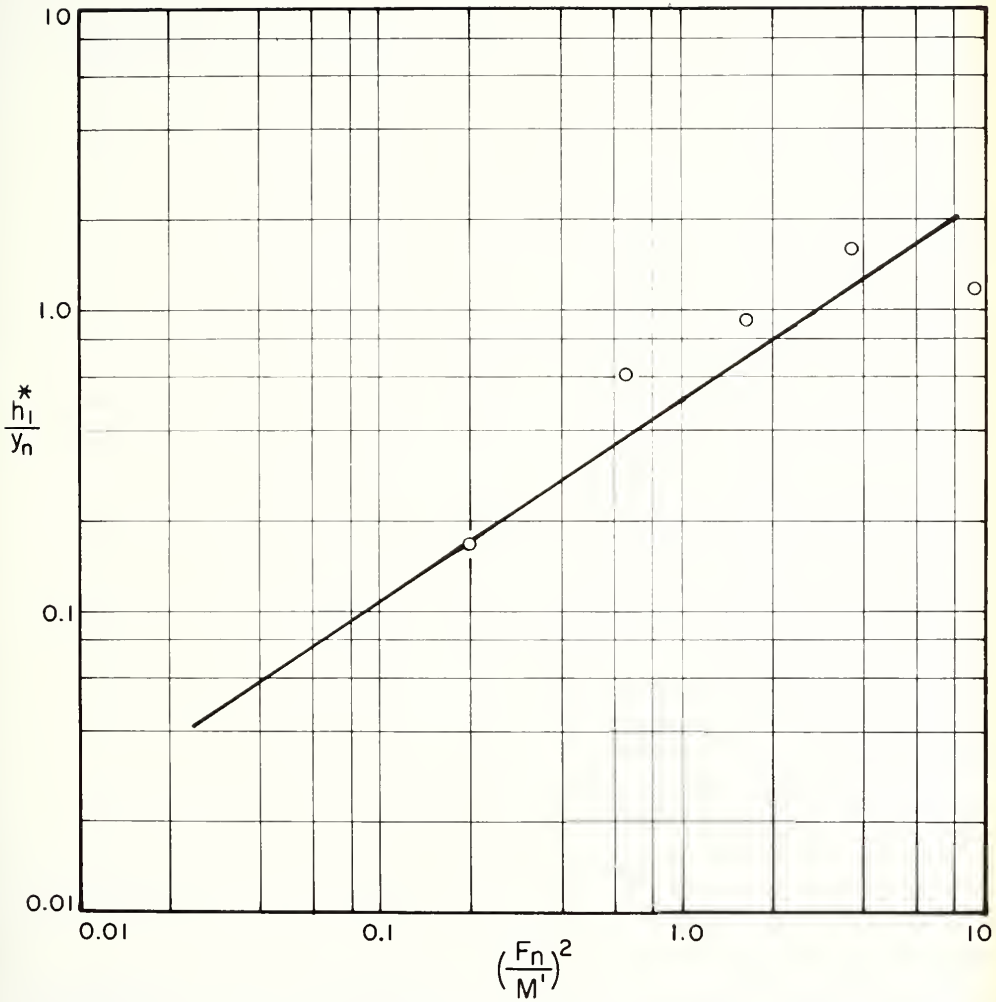


FIGURE 7-7-2 BACKWATER RATIO, GEOMETRY V_b ROUGH BOUNDARY $\Phi_2 = 30°$

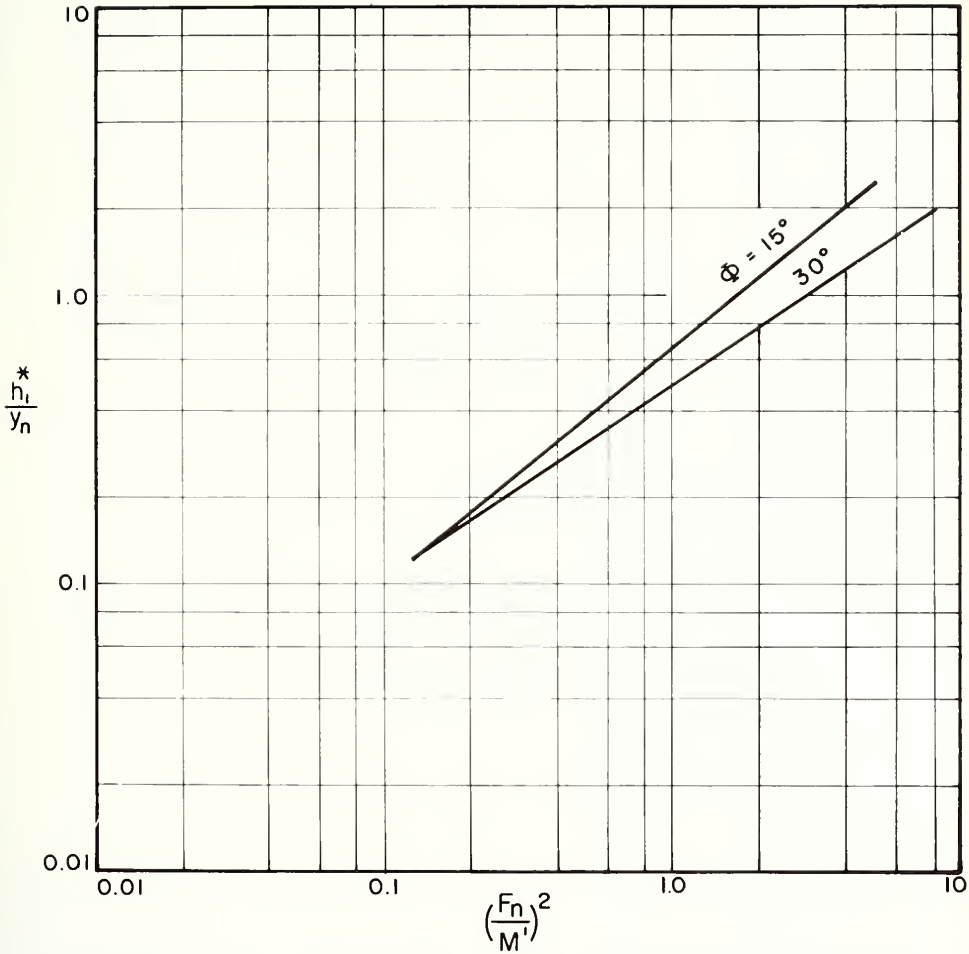


FIGURE 7-7-3 SUMMARY OF BACKWATER RATIO, GEOMETRY $\mathcal{V}_b$ ROUGH BOUNDARY

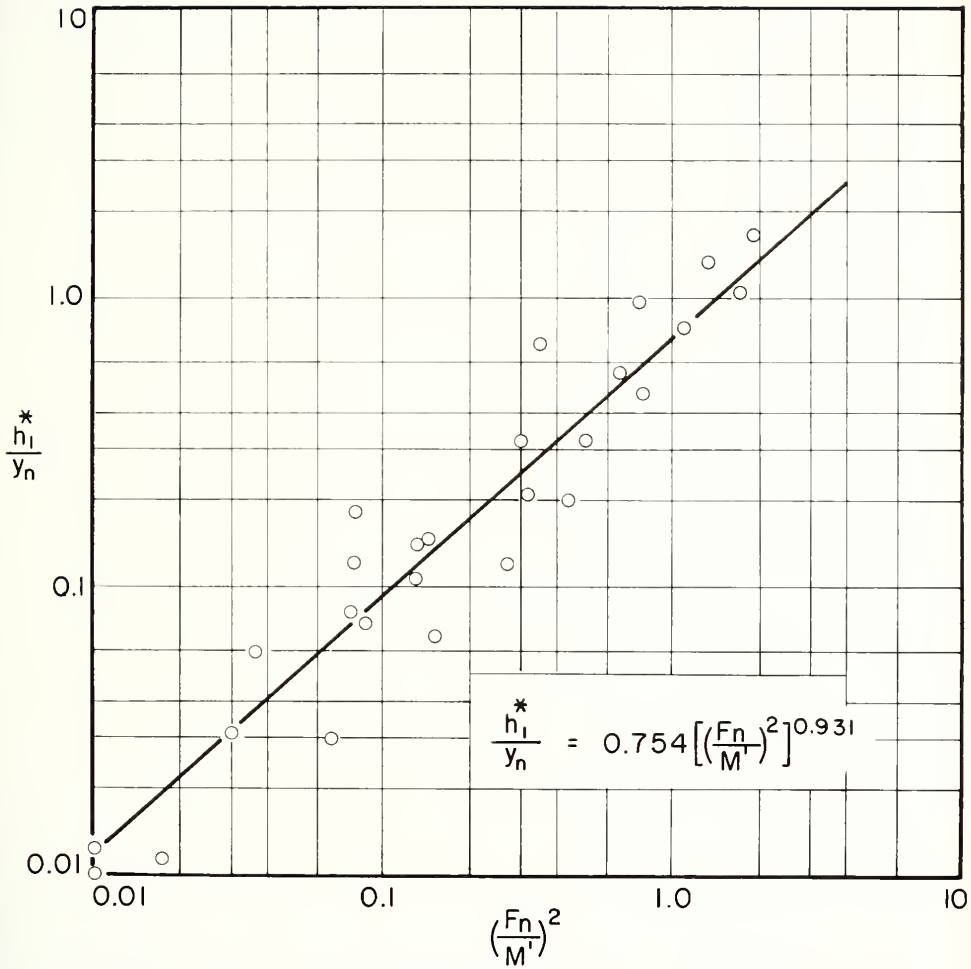


FIGURE 7-8-1 BACKWATER RATIO, GEOMETRY VI ROUGH BOUNDARY

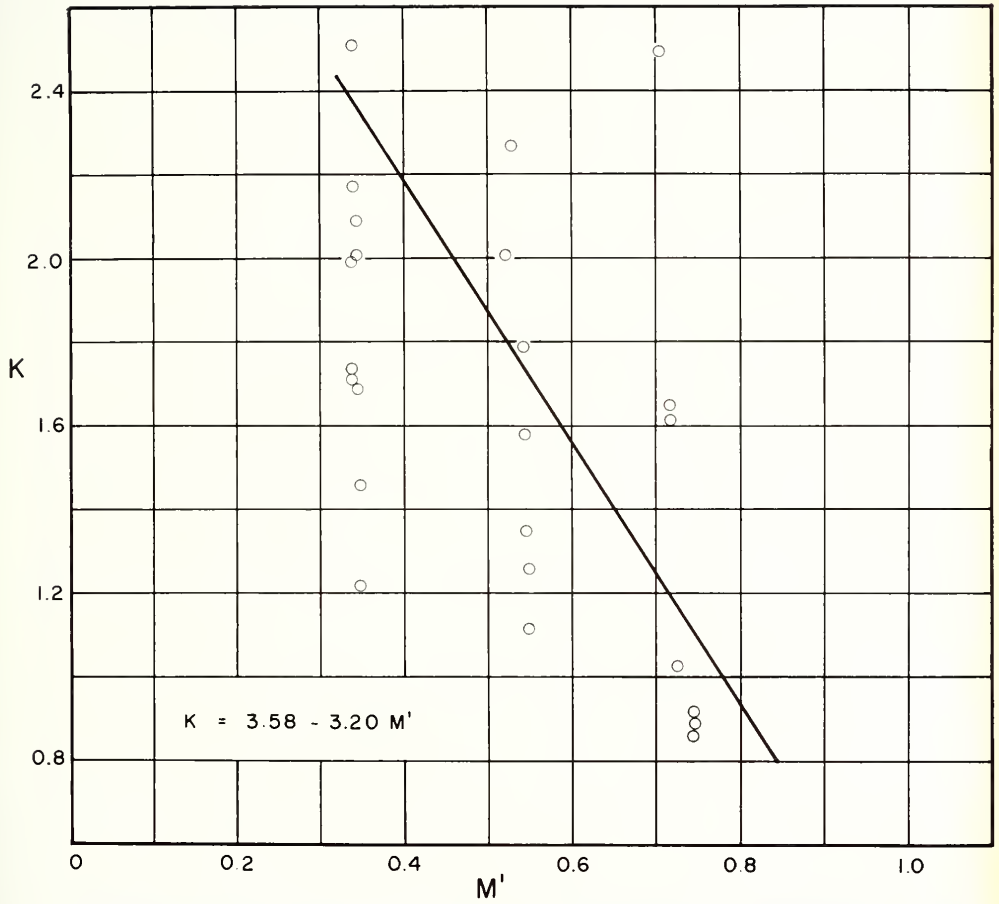


FIGURE 7-8-2 HEAD LOSS COEFFICIENT, GEOMETRY VI
ROUGH BOUNDARY

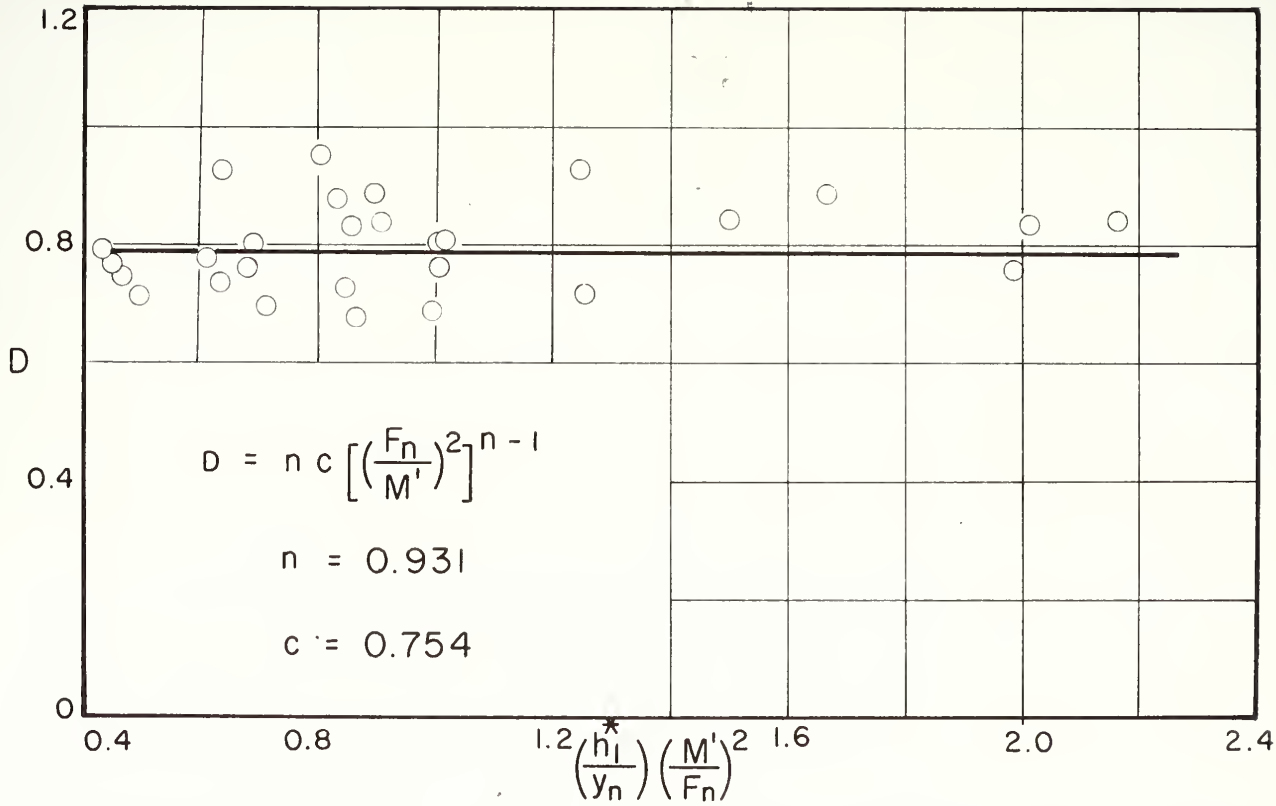


FIGURE 7-8-3 BACKWATER RATIO COEFFICIENT, GEOMETRY VI ROUGH BOUNDARY

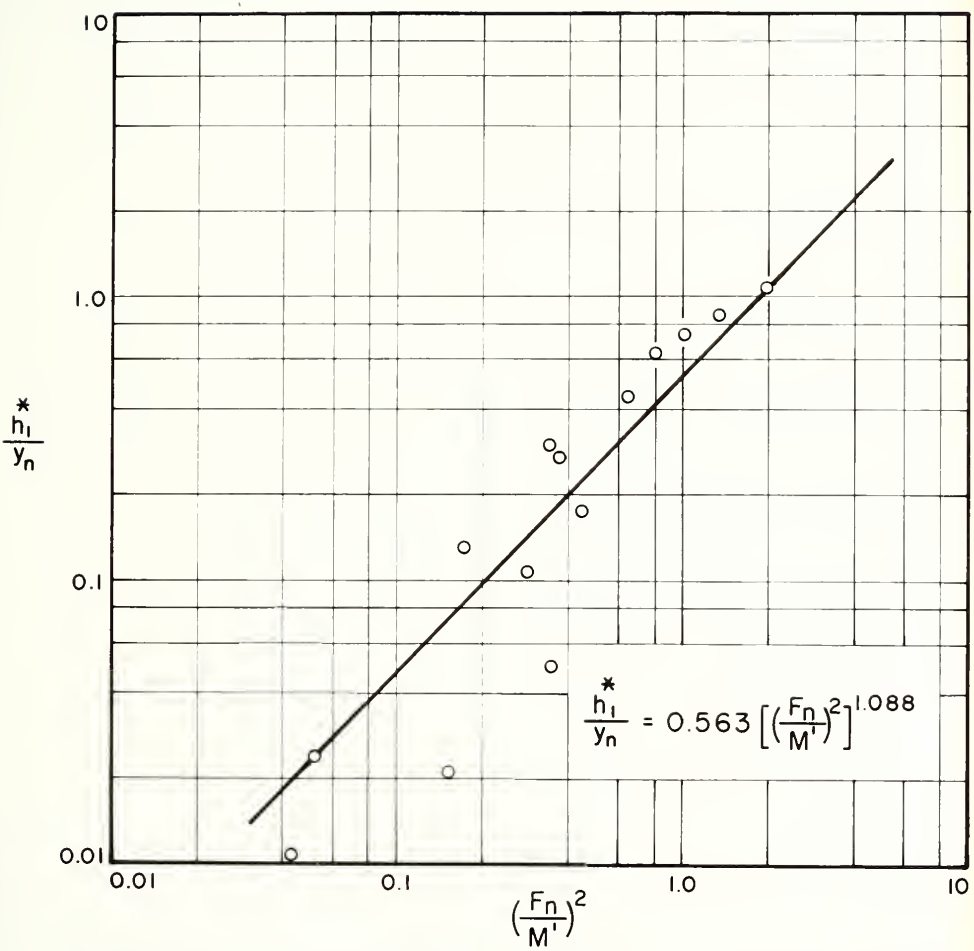


FIGURE 7-9-1 BACKWATER RATIO, GEOMETRY VII

ROUGH BOUNDARY $\beta = 0.00$

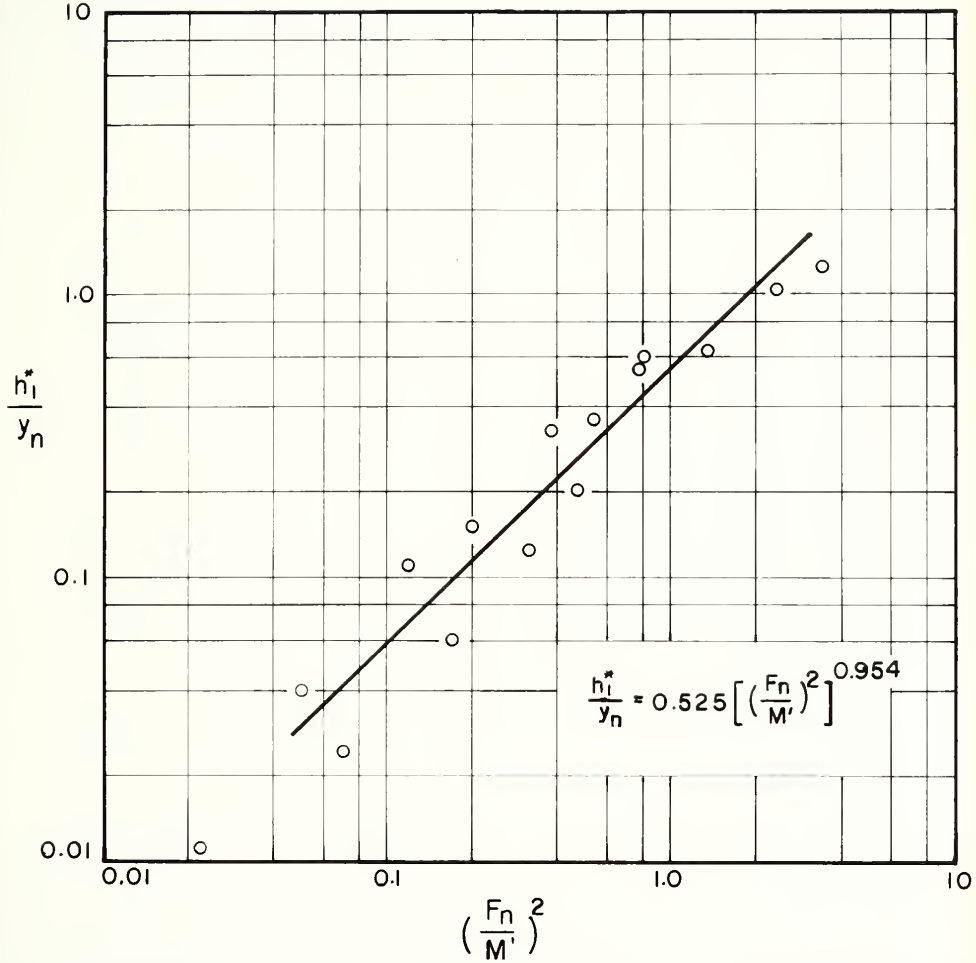


FIGURE 7-9-2 BACKWATER RATIO, GEOMETRY VII

ROUGH BOUNDARY $\beta = 0.3$

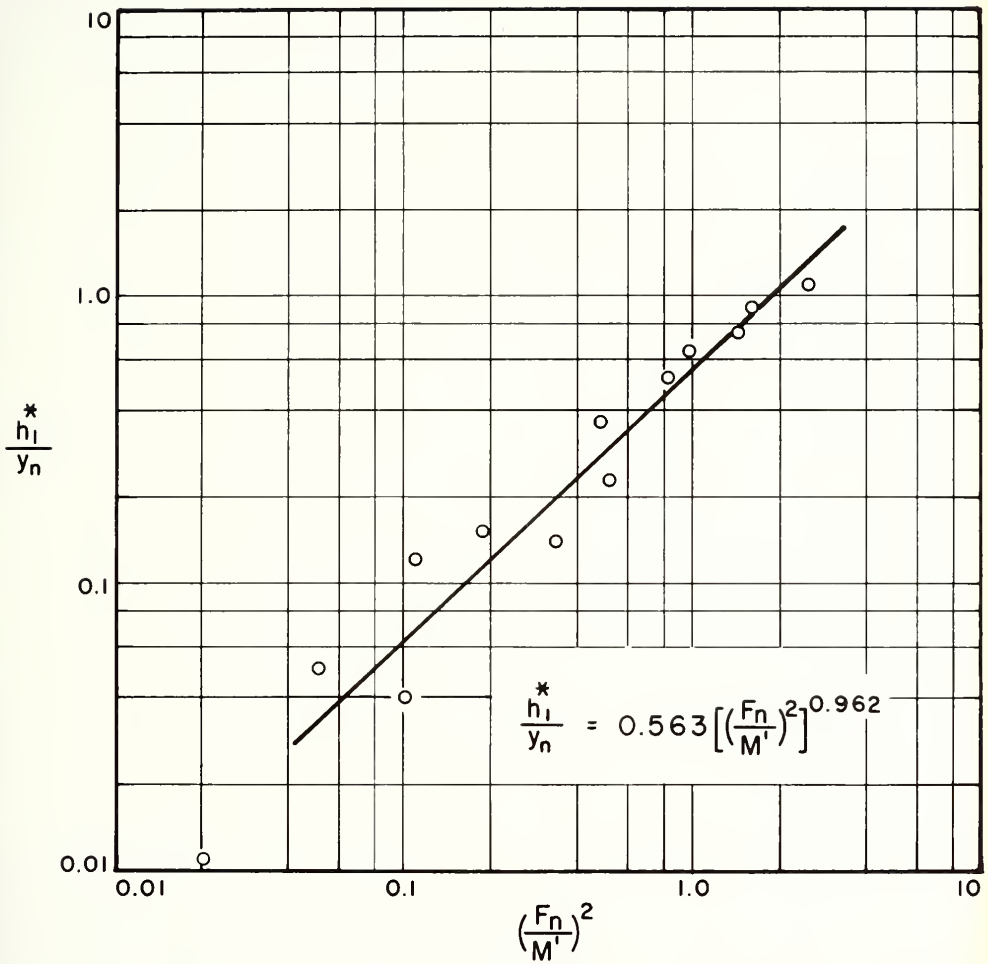


FIGURE 7-9-3 BACKWATER RATIO, GEOMETRY VII

ROUGH BOUNDARIES $\beta = 0.5$

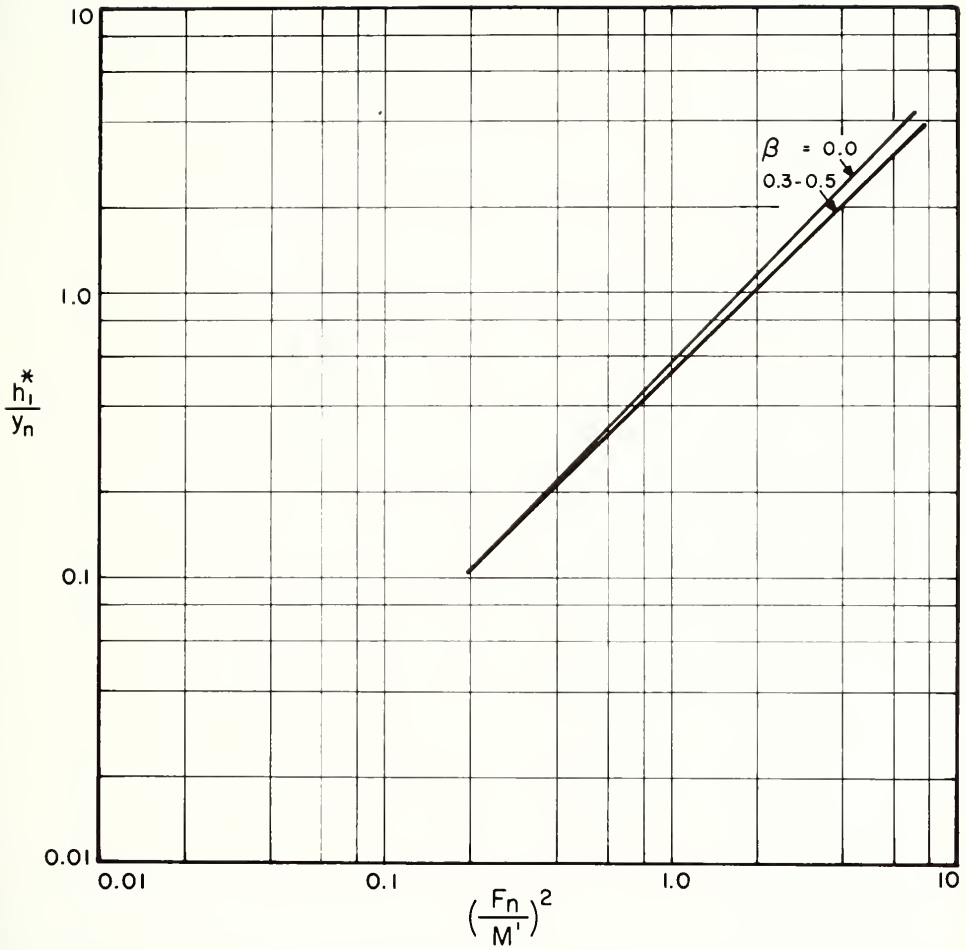


FIGURE 7-9-4 SUMMARY OF BACKWATER RATIO, GEOMETRY VII, ROUGH BOUNDARIES

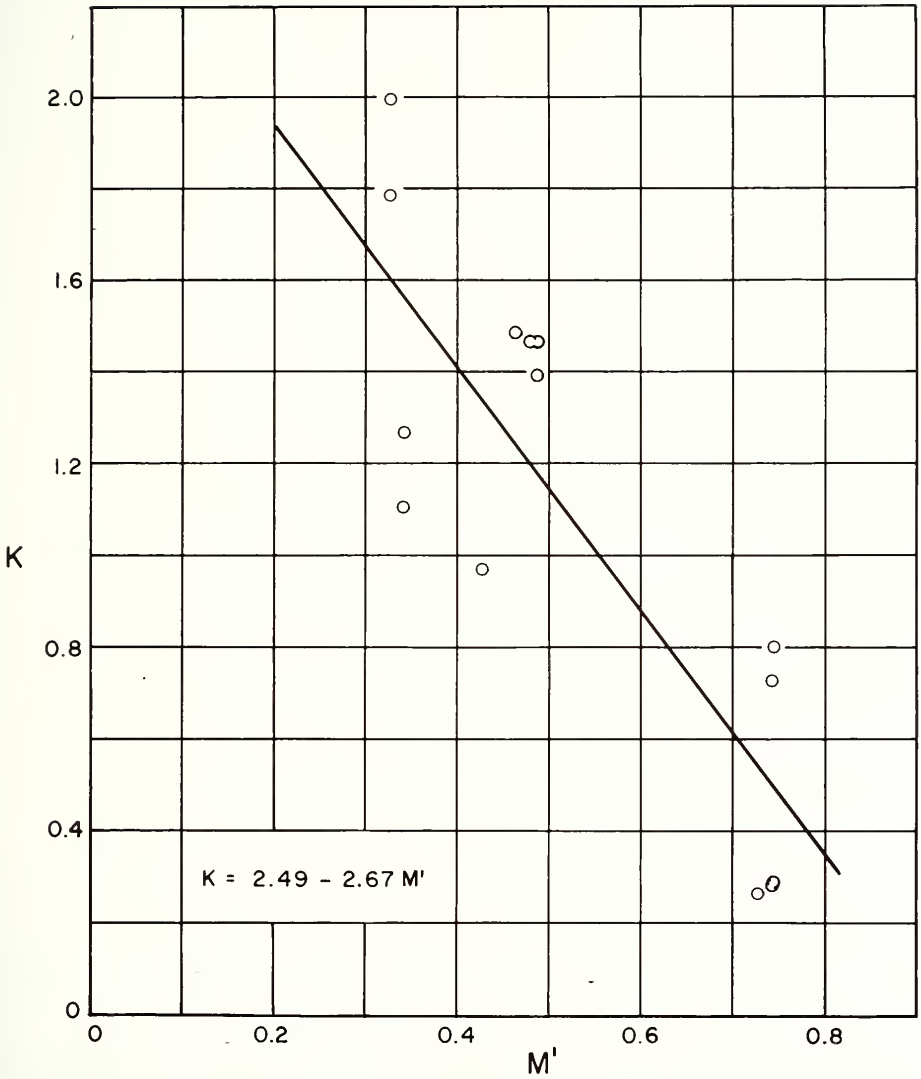


FIGURE 7-9-5 HEAD LOSS COEFFICIENT, GEOMETRY VII ROUGH BOUNDARY, $\beta = 0.00$

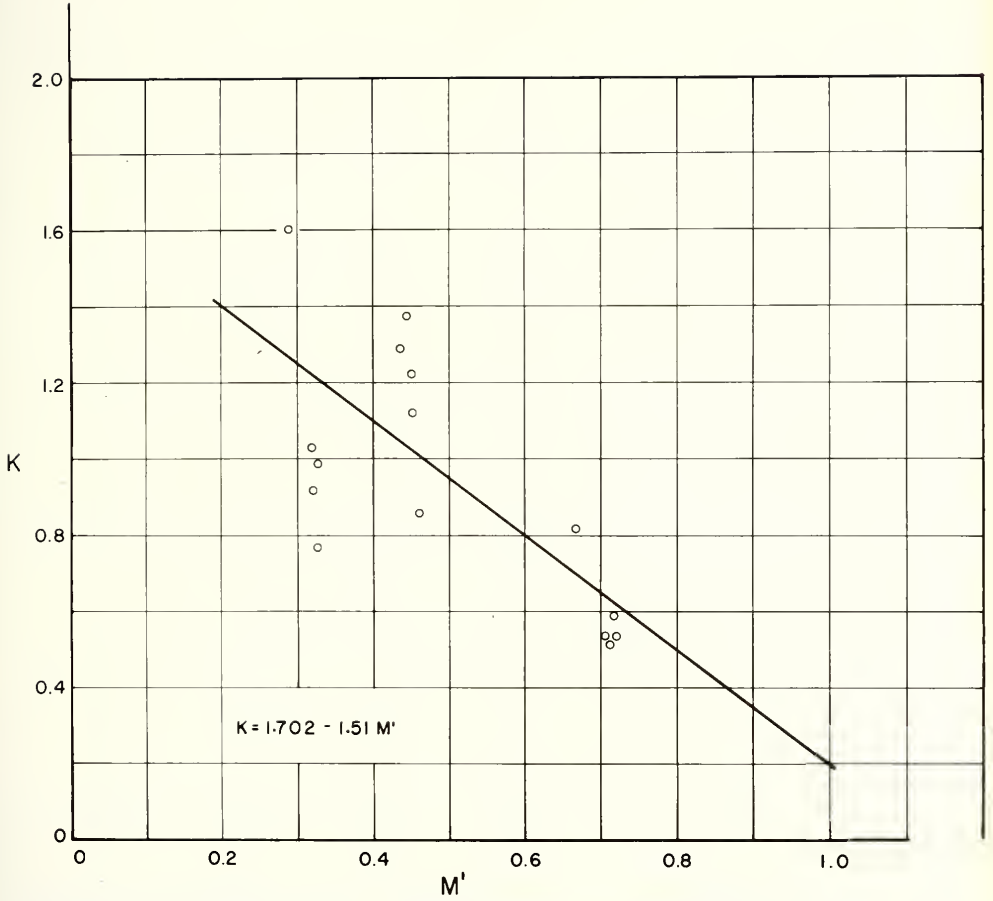


FIGURE 7-9-6 HEAD LOSS COEFFICIENT, GEOMETRY VII
ROUGH BOUNDARY, $\beta = 0.3$

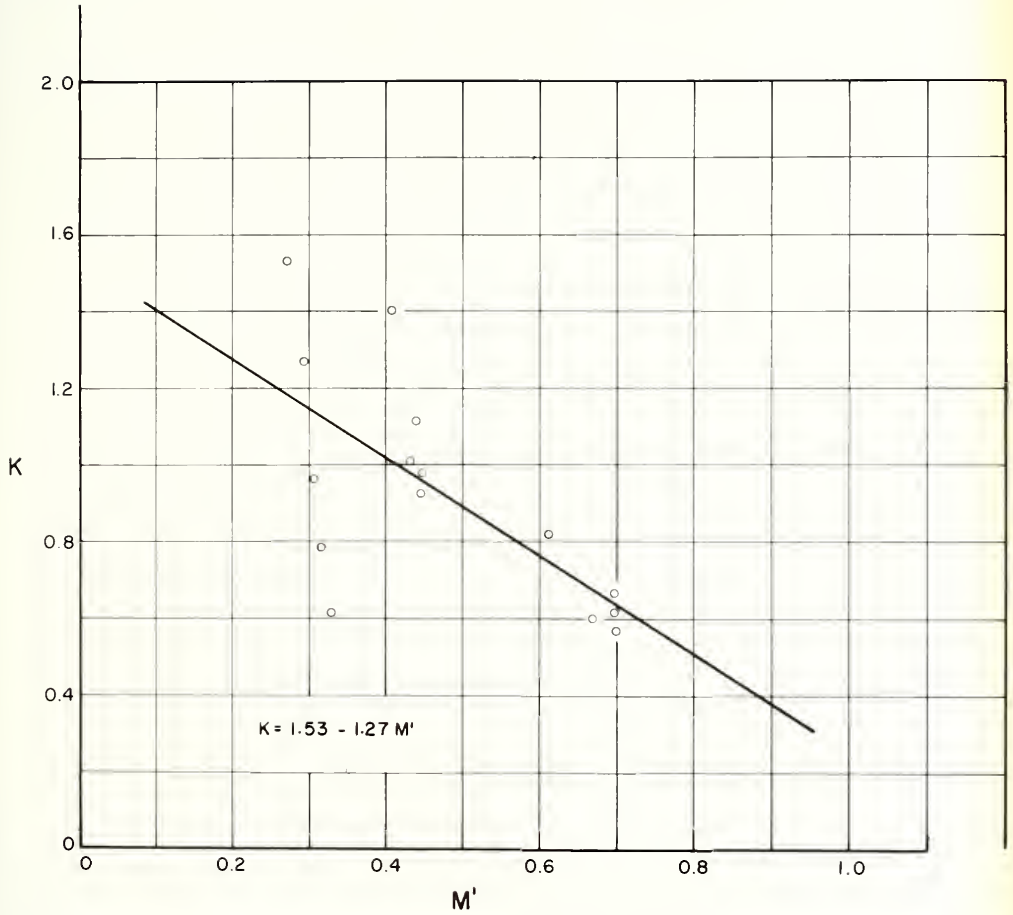


FIGURE 7-9-7 HEAD LOSS COEFFICIENT, GEOMETRY VII
ROUGH BOUNDARY, $\beta = 0.5$

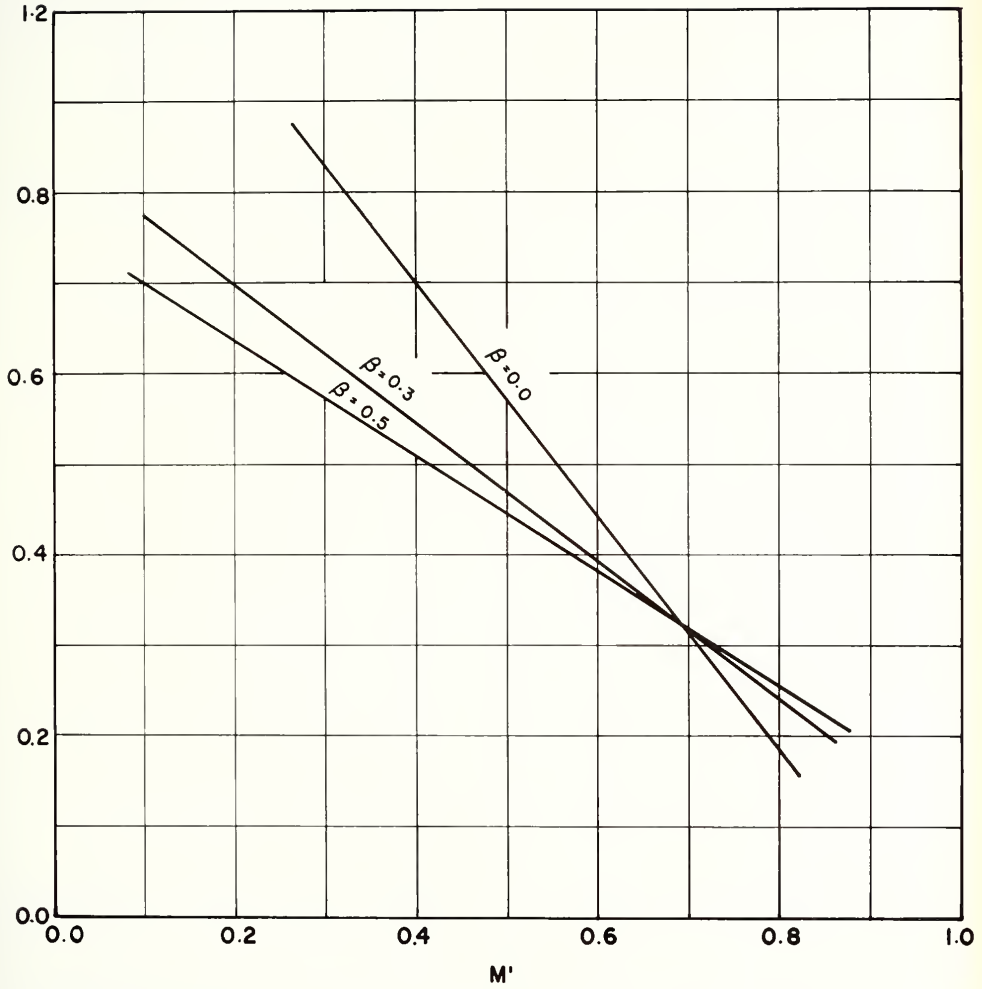


FIGURE 7-9-8 SUMMARY OF HEAD LOSS COEFFICIENT

GEOMETRY VII ROUGH BOUNDARY

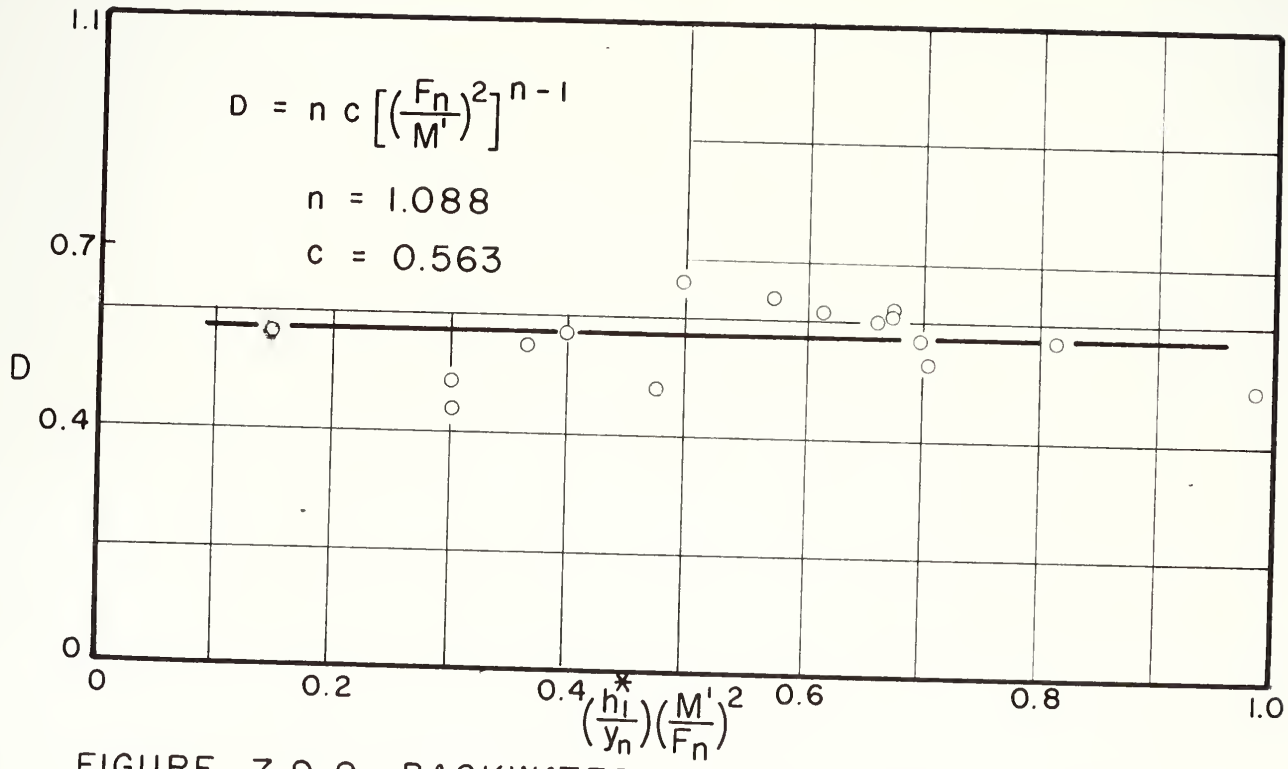


FIGURE 7-9-9 BACKWATER RATIO COEFFICIENT, GEOMETRY VII ROUGH BOUNDARY β = 0.0

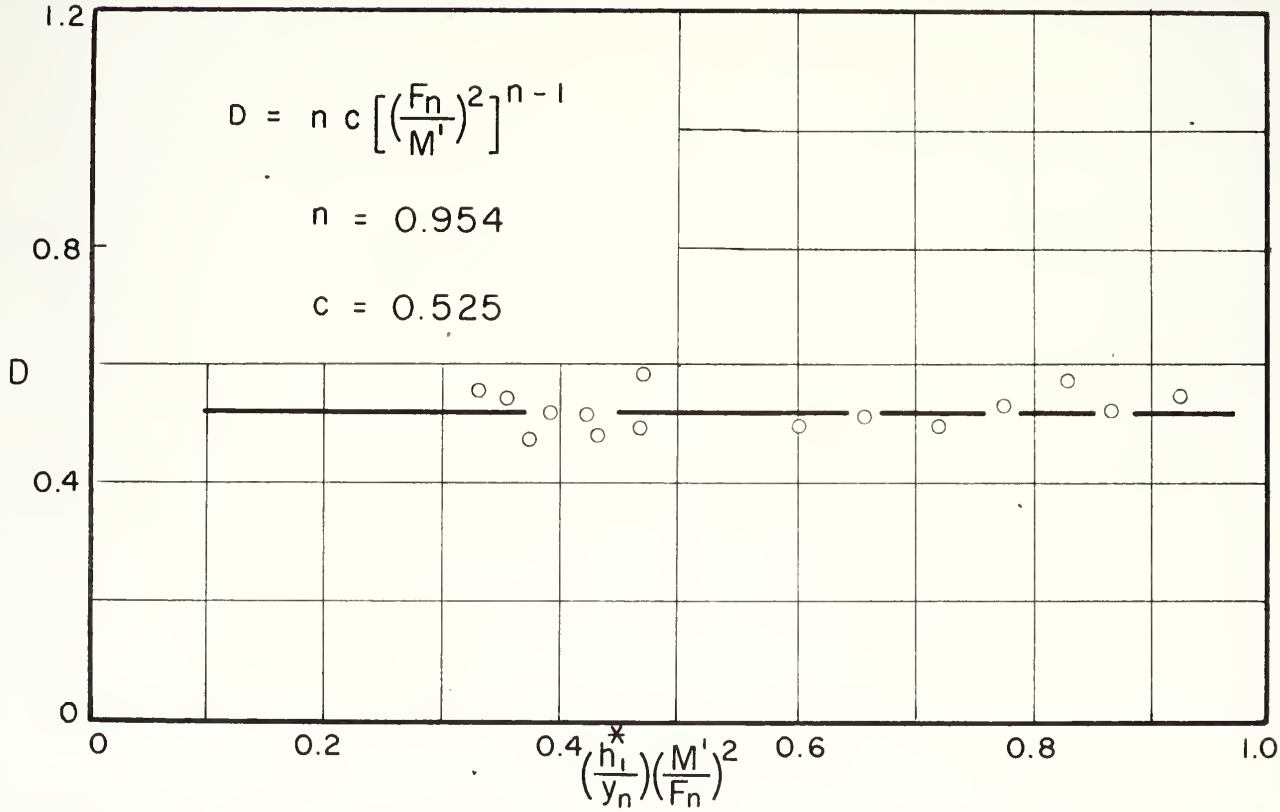


FIGURE 7-9-10 BACKWATER RATIO COEFFICIENT, GEOMETRY VII ROUGH BOUNDARY β = 0.3

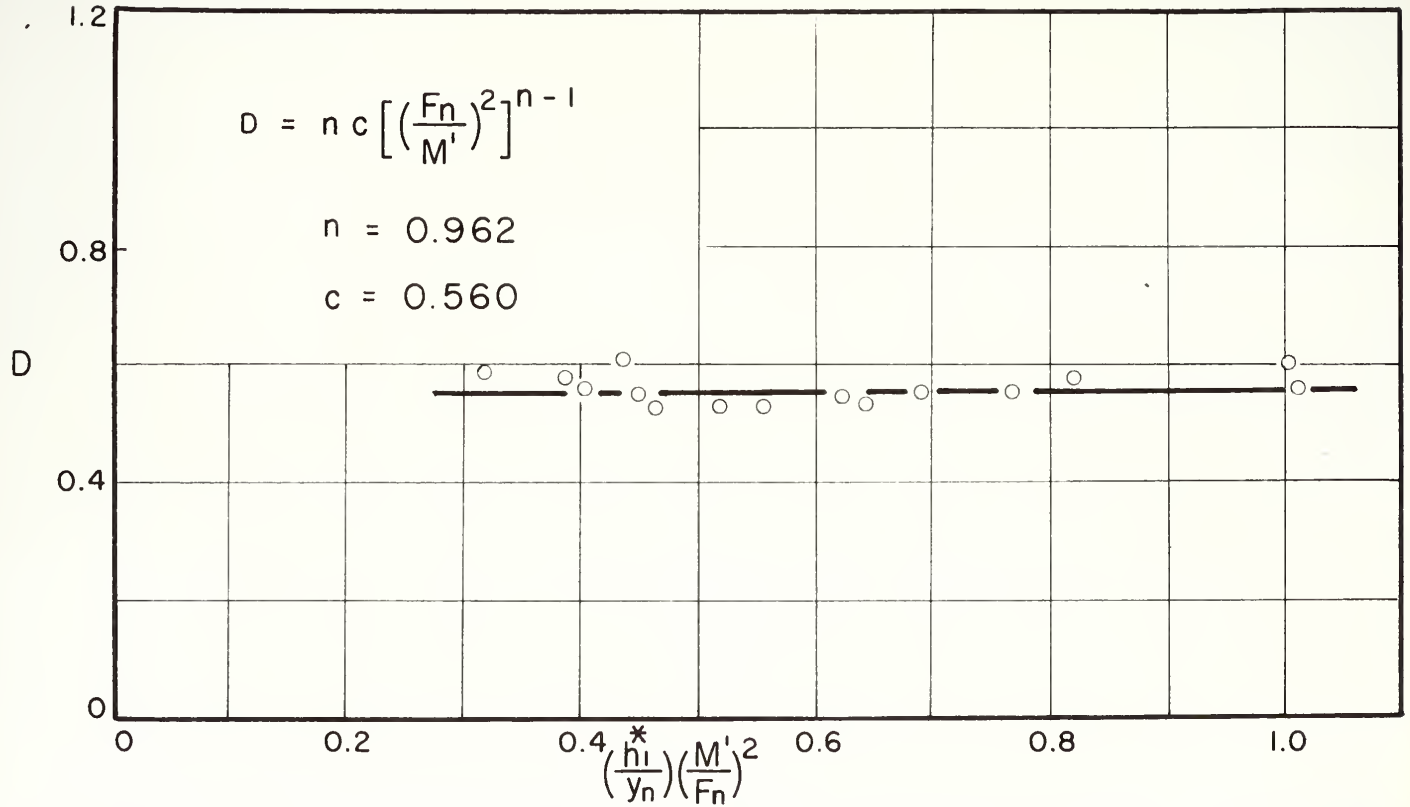


FIGURE 7-9-11 BACKWATER RATIO COEFFICIENT, GEOMETRY VII ROUGH BOUNDARY β = 0.5

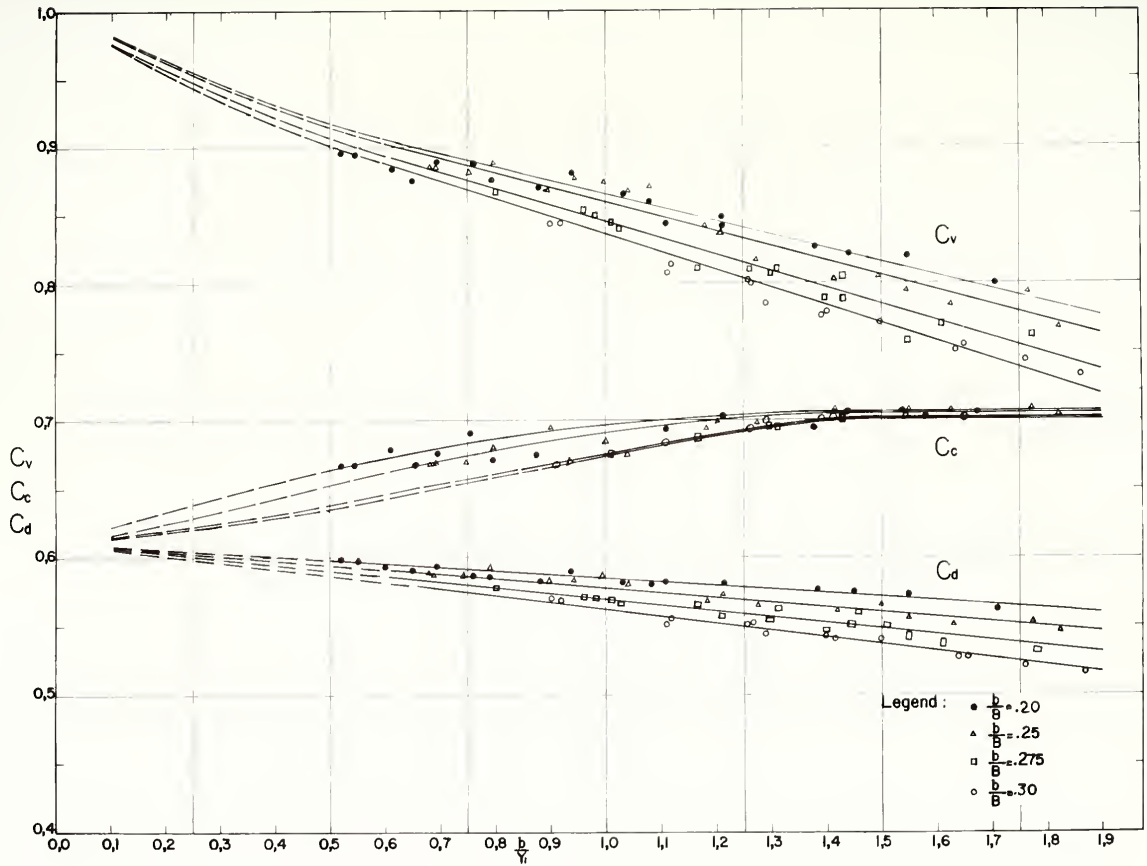


FIG. 8 - 3 - 1 COEFFICIENTS OF VELOCITY, CONTRACTION & DISCHARGE . SUBMERGED INLET BUT UNSUBMERGED DISCHARGE JET.

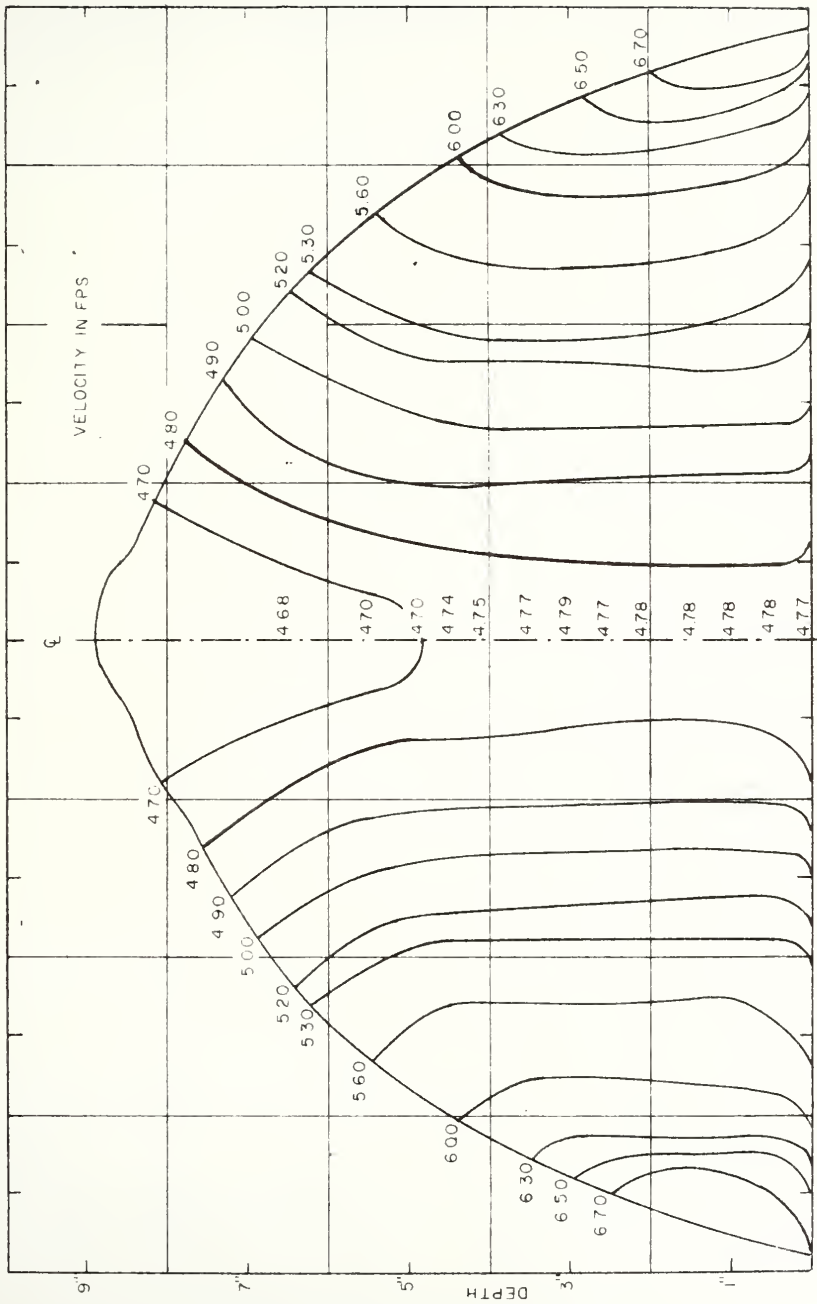


FIG 8-3-2 ISOVELOCITY CURVES AT VENA CONTRACTA

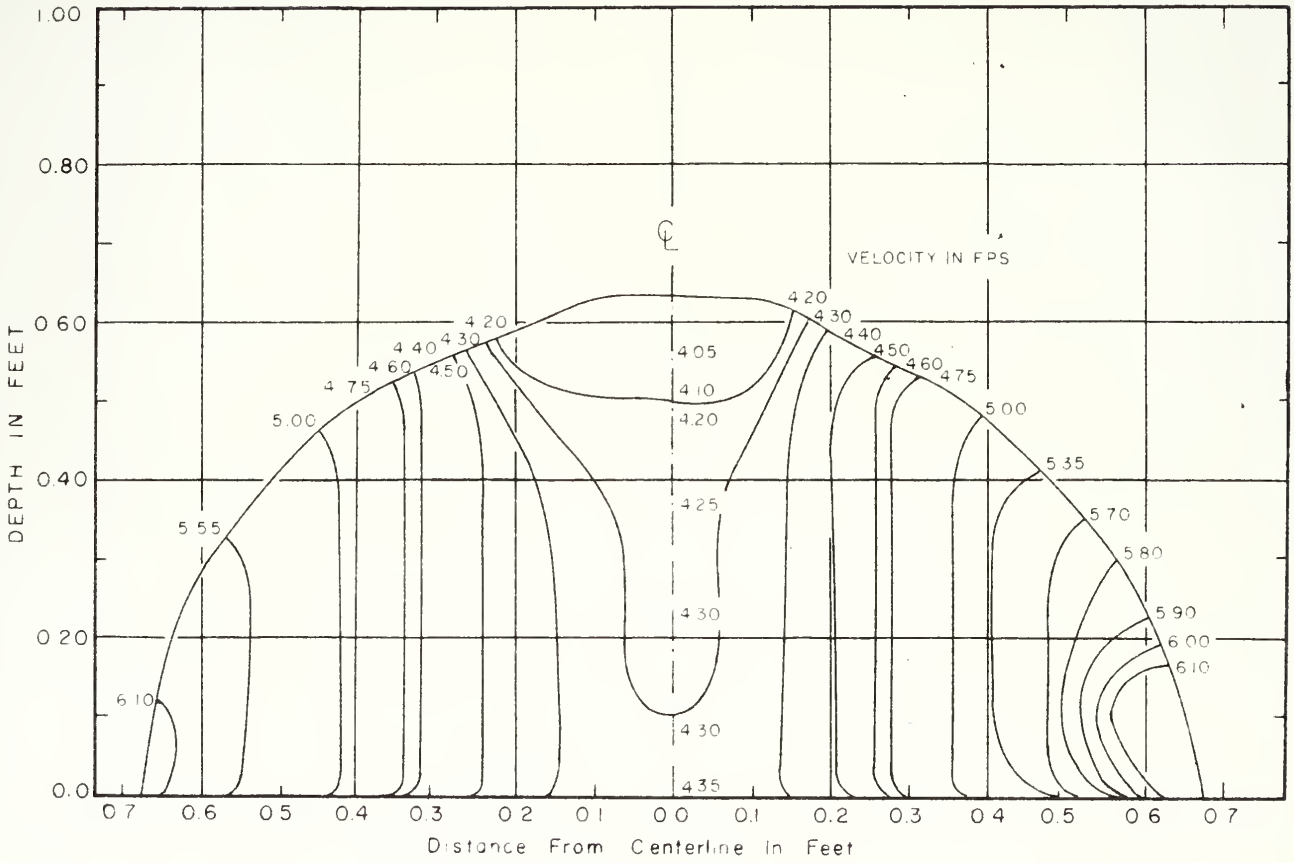


FIG. 8-3-3 ISOVELOCITY CURVES FOR CROSS SECTION AT VENA CONTRACTA

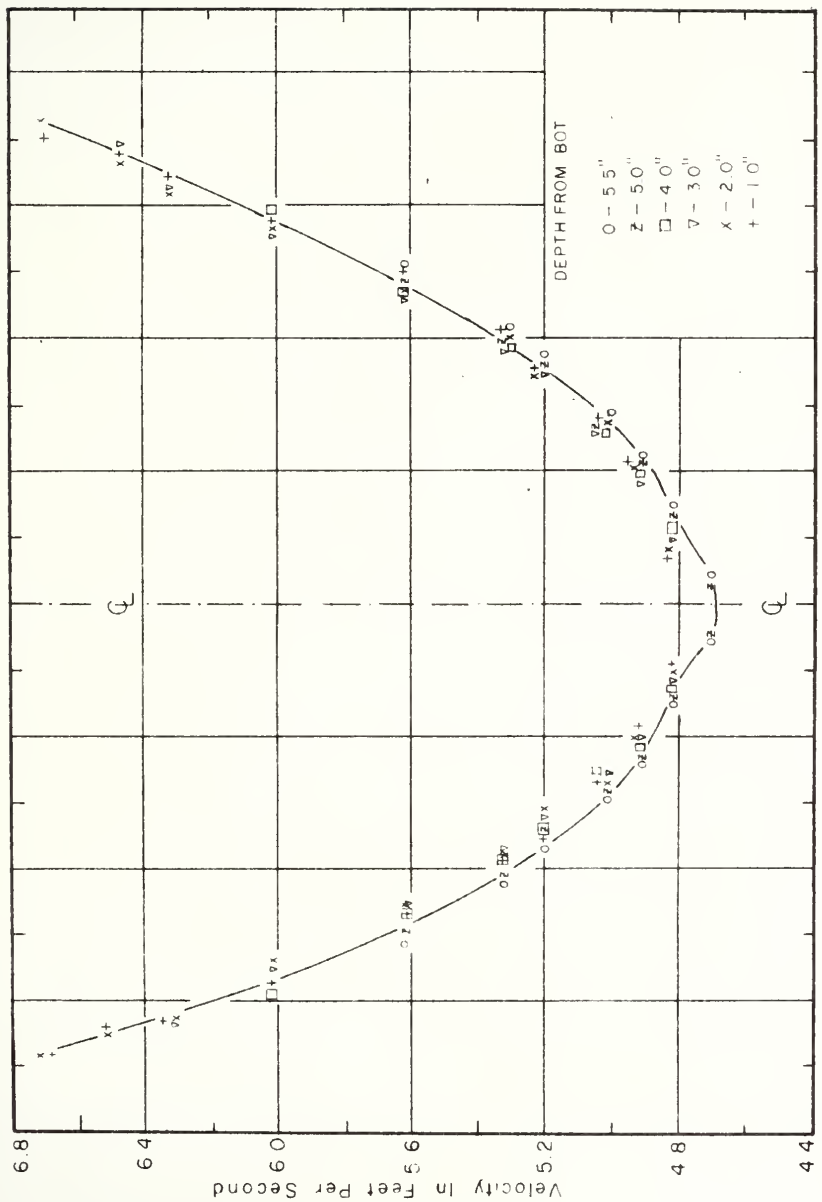


FIG. 8-3-4 VELOCITY DISTRIBUTION AT VENA CONTRACTA

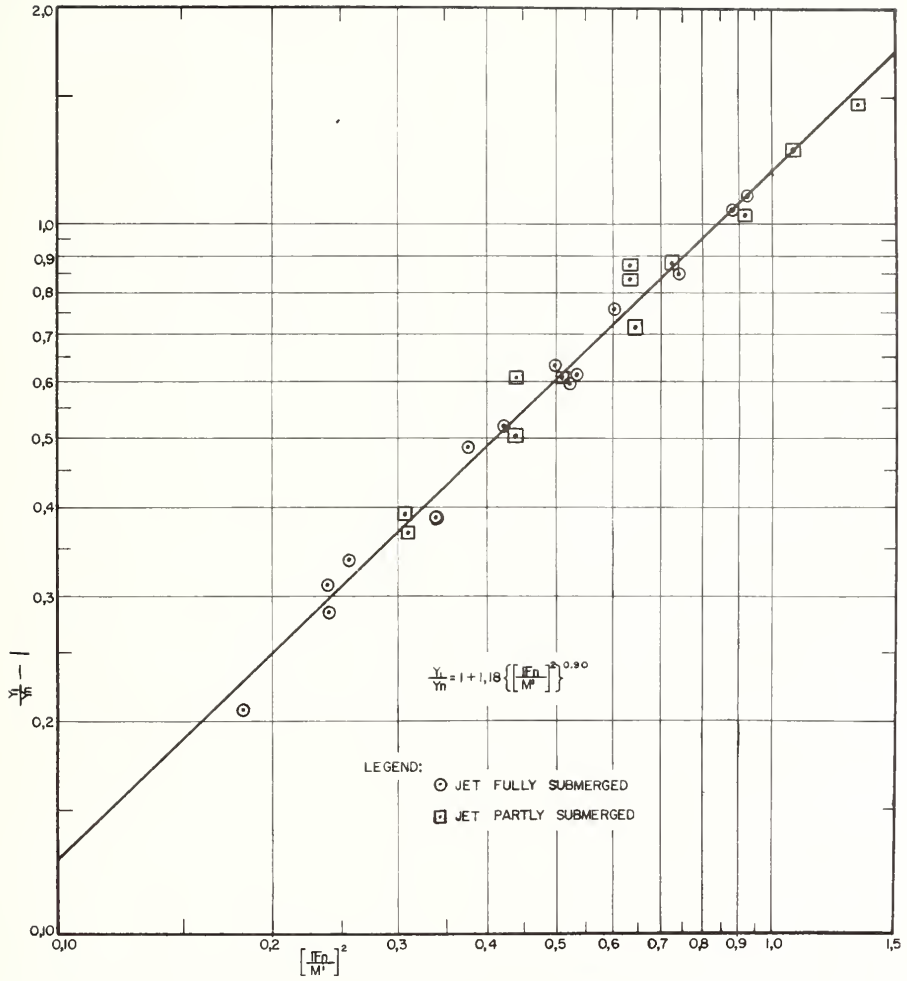


FIG. 8-3-5 GENERALIZED BACKWATER RATIO FOR SUBMERGED INLET. GEOMETRY Ia

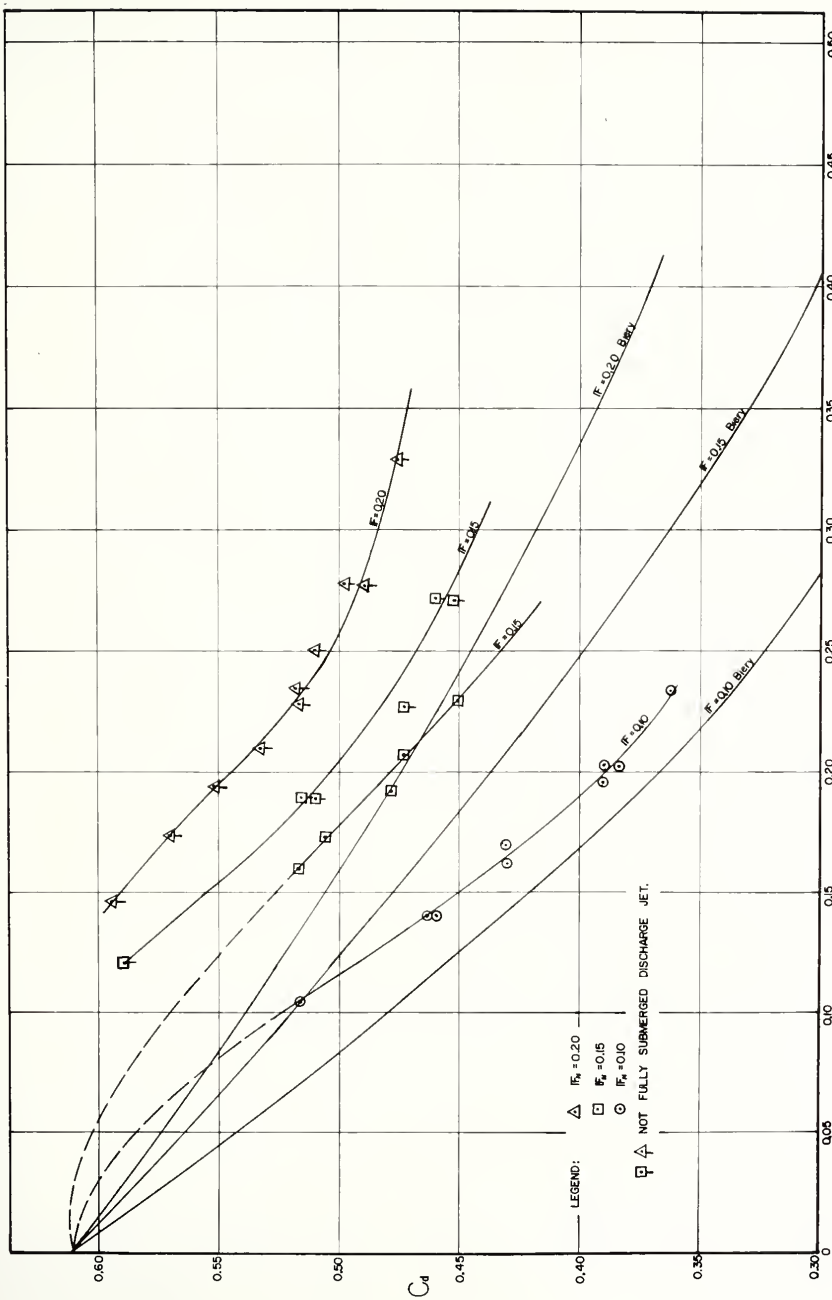


FIG. 8-3-6 DISCHARGE COEFFICIENT Vs CHANNEL OPENING RATIO, SMOOTH BOUNDARIES, GEOMETRY Ia

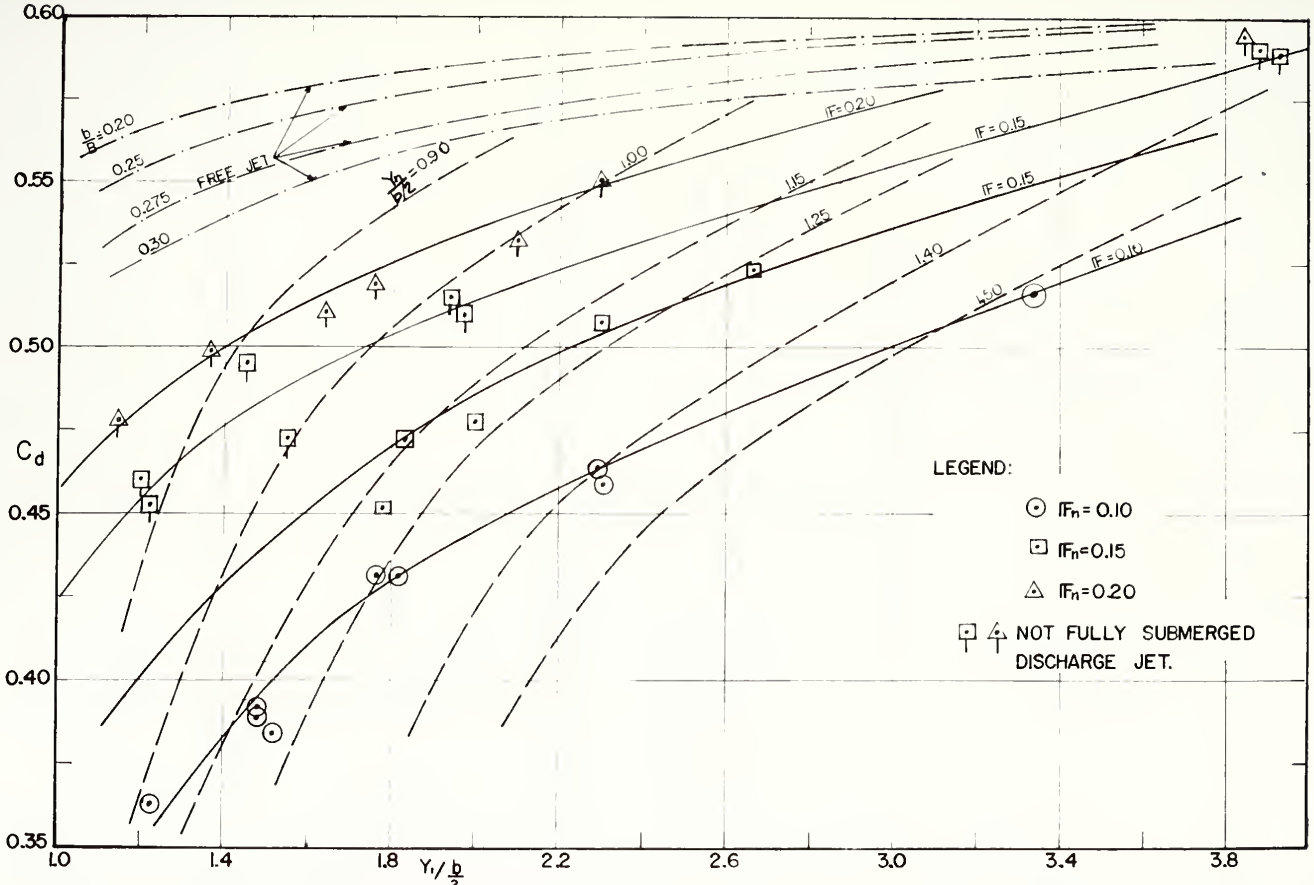


FIG. 8-3-7 DISCHARGE COEFFICIENT FOR FREE & SUBMERGED DISCHARGE & PARTLY SUBMERGED JET. GEOMETRY Ia

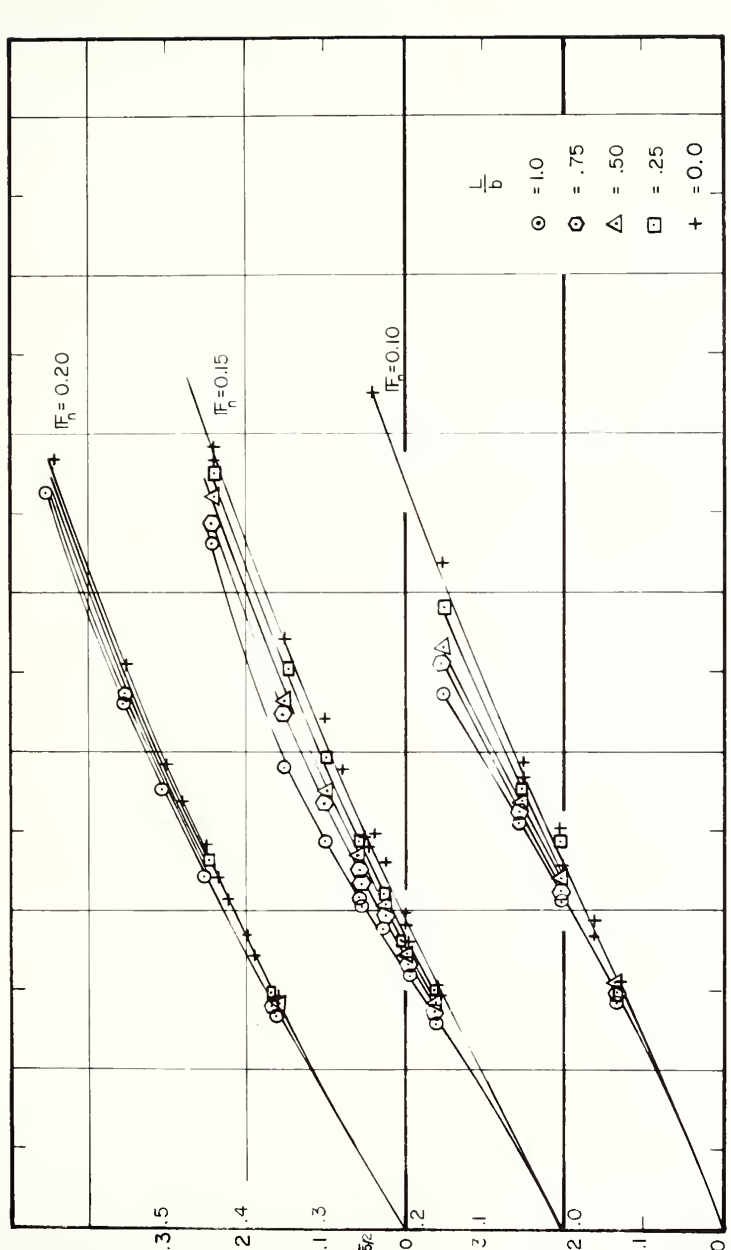


FIG. 8-4-1 DIMENSIONLESS CURVES FOR GEOMETRIES Ia AND Ib. SMOOTH BOUNDARIES

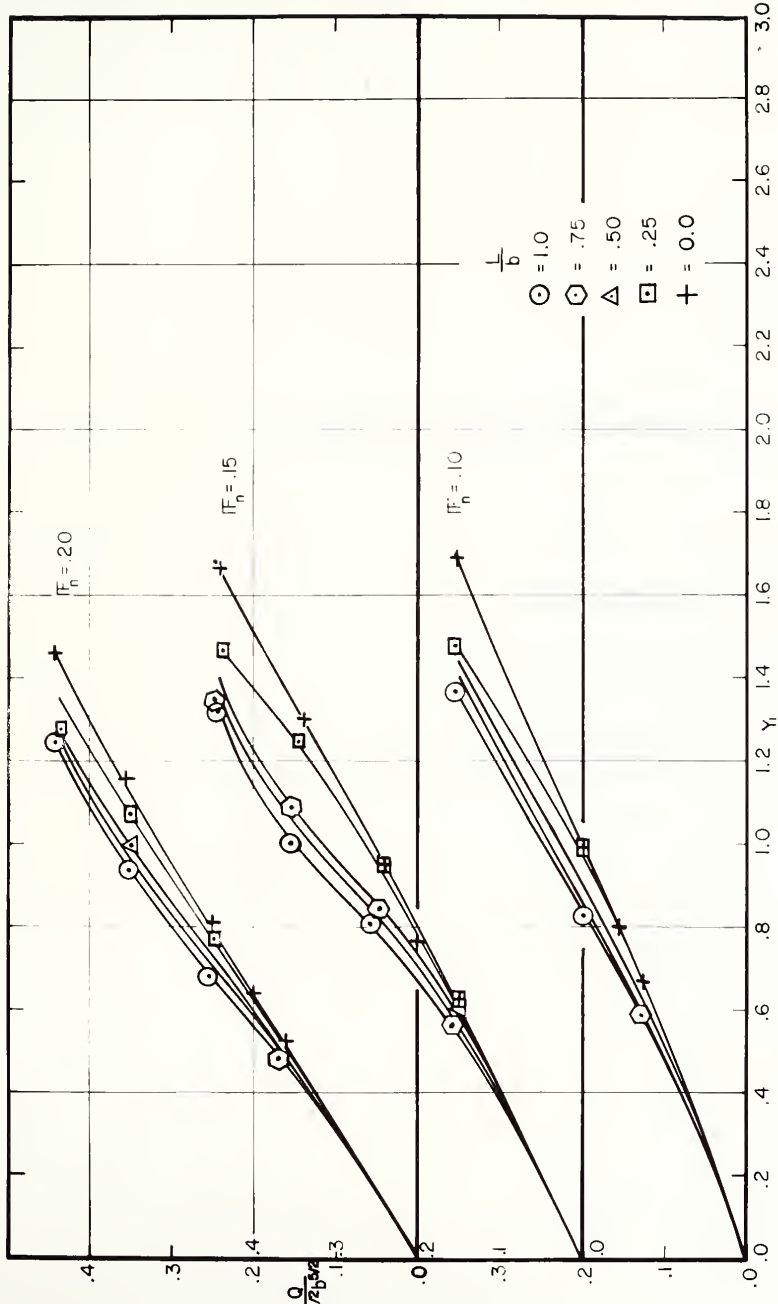


FIG. 8-5-1 DIMENSIONLESS CURVES FOR GEOMETRIES Ia AND Ib. ROUGH BOUNDARIES

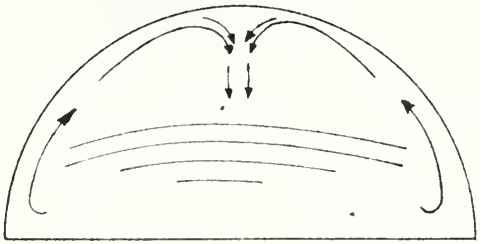


Fig 8-5-2$_a$ Spiral Motion in Barrel Section Downstream of Vena Contracta

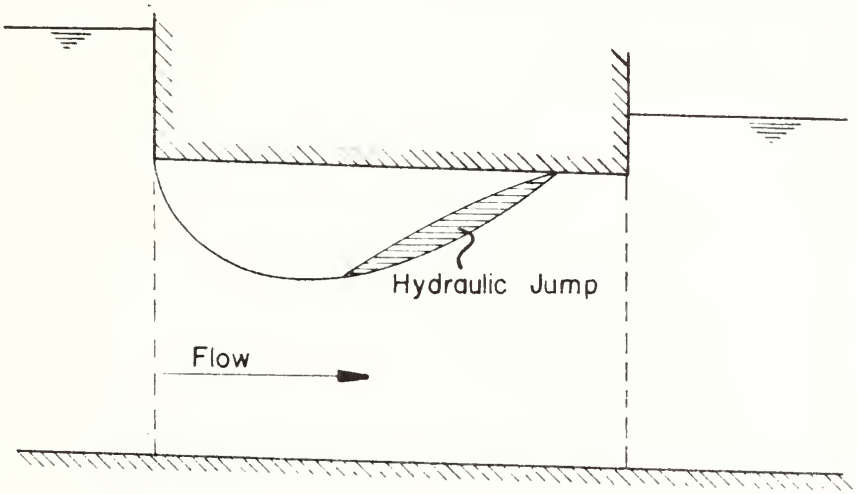


Fig 8-5-2$_b$ Typical Flow Condition Through Constriction

FIG 8-5-3 SLUG FLOW AT BARREL EXIT

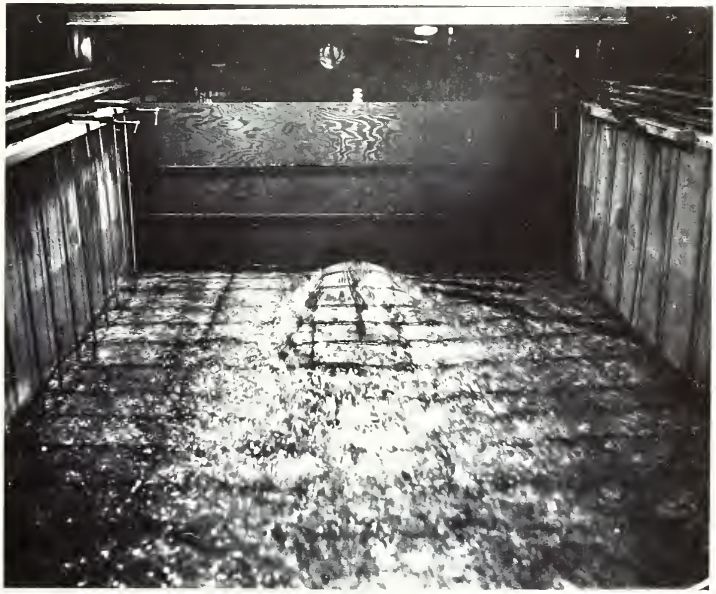


FIG 8-5-4 FREE DISCHARGE JET

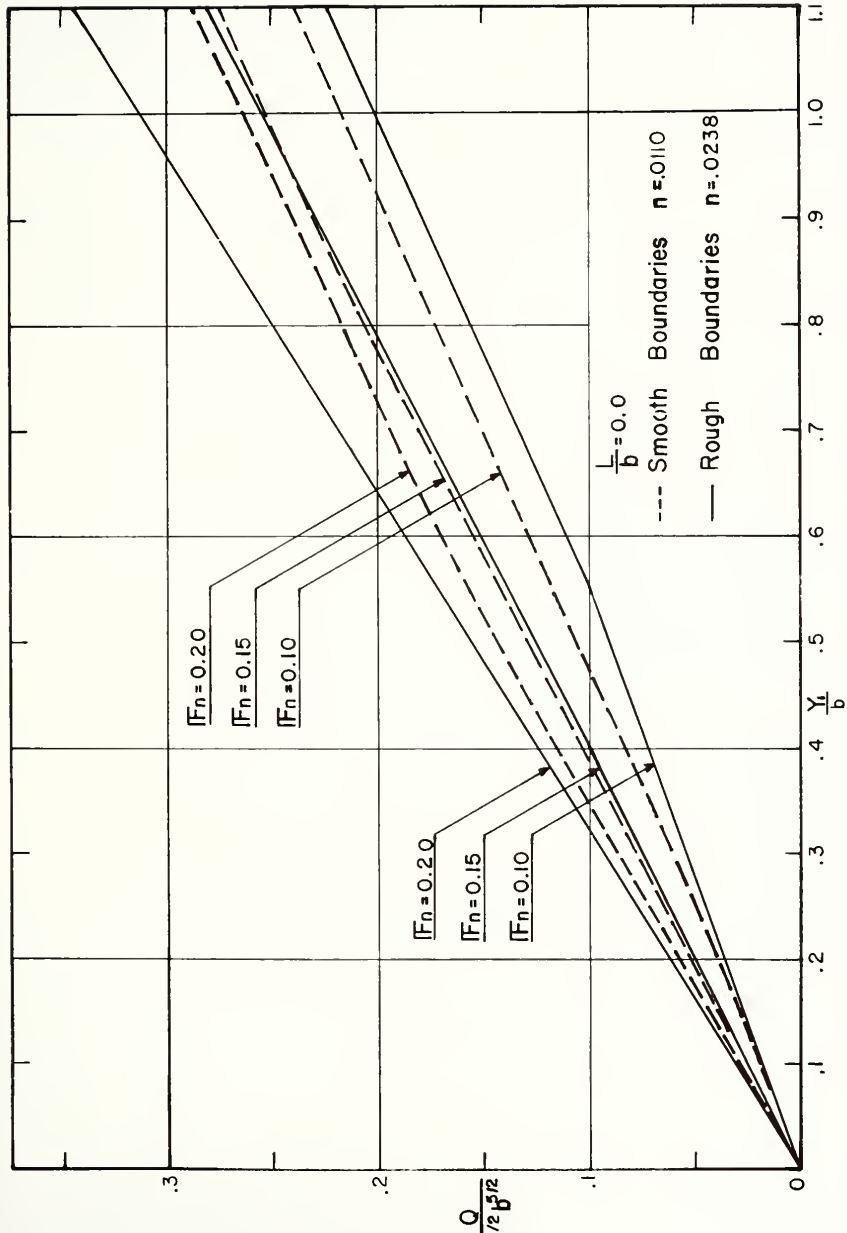


FIG. 8-5-5 Comparison of Dimensionless Curves for Geometry Ia for Smooth and Rough Boundaries

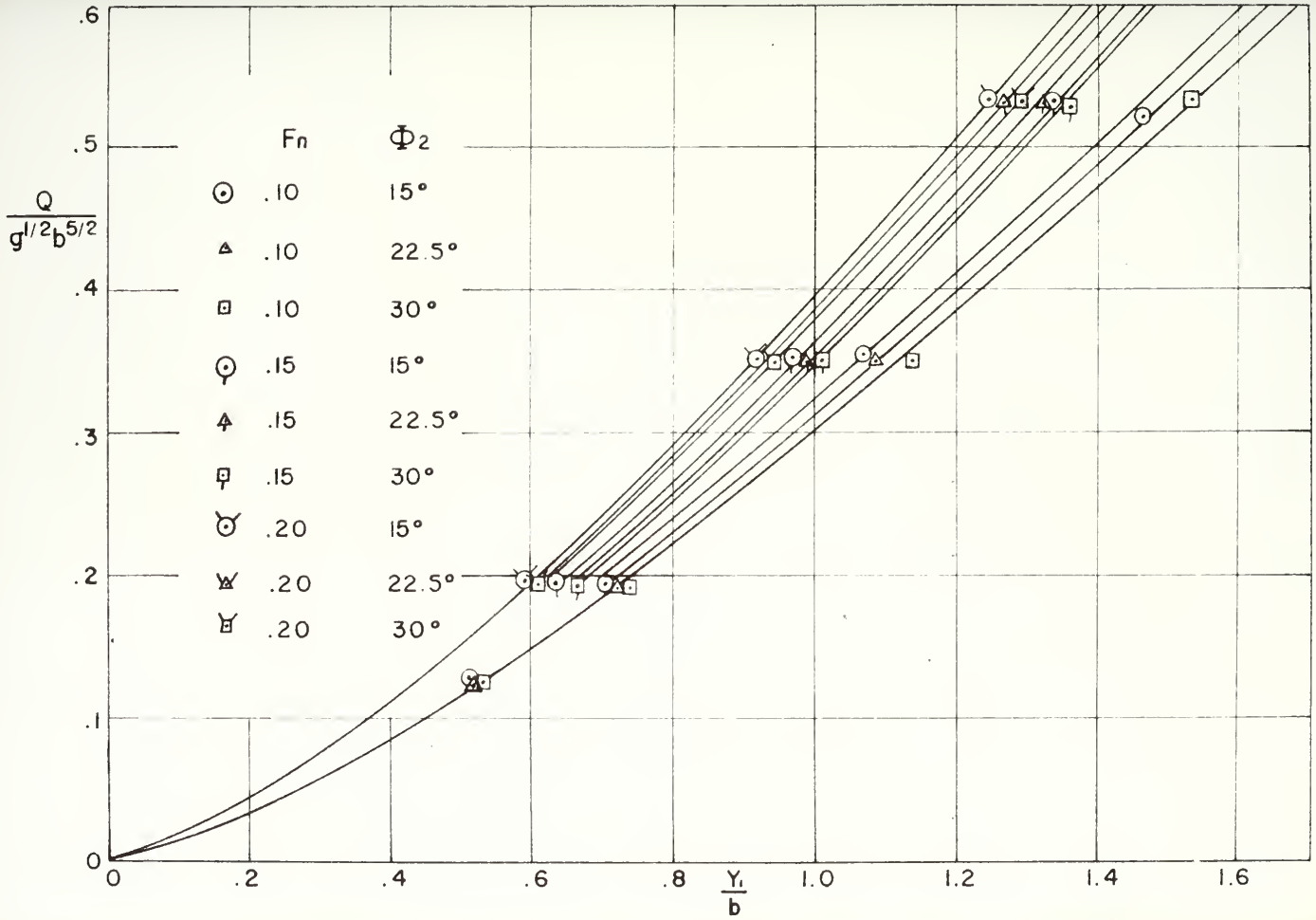


FIG. 8-6-1 Dimensionless Curves for Geometry ∇b, Rough Boundaries

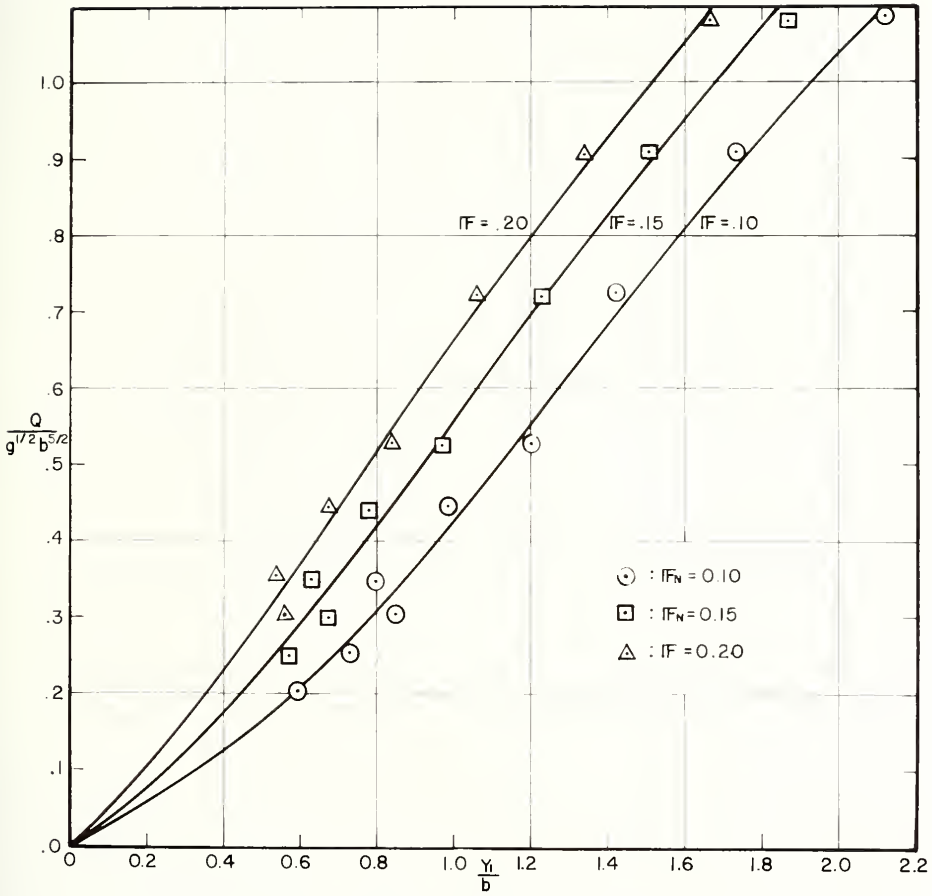


FIG. 8-7-1 DIMENSIONLESS CURVES FOR GEOMETRY VI USING IF_n AS PARAMETER. ROUGH BOUNDARIES

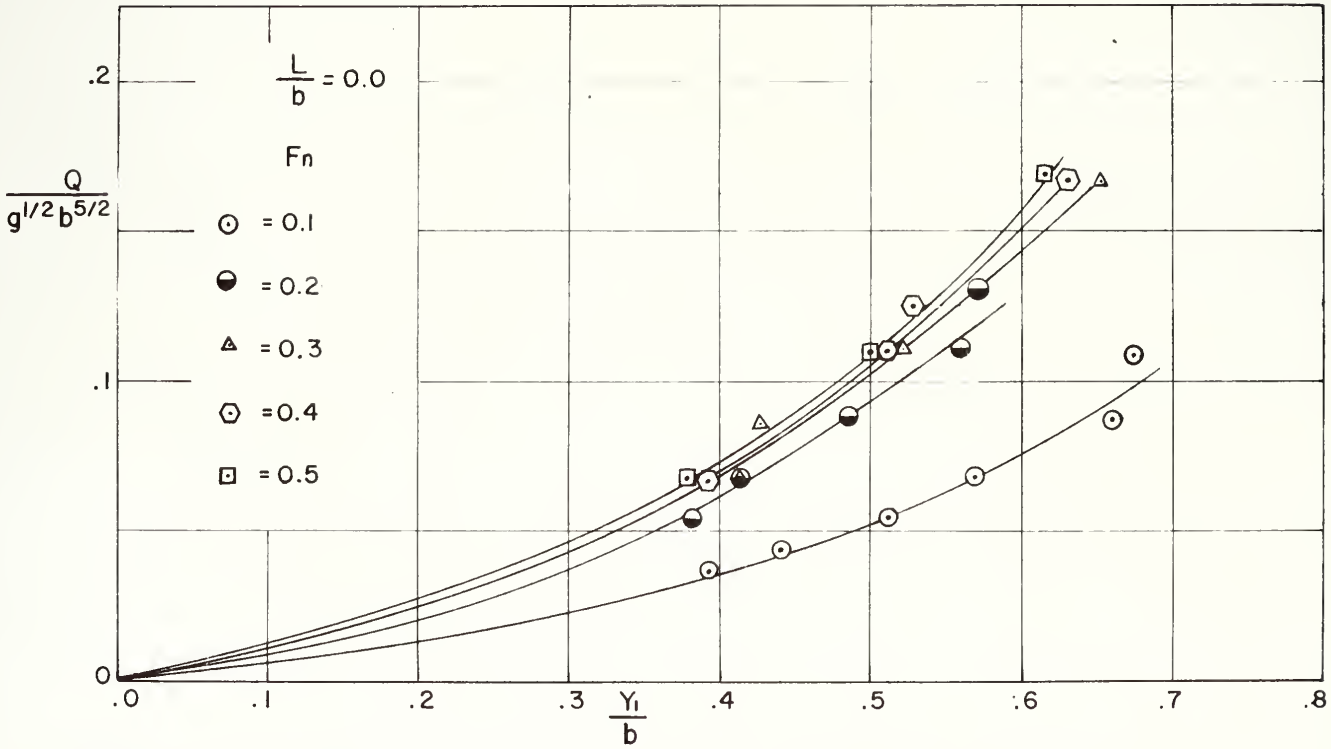


FIG. 8-8-1 Dimensionless Curves for Geometry VII Rough Boundaries

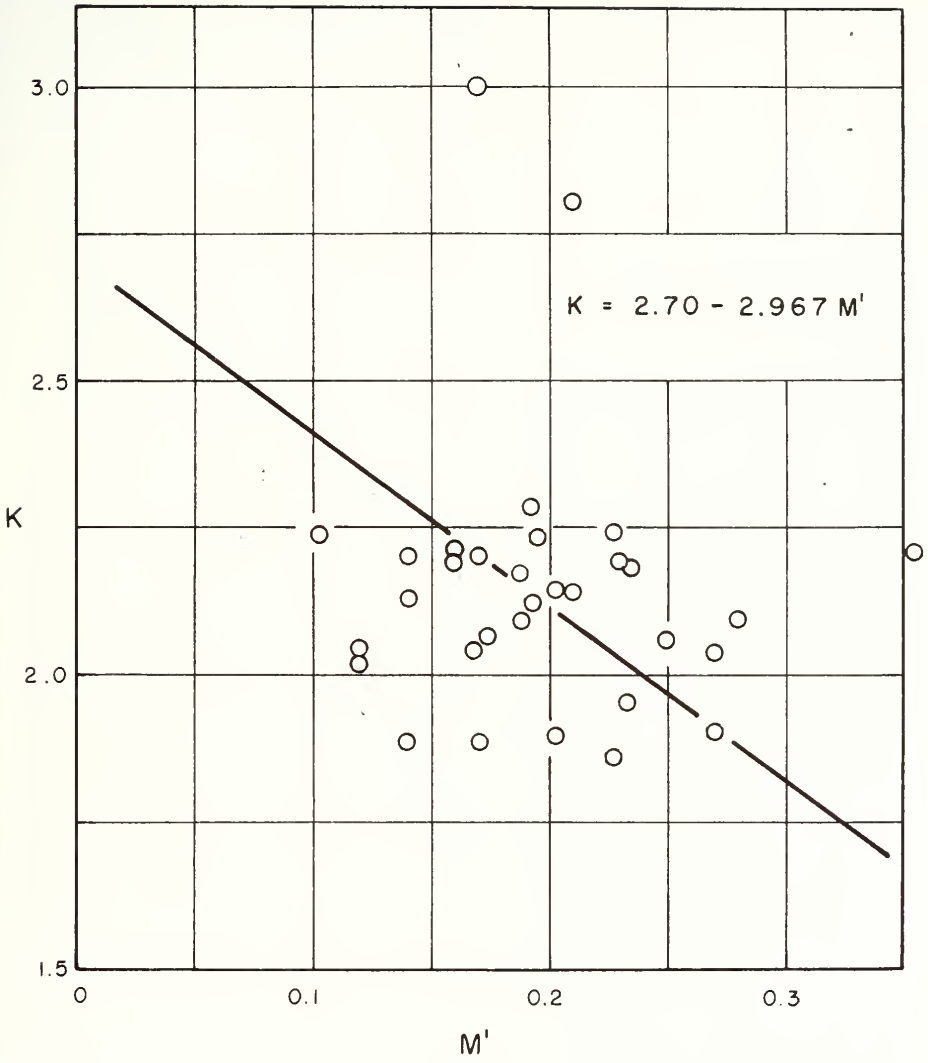


FIG. 8-9-1 HEAD LOSS COEFFICIENT FOR GEOMETRY Ia SMOOTH BOUNDARIES, $\frac{L}{b} = 0.0$

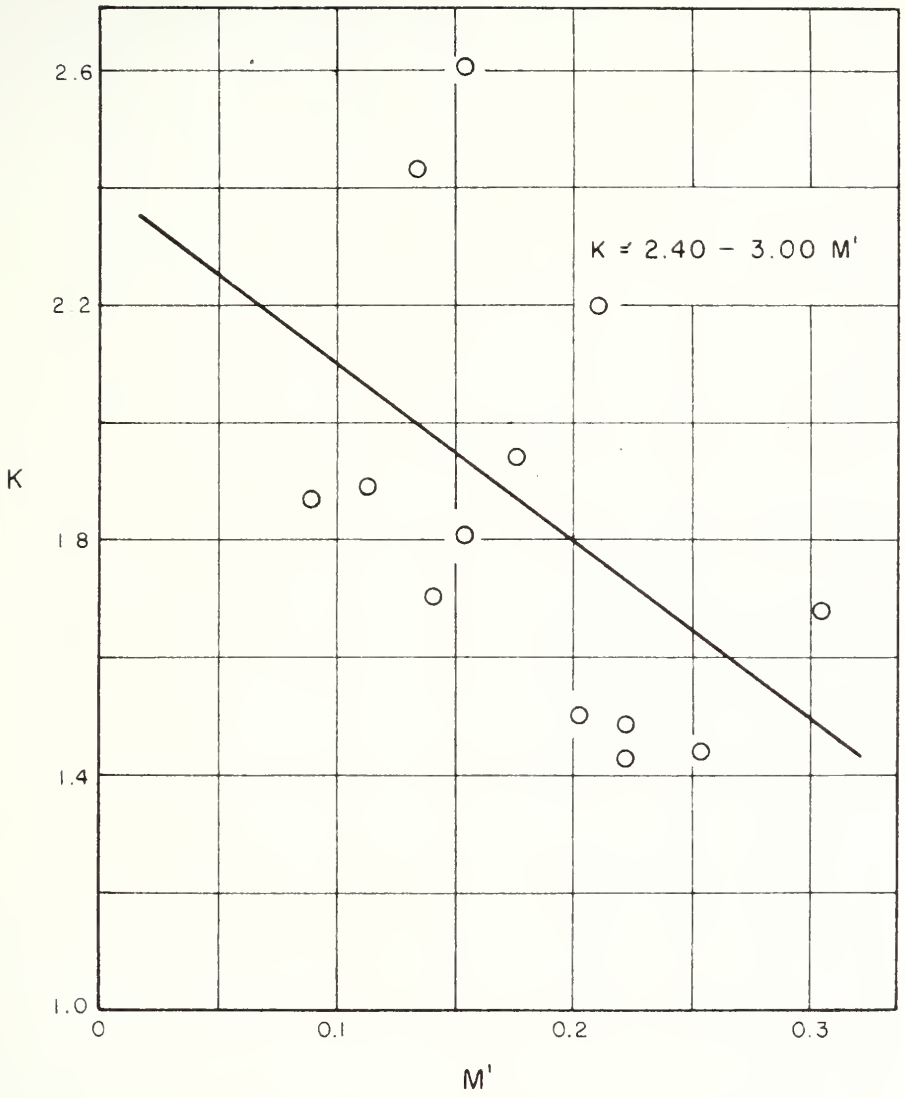


FIG. 8-9-2 HEAD LOSS COEFFICIENT FOR GEOMETRY I_b SMOOTH BOUNDARIES, $\frac{L}{b} = 0.25$

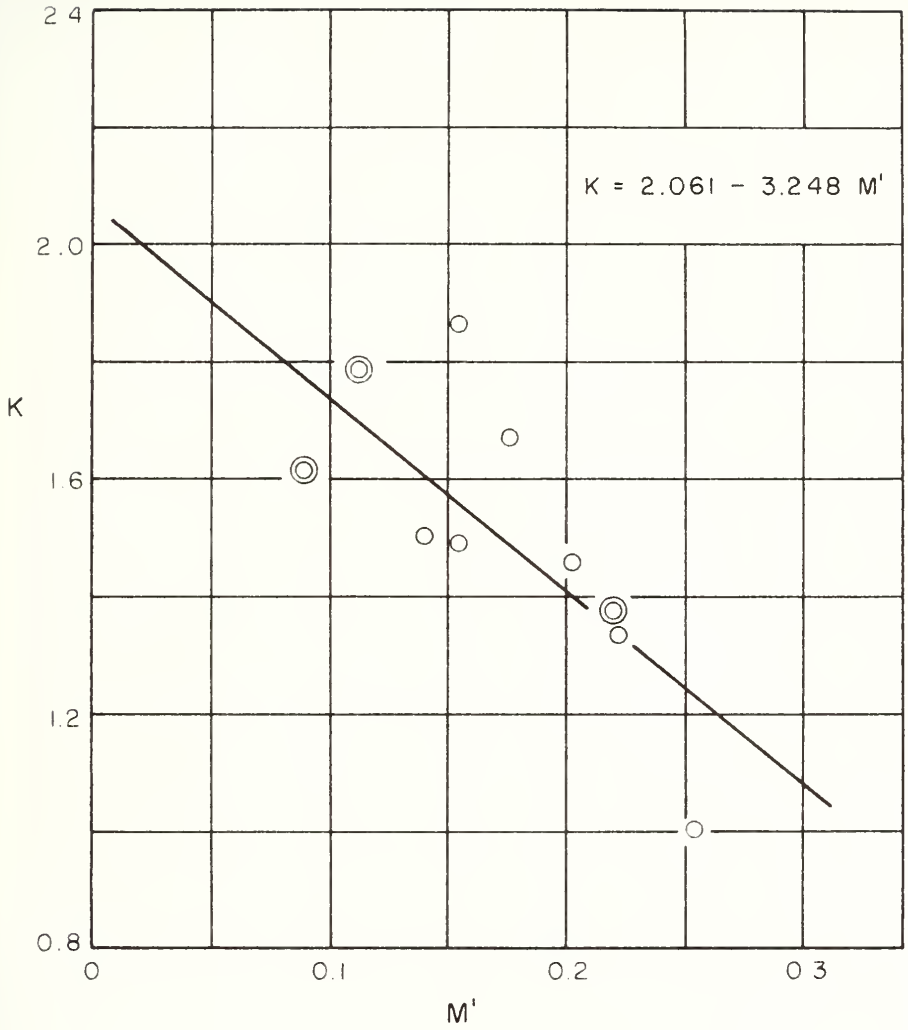


FIG. 8-9-3 HEAD LOSS COEFFICIENT FOR GEOMETRY

I_b SMOOTH BOUNDARIES, $\frac{L}{b} = 0.50$

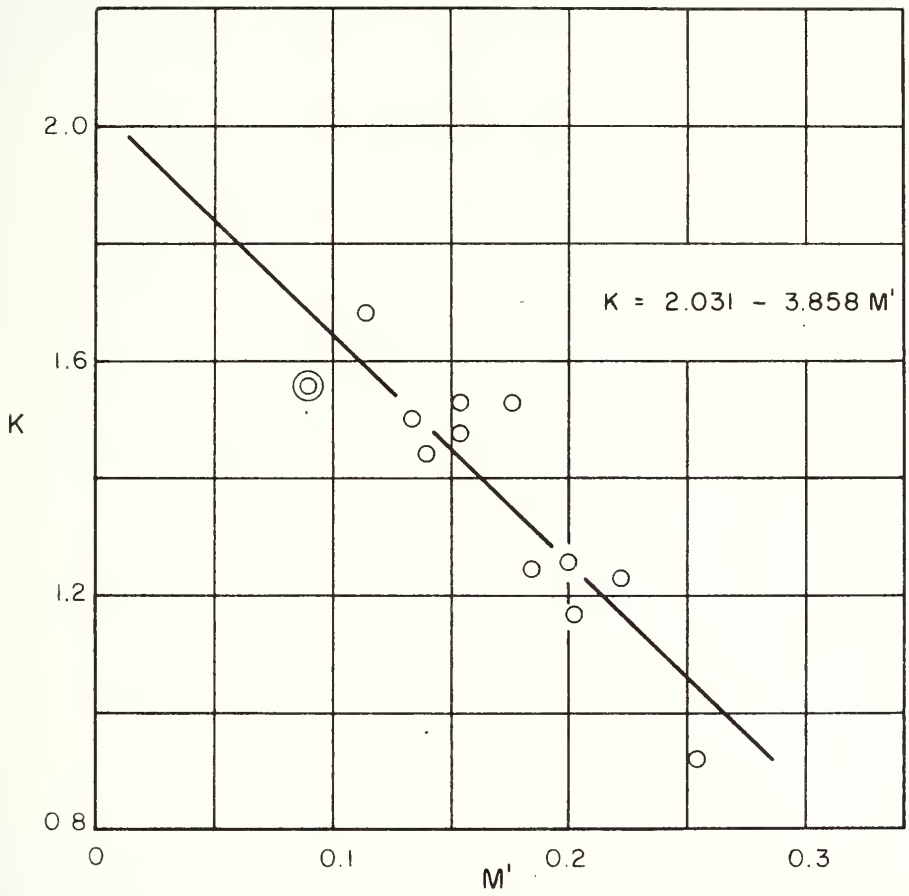


FIG. 8-9-4 HEAD LOSS COEFFICIENT FOR GEOMETRY I_b SMOOTH BOUNDARIES, $\frac{L}{b} = 0.75$

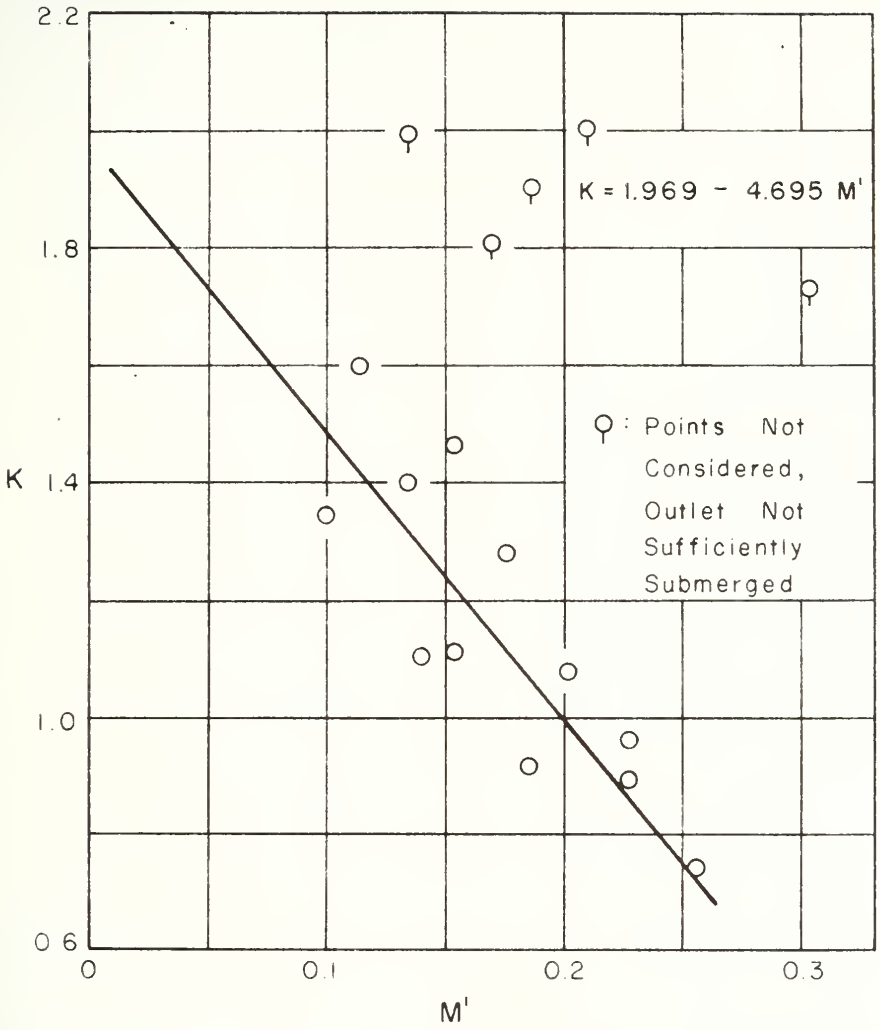


FIG. 8-9-5 HEAD LOSS COEFFICIENT FOR GEOMETRY I_b, SMOOTH BOUNDARIES, $\frac{L}{b} = 1.00$

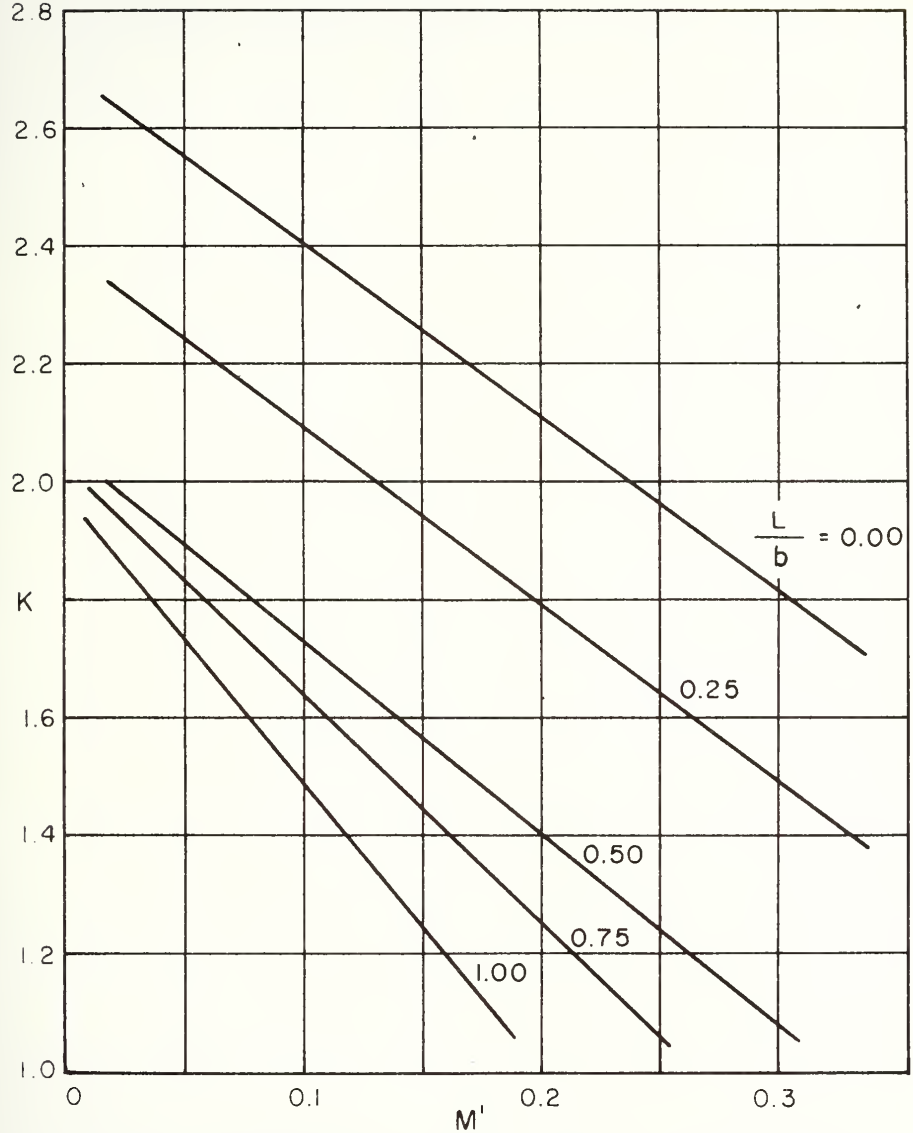


FIG. 8-9-6 SUMMARY OF HEAD LOSS COEFFICIENT CURVES FOR GEOMETRIES I_a, & I_b, SMOOTH BOUNDARIES

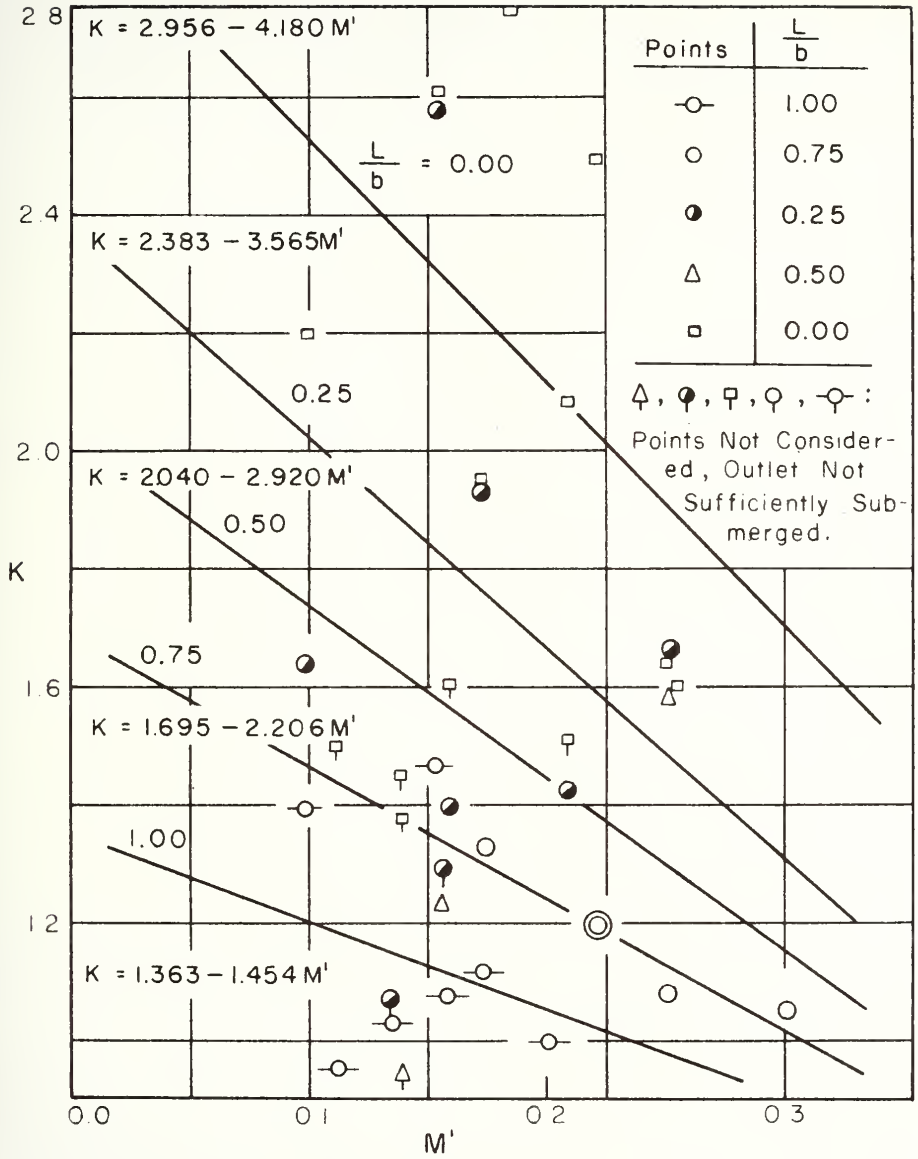


FIG. 8-9-7 HEAD LOSS COEFFICIENT CURVES FOR GEOMETRIES I_a, & I_b, ROUGH BOUNDARIES

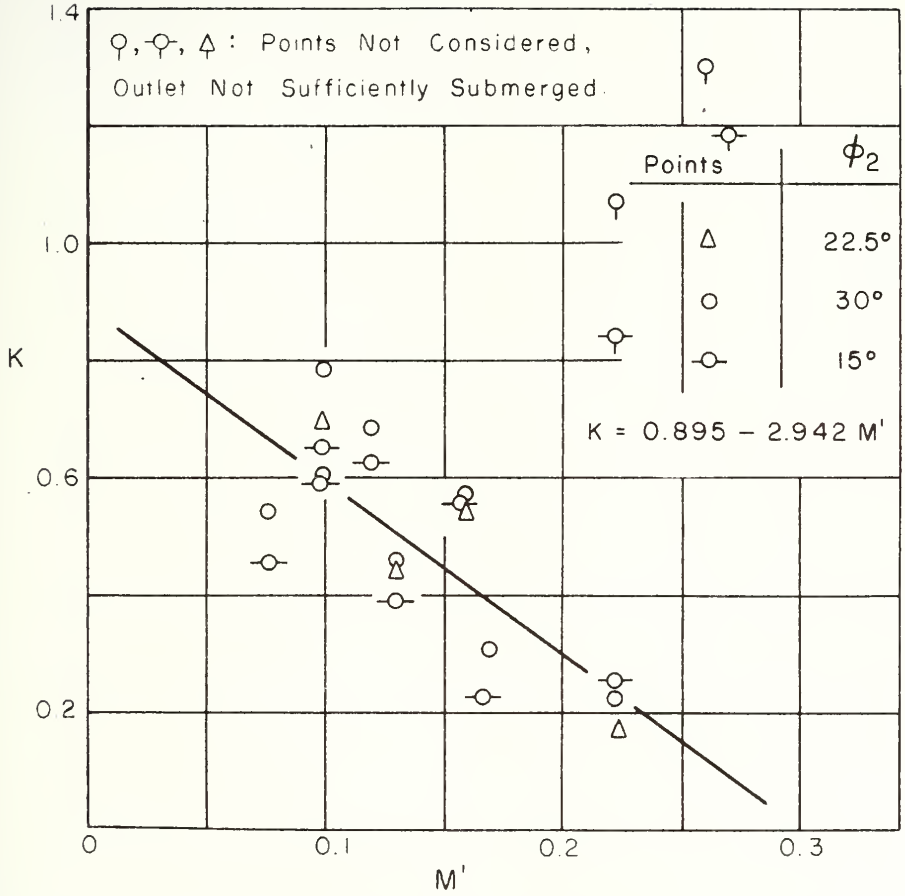


FIG 8-9-8 HEAD LOSS COEFFICIENT CURVE FOR GEOMETRY ∇_b, ROUGH BOUNDARIES

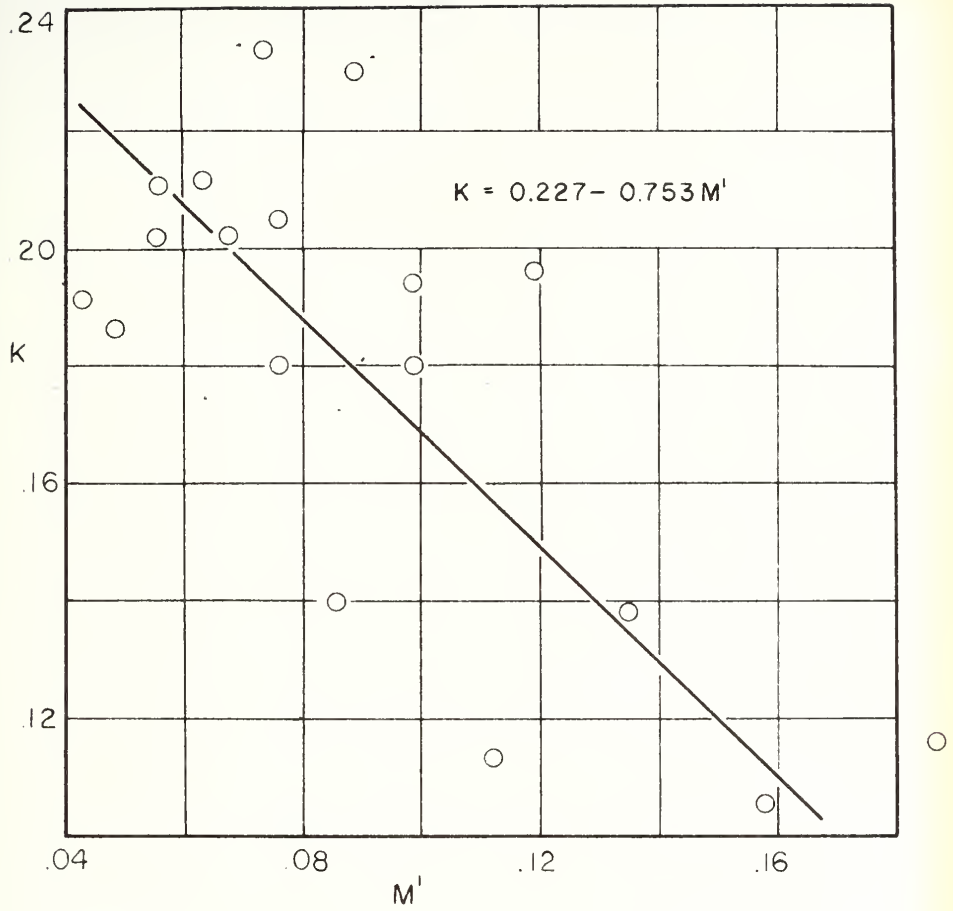


FIG. 8-9-9 HEAD LOSS COEFFICIENT CURVE FOR GEOMETRY VI, ROUGH BOUNDARIES

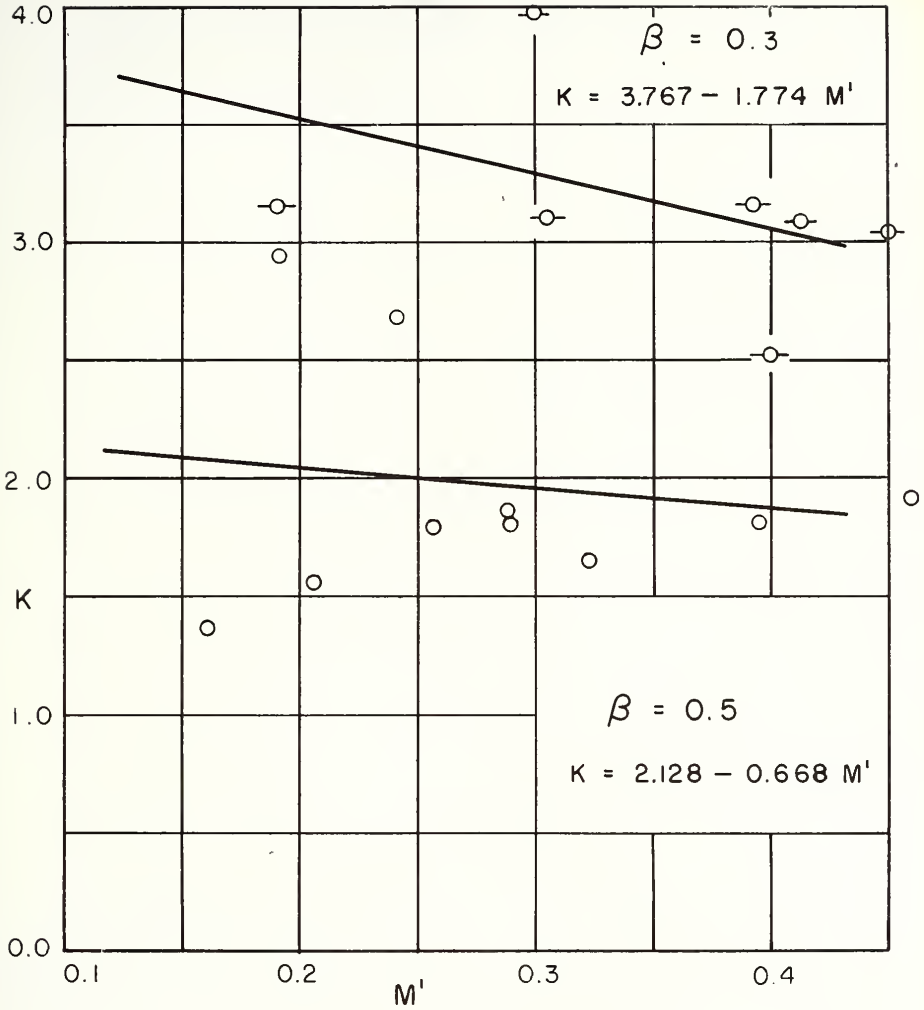


FIG. 8-9-10 HEAD LOSS COEFFICIENT CURVES FOR GEOMETRY VII, ROUGH BOUNDARIES

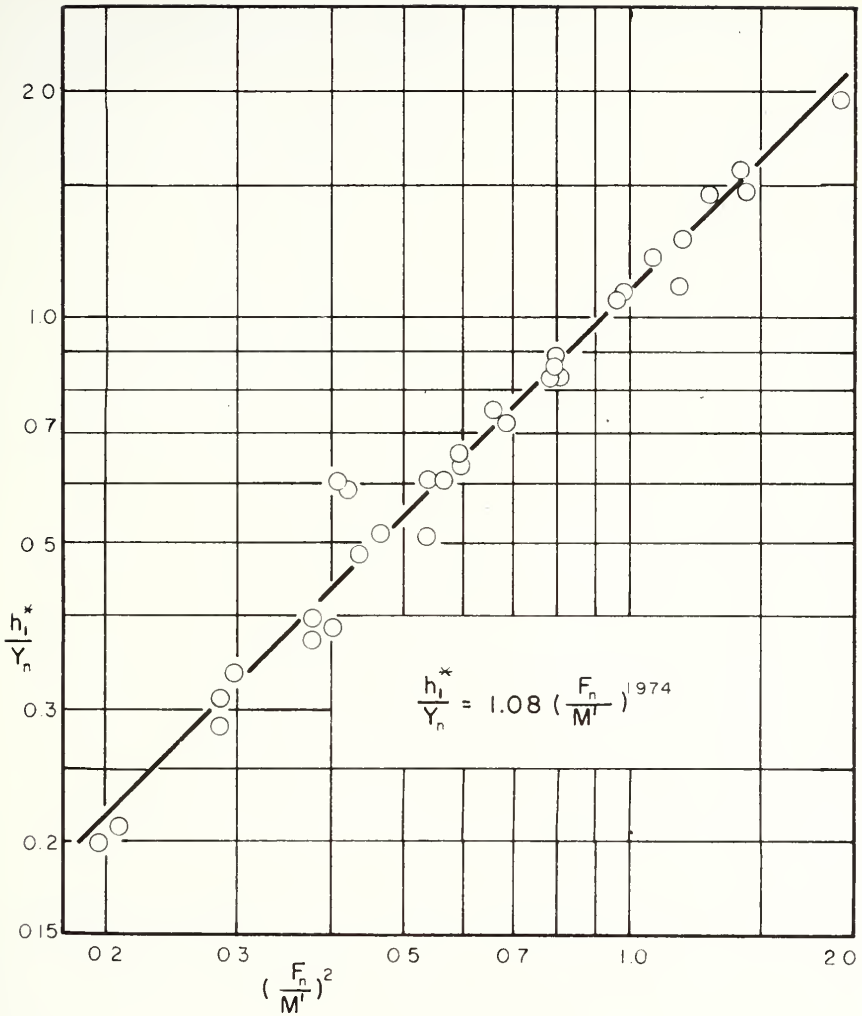


FIG. 8-10-I GENERALIZED BACKWATER RATIO GEOMETRY

Ia , SMOOTH BOUNDARIES , $\frac{L}{b} = 0.0$

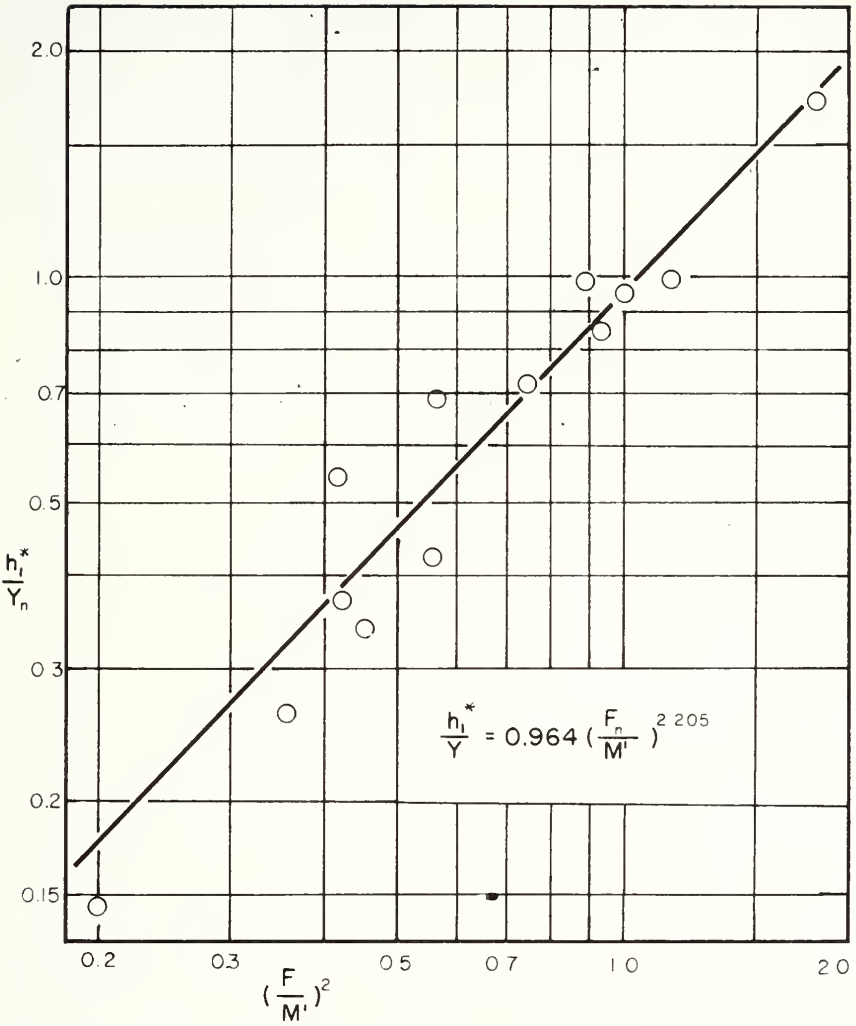


FIG. 8-10-2 GENERALIZED BACKWATER RATIO GEOMETRY Ib, SMOOTH BOUNDARIES, $\frac{L}{b} = 0.25$

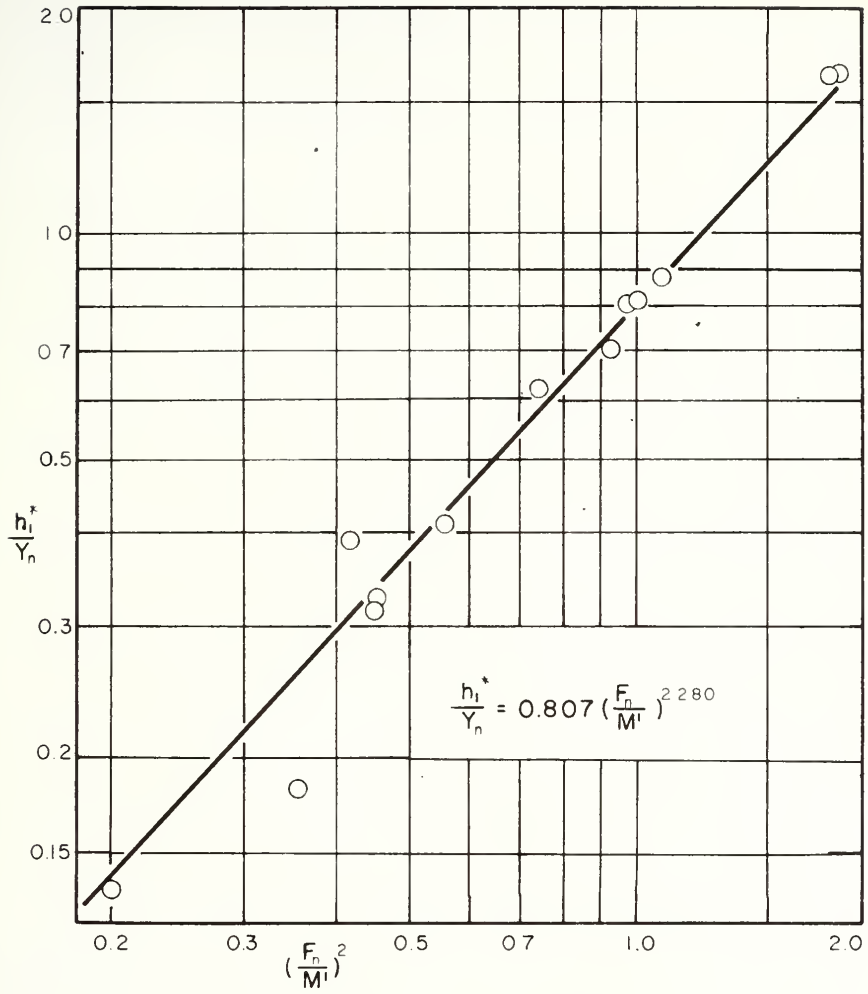


FIG 8-10-3 GENERALIZED BACKWATER RATIO GEOMETRY Ib, SMOOTH BOUNDARIES, $\frac{L}{b} = 0.50$

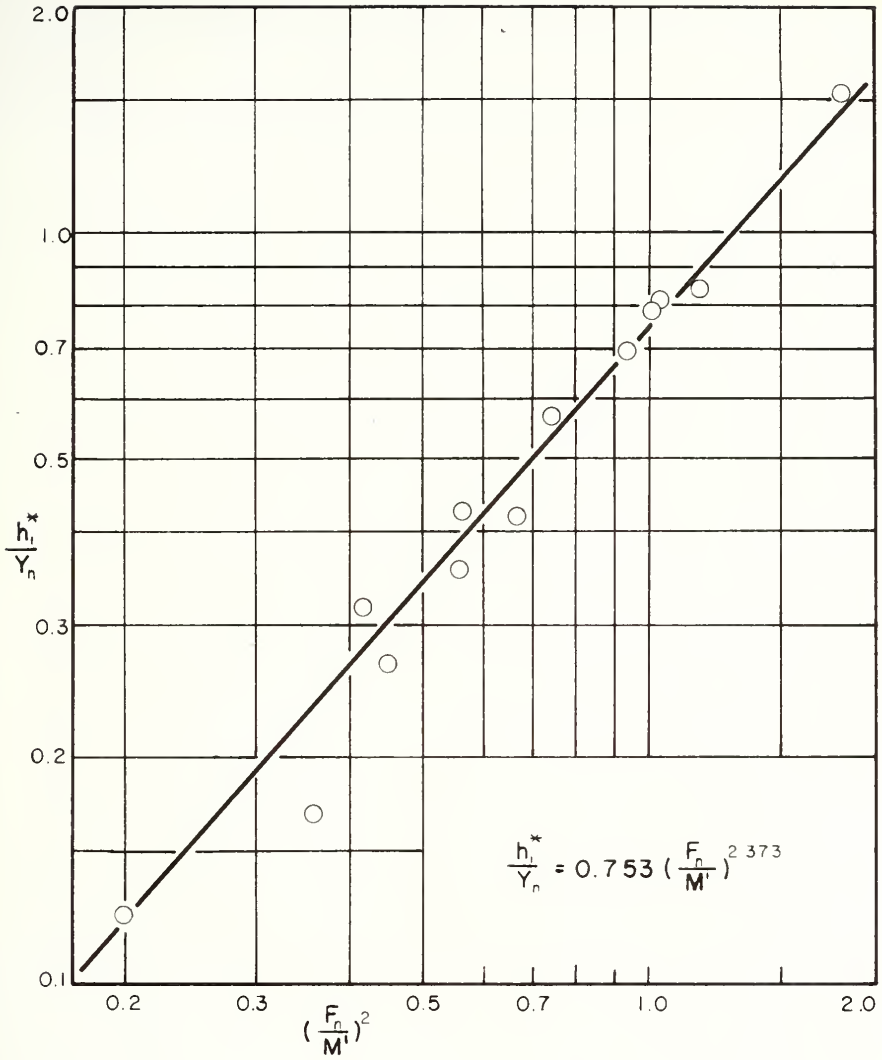


FIG. 8-10-4 GENERALIZED BACKWATER RATIO GEOMETRY Ib, SMOOTH BOUNDARIES, $\frac{L}{b} = 0.75$

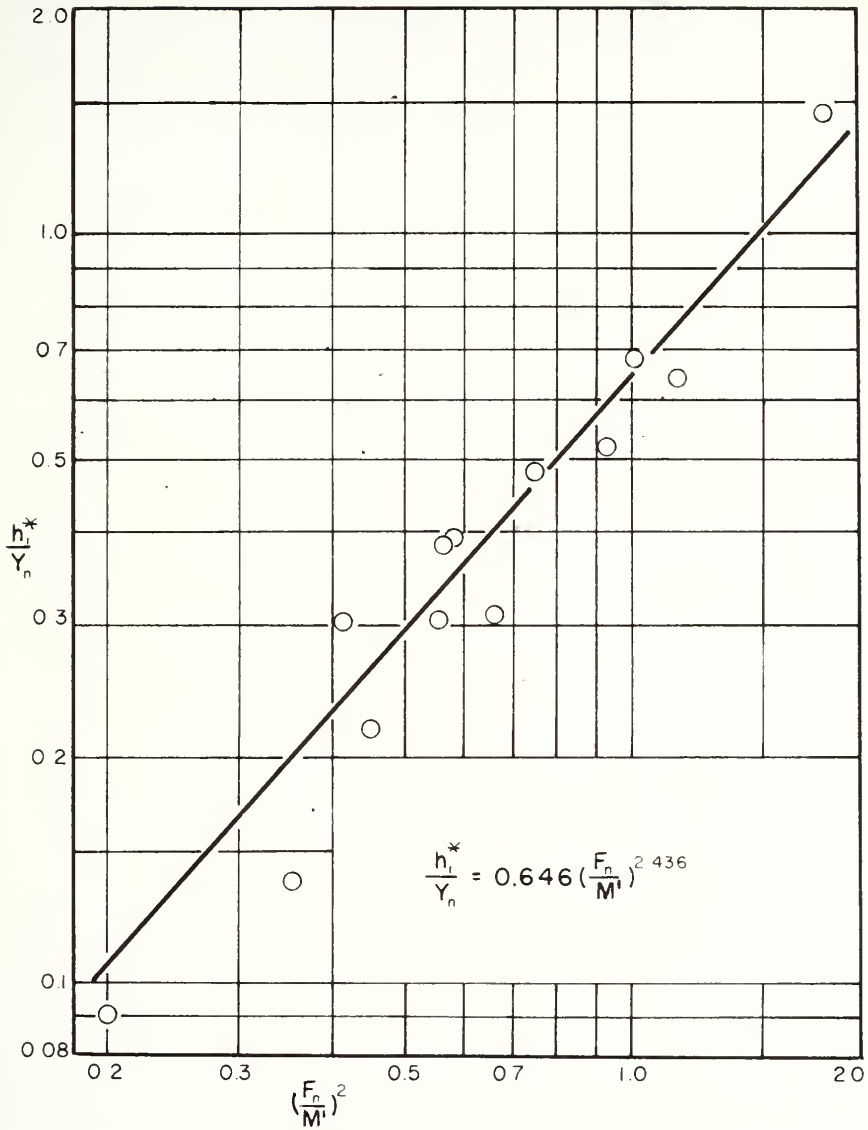


FIG. 8-10-5 GENERALIZED BACKWATER RATIO GEOMETRY Ib, SMOOTH BOUNDARIES, $\frac{L}{b} = 1.0$

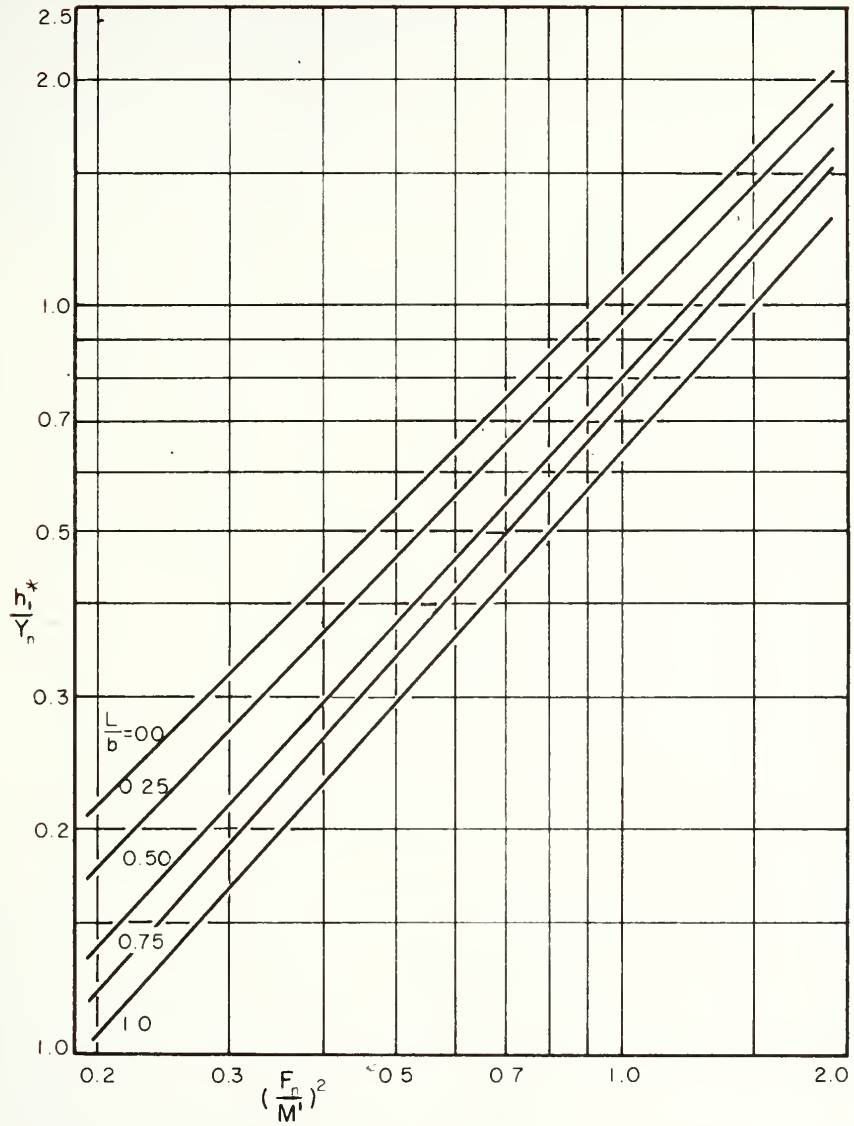


FIG. 8-10-6 SUMMARY OF BACKWATER RATIO CURVES FOR GEOMETRIES Ia AND Ib , SMOOTH BOUNDARIES

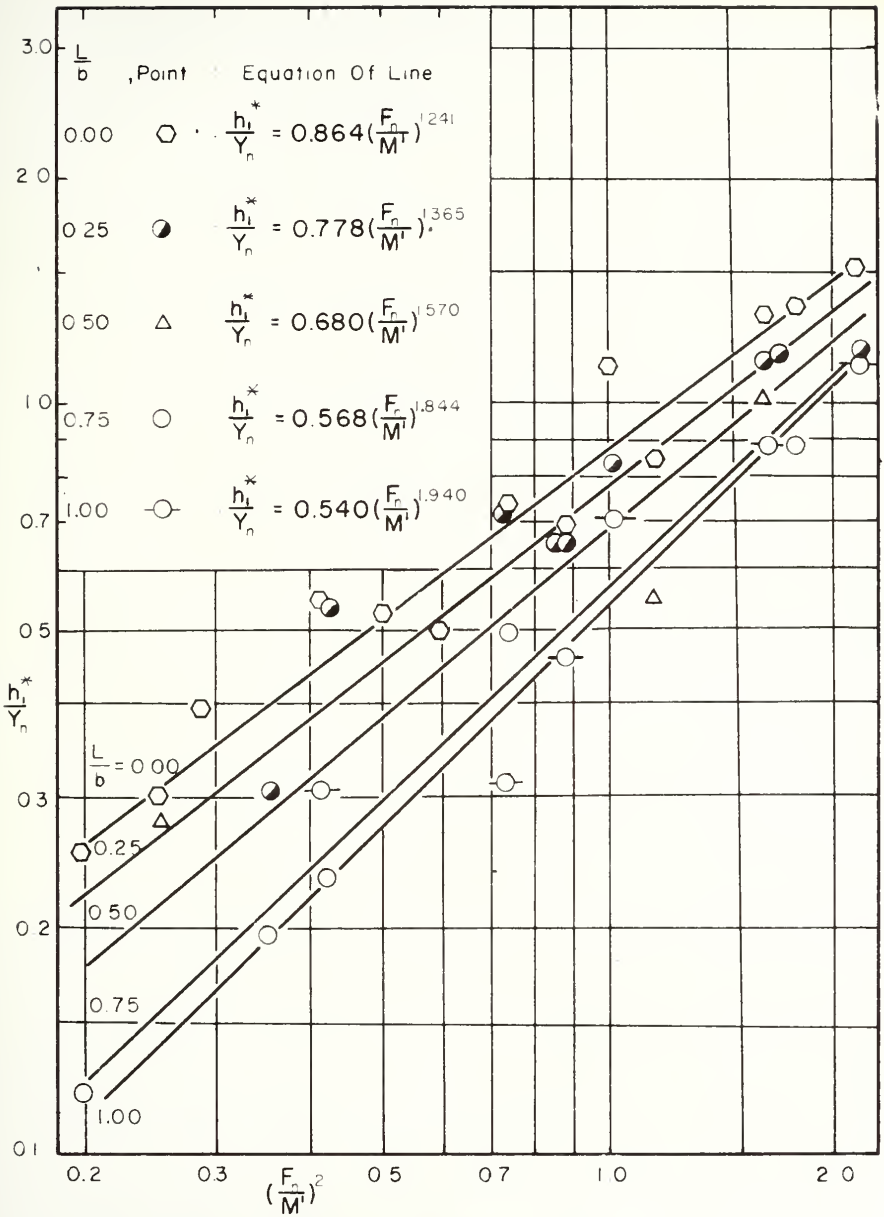


FIG. 8-10-7 GENERALIZED BACKWATER RATIO GEOMETRIES Ia AND Ib , ROUGH BOUNDARIES

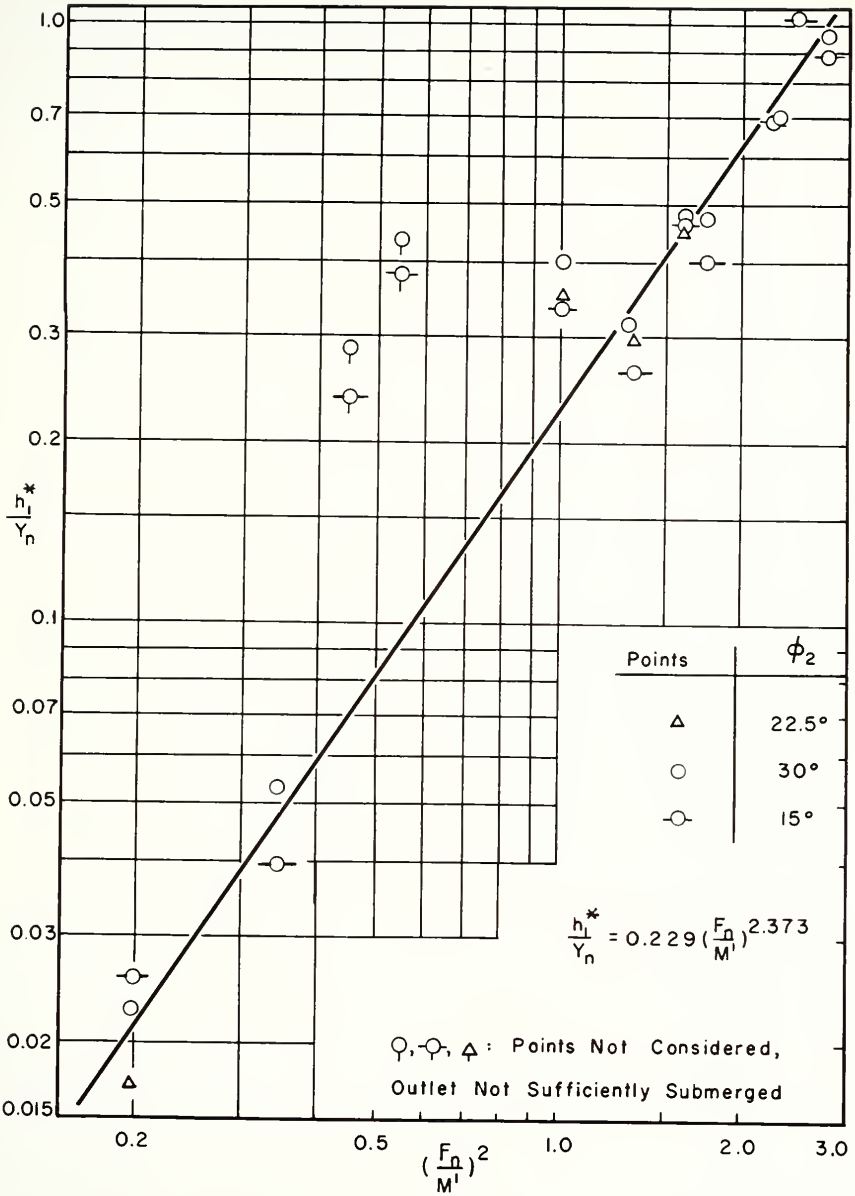


FIG. 8-10-8 GENERALIZED BACKWATER RATIO GEOMETRY ∇b, ROUGH BOUNDARIES

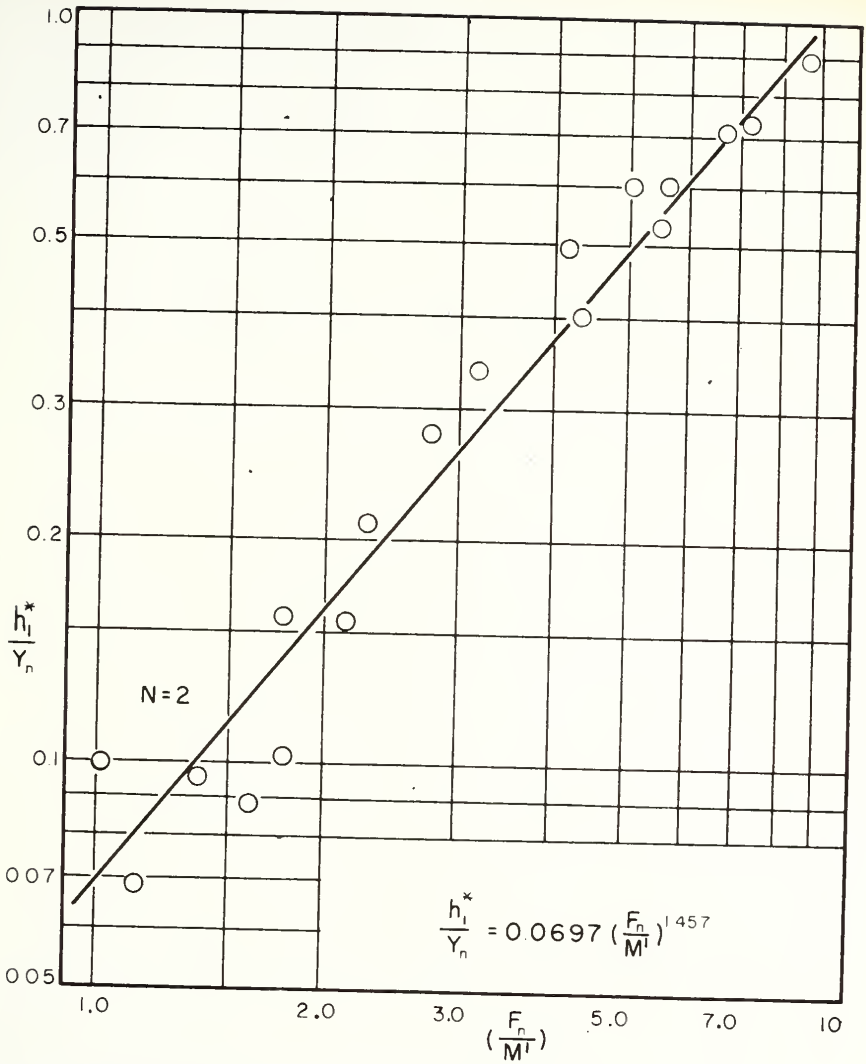


FIG. 8-10-9 GENERALIZED BACKWATER RATIO GEOMETRY VI , ROUGH BOUNDARIES

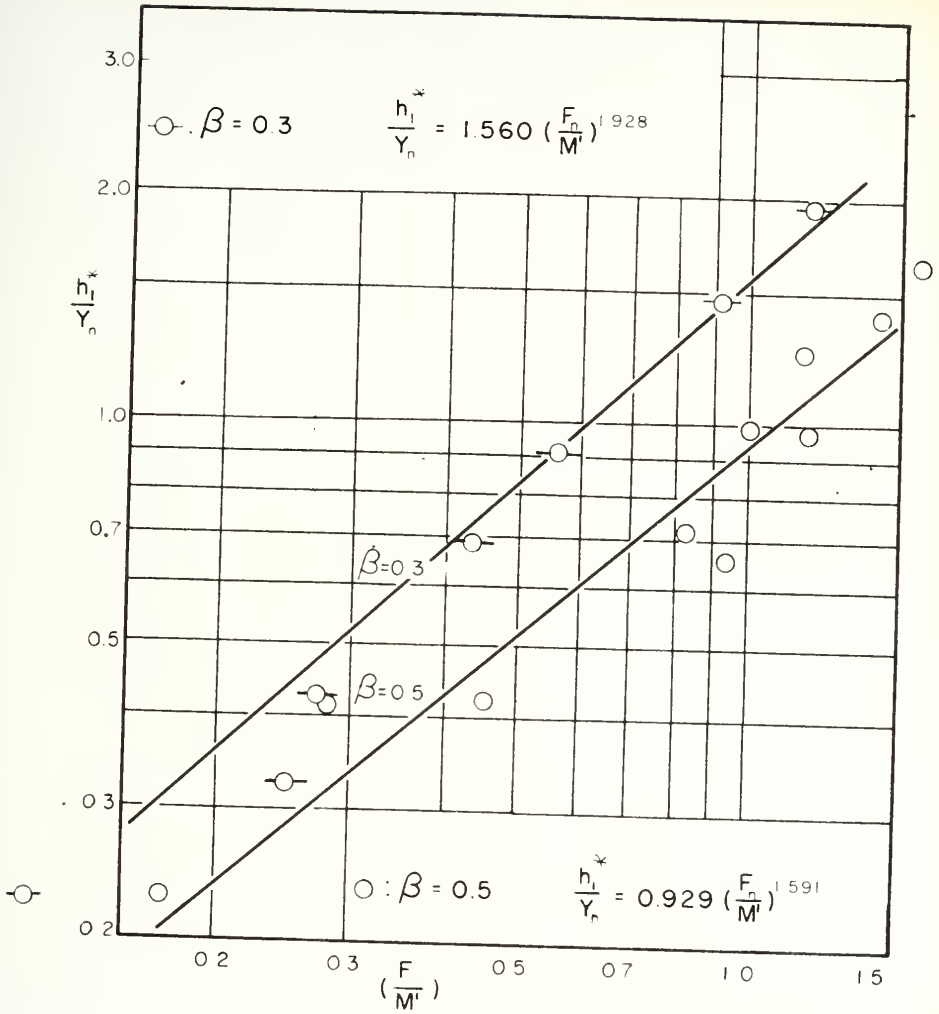
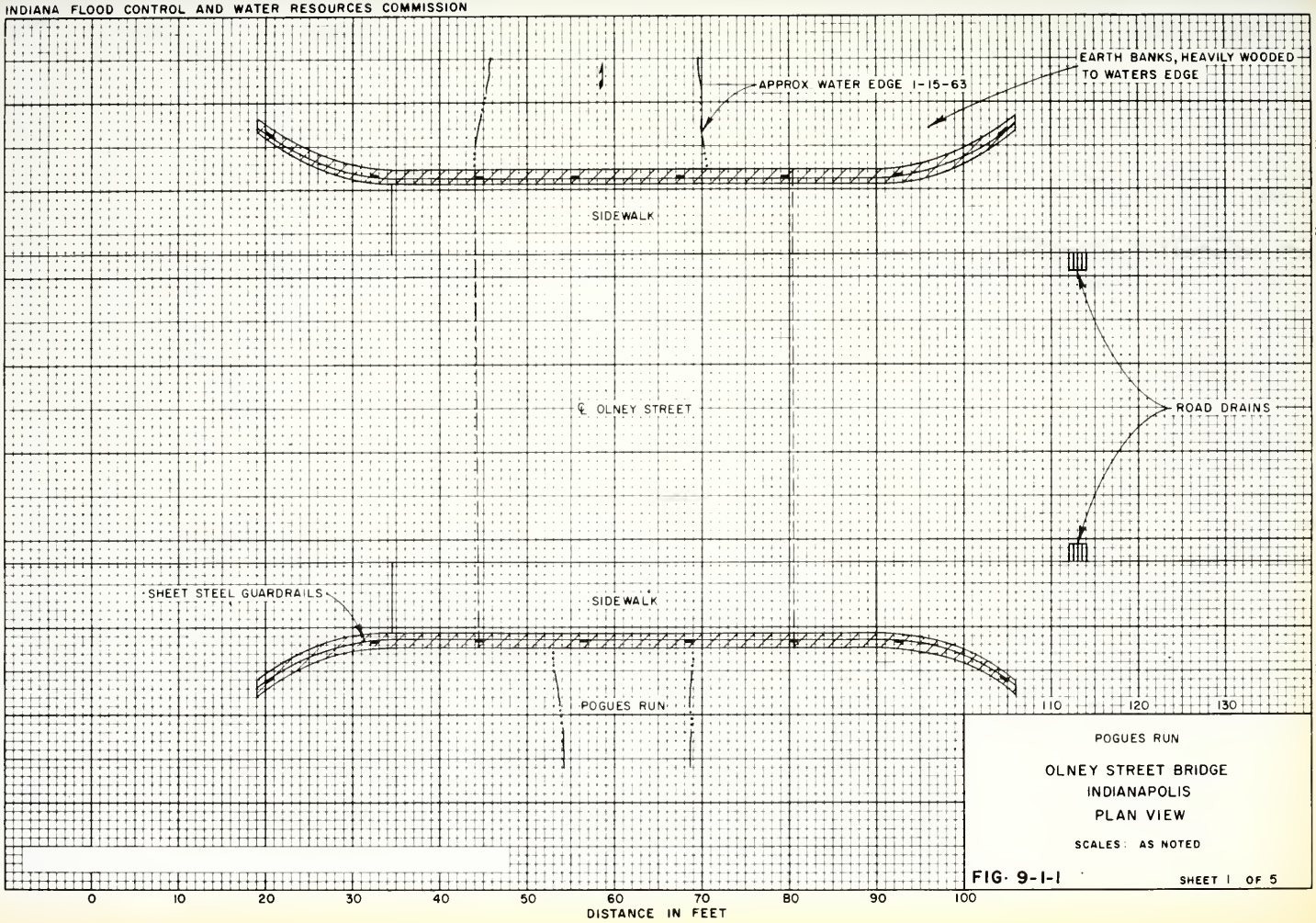


FIG. 8-10-10 GENERALIZED BACKWATER RATIO GEOMETRY VII, ROUGH BOUNDARIES



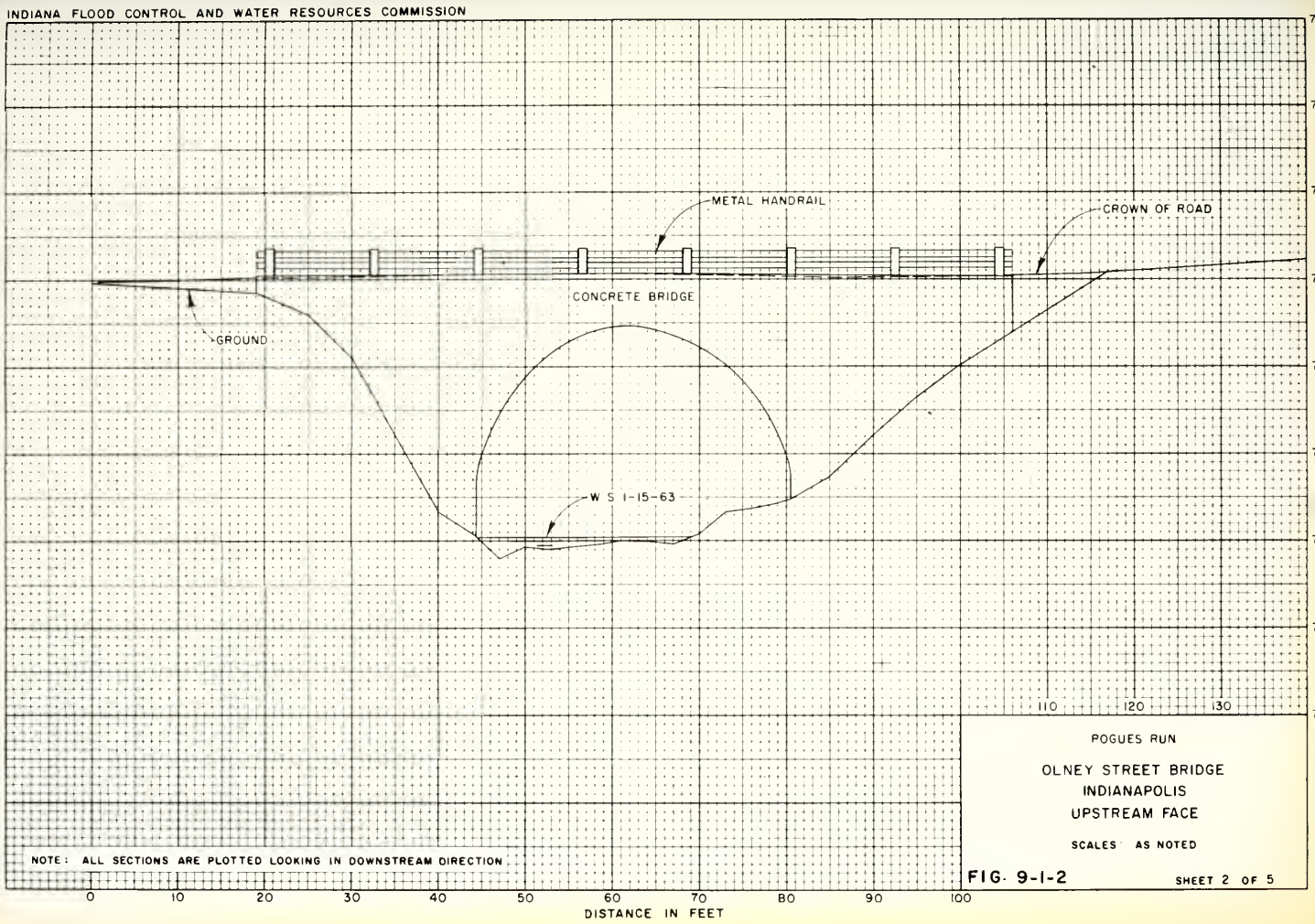
POGUES RUN

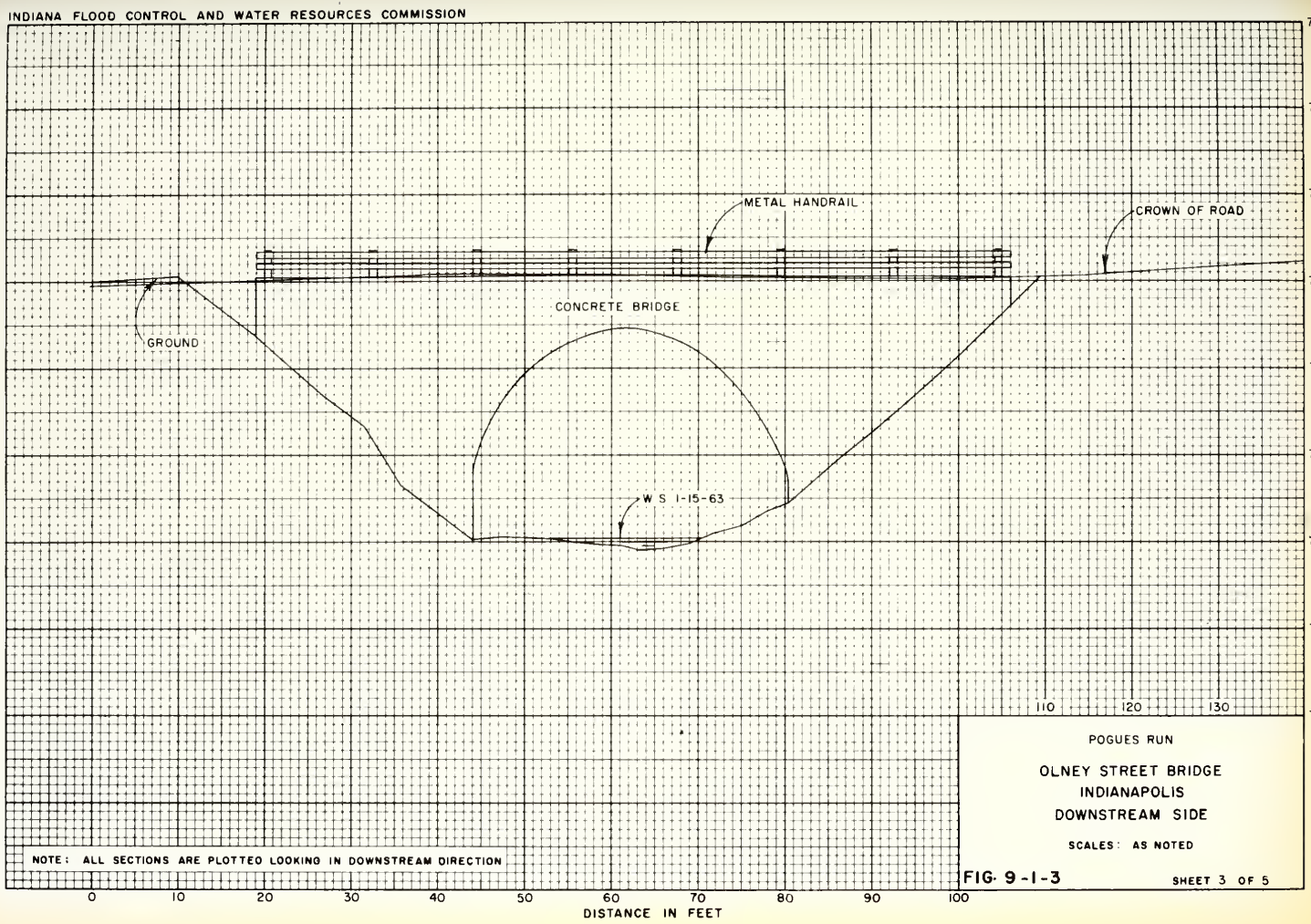
OLNEY STREET BRIDGE
INDIANAPOLIS
PLAN VIEW

SCALES: AS NOTED

FIG. 9-1-1

SHEET 1 OF 5


INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION
ELEVATION (M S L, 1929 ADJ)
775
770
765
760
755
750
745
740
735
METAL HANDRAIL
CROWN OF ROAD
CONCRETE BRIDGE
GROUND
W S 1-15-63
110
120
130
0
10
20
30
40
50
60
70
80
90
100
DISTANCE IN FEET
NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION
POGUES RUN
OLNEY STREET BRIDGE
INDIANAPOLIS
UPSTREAM FACE
SCALES AS NOTED
FIG. 9-1-2
SHEET 2 OF 5


INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION
ELEVATION (M S L, 1929 ADJ)
775
770
765
760
755
750
745
740
735
METAL HANDRAIL
CROWN OF ROAD
CONCRETE BRIDGE
GROUND
W S 1-15-63
110
120
130
0
10
20
30
40
50
60
70
80
90
100
DISTANCE IN FEET
NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION
POGUES RUN
OLNEY STREET BRIDGE
INDIANAPOLIS
DOWNSTREAM SIDE
SCALES: AS NOTED
FIG. 9-1-3
SHEET 3 OF 5

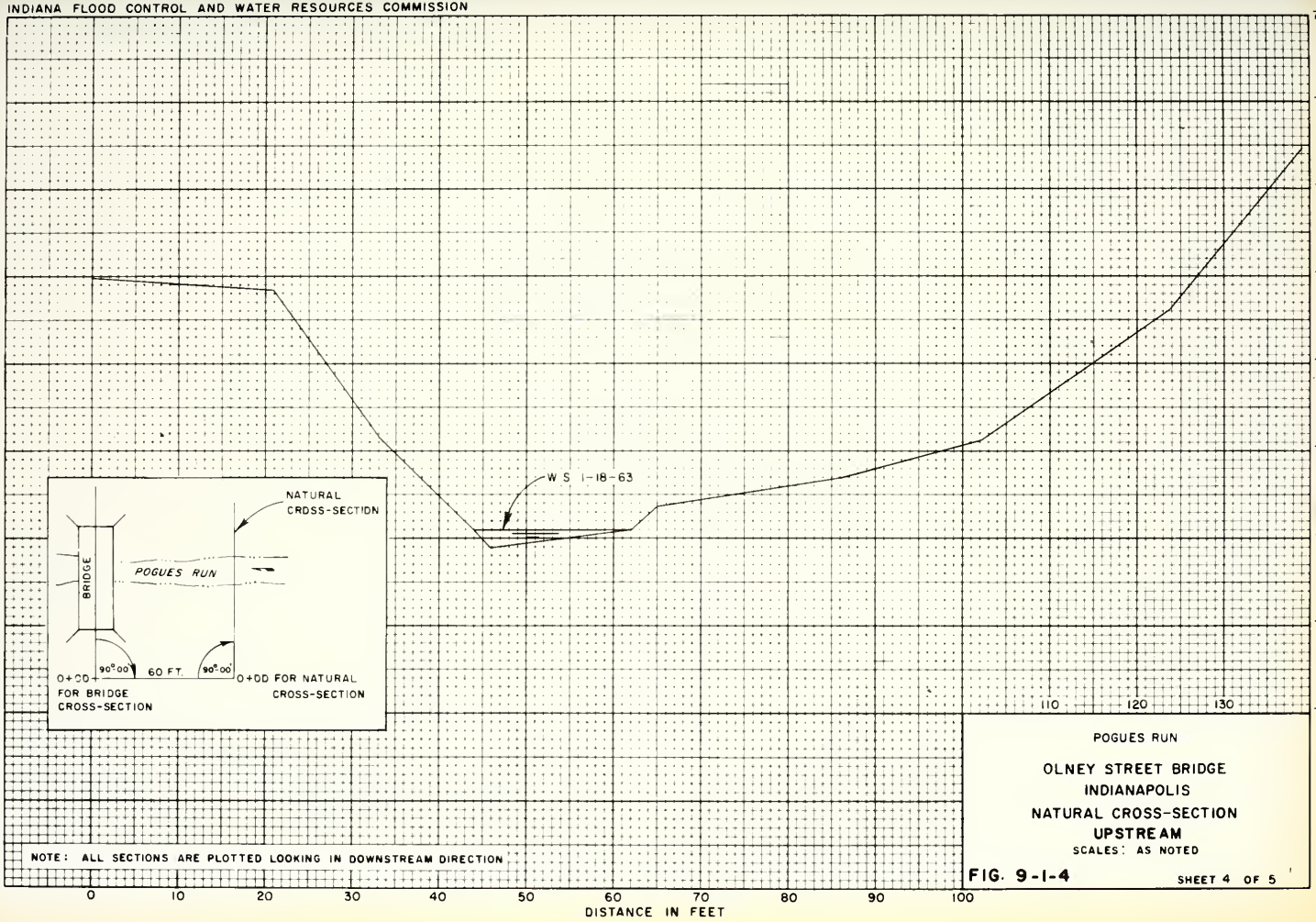
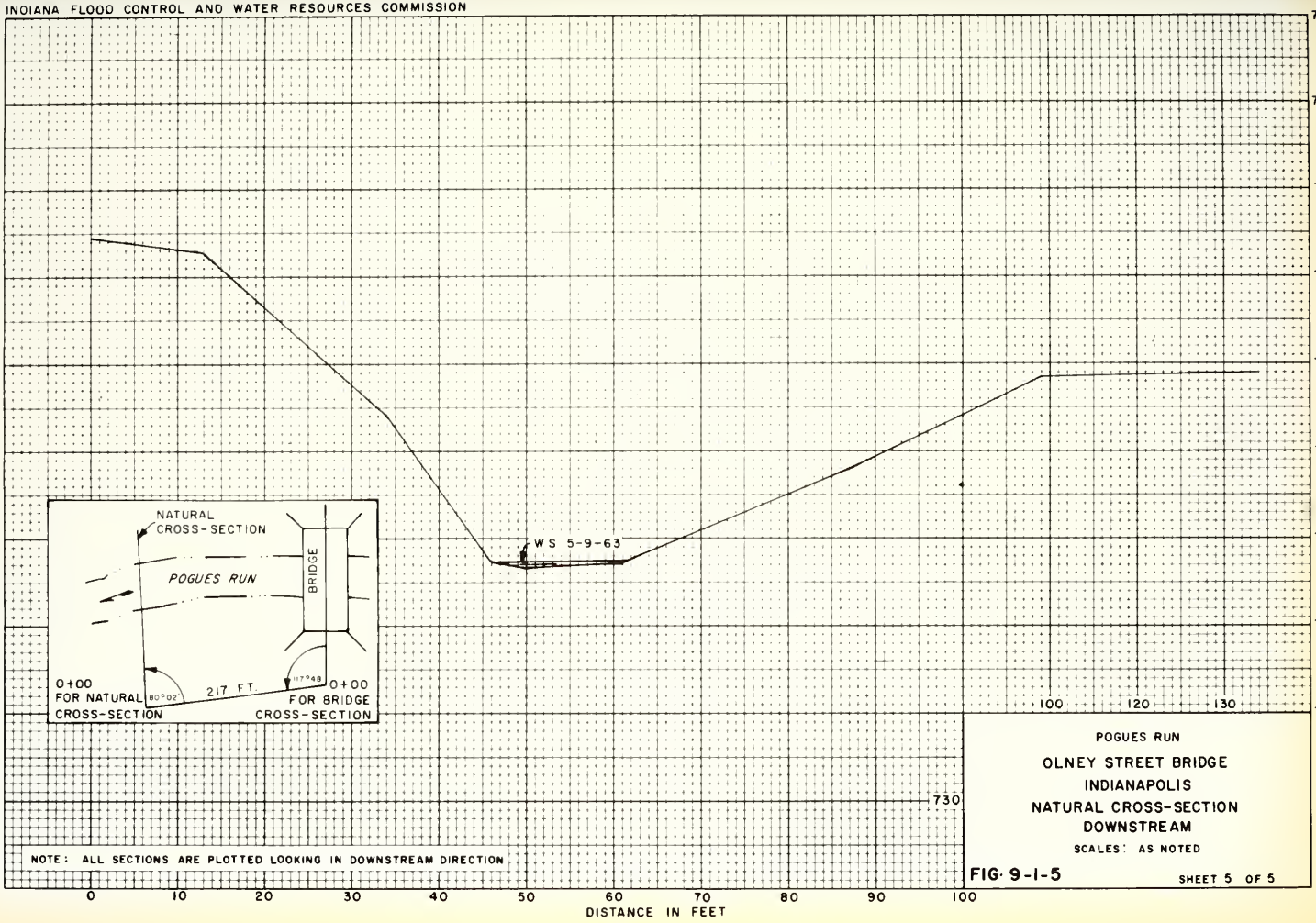


FIG. 9-1-4

SHEET 4 OF 5

INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION



NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION

POGUES RUN

OLNEY STREET BRIDGE

INDIANAPOLIS

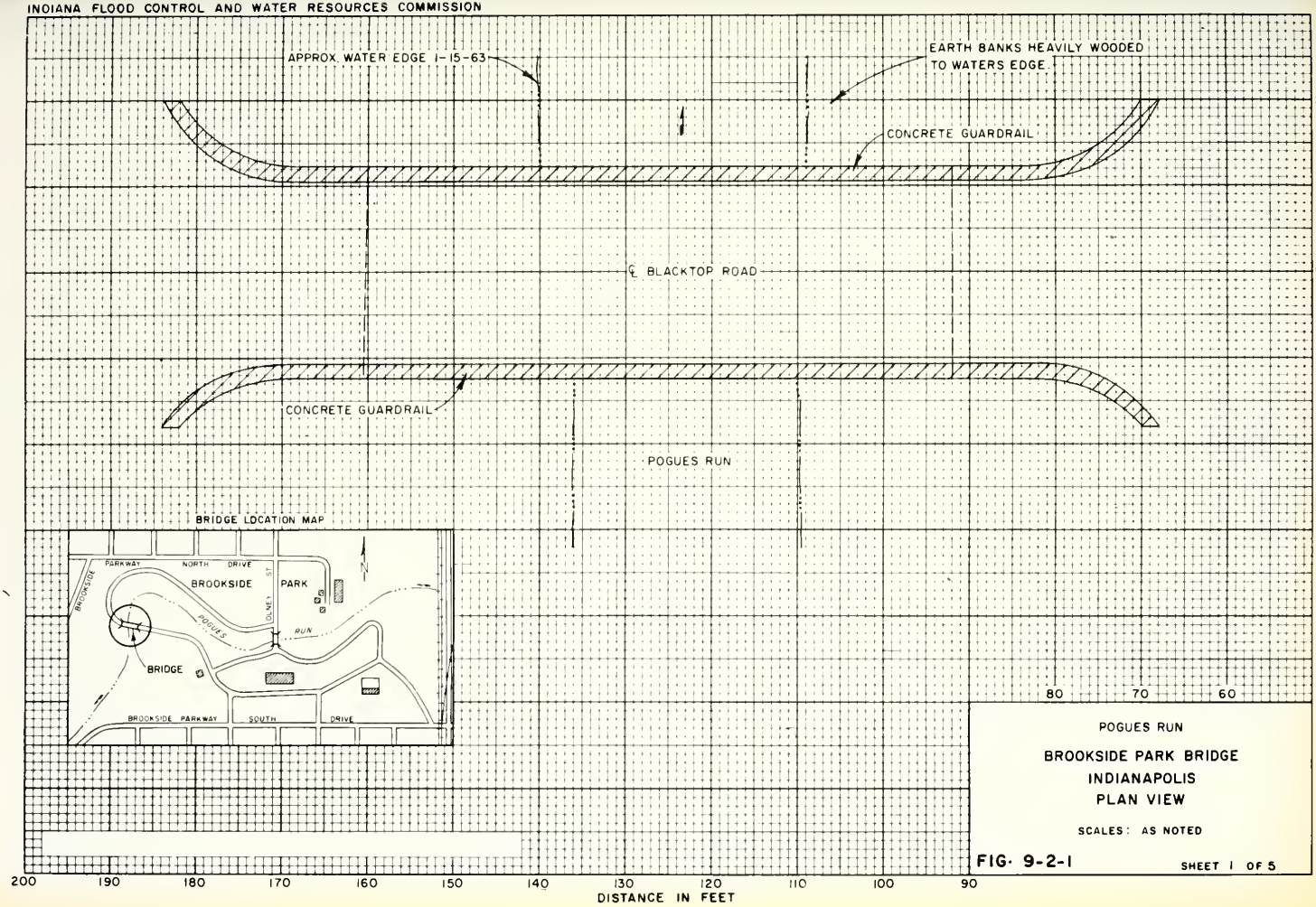
NATURAL CROSS-SECTION

DOWNSTREAM

SCALES: AS NOTED

FIG. 9-1-5

SHEET 5 OF 5



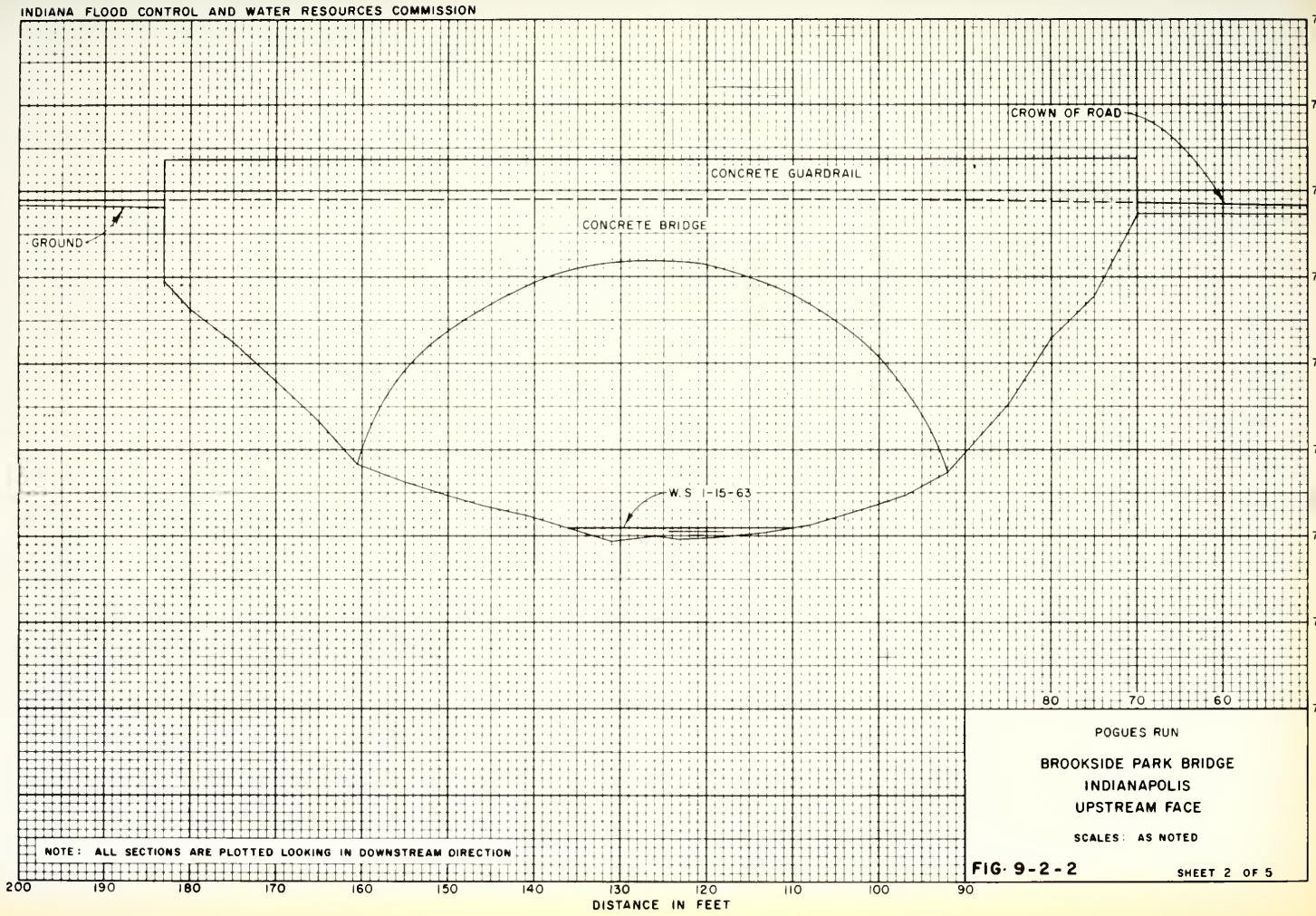
POGUES RUN

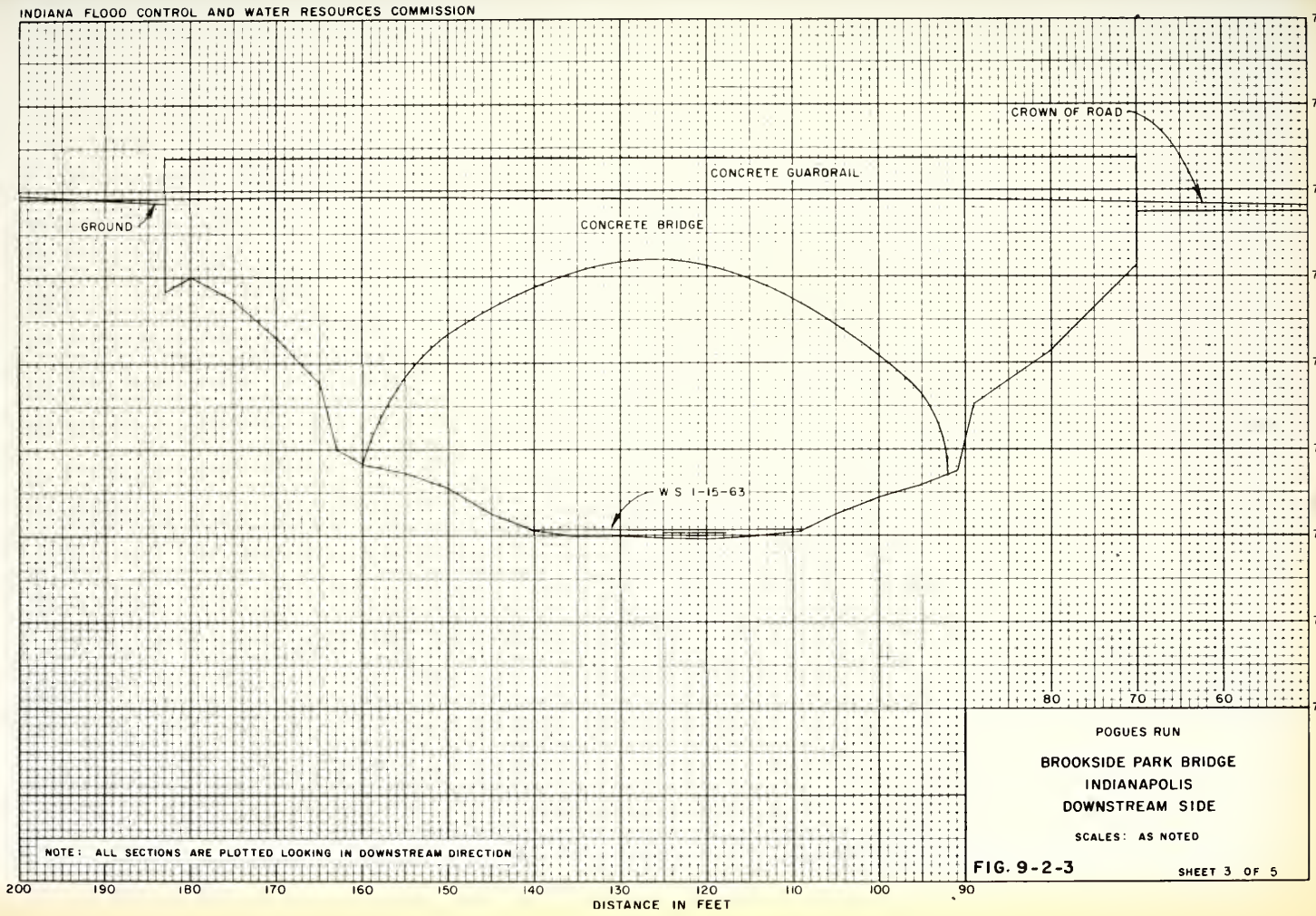
BROOKSIDE PARK BRIDGE
INDIANAPOLIS
PLAN VIEW

SCALES: AS NOTED

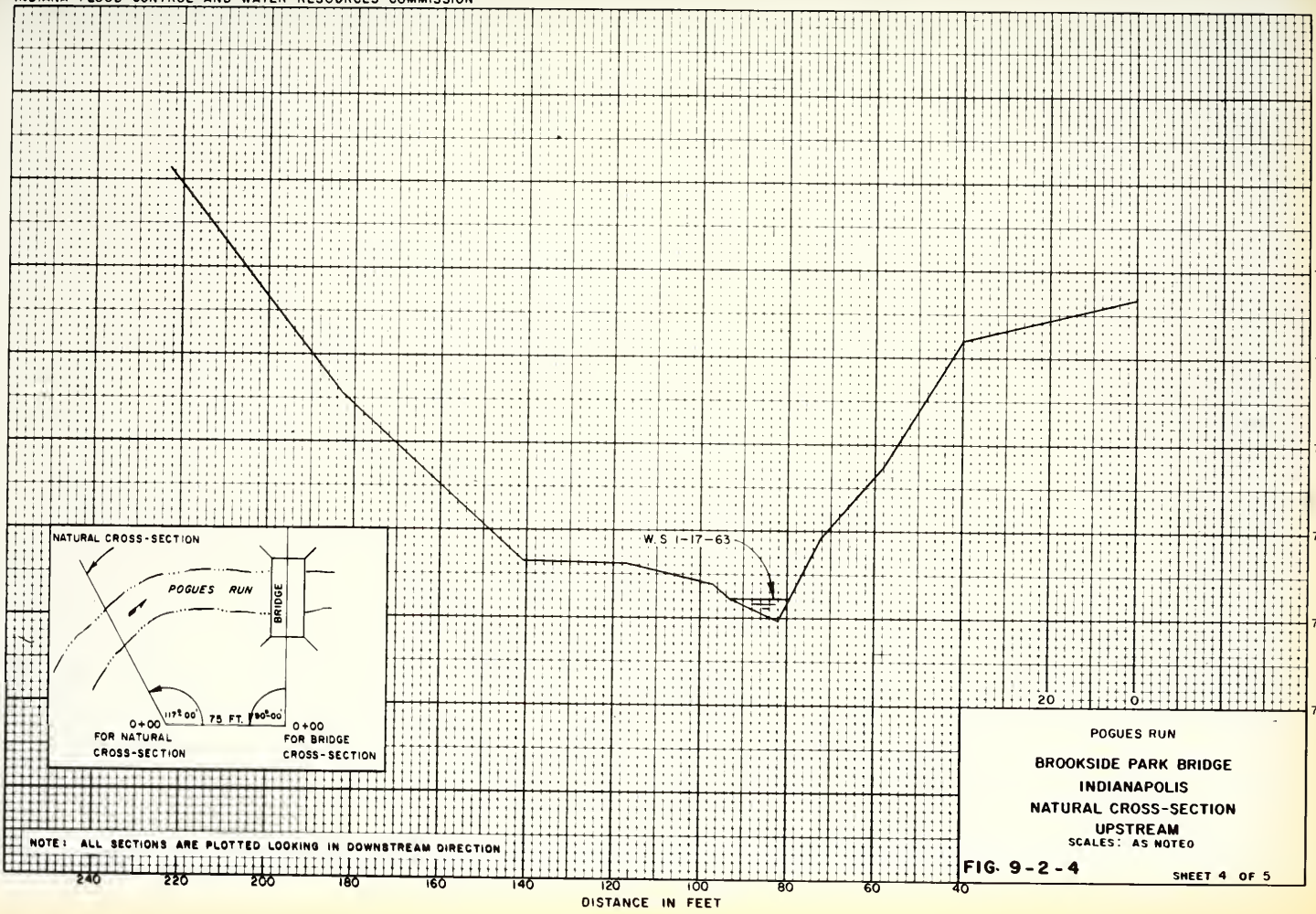
FIG. 9-2-1

SHEET 1 OF 5


INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION
CROWN OF ROAD
CONCRETE GUARDRAIL
CONCRETE BRIDGE
GROUND
W.S 1-15-63
ELEVATION (M S L, 1929 ADJ)
770
765
760
755
750
745
740
735
730
80
70
60
200
190
180
170
160
150
140
130
120
110
100
90
DISTANCE IN FEET
NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION
POGUES RUN
BROOKSIDE PARK BRIDGE
INDIANAPOLIS
UPSTREAM FACE
SCALES: AS NOTED
FIG. 9-2-2
SHEET 2 OF 5


INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION
CROWN OF ROAD
CONCRETE GUARDRAIL
GROUND
CONCRETE BRIDGE
W S 1-15-63
ELEVATION (M S L, 1929 ADJ)
770
765
760
755
750
745
740
735
730
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
DISTANCE IN FEET
NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION
POGUES RUN
BROOKSIDE PARK BRIDGE
INDIANAPOLIS
DOWNSTREAM SIDE
SCALES: AS NOTED
FIG. 9-2-3
SHEET 3 OF 5

INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION



POGUES RUN

BROOKSIDE PARK BRIDGE

INDIANAPOLIS

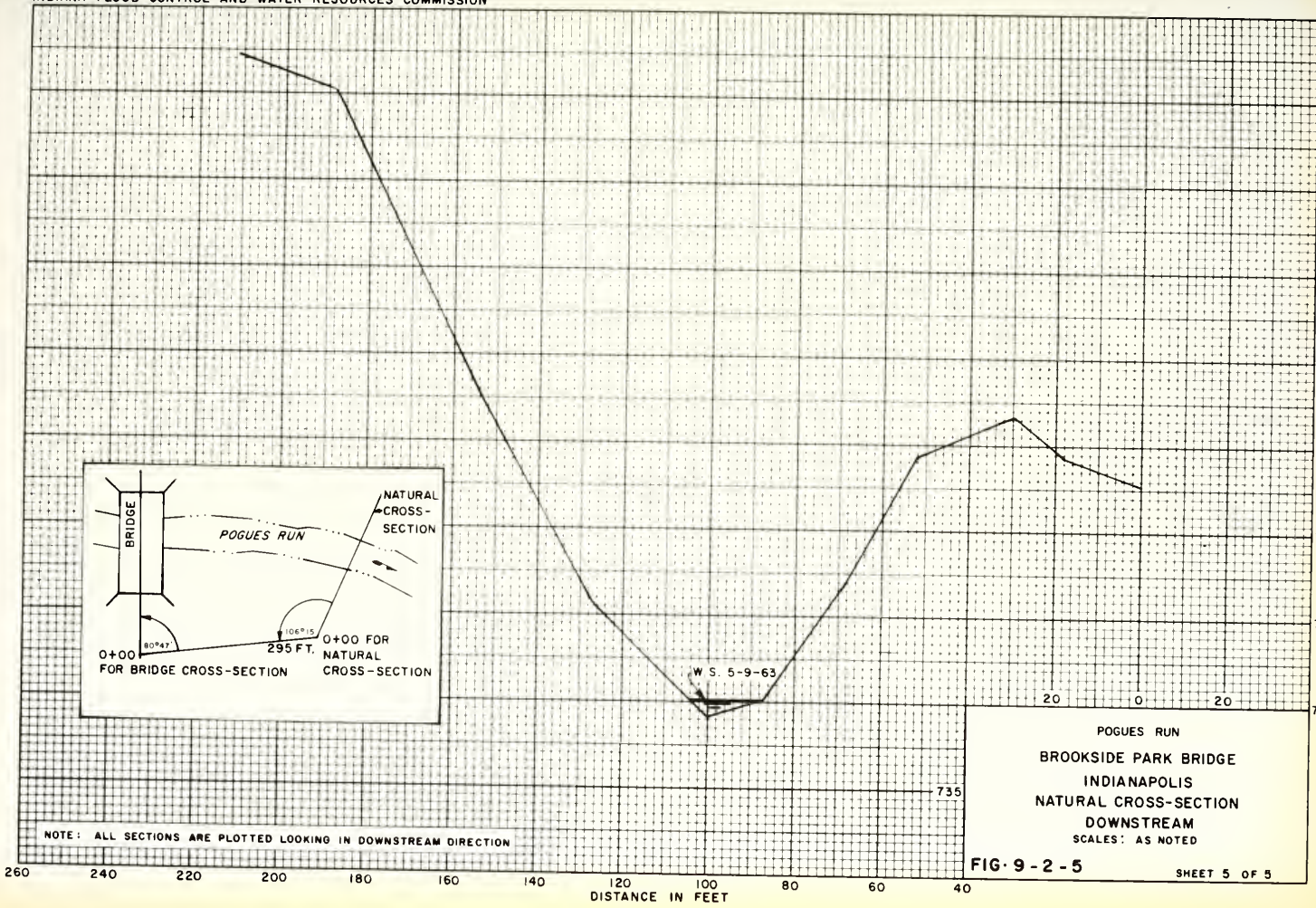
NATURAL CROSS-SECTION

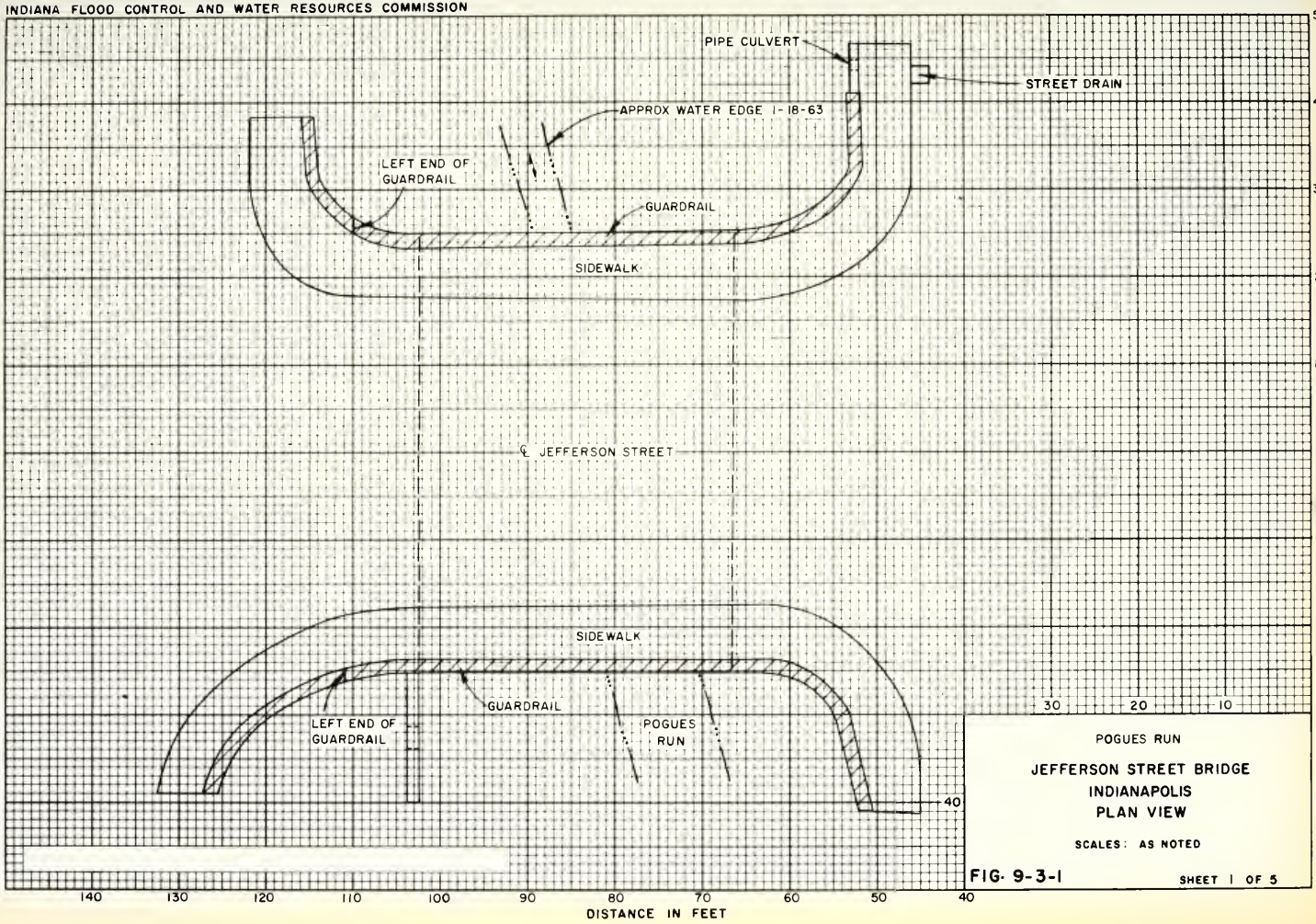
UPSTREAM

SCALES: AS NOTED

FIG. 9-2-4

SHEET 4 OF 5


ELEVATION (M S L, 1929 ADJ)
780
775
770
765
760
755
750
745
740
735
260
240
220
200
180
160
140
120
100
80
60
40
20
0
20
DISTANCE IN FEET
W S. 5-9-63
BRIDGE
POGUES RUN
NATURAL CROSS-SECTION
80°47'
106°15'
0+00 FOR BRIDGE CROSS-SECTION
295 FT.
0+00 FOR NATURAL CROSS-SECTION
NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION
POGUES RUN
BROOKSIDE PARK BRIDGE
INDIANAPOLIS
NATURAL CROSS-SECTION
DOWNSTREAM
SCALES: AS NOTED
FIG. 9-2-5
SHEET 5 OF 5



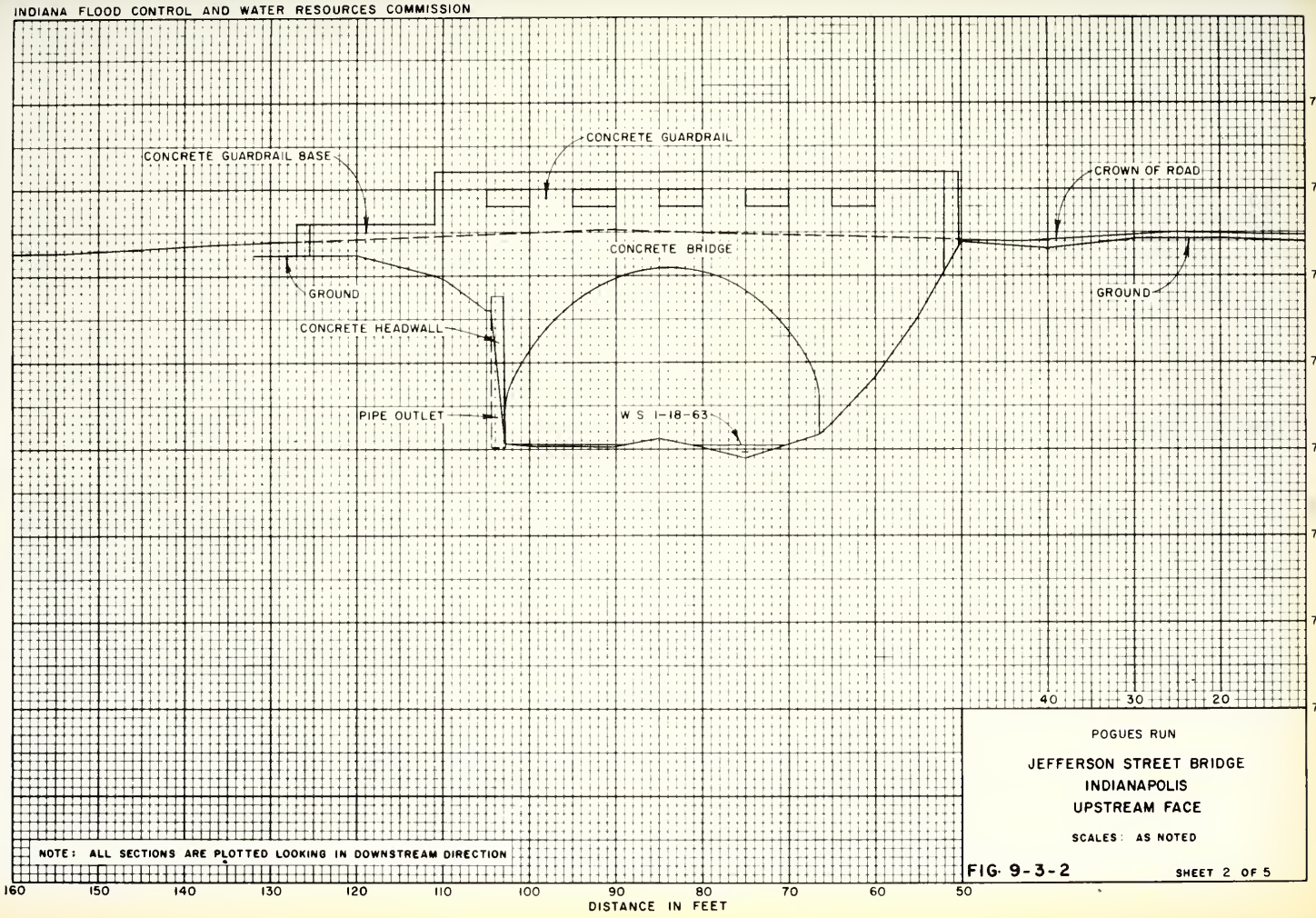
POGUES RUN

JEFFERSON STREET BRIDGE
INDIANAPOLIS
PLAN VIEW

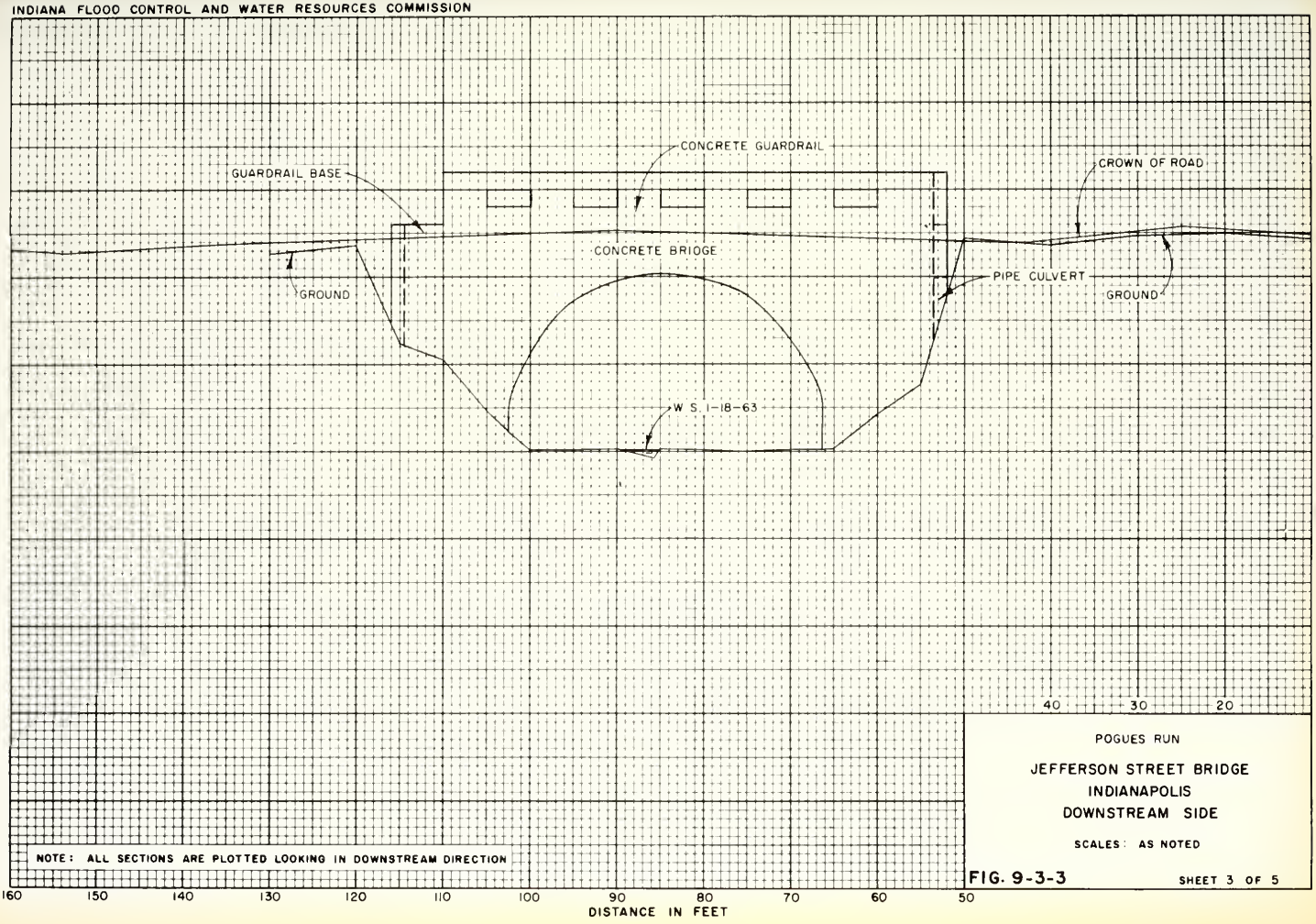
SCALES: AS NOTED

FIG. 9-3-1

SHEET 1 OF 5


INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION
CONCRETE GUARDRAIL BASE
CONCRETE GUARDRAIL
CROWN OF ROAD
CONCRETE BRIDGE
GROUND
GROUND
CONCRETE HEADWALL
PIPE OUTLET
W S 1-18-63
ELEVATION (M S L, 1929 ADJ)
745
740
735
730
725
720
715
710
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
DISTANCE IN FEET
NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION
POGUES RUN
JEFFERSON STREET BRIDGE
INDIANAPOLIS
UPSTREAM FACE
SCALES: AS NOTED
FIG. 9-3-2
SHEET 2 OF 5

INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION



ELEVATION (M S L, 1929 ADJ)

NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION

POGUES RUN

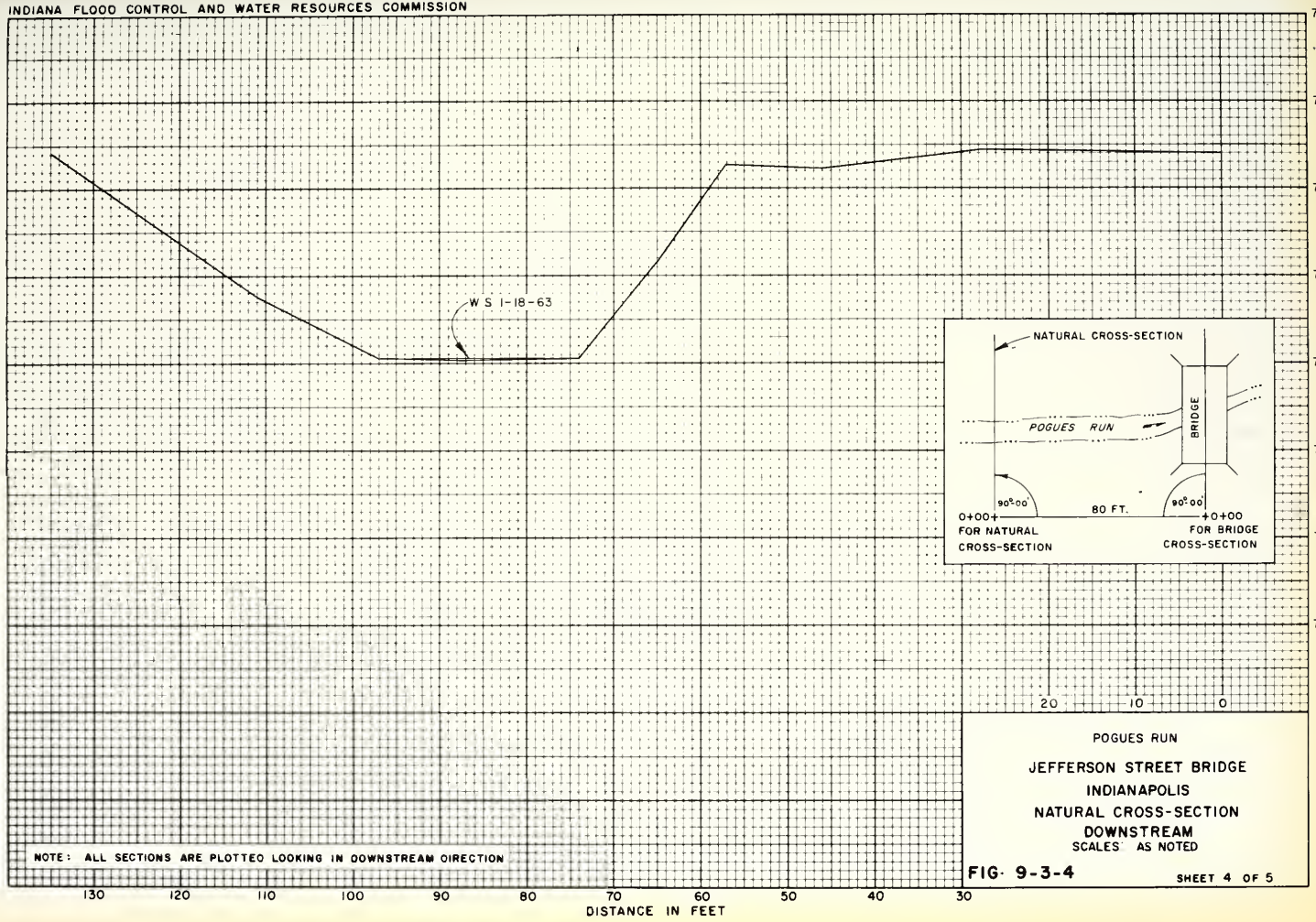
JEFFERSON STREET BRIDGE
INDIANAPOLIS
DOWNSTREAM SIDE

SCALES: AS NOTED

FIG. 9-3-3

SHEET 3 OF 5

INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION



NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION

POGUES RUN

JEFFERSON STREET BRIDGE

INDIANAPOLIS

NATURAL CROSS-SECTION

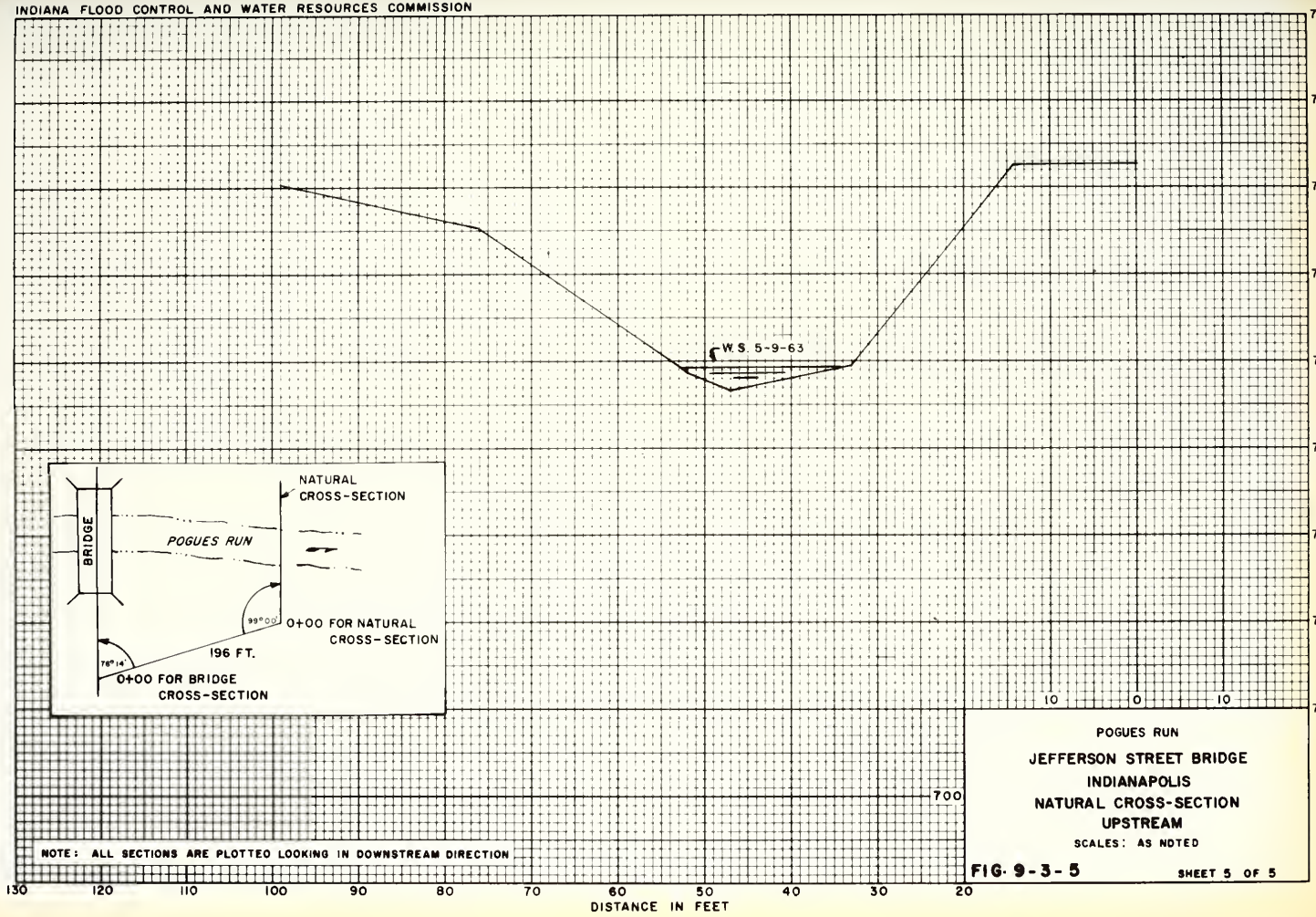
DOWNSTREAM

SCALES AS NOTED

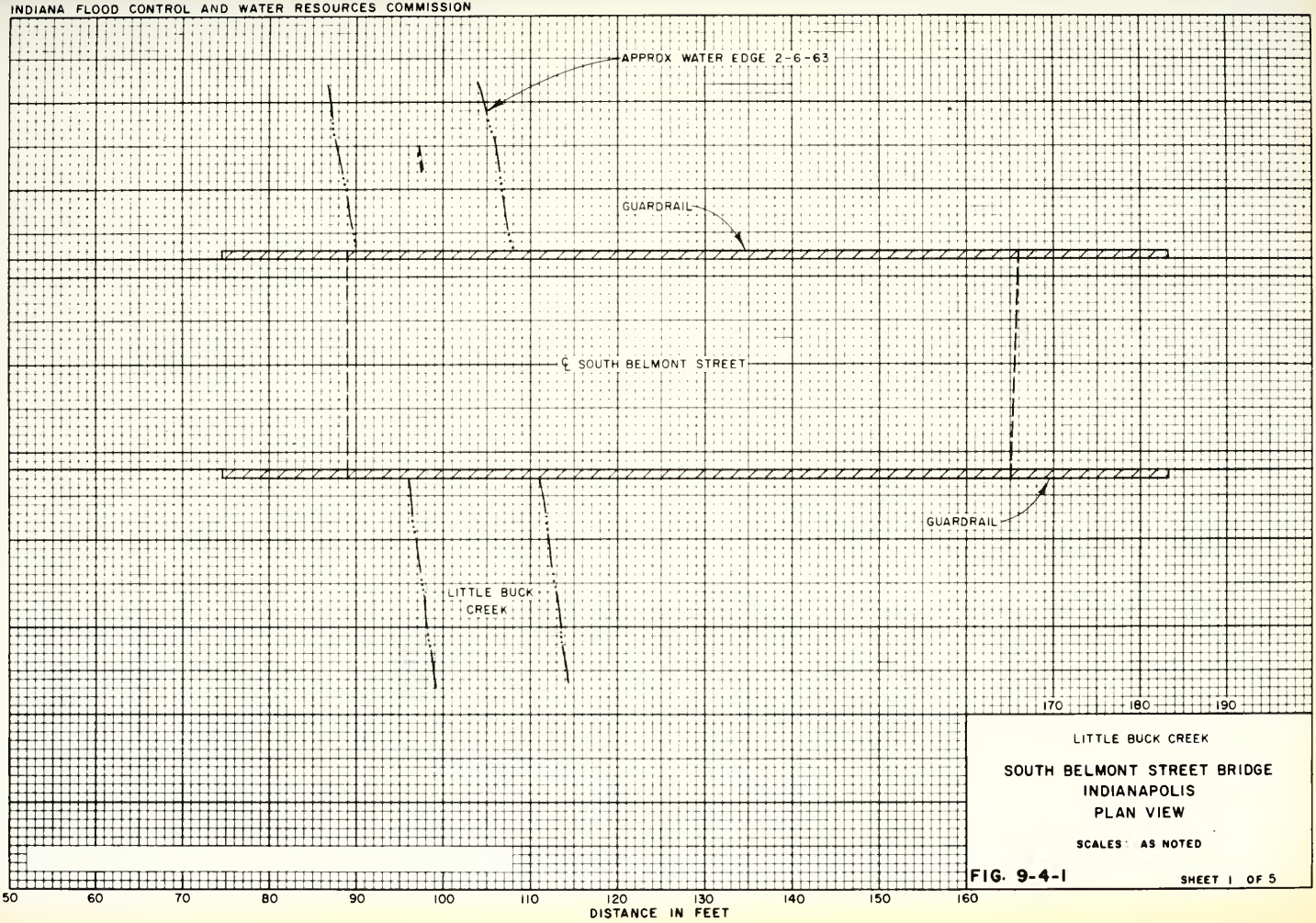
FIG. 9-3-4

SHEET 4 OF 5

INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION



INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION



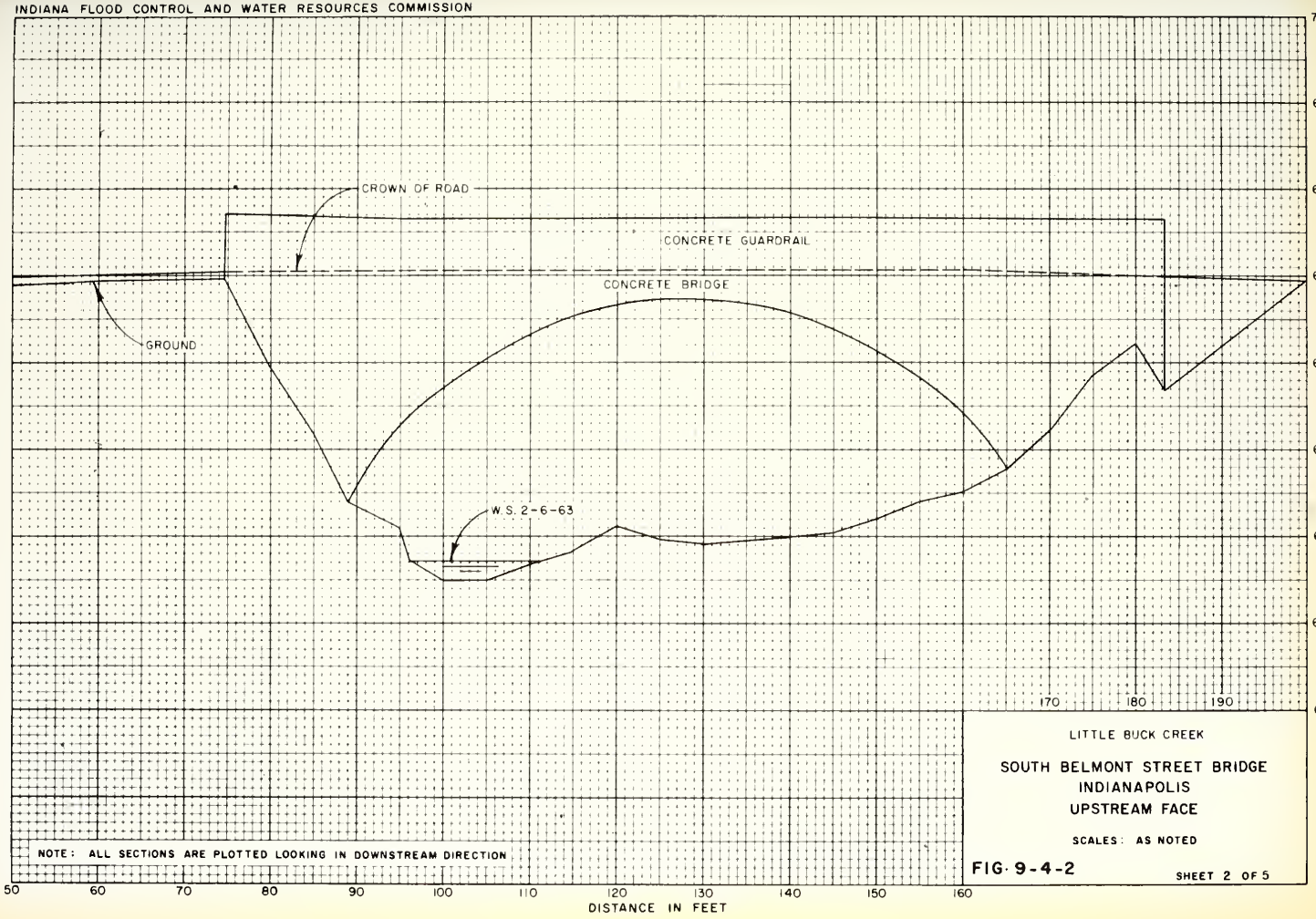
LITTLE BUCK CREEK

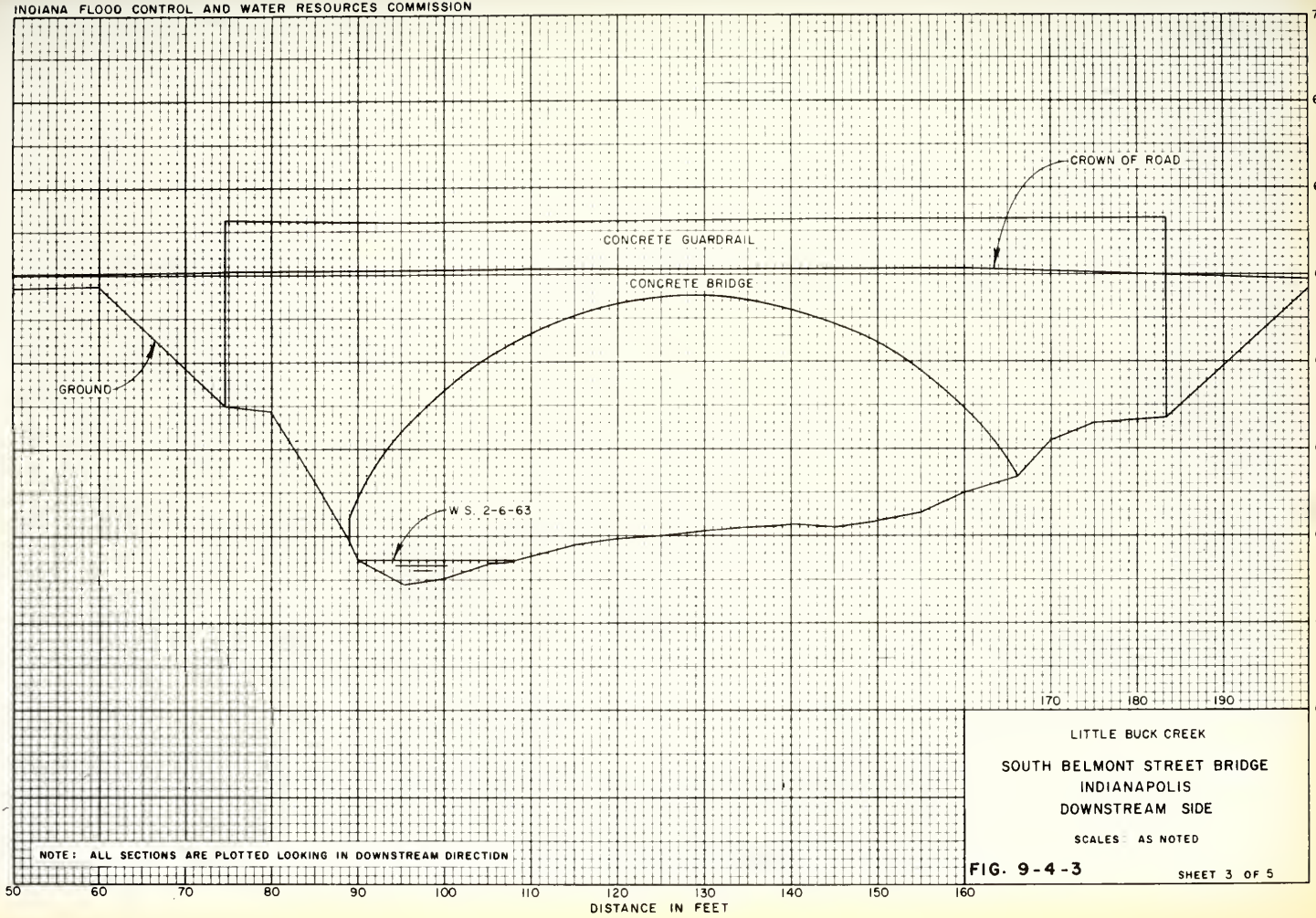
SOUTH BELMONT STREET BRIDGE
INDIANAPOLIS
PLAN VIEW

SCALES: AS NOTED

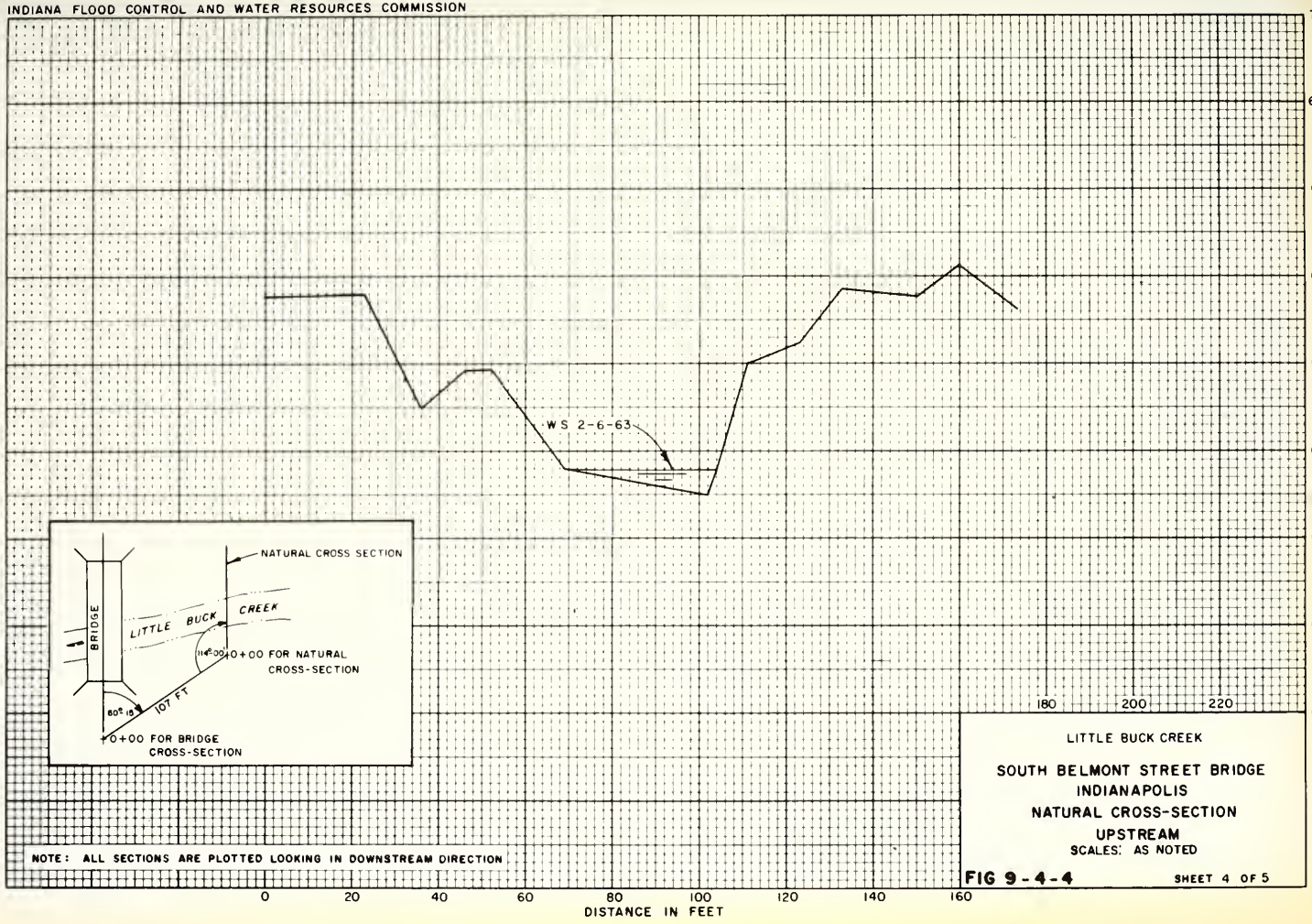
FIG. 9-4-1

SHEET 1 OF 5

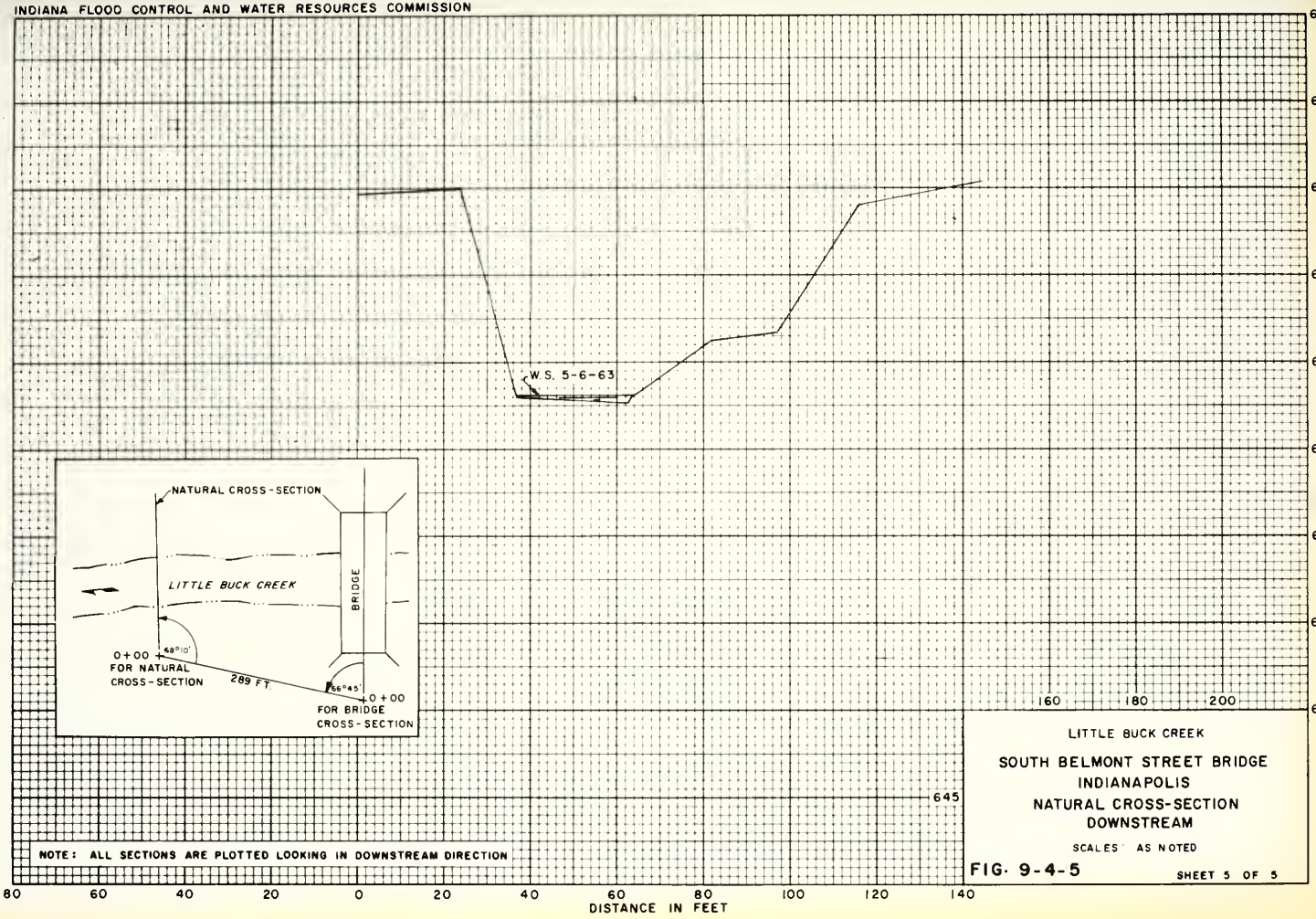

INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION
CROWN OF ROAD
CONCRETE GUARDRAIL
CONCRETE BRIDGE
GROUND
W.S. 2-6-63
ELEVATION (M S L, 1929 ADJ)
700
695
690
685
680
675
670
665
660
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
DISTANCE IN FEET
NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION
LITTLE BUCK CREEK
SOUTH BELMONT STREET BRIDGE
INDIANAPOLIS
UPSTREAM FACE
SCALES: AS NOTED
FIG. 9-4-2
SHEET 2 OF 5


INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION
ELEVATION (M S L, 1929 ADJ)
700
695
690
685
680
675
670
665
660
CROWN OF ROAD
CONCRETE GUARDRAIL
CONCRETE BRIDGE
GROUND
W.S. 2-6-63
170
180
190
50
60
70
80
90
100
110
120
130
140
150
160
DISTANCE IN FEET
NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION
LITTLE BUCK CREEK
SOUTH BELMONT STREET BRIDGE
INDIANAPOLIS
DOWNSTREAM SIDE
SCALES AS NOTED
FIG. 9-4-3
SHEET 3 OF 5

INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION



INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION



NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION

LITTLE BUCK CREEK

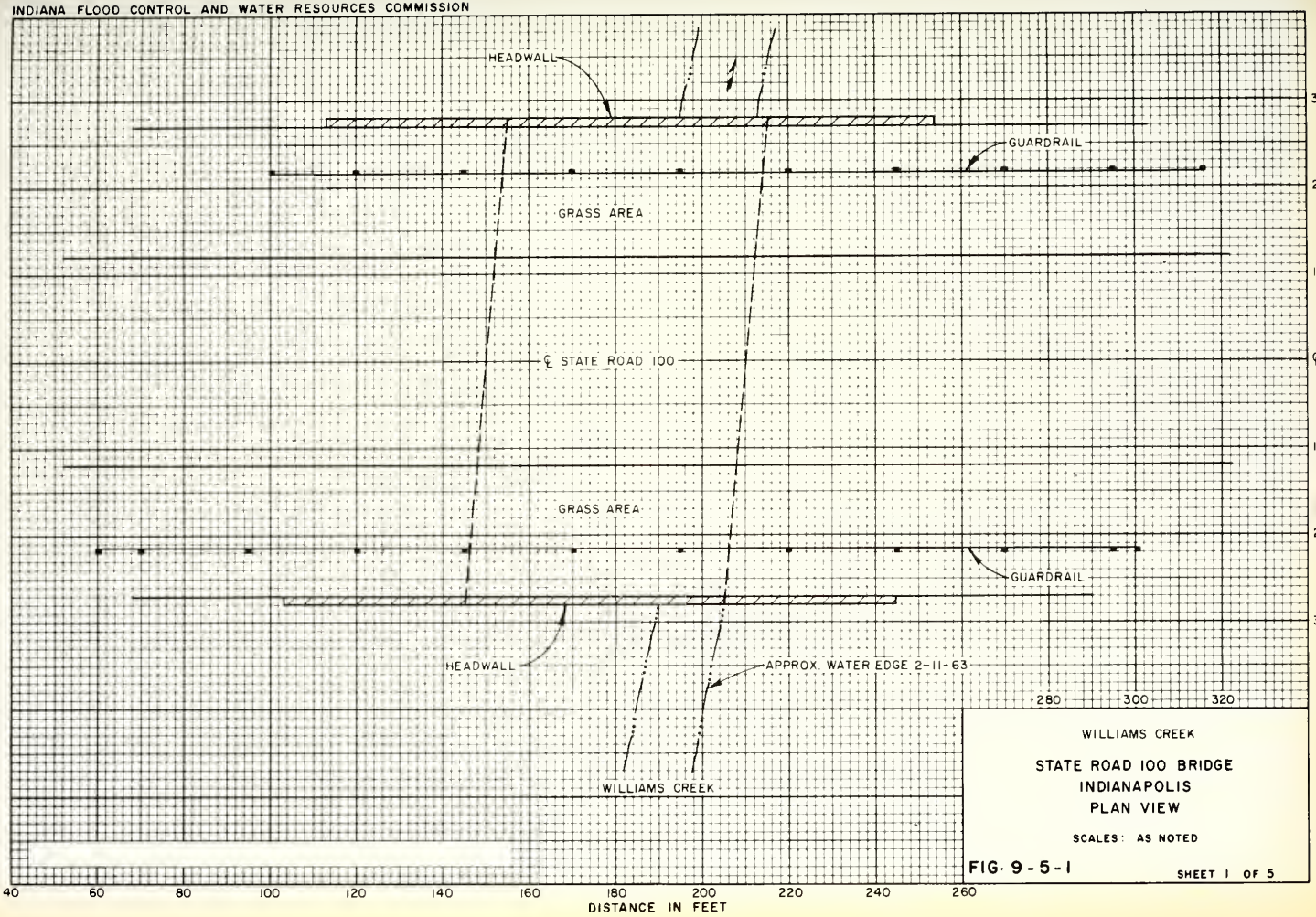
SOUTH BELMONT STREET BRIDGE
INDIANAPOLIS
NATURAL CROSS-SECTION
DOWNSTREAM

SCALES AS NOTED

FIG. 9-4-5

SHEET 5 OF 5

INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION



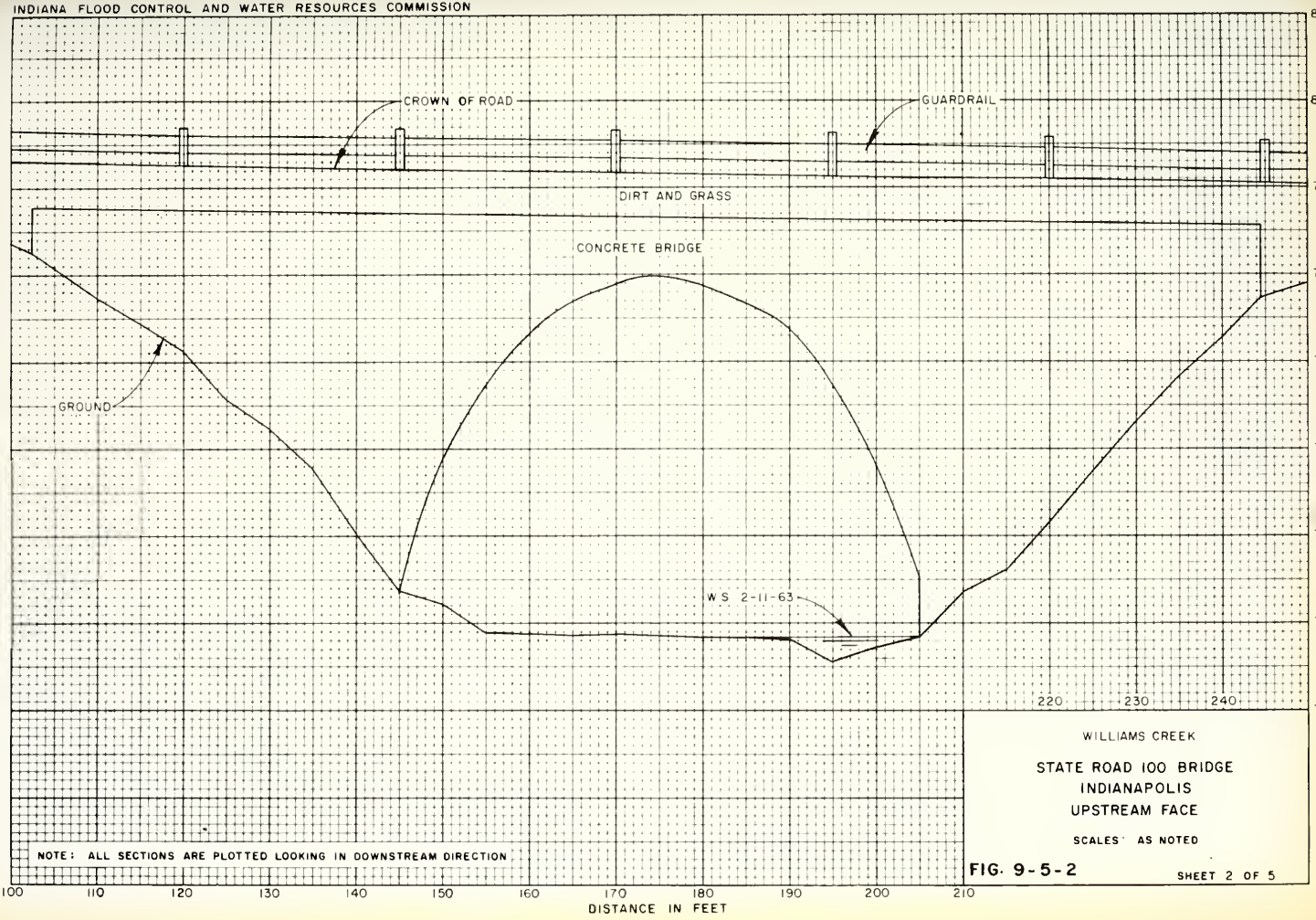
WILLIAMS CREEK

STATE ROAD 100 BRIDGE
INDIANAPOLIS
PLAN VIEW

SCALES: AS NOTED

FIG. 9-5-1

SHEET 1 OF 5



NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION

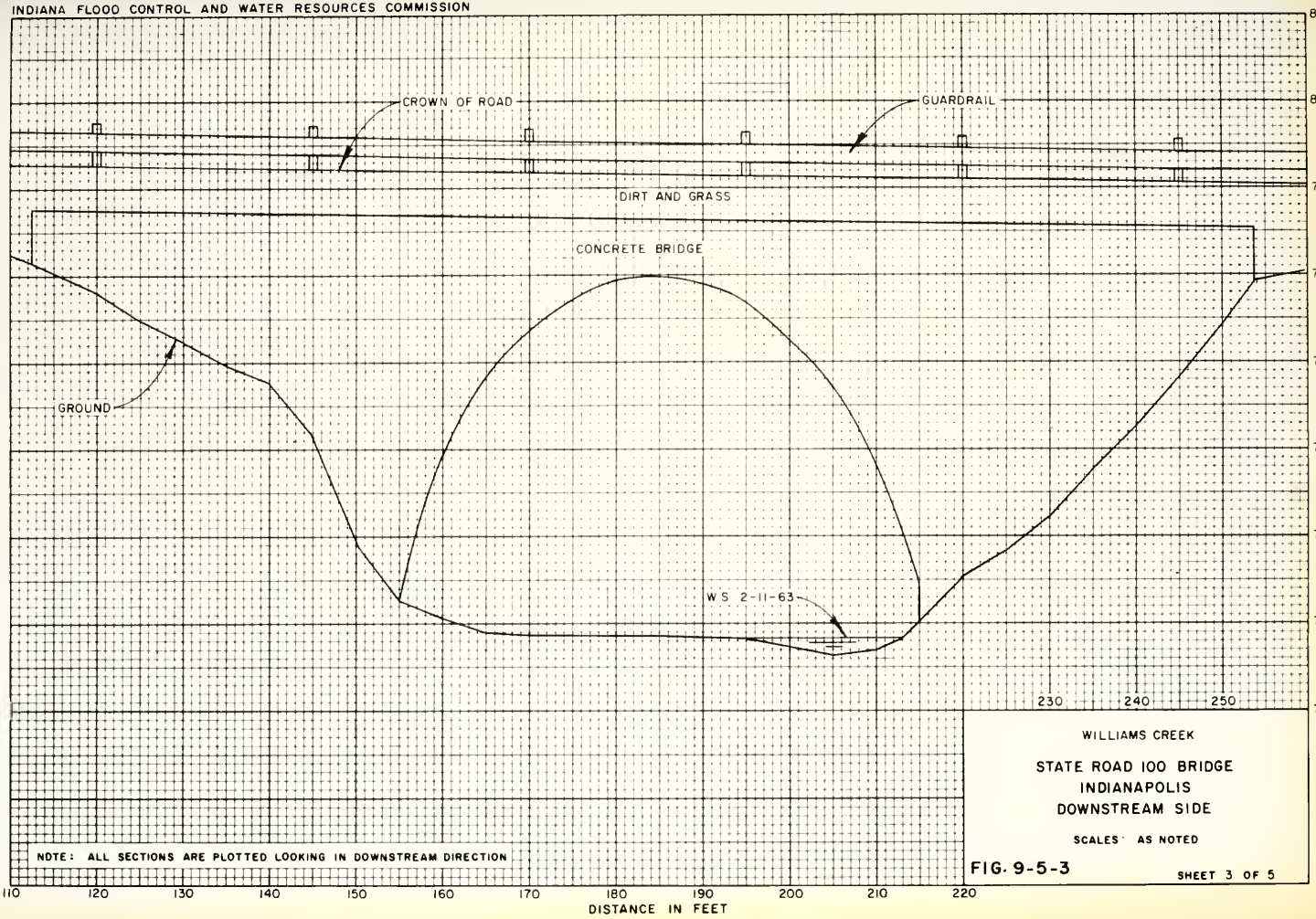
WILLIAMS CREEK

STATE ROAD 100 BRIDGE
INDIANAPOLIS
UPSTREAM FACE

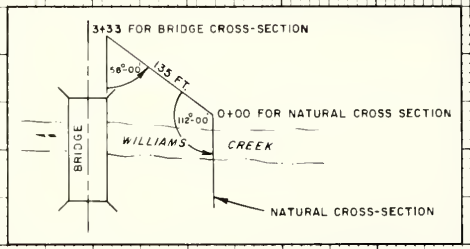
SCALES: AS NOTED

FIG. 9-5-2

SHEET 2 OF 5


INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION
CROWN OF ROAD
GUARDRAIL
DIRT AND GRASS
CONCRETE BRIDGE
GROUND
W.S. 2-11-63
ELEVATION (M.S.L., 1929 ADJ.)
805
800
795
790
785
780
775
770
765
230
240
250
110
120
130
140
150
160
170
180
190
200
210
220
DISTANCE IN FEET
NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION
WILLIAMS CREEK
STATE ROAD 100 BRIDGE
INDIANAPOLIS
DOWNSTREAM SIDE
SCALES: AS NOTED
FIG. 9-5-3
SHEET 3 OF 5

INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION



ELEVATION (M S L., 1929 ADJ)

810
805
800
795
790
785
780
775
770
765

W S 2-11-63

20 0 -20

260 240 220 200 180 160 140 120 100 80 60 40

DISTANCE IN FEET

NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION

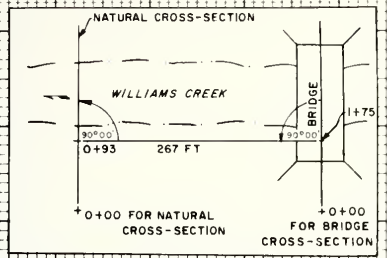
WILLIAMS CREEK

STATE ROAD 100 BRIDGE
INDIANAPOLIS
NATURAL CROSS SECTION
UPSTREAM

SCALES: AS NOTED

FIG. 9-5-4

SHEET 4 OF 5



ELEVATION (M S L, 1929 ADJ)

800
795
790
785
780
775
770
765
760
755

W S 5-10-63

180 200 220

60 40 20 0 20 40 60 80 100 120 140 160

DISTANCE IN FEET

NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION

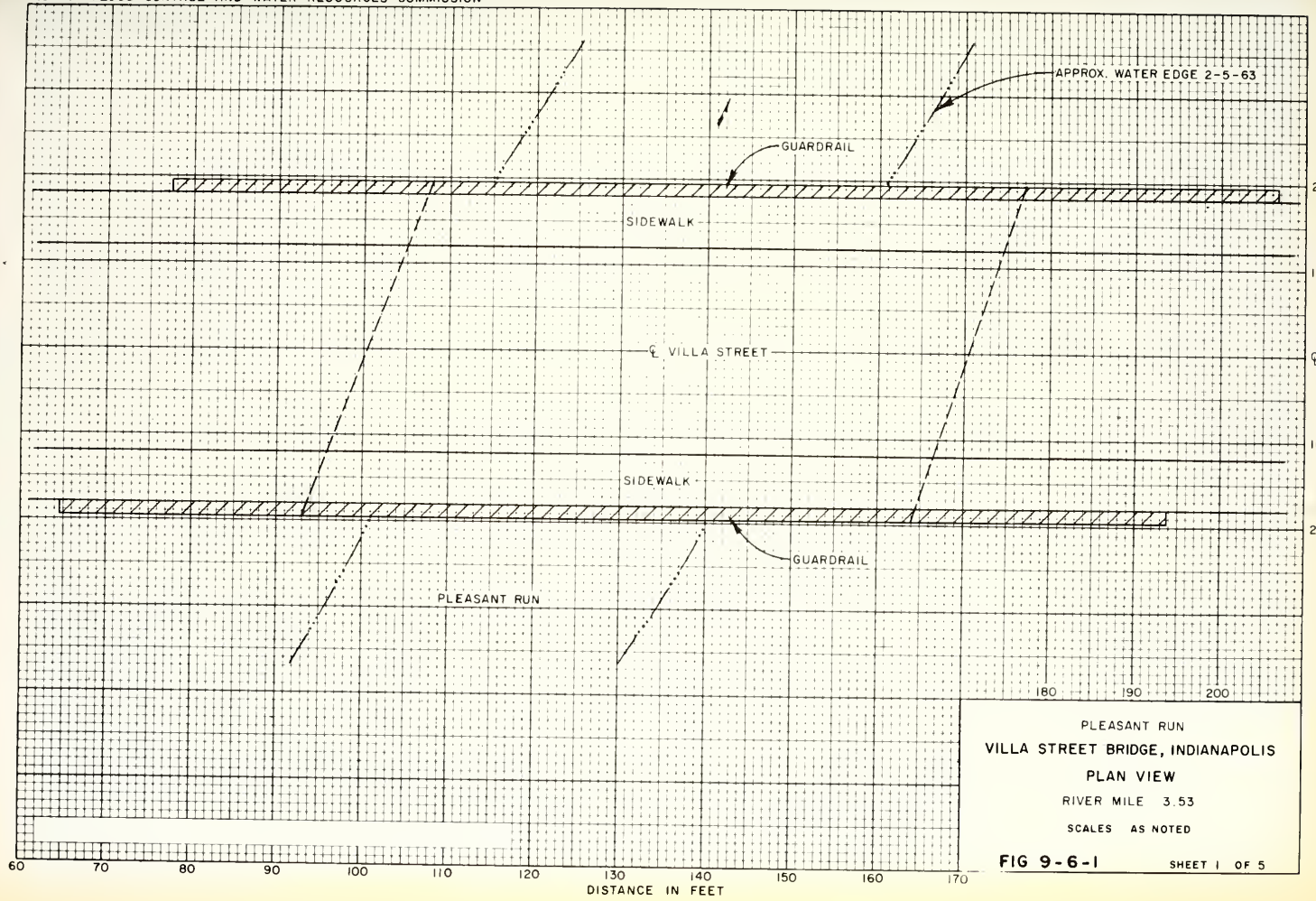
WILLIAMS CREEK

STATE ROAD 100 BRIDGE
INDIANAPOLIS
NATURAL CROSS SECTION
DOWNSTREAM

SCALES: AS NOTED

FIG. 9-5-5

SHEET 5 OF 5



PLEASANT RUN

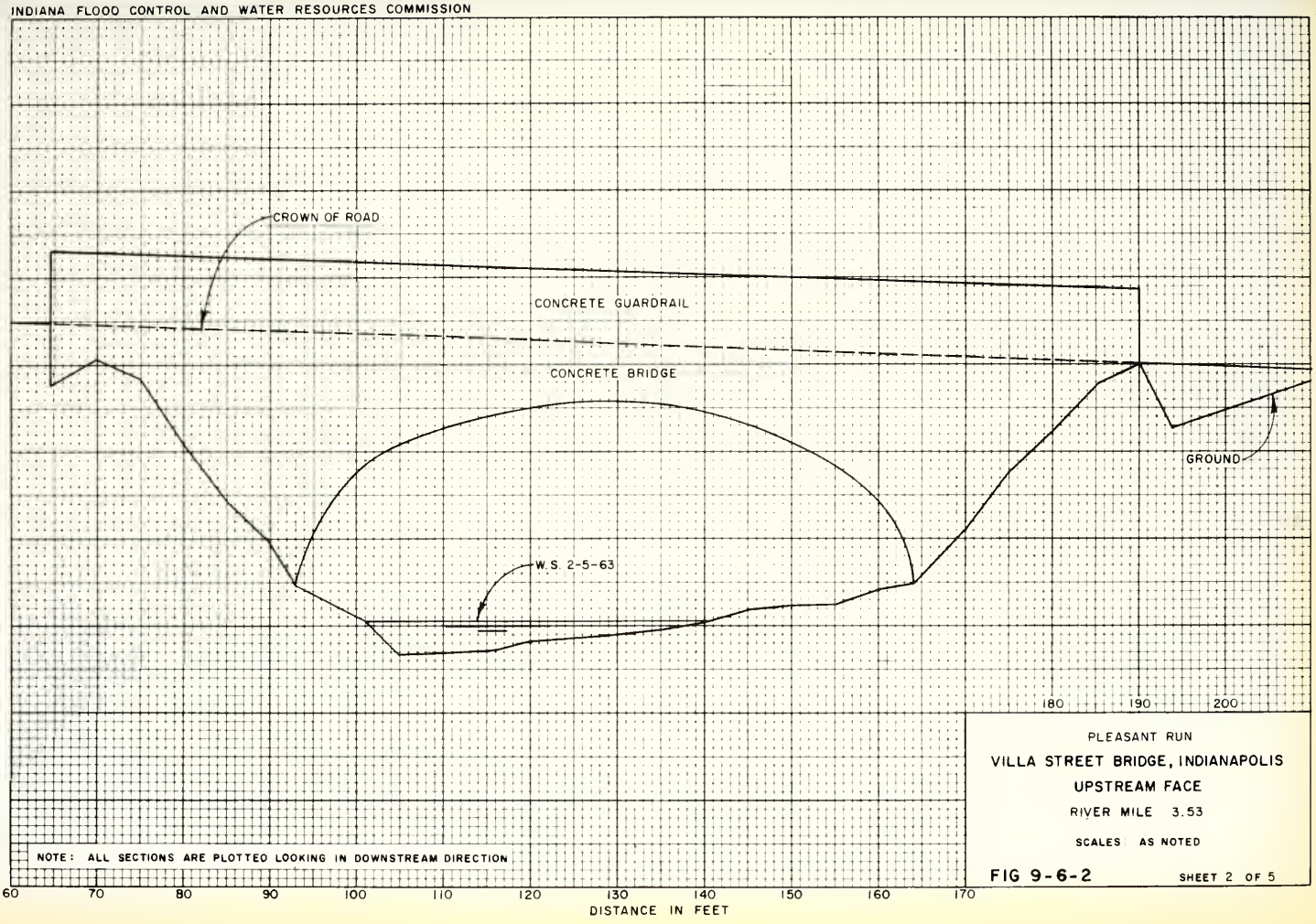
VILLA STREET BRIDGE, INDIANAPOLIS

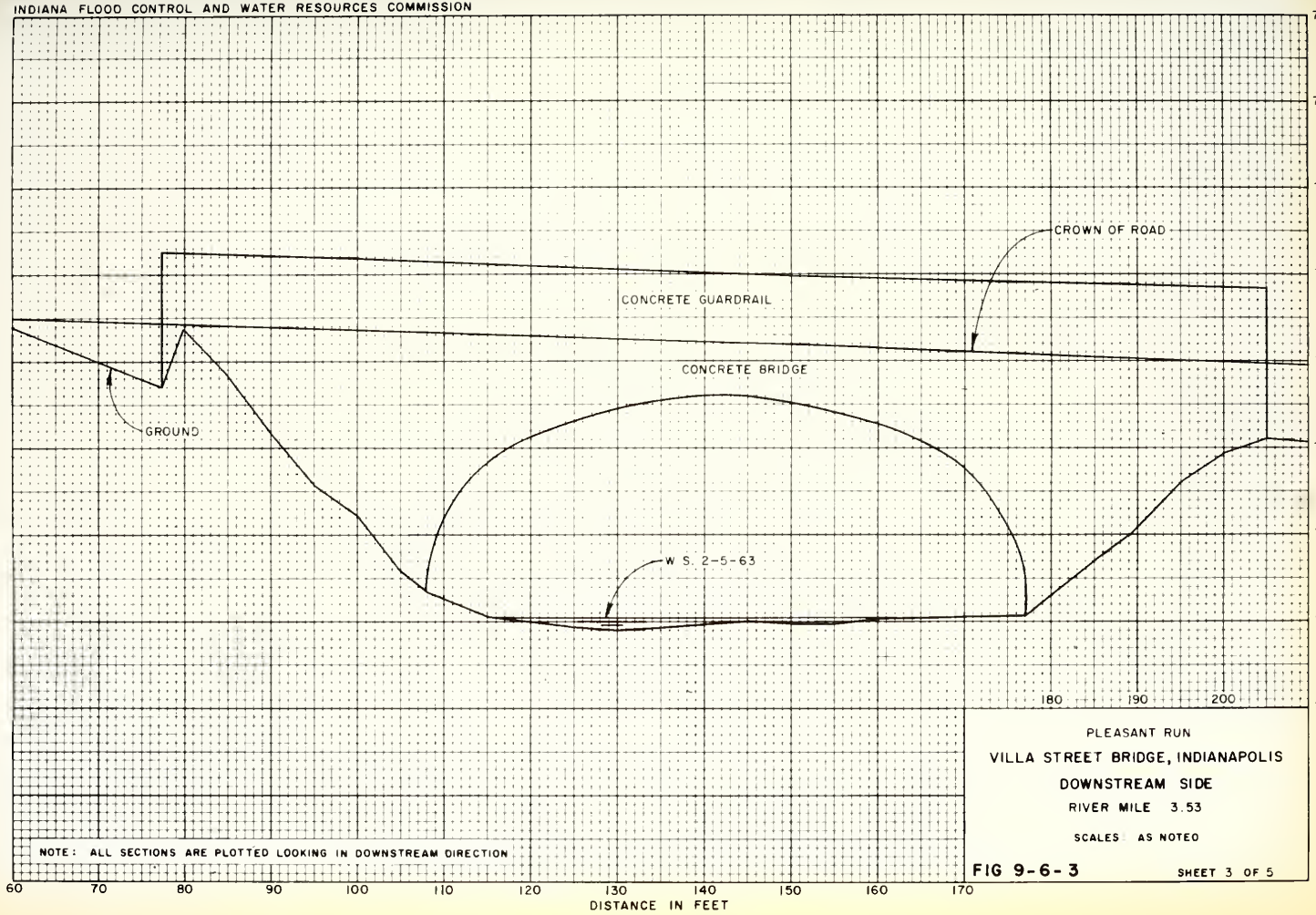
PLAN VIEW

RIVER MILE 3.53

SCALES AS NOTED

FIG 9-6-1 SHEET 1 OF 5


INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION
ELEVATION (M S L, 1929 ADJ.)
750
745
740
735
730
725
720
715
710
CROWN OF ROAD
CONCRETE GUARDRAIL
CONCRETE BRIDGE
GROUND
W.S. 2-5-63
180
190
200
60
70
80
90
100
110
120
130
140
150
160
170
DISTANCE IN FEET
NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION
PLEASANT RUN
VILLA STREET BRIDGE, INDIANAPOLIS
UPSTREAM FACE
RIVER MILE 3.53
SCALES AS NOTED
FIG 9-6-2
SHEET 2 OF 5



NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION

PLEASANT RUN

VILLA STREET BRIDGE, INDIANAPOLIS

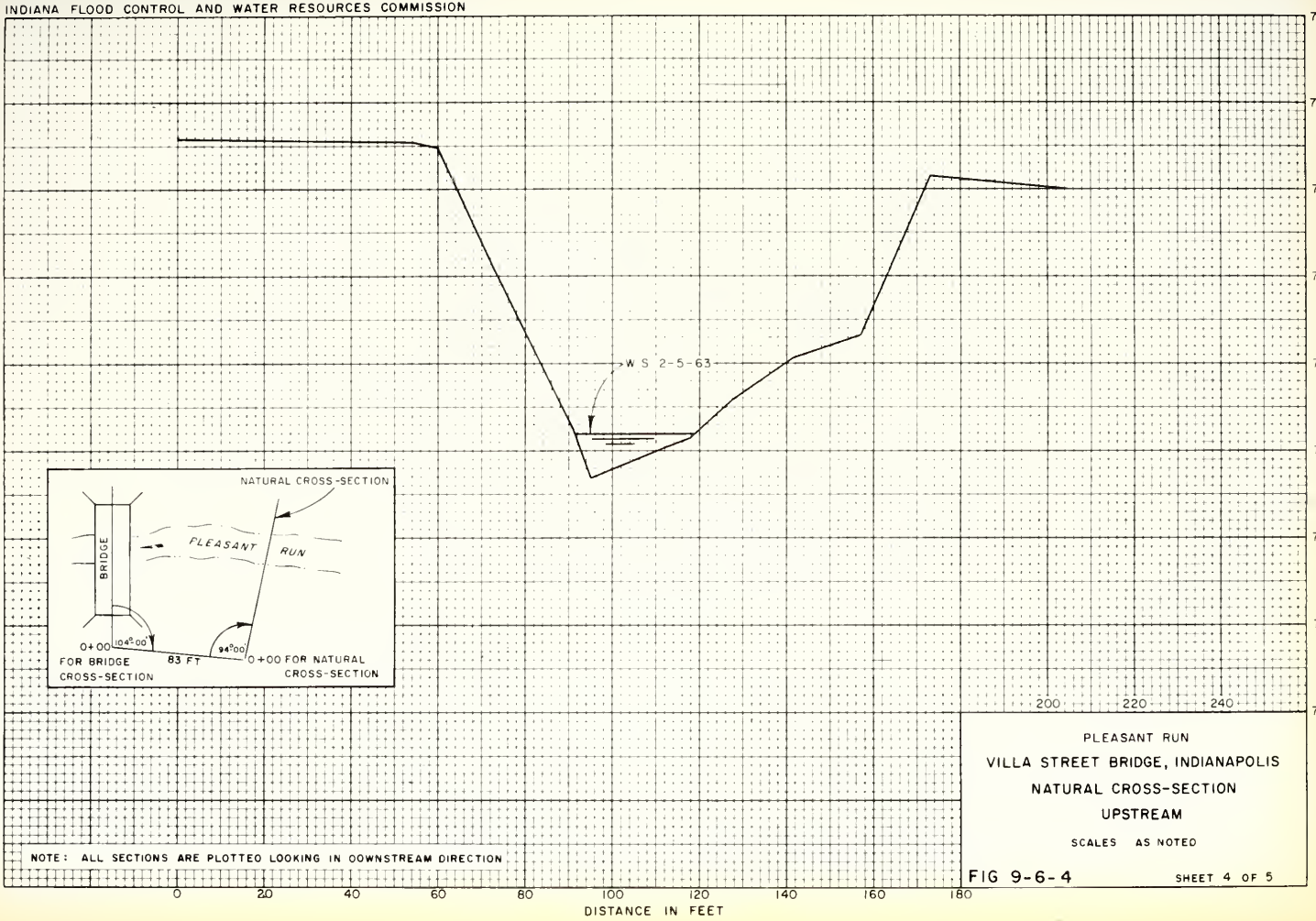
DOWNSTREAM SIDE

RIVER MILE 3.53

SCALES AS NOTED

FIG 9-6-3

SHEET 3 OF 5



NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION

PLEASANT RUN

VILLA STREET BRIDGE, INDIANAPOLIS

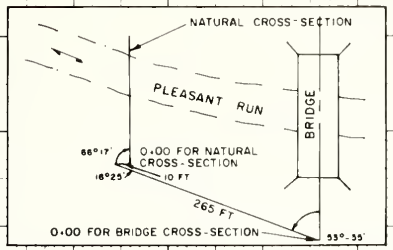
NATURAL CROSS-SECTION

UPSTREAM

SCALES AS NOTED

FIG 9-6-4 SHEET 4 OF 5

INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION



WS 7-5-63

ELEVATION (M S L, 1929 ADJ)

740
735
730
725
720
715
710
705
700

70 80 90

50 40 30 20 10 0 10 20 30 40 50 60

DISTANCE IN FEET

NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION

PLEASANT RUN

VILLA STREET BRIDGE, INDIANAPOLIS

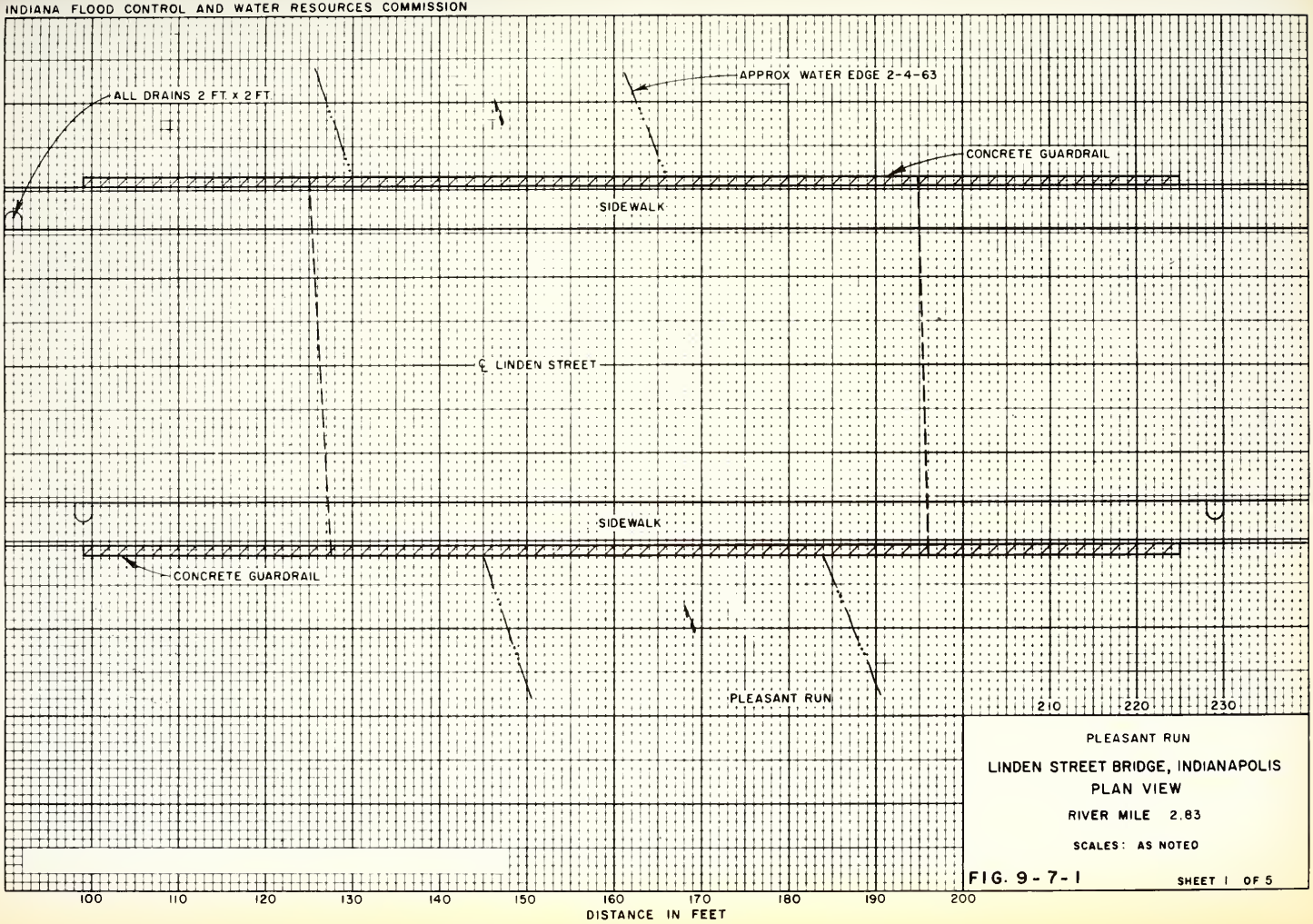
NATURAL CROSS-SECTION

DOWNSTREAM

RIVER MILE 3.53

SCALES: AS NOTED

FIG 9-6-5 SHEET 5 OF 5



PLEASANT RUN

LINDEN STREET BRIDGE, INDIANAPOLIS

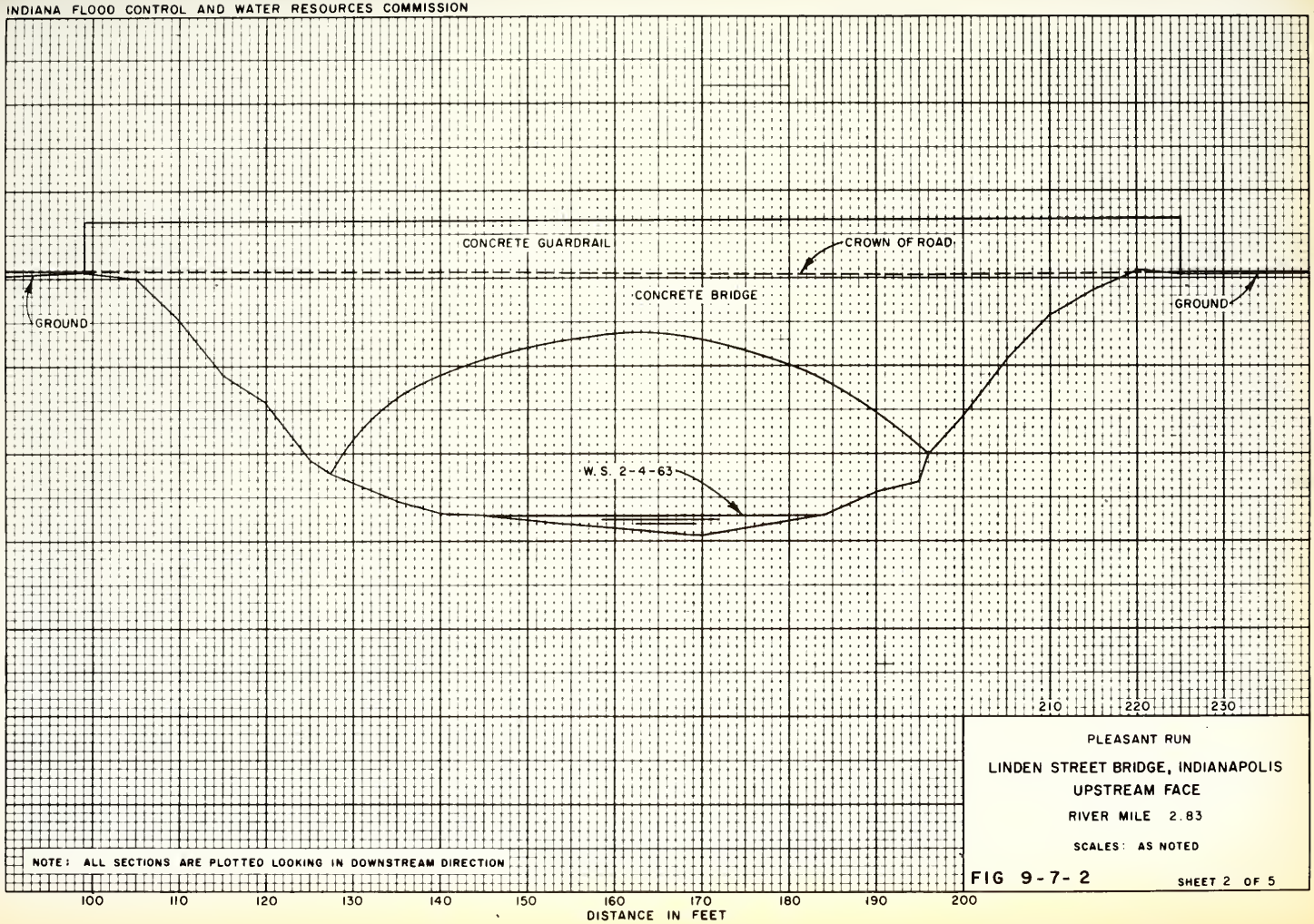
PLAN VIEW

RIVER MILE 2.83

SCALES: AS NOTED

FIG. 9-7-1

SHEET 1 OF 5



PLEASANT RUN

LINDEN STREET BRIDGE, INDIANAPOLIS

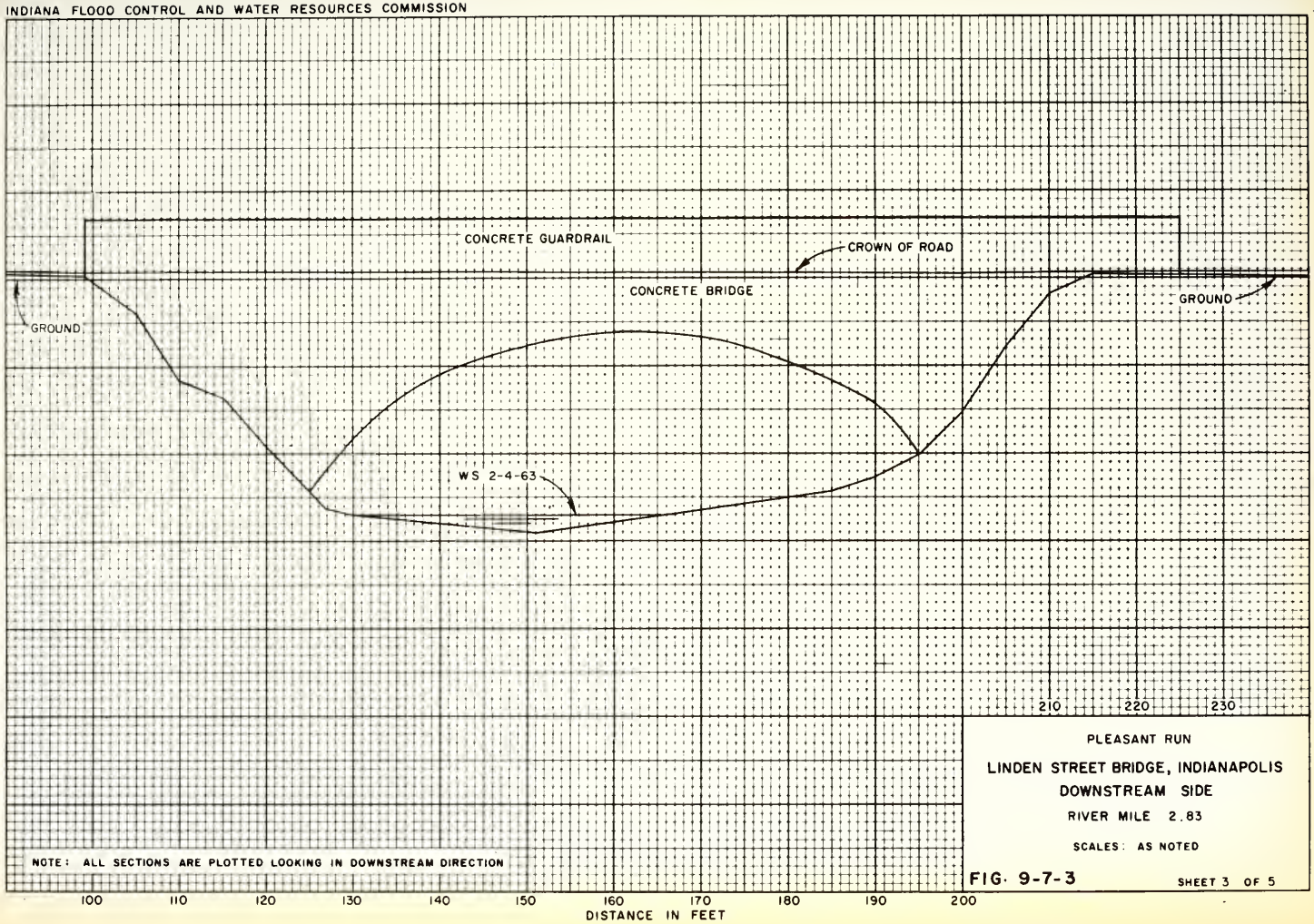
UPSTREAM FACE

RIVER MILE 2.83

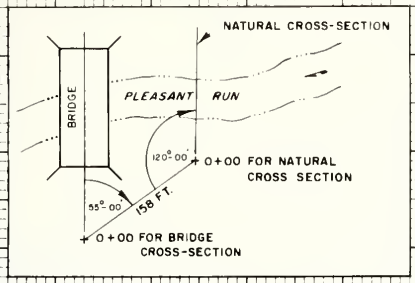
SCALES: AS NOTED

NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION

FIG 9-7-2 SHEET 2 OF 5


INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION
ELEVATION (M S L, 1929 ADJ)
735
730
725
720
715
710
705
700
695
CONCRETE GUARDRAIL
CROWN OF ROAD
CONCRETE BRIDGE
GROUND
GROUND
WS 2-4-63
210
220
230
100
110
120
130
140
150
160
170
180
190
200
DISTANCE IN FEET
NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION
PLEASANT RUN
LINDEN STREET BRIDGE, INDIANAPOLIS
DOWNSTREAM SIDE
RIVER MILE 2.83
SCALES: AS NOTED
FIG. 9-7-3
SHEET 3 OF 5

INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION



W S 2-4-63

ELEVATION (M S L, 1929 ADJ)

735 730 725 720 715 710 705 700 695

0 20 40 60 80 100 120 140 160 180 200 220

DISTANCE IN FEET

NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION

PLEASANT RUN

LINDEN STREET BRIDGE, INDIANAPOLIS

NATURAL CROSS-SECTION

UPSTREAM

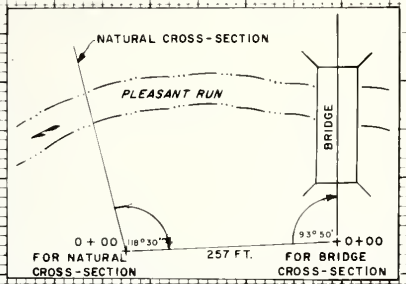
RIVER MILE 2.85.

SCALES: AS NOTED

FIG. 9-7-4

SHEET 4 OF 5

INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION



W.S. 5-6-63

ELEVATION (M S L, 1929 ADJ)

735 730 725 720 715 710 705 700 695 690

160 180 200

80 60 40 20 0 20 40 60 80 100 120 140

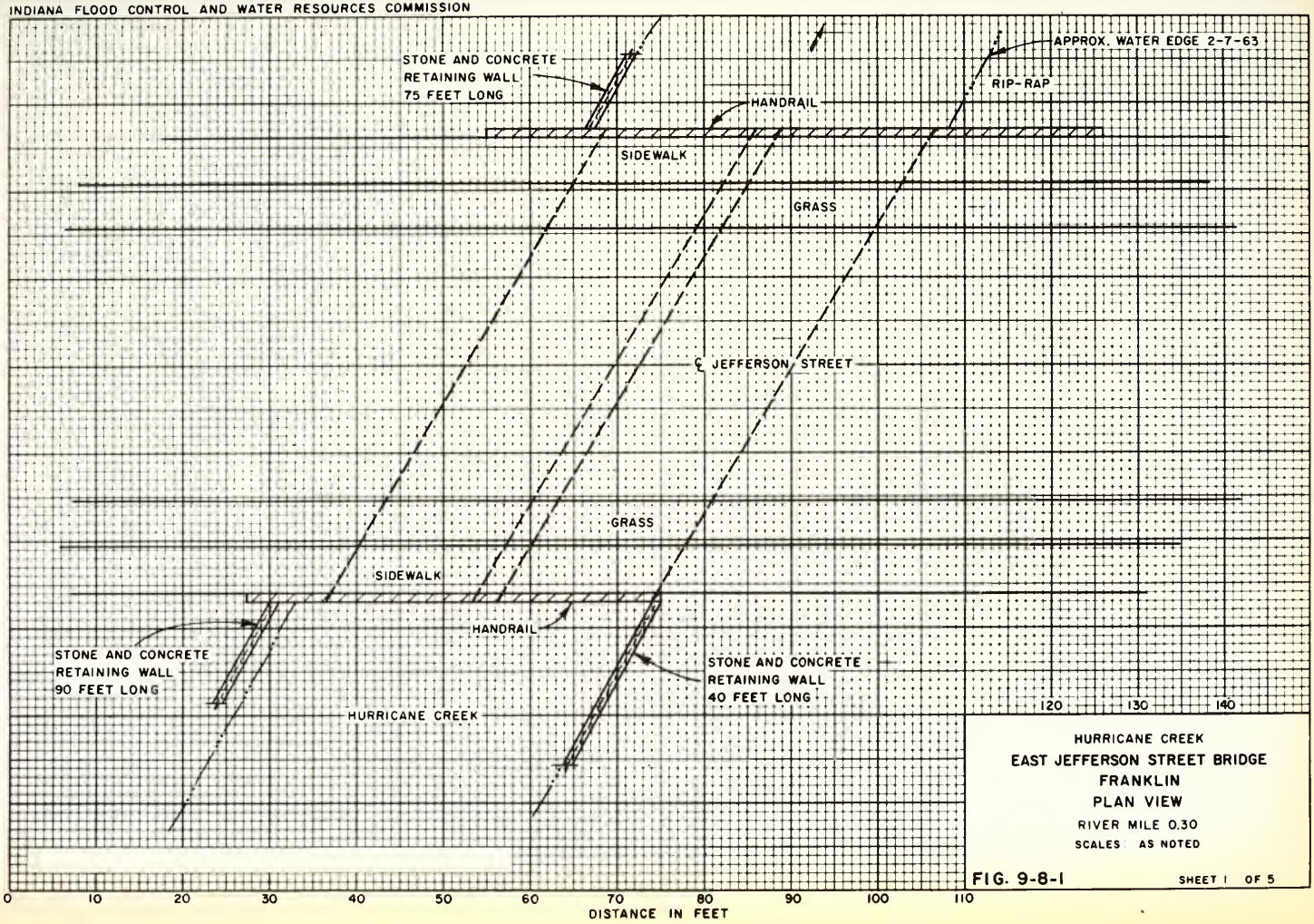
DISTANCE IN FEET

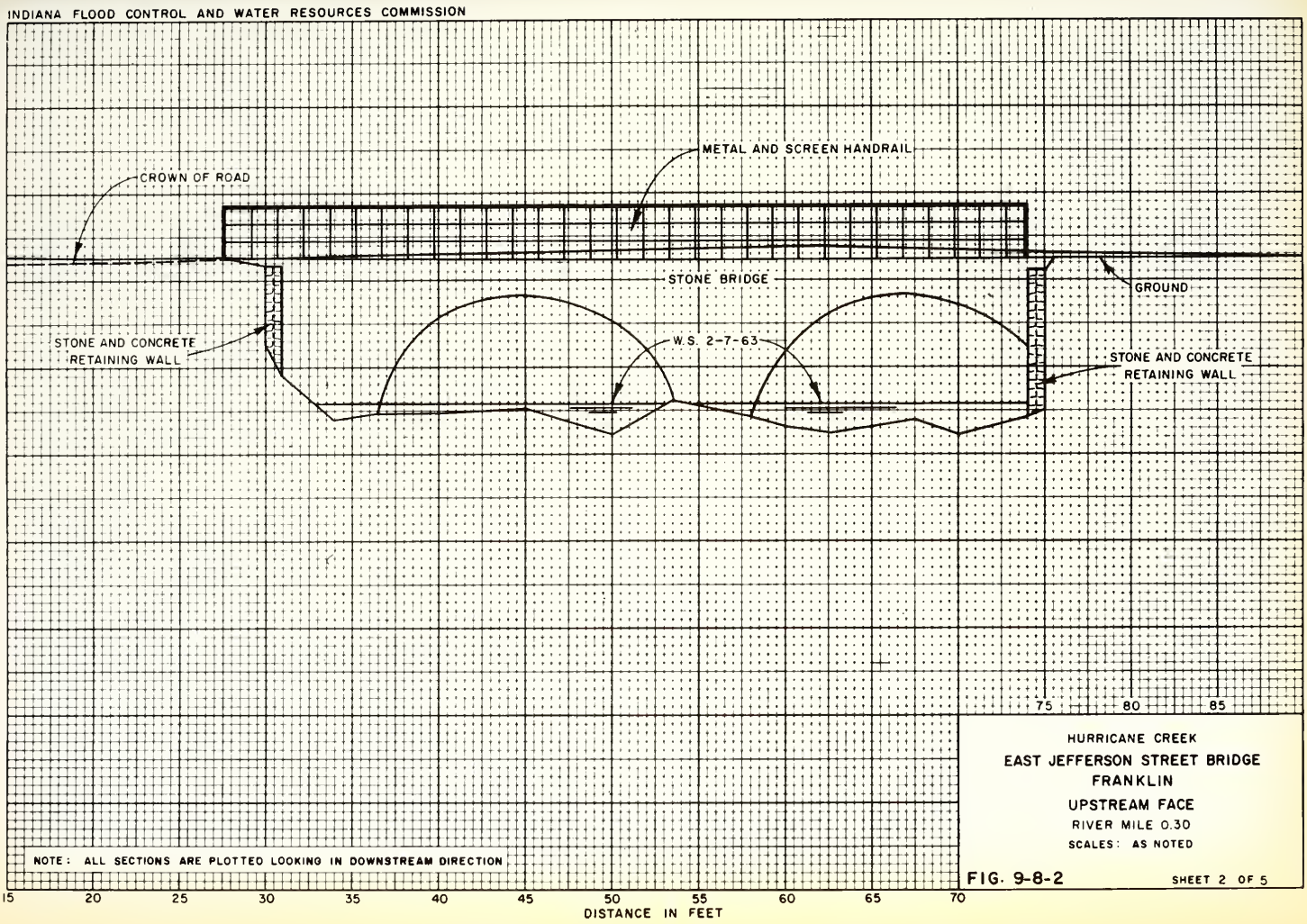
NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION

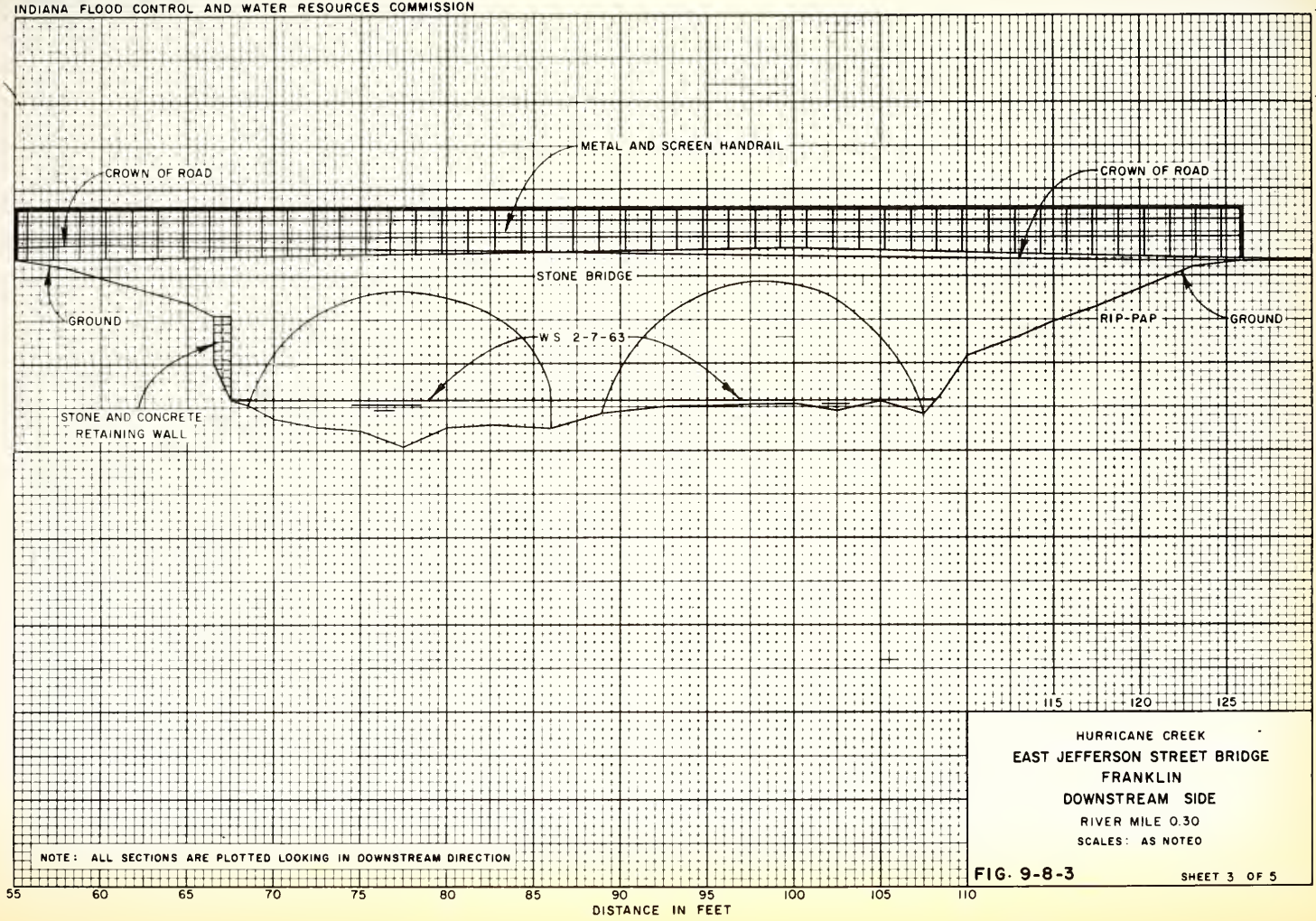
PLEASANT RUN
LINDEN STREET BRIDGE, INDIANAPOLIS
NATURAL CROSS-SECTION
DOWNSTREAM
RIVER MILE 2.78
SCALES: AS NOTED

FIG. 9-7-5

SHEET 5 OF 5


INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION
STONE AND CONCRETE RETAINING WALL 75 FEET LONG
HANDRAIL
APPROX. WATER EDGE 2-7-63
RIP-RAP
SIDEWALK
GRASS
℄ JEFFERSON STREET
GRASS
SIDEWALK
HANDRAIL
STONE AND CONCRETE RETAINING WALL 90 FEET LONG
STONE AND CONCRETE RETAINING WALL 40 FEET LONG
HURRICANE CREEK
HURRICANE CREEK
EAST JEFFERSON STREET BRIDGE
FRANKLIN
PLAN VIEW
RIVER MILE 0.30
SCALES AS NOTED
FIG. 9-8-1
SHEET 1 OF 5
DISTANCE IN FEET


INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION
METAL AND SCREEN HANDRAIL
CROWN OF ROAD
STONE BRIDGE
GROUND
STONE AND CONCRETE RETAINING WALL
W.S. 2-7-63
STONE AND CONCRETE RETAINING WALL
ELEVATION (M S L, 1929 ADJ)
735
730
725
720
715
710
705
700
695
75
80
85
15
20
25
30
35
40
45
50
55
60
65
70
DISTANCE IN FEET
NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION
HURRICANE CREEK
EAST JEFFERSON STREET BRIDGE
FRANKLIN
UPSTREAM FACE
RIVER MILE 0.30
SCALES: AS NOTED
FIG. 9-8-2
SHEET 2 OF 5



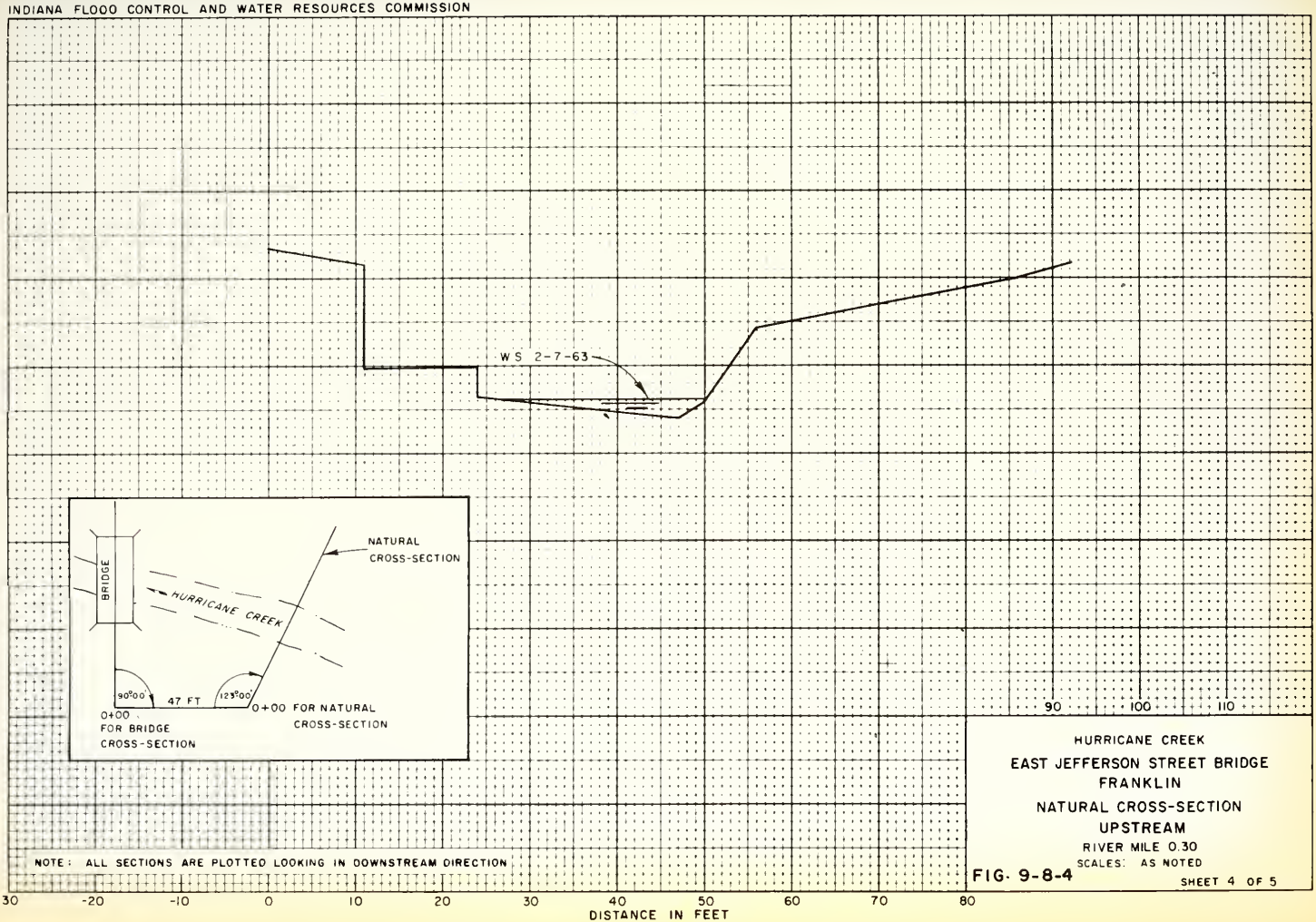
HURRICANE CREEK
EAST JEFFERSON STREET BRIDGE
FRANKLIN
DOWNSTREAM SIDE
RIVER MILE 0.30
SCALES: AS NOTED

NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION

FIG. 9-8-3

SHEET 3 OF 5

INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION



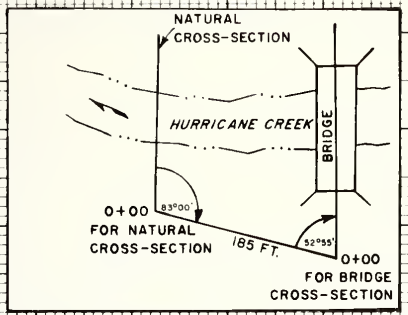
NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION

HURRICANE CREEK
EAST JEFFERSON STREET BRIDGE
FRANKLIN
NATURAL CROSS-SECTION
UPSTREAM
RIVER MILE 0.30
SCALES: AS NOTED

FIG. 9-8-4

SHEET 4 OF 5

INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION



W.S. 5-23-63

ELEVATION (M.S.L., 1929 ADJ.)

735 730 725 720 715 710 705 700 695 690

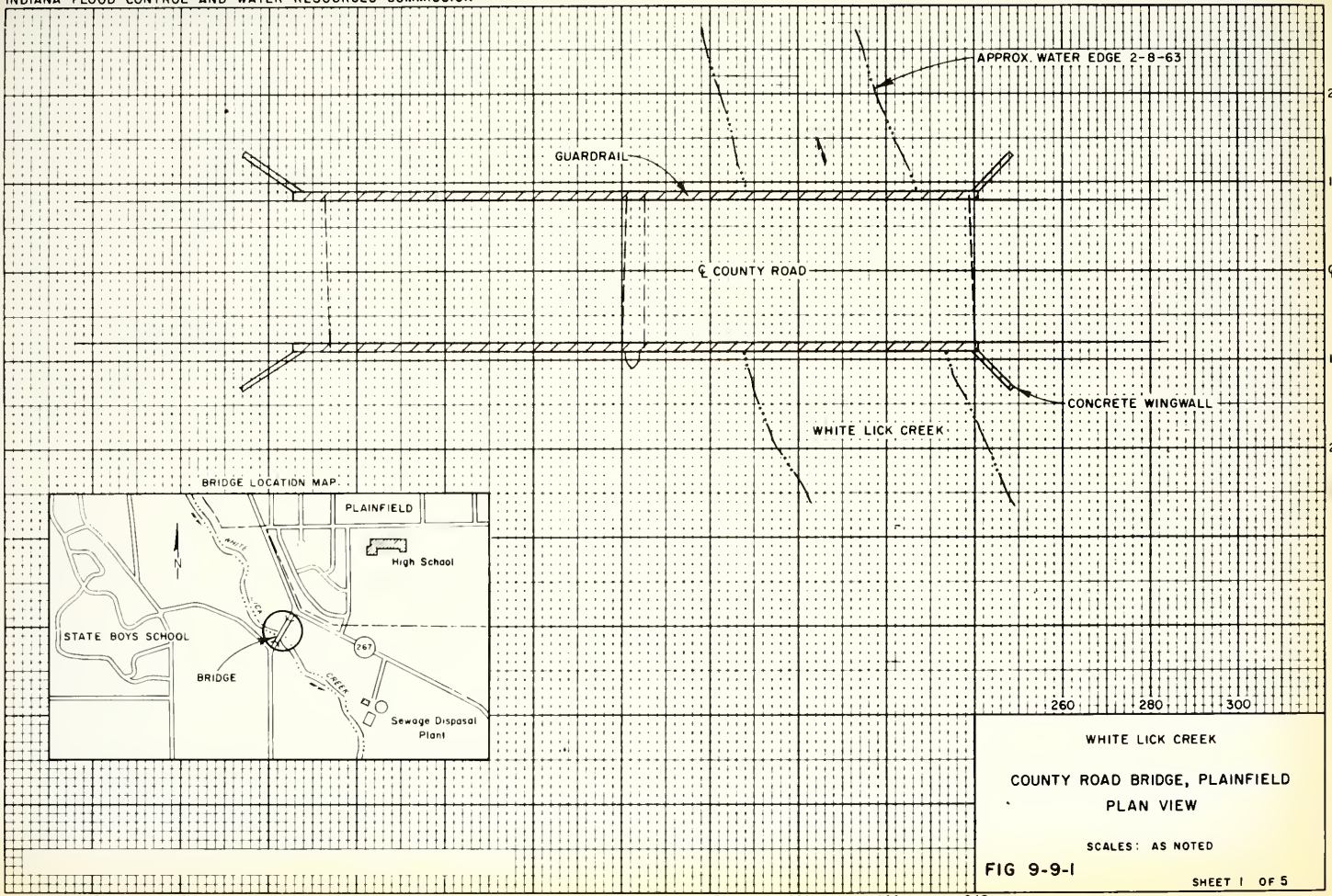
-30 -20 -10 0 10 20 30 40 50 60 70 80 90 100 110

DISTANCE IN FEET

NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION

HURRICANE CREEK
EAST JEFFERSON STREET BRIDGE
FRANKLIN
NATURAL CROSS-SECTION
DOWNSTREAM
RIVER MILE 0.30
SCALES: AS NOTED

FIG. 9-8-5 SHEET 5 OF 5



BRIDGE LOCATION MAP

WHITE LICK CREEK

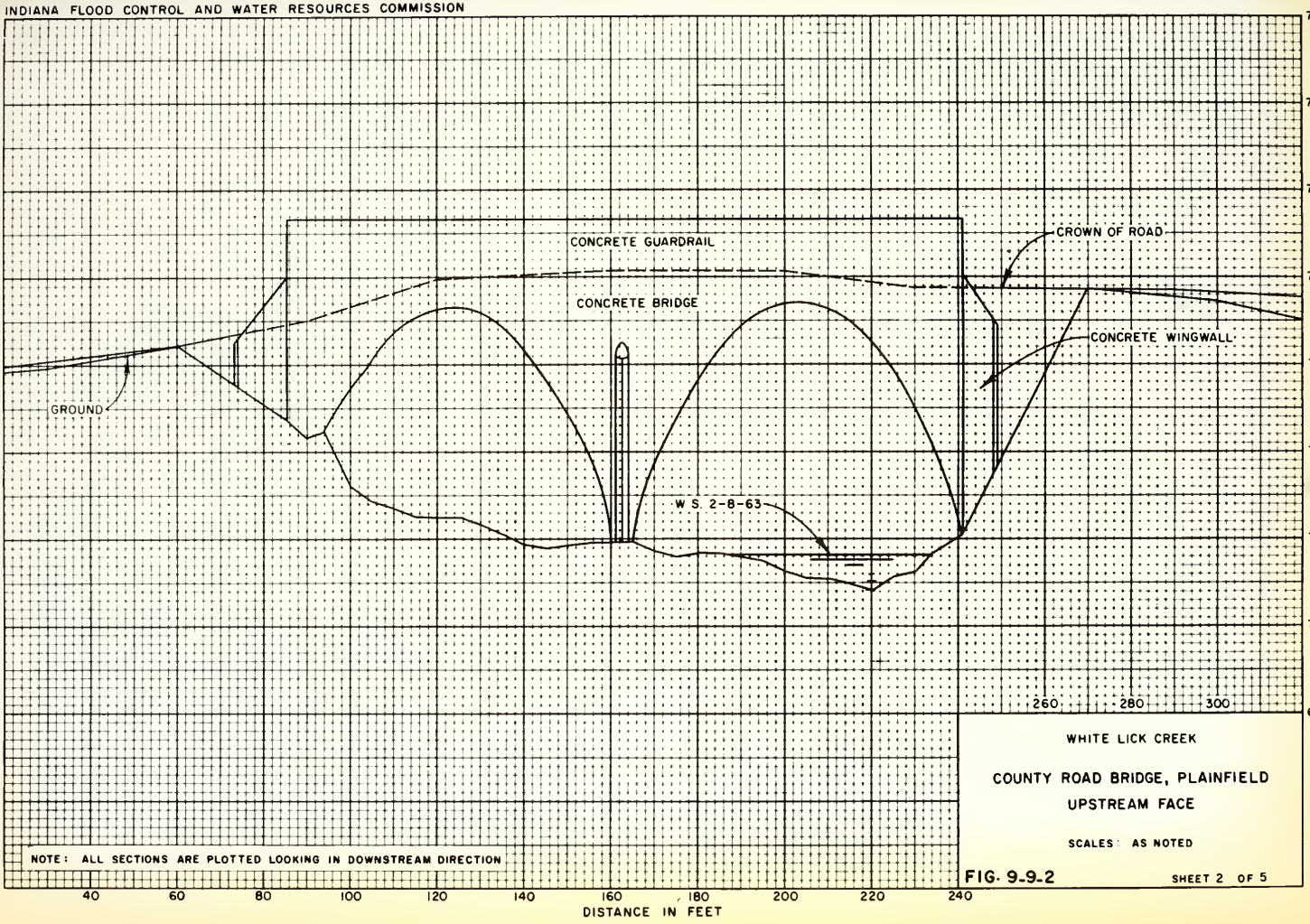
COUNTY ROAD BRIDGE, PLAINFIELD

PLAN VIEW

SCALES: AS NOTED

FIG 9-9-1

SHEET 1 OF 5



WHITE LICK CREEK

COUNTY ROAD BRIDGE, PLAINFIELD

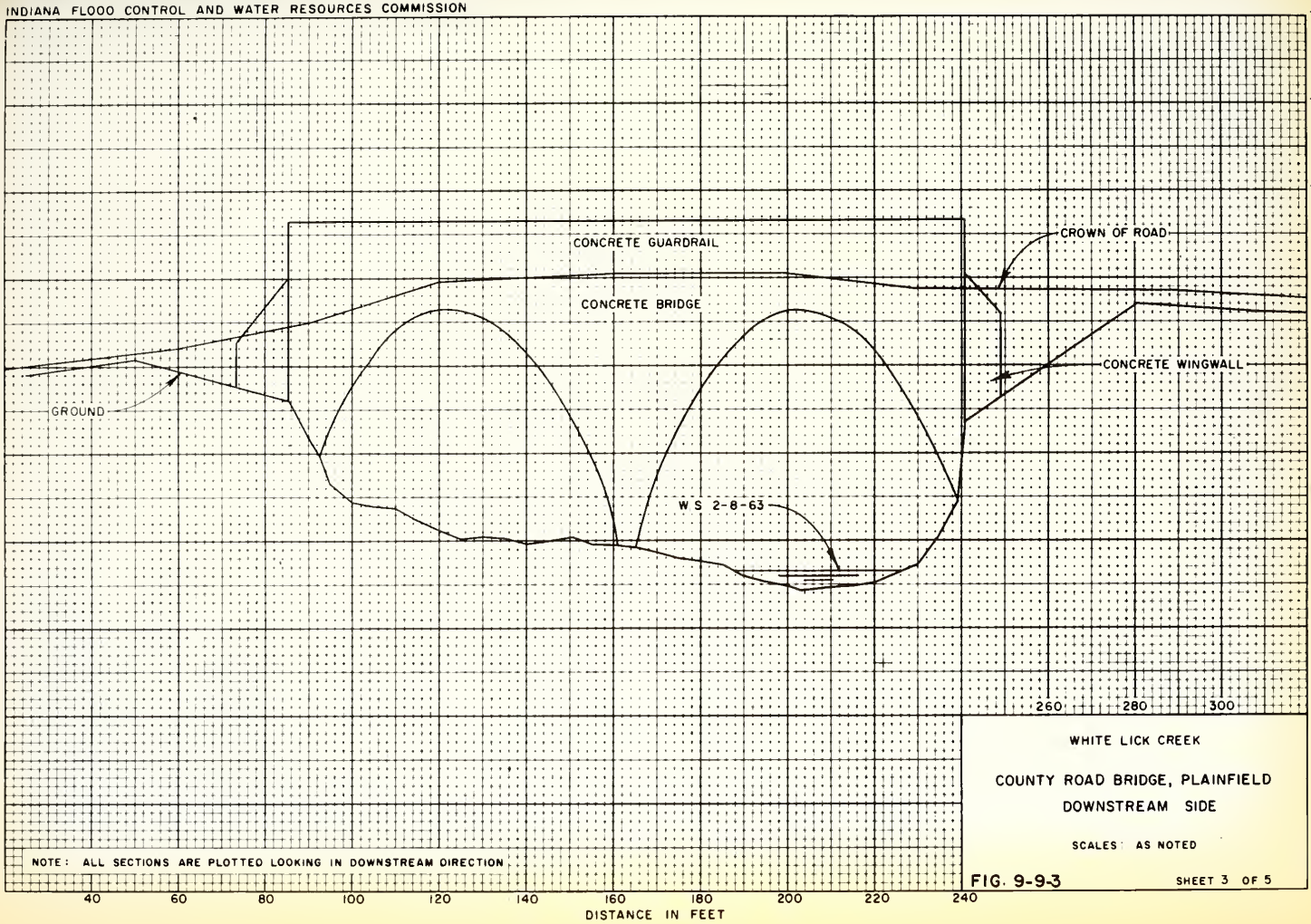
UPSTREAM FACE

SCALES: AS NOTED

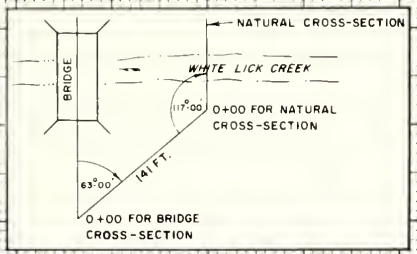
NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION

FIG. 9-9-2

SHEET 2 OF 5


INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION
ELEVATION (M S L., 1929 ADJ.)
735
730
725
720
715
710
705
700
695
CONCRETE GUARDRAIL
CROWN OF ROAD
CONCRETE BRIDGE
CONCRETE WINGWALL
GROUND
W S 2-8-63
260
280
300
40
60
80
100
120
140
160
180
200
220
240
DISTANCE IN FEET
NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION
WHITE LICK CREEK
COUNTY ROAD BRIDGE, PLAINFIELD
DOWNSTREAM SIDE
SCALES: AS NOTED
FIG. 9-9-3
SHEET 3 OF 5

INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION



W.S. 2-8-63

ELEVATION (M S L, 1929 ADJ)

720
715
710
705
700
695
690
685
680

200 220 240

-40 -20 0 20 40 60 80 100 120 140 160 180

DISTANCE IN FEET

NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION

WHITE LICK CREEK

COUNTY ROAD BRIDGE, PLAINFIELD

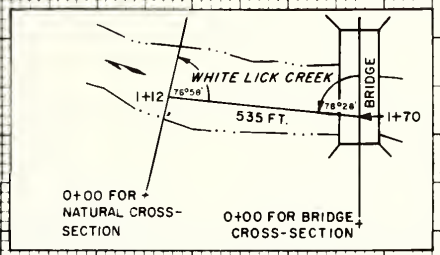
NATURAL CROSS-SECTION
UPSTREAM

SCALES: AS NOTED

FIG. 9-9-4

SHEET 4 OF 5

INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION



W.S. 5-10-63

ELEVATION (M S L, 1929 ADJ)

730 725 720 715 710 705 700 695 690 685

220 240 260

0 20 40 60 80 100 120 140 160 180 200

DISTANCE IN FEET

NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION

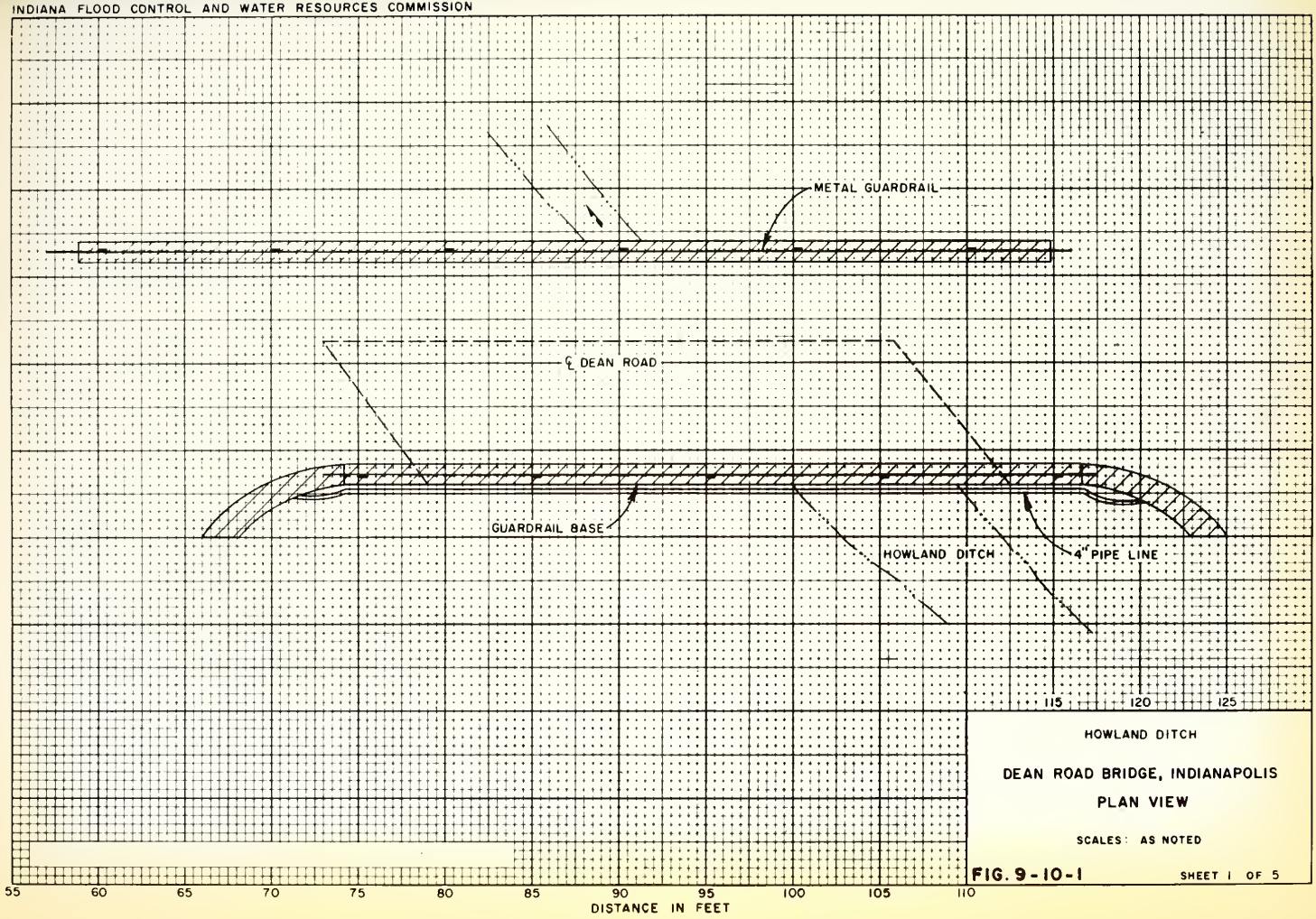
WHITE LICK CREEK

COUNTY ROAD BRIDGE, PLAINFIELD

NATURAL CROSS-SECTION DOWNSTREAM

SCALES: AS NOTED

FIG 9-9-5 SHEET 5 OF 5



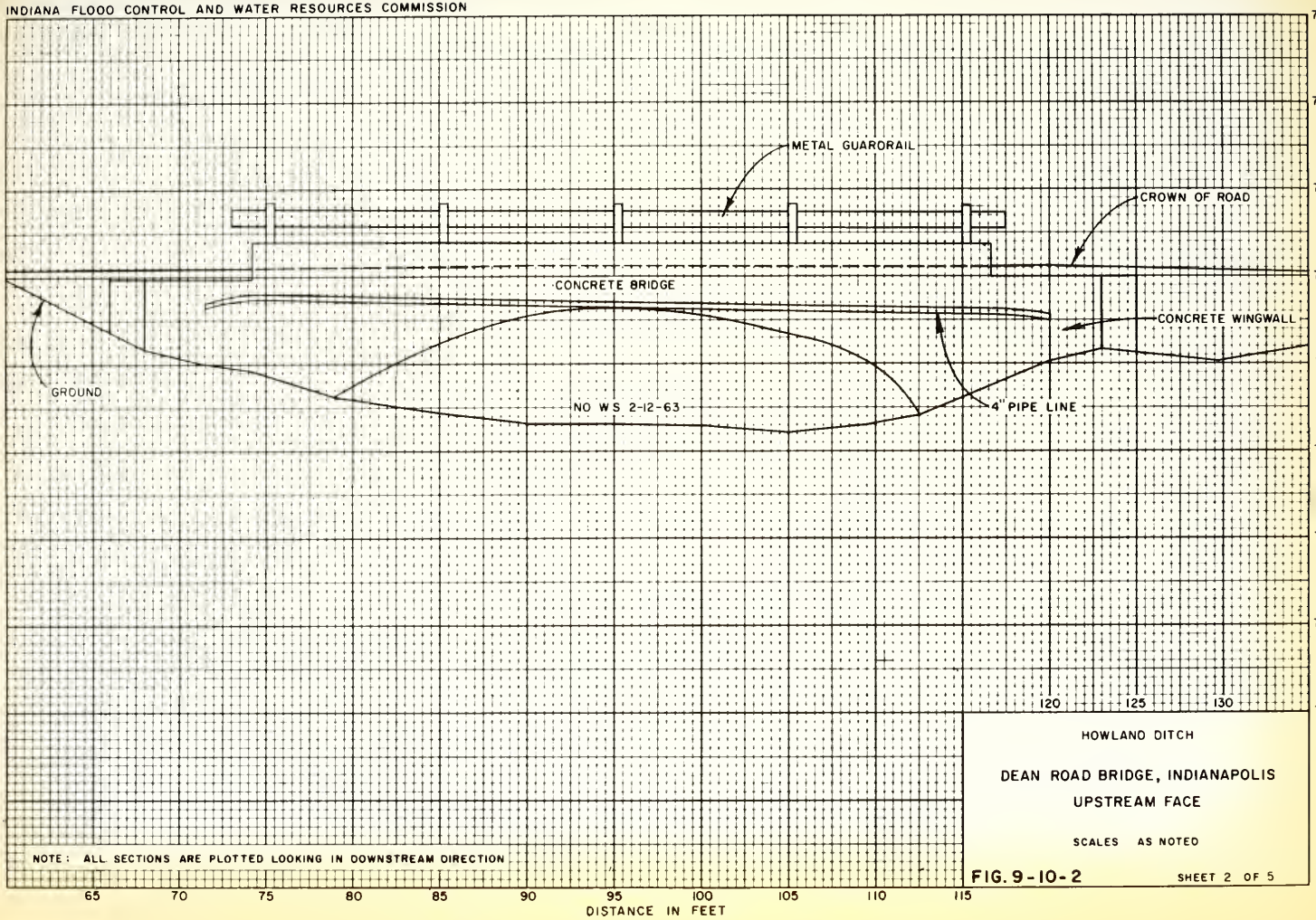
HOWLAND DITCH

DEAN ROAD BRIDGE, INDIANAPOLIS

PLAN VIEW

SCALES: AS NOTED

FIG. 9-10-1 SHEET 1 OF 5



HOWLAND DITCH

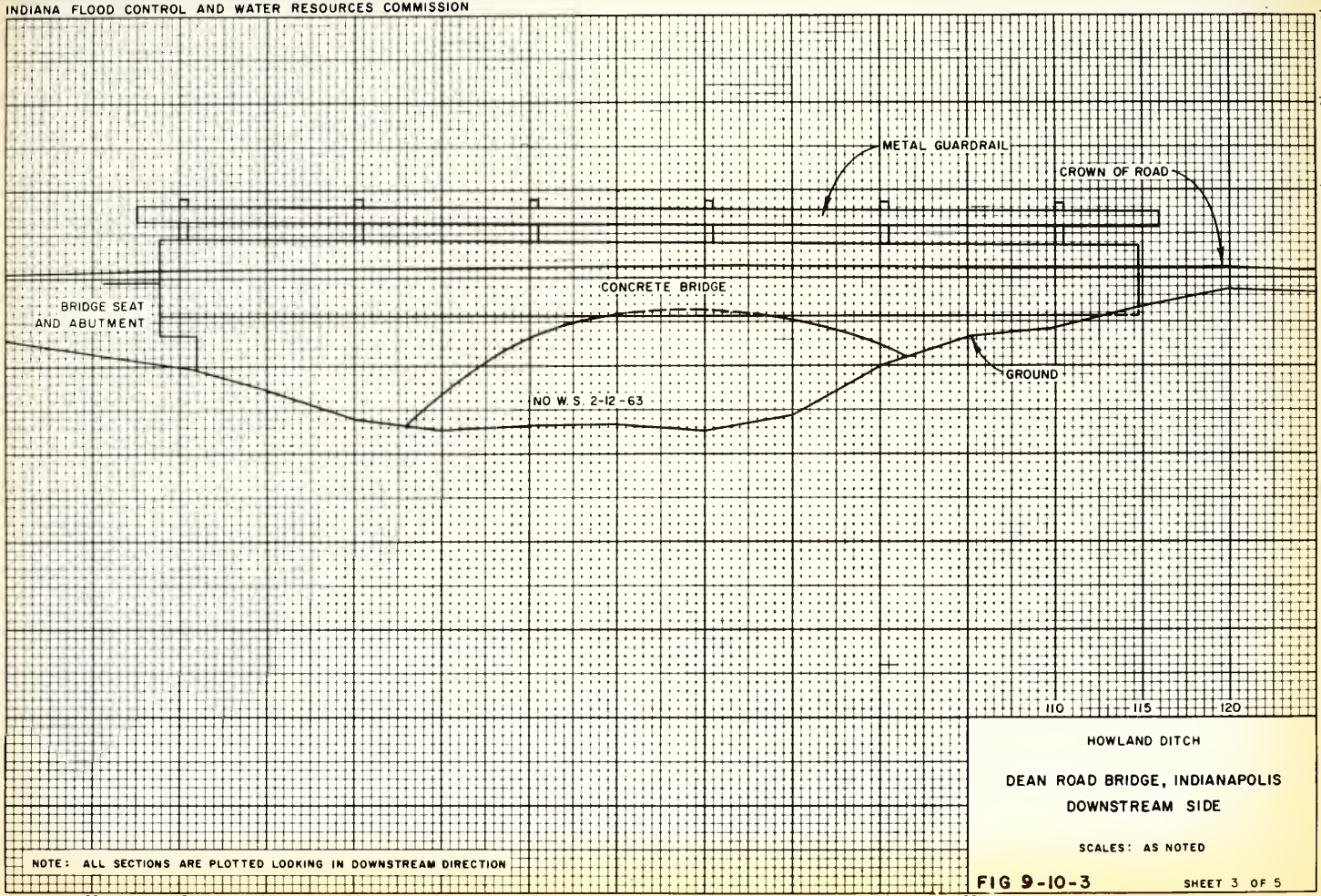
DEAN ROAD BRIDGE, INDIANAPOLIS

UPSTREAM FACE

SCALES AS NOTED

NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION

FIG. 9-10-2 SHEET 2 OF 5



NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION

HOWLAND DITCH

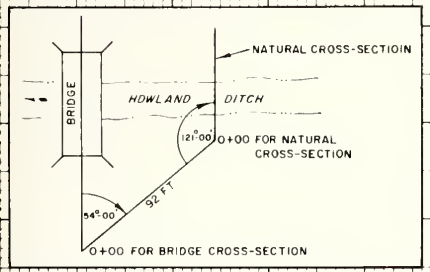
DEAN ROAD BRIDGE, INDIANAPOLIS

DOWNSTREAM SIDE

SCALES: AS NOTED

FIG 9-10-3 SHEET 3 OF 5

INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION



ELEVATION (M S L., 1929 ADJ.)

740
739
738
737
736
735
734
733

110 120 130

W.S. 2-12-63

0 10 20 30 40 50 60 70 80 90 100

DISTANCE IN FEET

NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION

HOWLAND DITCH

DEAN ROAD BRIDGE, INDIANAPOLIS

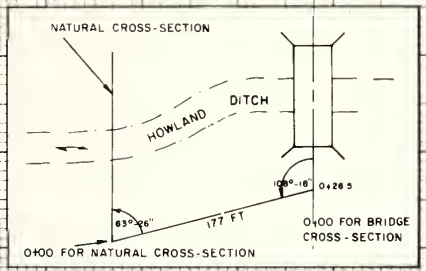
NATURAL CROSS-SECTION

UPSTREAM

SCALES AS NOTED

FIG 9-10-4 SHEET 4 OF 5

INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION



NOTE: ALL SECTIONS ARE PLOTTED LOOKING IN DOWNSTREAM DIRECTION

HOWLAND DITCH

DEAN ROAD BRIDGE, INDIANAPOLIS

NATURAL CROSS-SECTION

DOWNSTREAM

SCALES: AS NOTED

FIG 9-10-5 SHEET 5 OF 5

ELEVATION (M S L, 1929 ADJ)

DISTANCE IN FEET

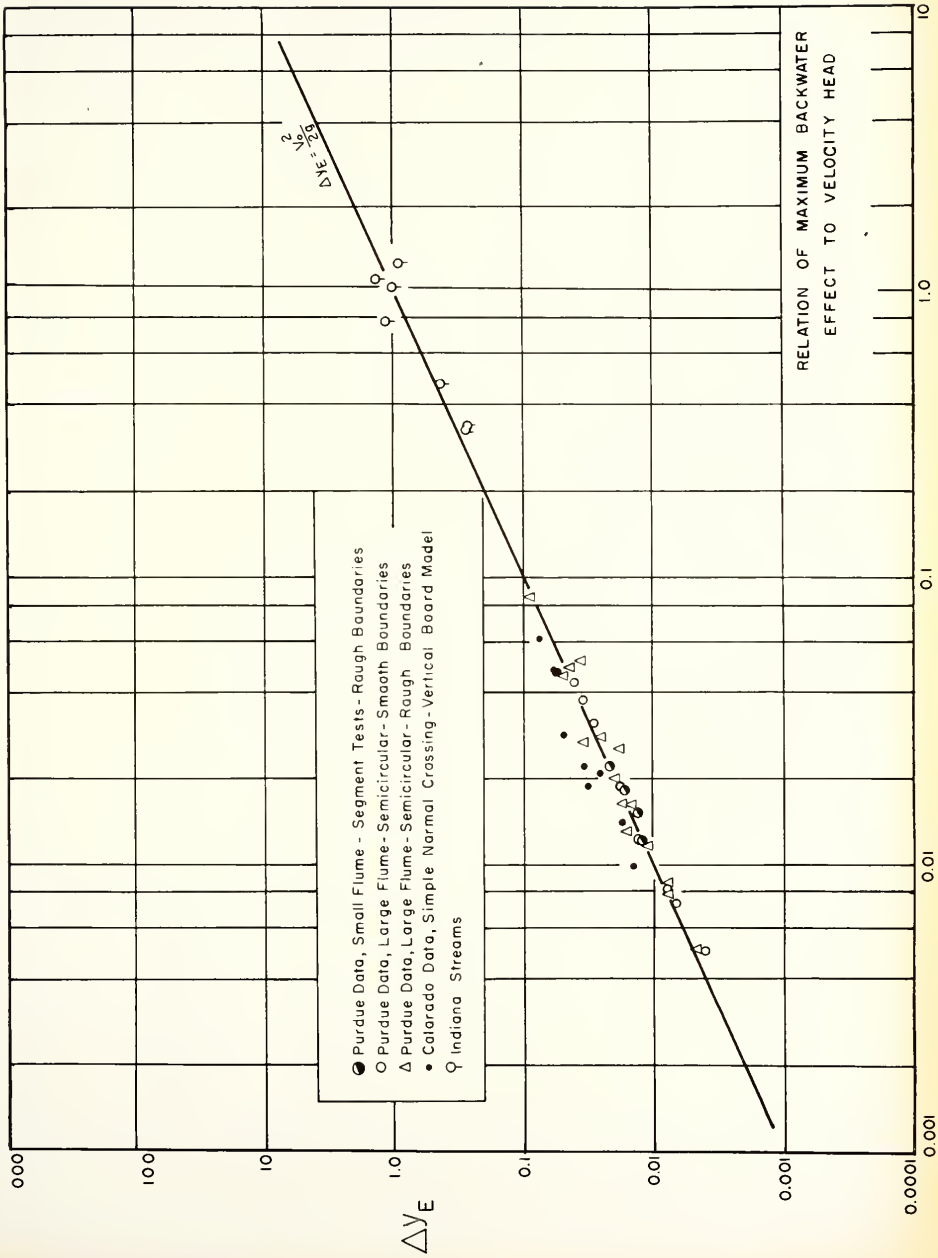

RELATION OF MAXIMUM BACKWATER
EFFECT TO VELOCITY HEAD
Purdue Data, Small Flume - Segment Tests - Rough Boundaries
Purdue Data, Large Flume - Semicircular - Smooth Boundaries
Purdue Data, Large Flume - Semicircular - Rough Boundaries
Colorado Data, Simple Normal Crossing - Vertical Board Model
Indiana Streams
$\Delta y_E = \frac{v_o^2}{2g}$
Δy_E
$\frac{v_o^2}{2g}$
1000
100
10
1.0
0.1
0.01
0.001
0.0001
0.001
0.01
0.1
1.0
10

FIG. 9-11-1

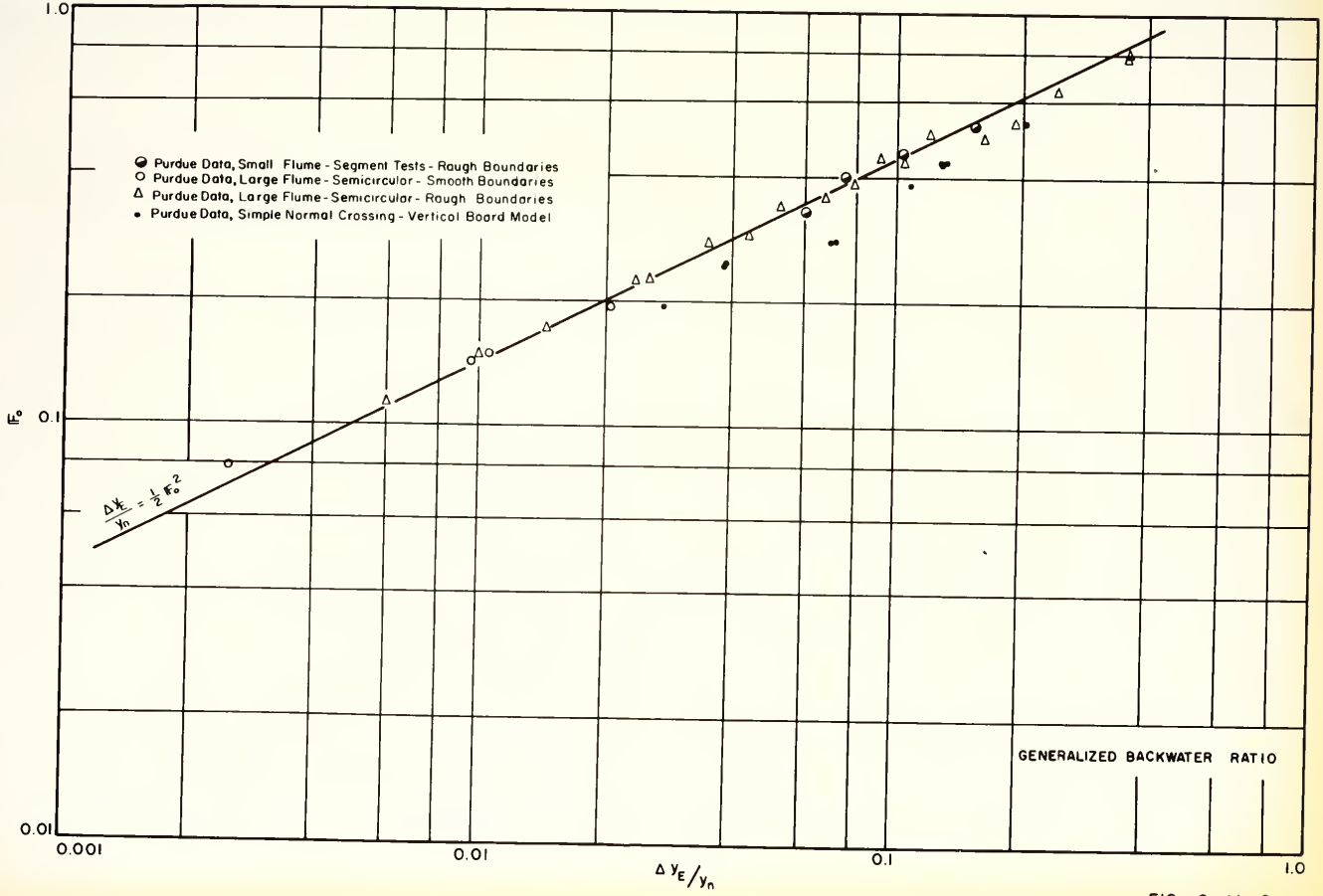
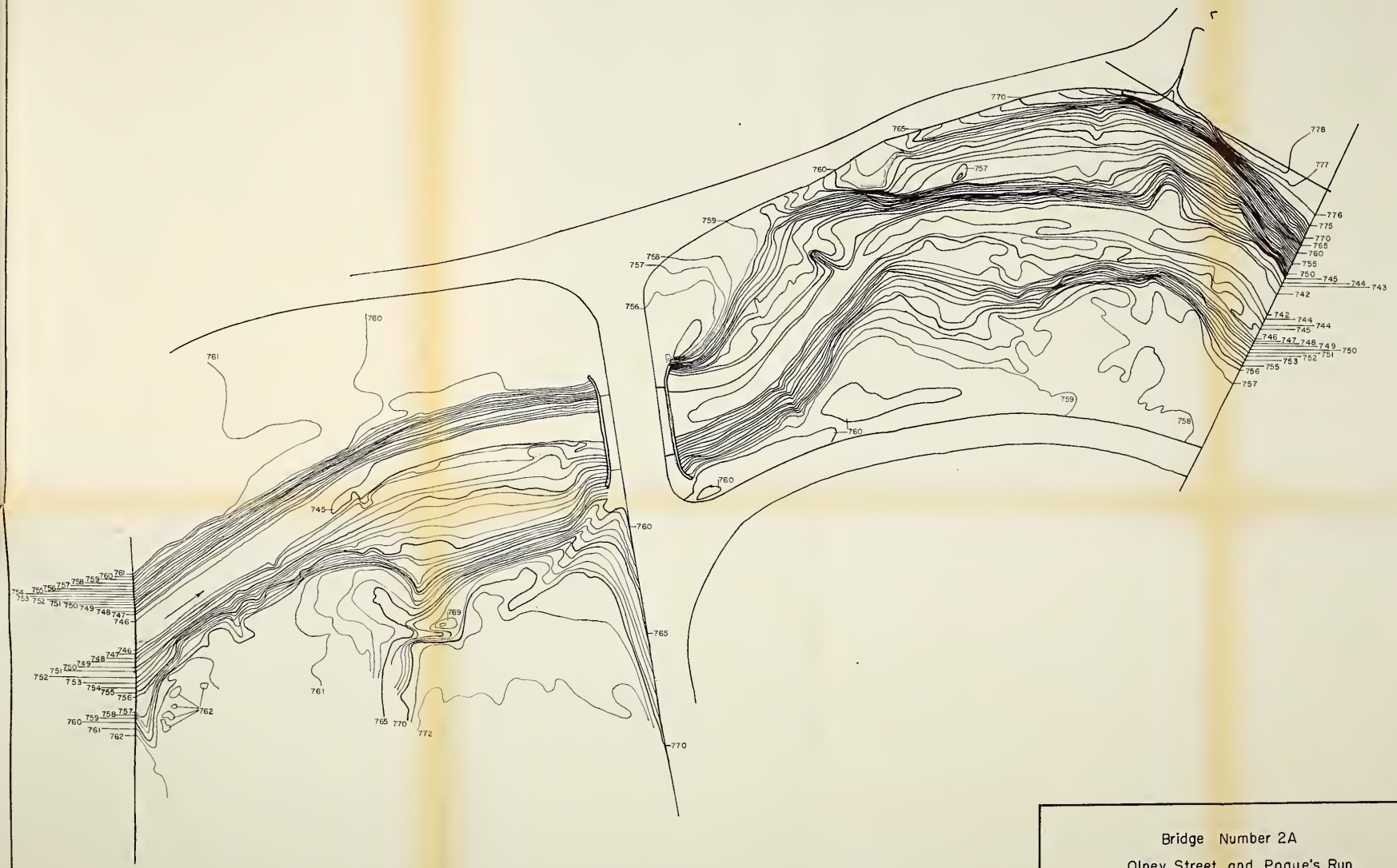

Purdue Data, Small Flume - Segment Tests - Rough Boundaries
Purdue Data, Large Flume - Semicircular - Smooth Boundaries
Purdue Data, Large Flume - Semicircular - Rough Boundaries
Purdue Data, Simple Normal Crossing - Verticol Board Model
$\frac{\Delta y_E}{y_n} = \frac{1}{2} F_o^2$
GENERALIZED BACKWATER RATIO
F_o
1.0
0.1
0.01
0.001
0.01
0.1
1.0
$\Delta y_E / y_n$

FIG. 9 - 11 - 2



Bridge Number 2A

Olney Street and Pogue's Run

Aerial Photographs Numbers 48 (166-167)

Scale: one inch represents fifty feet

July 1963

FIG. 9-1-6

Bridge Number 2C

Pogue's Run to Jefferson

Aerial photographs 48 (170-1)

Scale: one inch represents 50 feet

July 1963

FIG 9-3-6

Bridge Number 8A

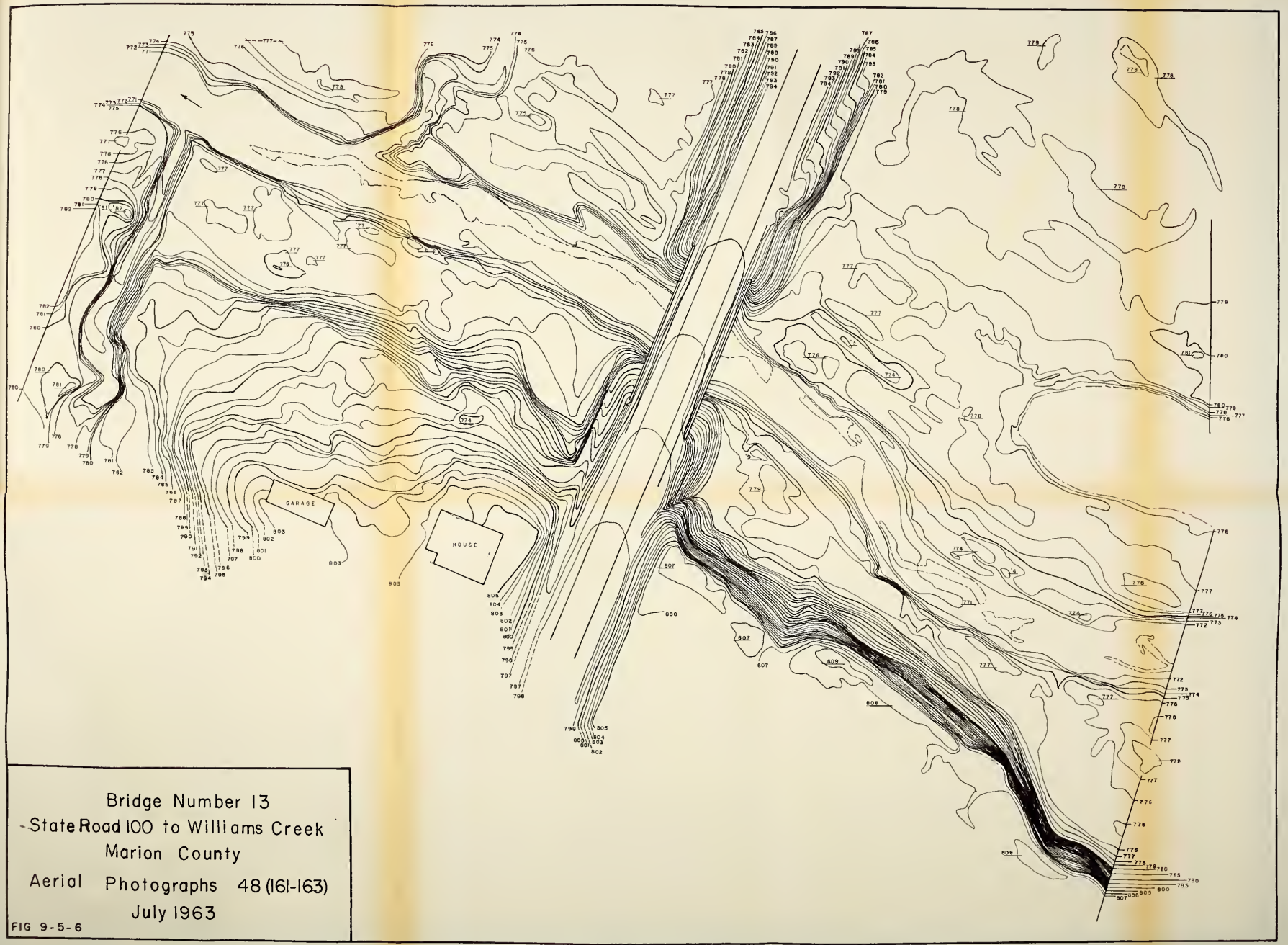
South Belmont and Little Buck Creek

Aeriol Photographs 48(157-8)

Scale: one inch represents 50 feet

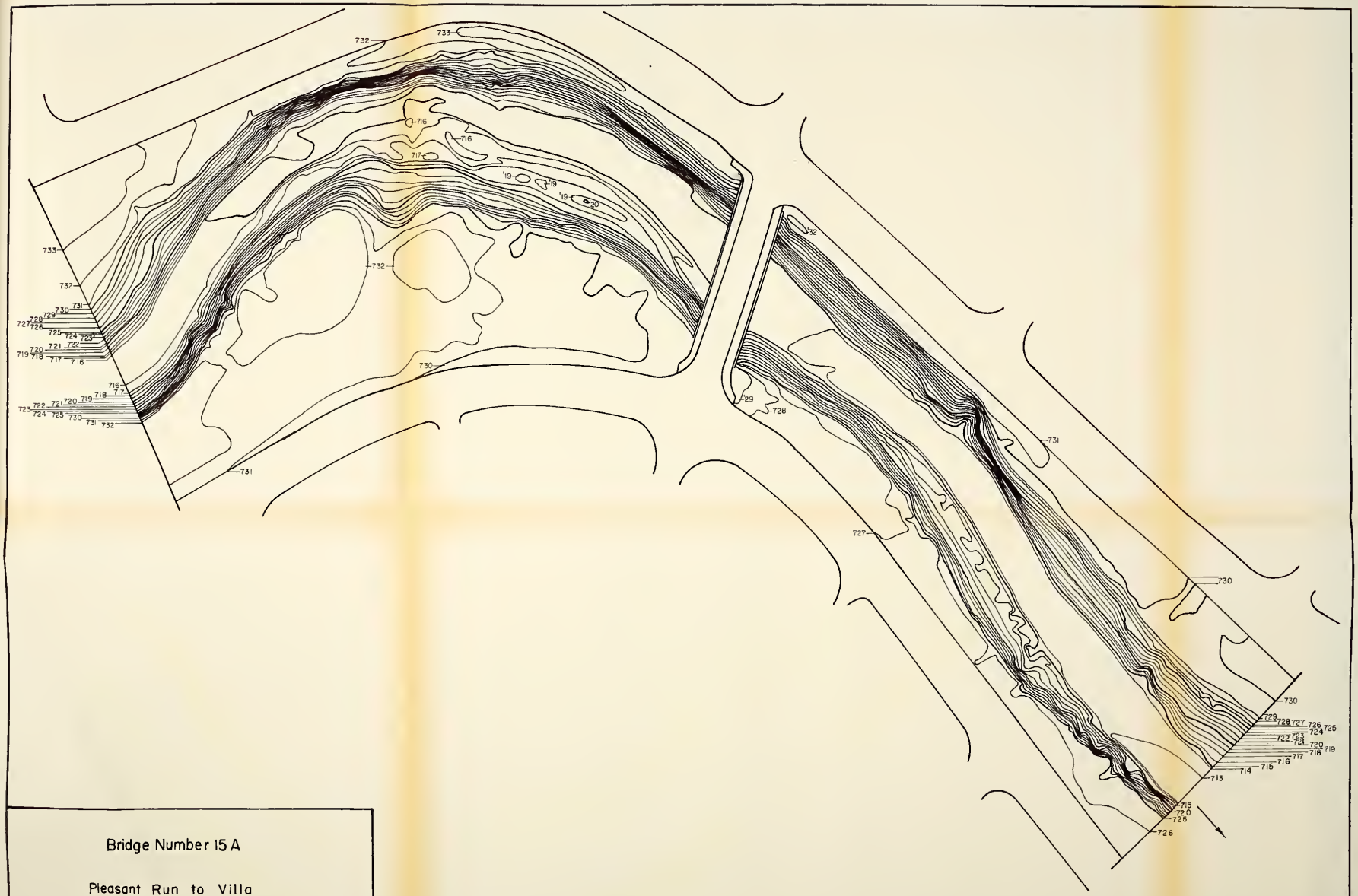
July 1963

FIG. 9-4-6



Bridge Number 13
State Road 100 to Williams Creek
Marion County
Aerial Photographs 48 (161-163)
July 1963

FIG 9-5-6



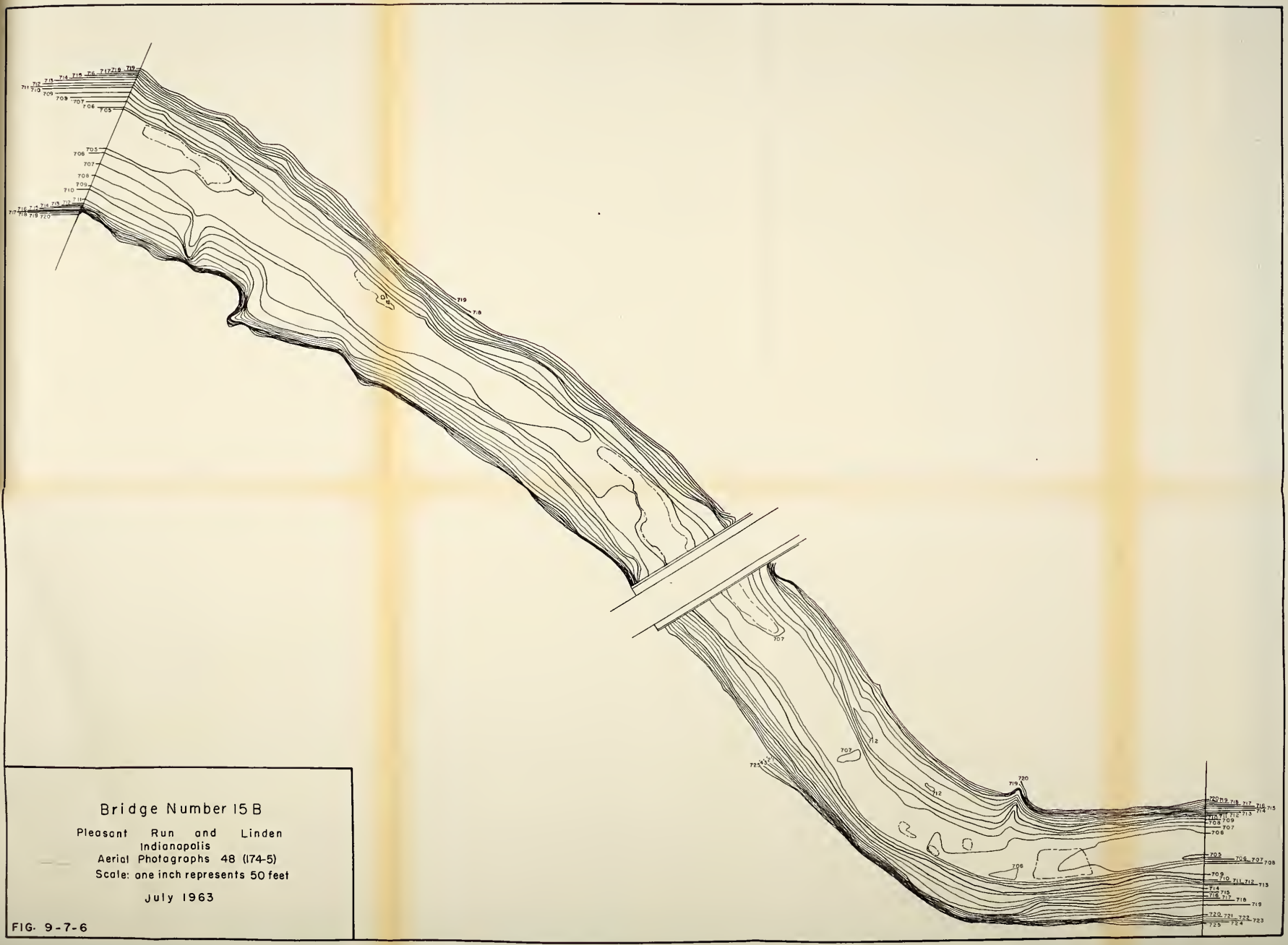
Bridge Number 15 A

Pleasant Run to Villa

Aerial Photographs 48 (172-3)

Scale: one inch represents 50 feet

FIG. 9-6-6 July 1963



Bridge Number 15 B

Pleasant Run and Linden
Indianapolis
Aerial Photographs 48 (174-5)
Scale: one inch represents 50 feet

July 1963

FIG. 9-7-6

Bridge Number 51

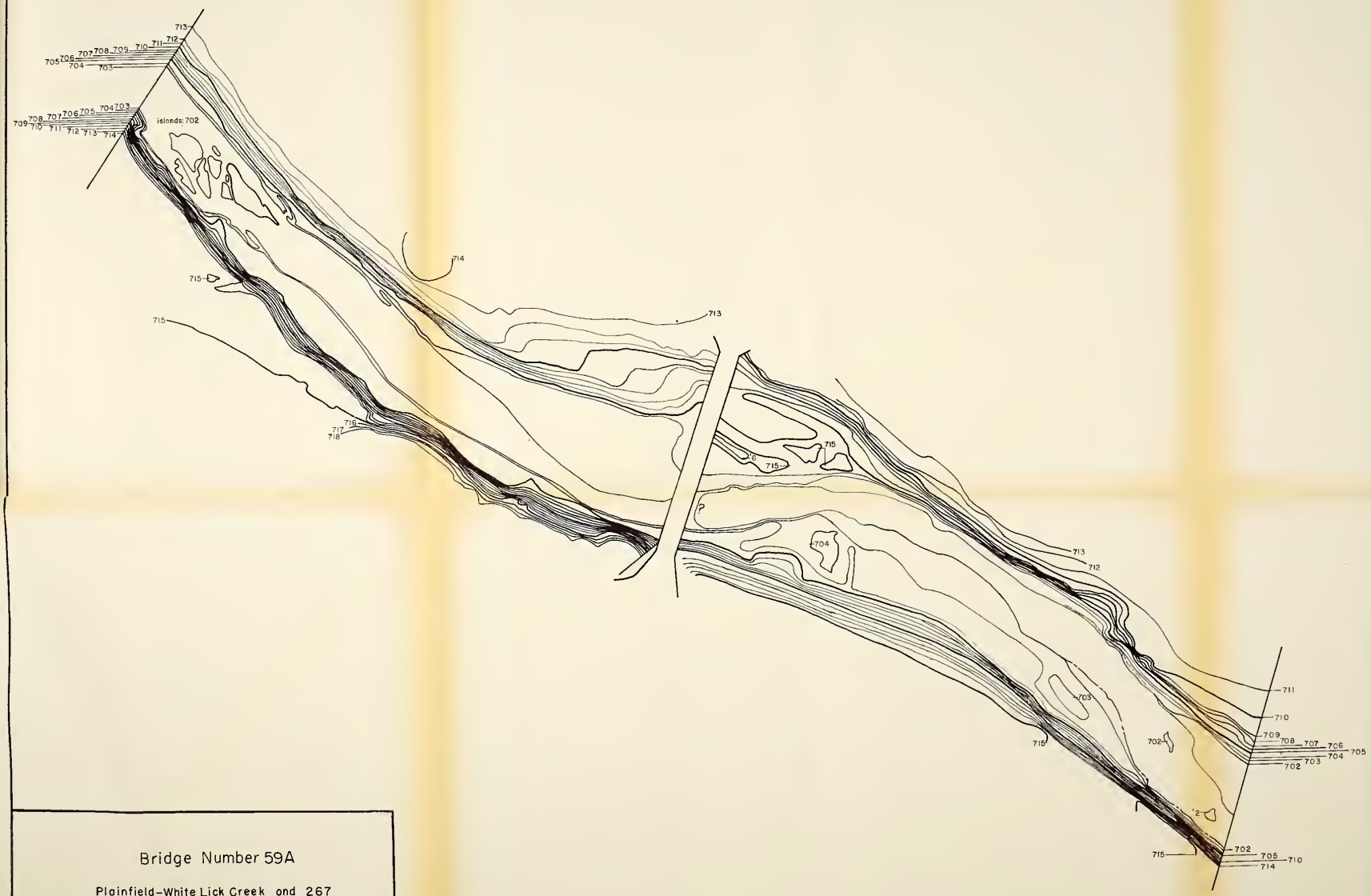
East Jeffersan Street and Hurricane Creek

Franklin, Indiana

Aerial Photographs 148 (155-156)

Scale: One inch represents 50 feet

FIG. 9-8-6



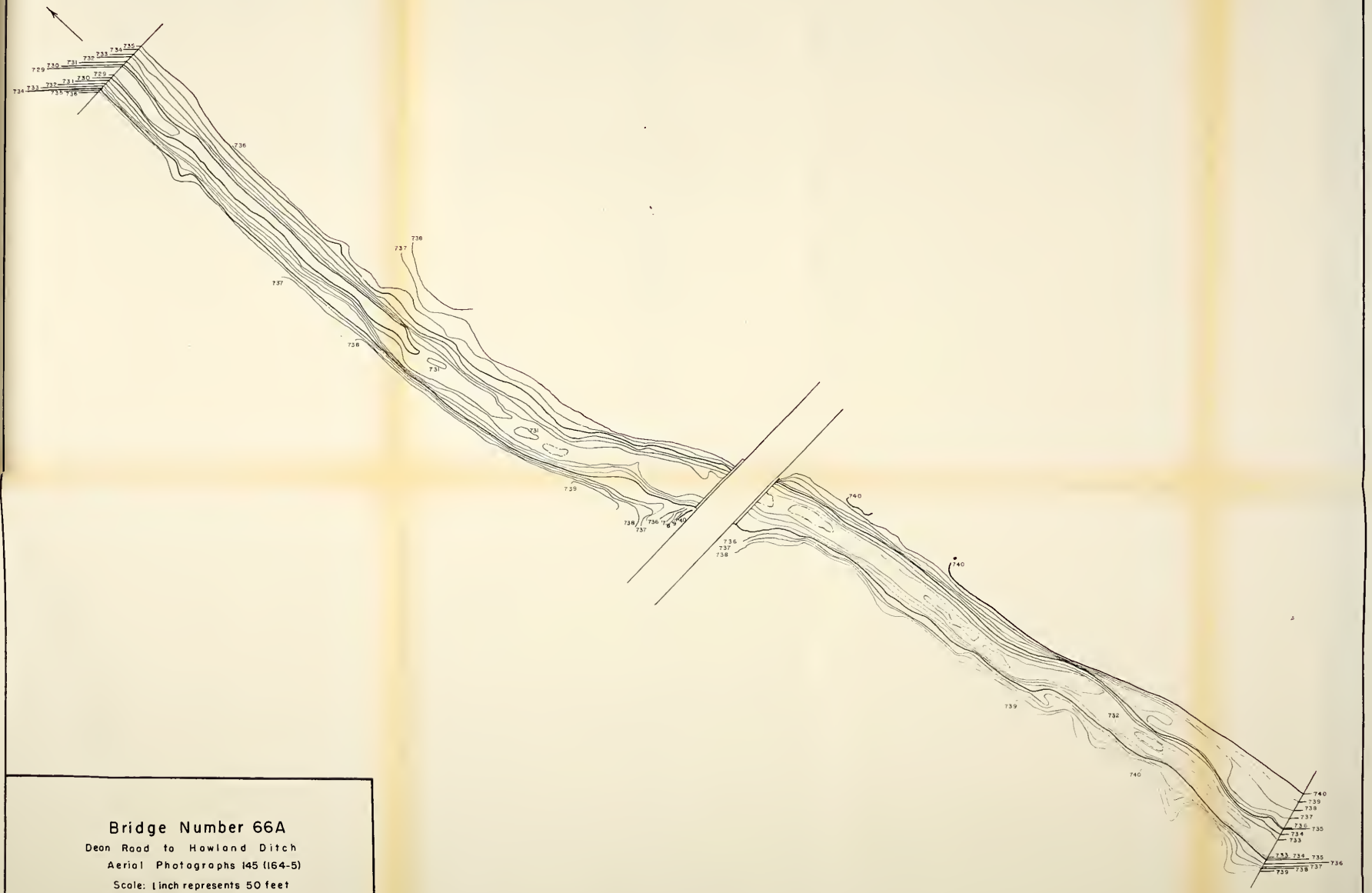
Bridge Number 59A

Plainfield–White Lick Creek and 267

Aerial Photographs 48(159-60)

Scale: one inch represents 50 feet

FIG 9-9-6 July 1963



Bridge Number 66A

Deon Road to Howland Ditch

Aerial Photographs 145 (164-5)

Scale: 1 inch represents 50 feet

July 1963

FIG. 9-10-6