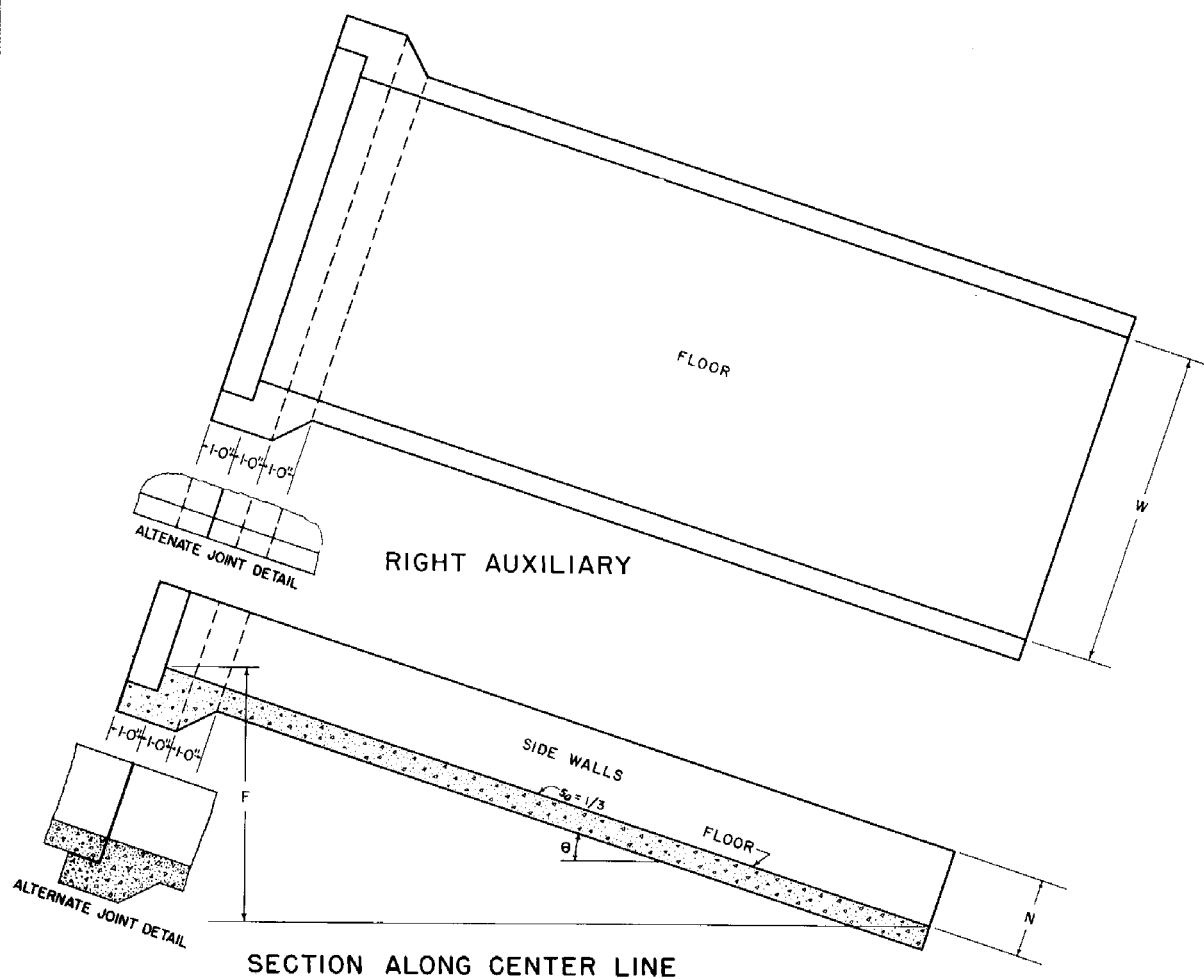
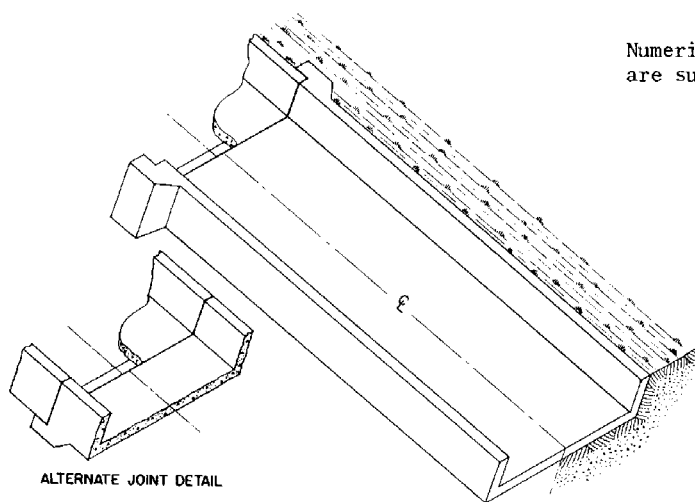


CHUTE SPILLWAYS: CHANNELS

Layout



Numerical values shown
are suggested minimums.



ISOMETRIC VIEW

REFERENCE

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION-DESIGN SECTION

STANDARD DWG. NO.

ES-84

SHEET 1 OF 4

DATE April 1954

Revised 10/77

CHUTE SPILLWAYS: CHANNELS; Definition of symbols and Formulas

Capacities of
Channel Sections

N	q_{mN}	$N \cos \theta^\dagger$
2.00	41.00	1.90
2.25	46.80	2.13
2.50	52.65	2.37
2.75	58.65	2.60
3.00	64.80	2.85
3.25	71.15	3.08
3.50		3.32
3.75		3.56
4.00		3.80
4.25		4.03

*Values of q_{mN} are for values of $\bar{z} = 8$ ft. For other values of $\bar{z}$ see table 2, ES-88.

†Values are for channels of $\bar{z}$ to 1 slope.

DEFINITION OF SYMBOLS

- N = Height normal to slope s_o of side-wall of channel in ft
 Z = Vertical drop from crest of inlet to floor of outlet in ft
 D = Vertical distance from crest of inlet to top of floor at entrance of vertical curve section in ft. This is zero for straight inlets
 F = Vertical distance from upstream end to downstream end of channel in ft
 J = Height of sidewalls of SAF above floor in ft
 $\bar{z}$ = Vertical drop of vertical curve section in ft
 W = Width of vertical curve section in ft
 n = Number of channel sections required
 $\theta = \tan^{-1} s_o$
 s_o = Slope of floor of channel in ft/ft
 Q_r = Design discharge in cfs
 Q_{fr} = Required capacity without freeboard in cfs
 q_{mc} = Capacity per foot width of channel without freeboard in cfs/ft

FORMULAS

$$F = Z + N \cos \theta - (J + \bar{z} + D)$$

$$Q_{fr} = (1.20 + 0.003 Z) Q_r$$

$$q_{mN} = q_{mc}$$

REFERENCE

U.S. DEPARTMENT OF AGRICULTURE
 SOIL CONSERVATION SERVICE
 ENGINEERING DIVISION - DESIGN SECTION

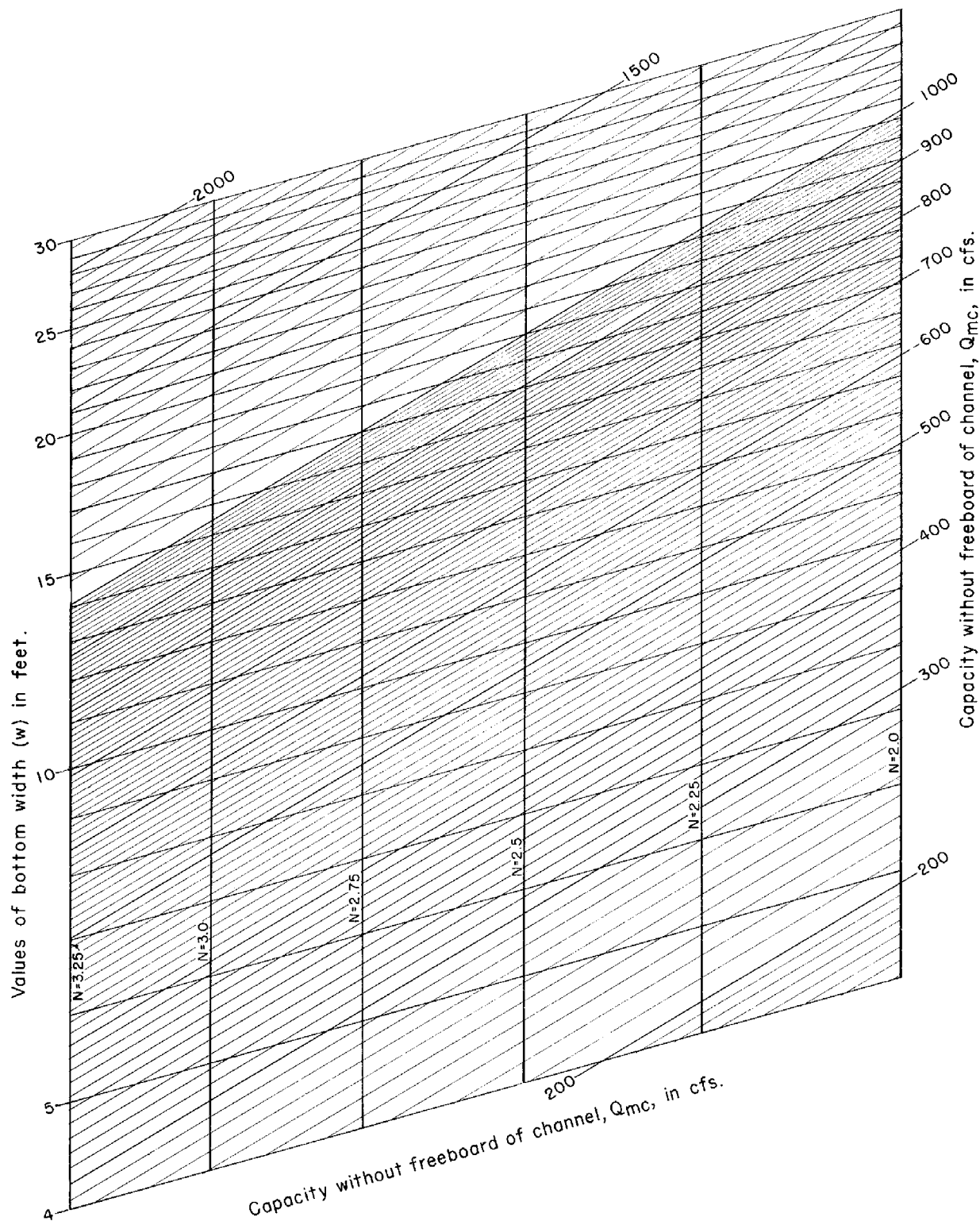
STANDARD DWG. NO.

ES-84

SHEET 2 OF 4
 DATE March 1954

Revised 10/77

CHUTE SPILLWAYS: CHANNELS; Capacities Without Freeboard.



REFERENCE

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION-DESIGN SECTION

STANDARD DWG. NO.

ES-84

SHEET 3 OF 4
DATE 5-3-54

Revised 10/77

CHUTE SPILLWAY: CHANNEL; Example

EXAMPLE

Given: A chute of width, $W = 10$ ft, has a design discharge, $Q_r = 380$ cfs, and a 3 to 1 slope. The chute has a vertical drop from the crest of the straight inlet to the floor of the outlet of $Z = 47$ ft. The vertical curve section has a vertical drop of $\bar{z} = 8$ ft and the SAR outlet has the dimension $J = 15$ ft. The inlet will require no freeboard as a result of waves.

- Determine:
1. The recommended required capacity of the chute: (i) Q_{fr} ; (ii) q_{fr}
 2. The required height of the sidewalls, N , of the channel
 3. The vertical drop, F , required for the channel
 4. The number of joints in the channel if they are spaced less than or equal to 9.5 ft (vertically) apart
 5. The velocity and depth of flow with air entrainment and without air entrainment at the end of the channel section for the discharge Q_{fr}

Solution: 1. The recommended required capacity of the chute is

$$\begin{aligned} \text{(i)} \quad Q_{fr} &= (1.20 + 0.003 Z) Q_r \\ Q_{fr} &= [1.20 + 0.003 (47)] 380 \\ Q_{fr} &= 509.6 \text{ cfs} \end{aligned}$$

$$\text{(ii)} \quad q_{fr} = \frac{Q_{fr}}{W} = \frac{509.6}{10} = 50.96 \text{ cfs/ft}$$

2. (a) The required height of the sidewalls of the channel may be read from the table on sheet 2 as

$$N = 2.50 \text{ ft}$$

- (b) The required height of the sidewalls of the channel may also be read on sheet 3 at the intersection of $Q_{fr} = 509.6$ cfs and $W = 10$ ft as

$$N = 2.50 \text{ ft}$$

3. The vertical drop of the channel is given by the formula ($D = 0$)

$$F = Z + N \cos \theta - (J + \bar{z})$$

$$F = 47 + 2.37 - (15 + 8)$$

$$F = 26.37 \text{ ft}$$

Values of $N \cos \theta$ when $\theta = \tan^{-1} 0.33333$ are given in the table on sheet 2.

4. The number of joints is

$$n = \frac{F}{9.5} = \frac{26.37}{9.5} = 2.77$$

Three joints are required.

5. The downstream end of the channel is located a vertical distance of $\bar{z} + F$ or $8 + 26.37 = 34.37$ ft below the floor of the inlet. Read on ES-78 the intersection of $q = 50.96$ cfs and $y = 34.37$ ft the values

$$d = 1.066 \text{ ft}$$

$$p = 1.33$$

The velocity, v , of the air-water admixture is

$$v = \frac{q}{d} = \frac{50.96}{1.066} = 47.8 \text{ ft/sec}$$

The depth of water without air entrainment is

$$d = 1.066 \text{ ft}$$

The depth of air-water admixture, d_a , is

$$d_a = p d = (1.33)(1.066) = 1.42 \text{ ft}$$

REFERENCE

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.

ES-84

SHEET 4 OF 4

DATE March 1954

SAF OUTLETS

The criteria for the dimensions of the SAF outlet were developed by Fred W. Blaisdell¹, Hydraulic Engineer, SCS, St. Anthony Falls Hydraulic Laboratory. These criteria are given as design formulas in ES-73, page 2.193, and ES-86, page 2.198. (See ES-73, page 2.193, for nomenclature.)

Function of SAF Outlet. The function of the SAF outlet is to convert, for all discharges equal to or less than the design discharge, supercritical velocities to subcritical velocities in a manner which will be nonerosive in erodible channels. Obviously, certain criteria will be required of the channels downstream from the outlet for its proper functioning. These requirements will be presented later.

Freeboard. The SAF outlet functions well for all discharges less than its capacity without freeboard. It will generally function quite well for greater discharges for short periods of flow. The freeboard recommended for SAF outlets is expressed in terms of the increased discharge f_r . (See Eq. 2.1, page 2.7.) The recommended required capacity of the SAF outlet without freeboard is Q_{fr} as defined by Eq. 2.2, page 2.7.

Hydraulic Criteria. The criteria for the SAF outlet are expressed by a graph having the coordinates v_1 and d_1 . (See ES-73.) These criteria are applicable for a range of Froude's numbers from 3 to 300. The coordinate d_1 (entrance depth) is the fictitious depth of flow d as given by ES-78 and ES-86. As given by ES-78, the value of y is the vertical distance between the floors of the inlet and outlet of a chute spillway having a 3 to 1 slope. The depth of d_1 for chutes having bottom slopes other than 3 to 1, 4 to 1, and 10 to 1 may be calculated by the general differential equation given in ES-78, page 2.145 or interpolated using the diagrams of ES-78. The effect of air entrainment can be neglected in the design of SAF outlet. The coordinate v_1 is the entrance velocity as determined by ES-78 and the equation

$$v_1 = \frac{q}{d_1} \quad 7.1$$

Knowing d_1 and v_1 make it possible to determine L_B and J from sheet 2 of ES-73. For Froude's numbers less than 20, the crest of the boil occurs in the stilling basin. For higher Froude's numbers, the crest occurs downstream from the endsill. The height J of the stilling basin sidewalls is sufficient to keep most splash in the basin. This height is not excessive in most cases.

The wingwalls can be used as retaining walls for earth. Their prime function, however, is to prevent eddies along each side of the downstream channel which would cause excessive scour. Wingwalls can be set parallel or perpendicular to the sidewalls if necessary, but the 45° angle with the chute axis is the preferred location in terms of hydraulic functioning.

Knowing d_1 and v_1 make it possible to determine the dimensions of the endsill s and the required tailwater height d_2' . The endsill is used to

¹Blaisdell, Fred W., Development and Hydraulic Design, Saint Anthony Falls Stilling Basin, Trans. ASCE, Vol. 113, p. 483, 1948.

deflect the bottom currents in the floor of the basin upward and off of the stream bed. It is also used to deflect the bottom currents of the roller, which are in an upstream direction, upward. This roller brings bed material from downstream and deposits it against the endsill. Because of this, a toe-wall of only nominal depth is required. The criterion of tailwater depth d_2' is a minimum requirement for the SAF outlet to function properly. When the tailwater depth is too low, the roller is forced away from the endsill of the outlet. When the tailwater is too great, the tailwater will flow in an eddy upstream along the sidewalls to re-enter the stilling basin and the outlet will not function properly. For those situations in which the tailwater can fluctuate in depth for a discharge equal to the required capacity without freeboard, the minimum tailwater depth will determine the elevation of the endsill. (See below.) The sidewall height J should be increased in amount equal to the difference between the maximum and minimum tailwater depths which may be expected for a discharge equal to the required capacity without freeboard. The SAF outlet will operate satisfactorily for greater tailwater depths than the d_2' provided the sidewall heights are sufficiently great to prevent re-entrance of the tailwater over the top of the sidewalls into the basin. The tailwater elevation at the endsill can be determined by computing the water-surface profile from a point sufficiently far downstream from the endsill for a discharge equal to the discharge Q_{fr} . (See Engineering Handbook, Section 5, Hydraulics.) The flow in this region is subcritical; therefore, these calculations are made in an upstream direction. The SAF outlet will not prevent erosion in the channel downstream from the SAF if the channel is scouring. When a scouring condition exists, it should be realized that the tailwater elevation will be lowered after a period of time because the channel bottom is lowered as a result of erosion. Scouring can be controlled by a gradient control structure downstream from the SAF outlet. The minimum required tailwater elevation in terms of depth d_2' above the SAF floor can be attained in one of two ways:

1. Proper determination of the elevation of the SAF outlet floor with respect to the nonerosive channel bottom.
2. Construction of a structure downstream from the SAF outlet to fix the tailwater elevation.

The criteria for chute and floor blocks and their placement are given on sheet 1 of ES-73. Pitting of concrete due to cavitation will occur at the floor and chute blocks when the entrance velocity v_1 is greater than 65 ft/sec.¹ When such a condition occurs, these blocks can be designed of a shape to eliminate cavitation. The purpose of these blocks is to remove energy from the water and help create turbulence to effectively cause energy dissipation.

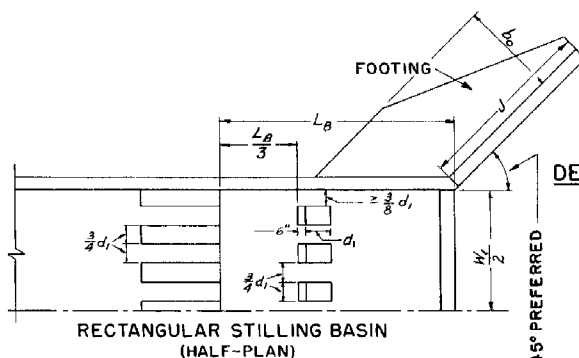
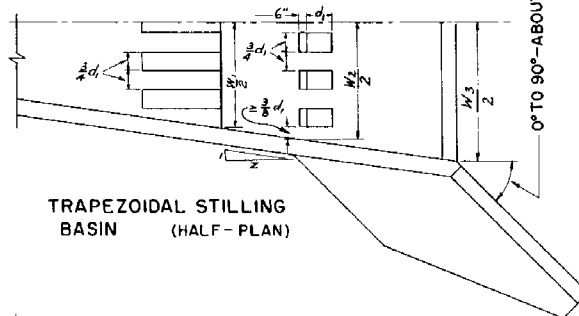
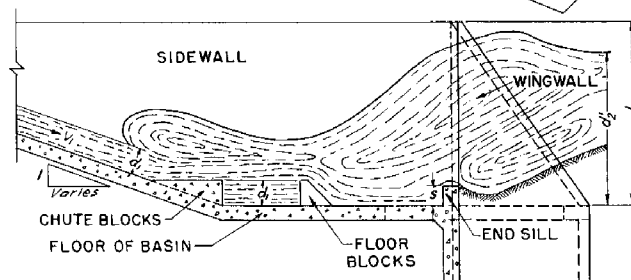
The basin having diverging sidewalls appears to be slightly more effective than the basin with parallel sidewalls.

All odd dimensions read from ES-73 should be increased to the next even number to simplify construction.

¹Thomas, H. A., and Hopkins, Cavitation on Baffle Piers, Proceedings of the Second Hydraulic Conference, Iowa, June 1942.

ES-86, page 2.202, gives the capacity without freeboard q_{mo} of SAF outlets for various values of d_1 , J , and L_B . For a given required capacity without freeboard, a study of ES-78 and ES-86 will show an increase in the width of the chute will decrease q_{mo} , d_1 , J , and L_B . The corresponding values for required tailwater depth d_2' and height of endsill s is given on page 2.203. These values are also listed in tabular form on pages 2.199 to 2.201.

HYDRAULIC DESIGN CRITERIA AND CHARTS FOR SAF STILLING BASIN

RECTANGULAR STILLING BASIN
(HALF-PLAN)TRAPEZOIDAL STILLING
BASIN
(HALF-PLAN)

SECTION ALONG CENTER LINE

DETAILS OF LAYOUT FOR FLOOR AND CHUTE BLOCKS

1. HEIGHT OF FLOOR AND CHUTE BLOCKS IS d_1
2. WIDTH AND SPACING OF FLOOR AND CHUTE BLOCKS APPROXIMATELY $\frac{3d_1}{4}$
3. NO FLOOR BLOCK SHOULD BE PLACED CLOSER TO SIDEWALL THAN $\frac{3d_1}{8}$
4. FLOOR BLOCKS OCCUPY BETWEEN 40 AND 55 PERCENT OF STILLING BASIN WIDTH AT BLOCKS
5. CHUTE BLOCKS TO BE STAGGERED WITH FLOOR BLOCKS
6. A PORTION OF A CHUTE BLOCK OR A WHOLE CHUTE BLOCK MAY BE ADJACENT TO A SIDEWALL
7. SPACE BETWEEN SIDEWALL AND FIRST CHUTE BLOCK IS NOT TO BE GREATER THAN APPROXIMATELY $\frac{3d_1}{4}$
8. BLOCKS ARE TO BE SYMMETRICAL ABOUT STILLING BASIN CENTER LINE

DESIGN FORMULAS

$$3 \leq F_1 \leq 300$$

$$1. \quad F_1 = \frac{v_1^2}{g d_1}$$

$$2. \quad d_2 = \frac{d_1}{2} (-1 + \sqrt{8 F_1 + 1})$$

$$3. \quad d_2' = 1.4 d_1 F_1^{0.45}$$

$$4. \quad L_B = \frac{4.5 d_2}{F_1^{0.38}}$$

$$5. \quad J = \frac{d_2}{3} + d_2'$$

$$6. \quad s = 0.07 d_2$$

$$7. \quad z \geq 3 \sqrt{F_1}$$

DEFINITION OF SYMBOLS

F_1 = FROUDE'S NUMBER $\equiv \frac{v_1^2}{g d_1}$ (DIMENSIONLESS NUMBER)

v_1 = ENTRANCE VELOCITY OF WATER TO SAF STILLING BASIN — FT./SEC.

d_1 = ENTRANCE DEPTH OF WATER TO SAF STILLING BASIN — FEET

L_B = LENGTH OF SAF STILLING BASIN — FEET

J = HEIGHT OF SIDEWALLS OF SAF STILLING BASIN — FEET

s = HEIGHT OF TRANSVERSE END SILL OF SAF STILLING BASIN — FEET

d_2' = REQUIRED HEIGHT OF TAILWATER OVER SAF STILLING BASIN — FEET

d_2 = SEQUENT DEPTH OF FLOW TO DEPTH d_1 — FEET

g = ACCELERATION DUE TO GRAVITY — 32.16 FT./SEC.²

W_1 = WIDTH OF SAF STILLING BASIN AT DOWNSTREAM END OF CHUTE BLOCKS — FEET

W_2 = WIDTH OF SAF STILLING BASIN AT UPSTREAM END OF FLOOR BLOCKS — FEET

W_3 = WIDTH OF SAF STILLING BASIN AT DOWNSTREAM END — FEET

z = DIVERGENCE OF SIDEWALL (RATIO)

REFERENCE

Blaisdell, F.W. "Development and Hydraulic Design, Saint Anthony Falls Stilling Basin." (SAF Stilling Basin)
Trans. A S C E 113 P. 483-561; 1948

U. S. DEPARTMENT OF AGRICULTURE
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STANDARD DRAWING NO.

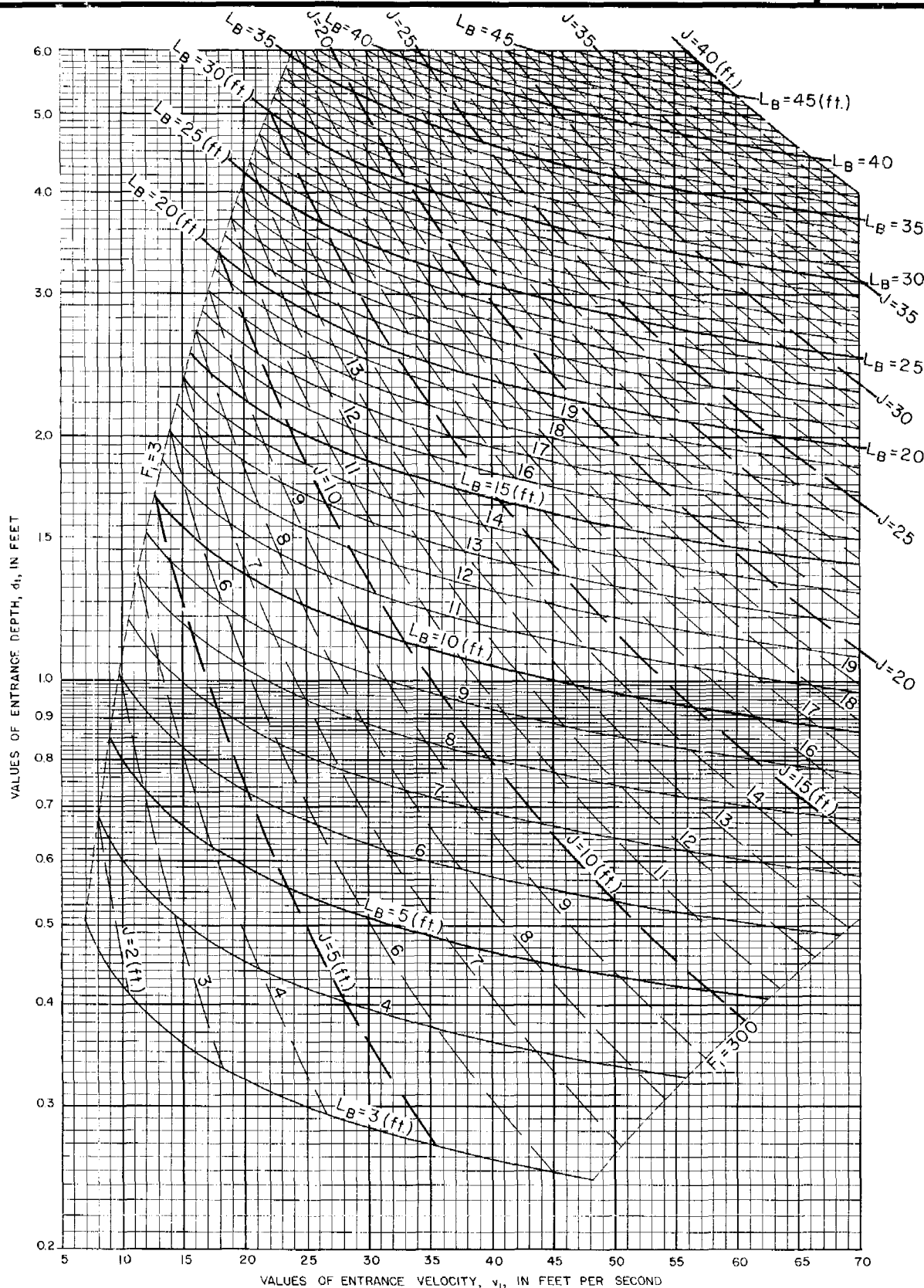
ES-73

SHEET 1 OF 3

DATE: 3-23-53
Revised 4-10-54

HYDRAULIC DESIGN CRITERIA AND CHARTS FOR SAF STILLING BASIN

L_B -Feet
J-Feet



REFERENCE

Blaisdell, F. W. "Development And Hydraulic Design, Saint Anthony Falls Stilling Basin." (SAF Stilling Basin) Trans. A S C E 113 P 483-561, 1948
This diagram was developed by Paul D. Doubt, Engineering Design Section.

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ENGINEERING DIVISION-DESIGN SECTION

STANDARD DRAWING NO.

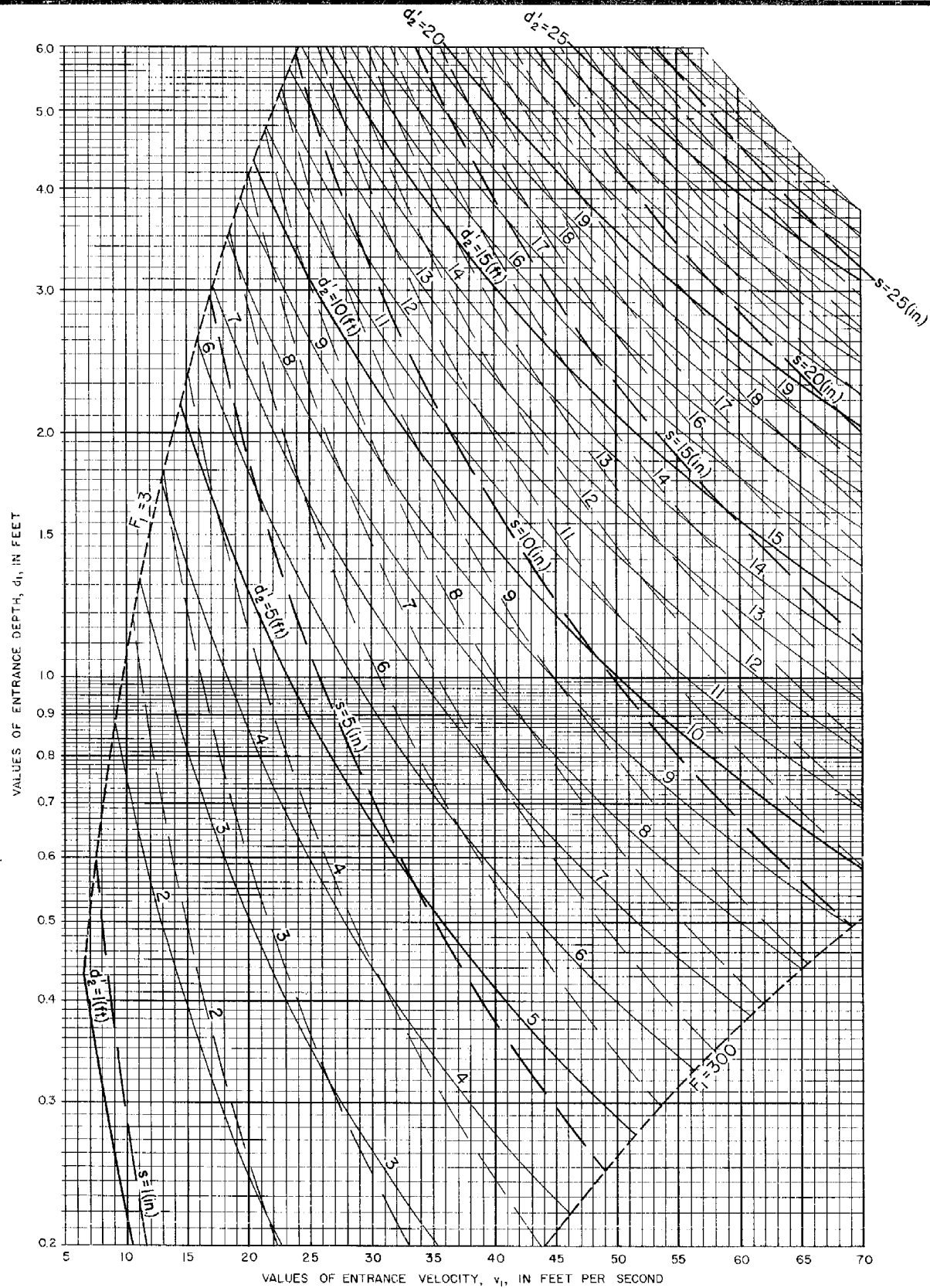
ES-73

SHEET 2 OF 3

DATE: 3-23-53
Revised 4-10-54

HYDRAULIC DESIGN CRITERIA AND CHARTS FOR SAF STILLING BASIN

s - Inches
d₂ - Feet



REFERENCE

Elaissell, F. W. "Development And Hydraulic Design, Saint Anthony Falls Stilling Basin." (SAF Stilling Basin)

Trans. A S C E 113 P. 483-561; 1948

This diagram was developed by Paul D. Doubt, Engineering Design Section.

U. S. DEPARTMENT OF AGRICULTURE
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STANDARD DRAWING NO.

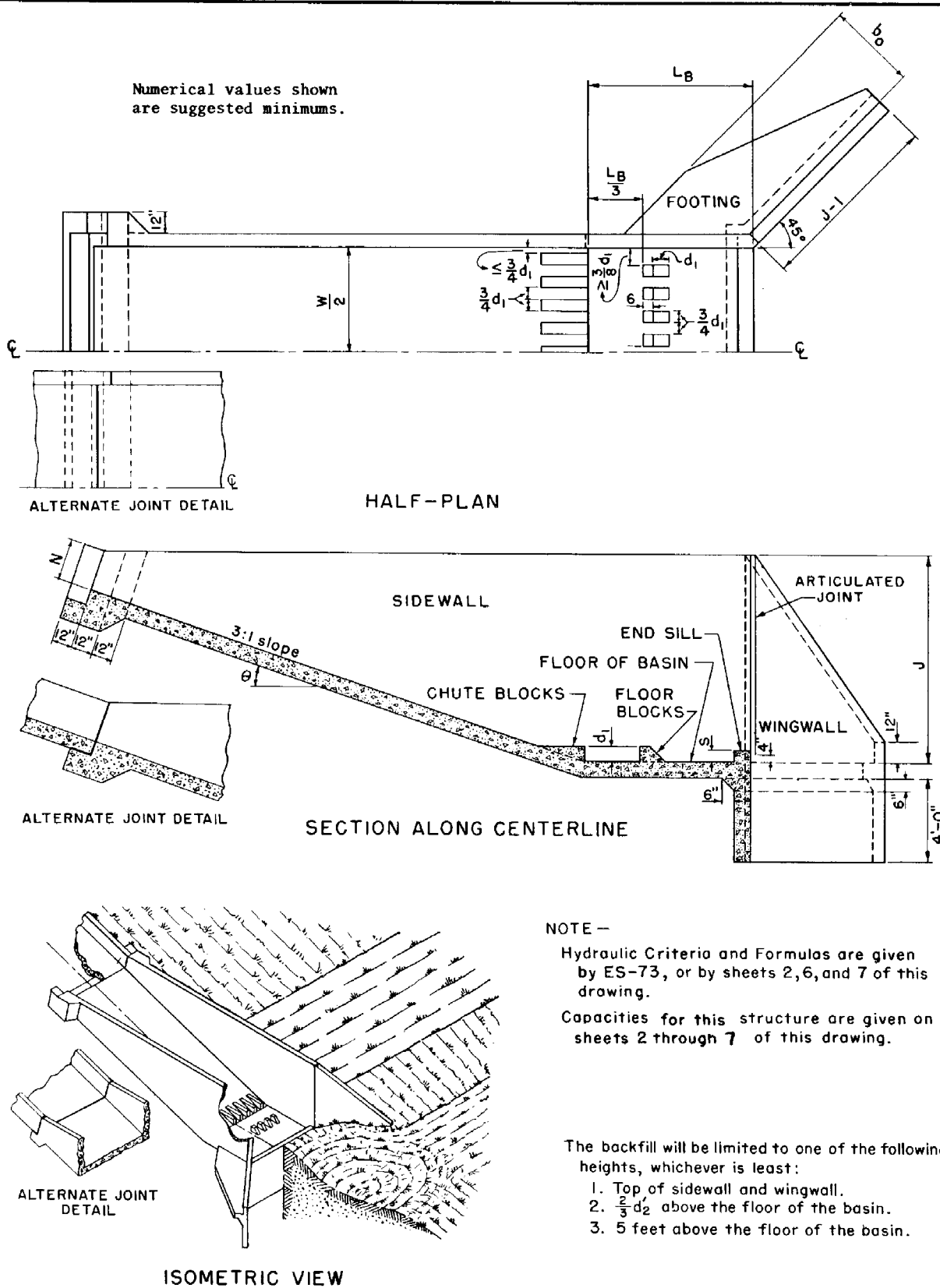
ES-73

SHEET 3 OF 3

DATE: 3-23-53
Revised 4-10-54

CHUTE SPILLWAYS: SAF OUTLETS

The General Layout Drawing



REFERENCE:

U. S. DEPARTMENT OF AGRICULTURE
 SOIL CONSERVATION SERVICE
 ENGINEERING DIVISION- DESIGN SECTION

STANDARD DWG. NO.

ES- 86

SHEET 1 OF 8 SHEETS

DATE 3-30-54

Revised: 11-1-54

Revised 10/77

CHUTE SPILLWAYS: SAF OUTLETS;

Definition of symbols and Formulas

DEFINITION OF SYMBOLS

- F_1 = Froude's number $= \frac{v_1^2}{gd_1}$ at entrance of SAF basin (dimensionless number)
 J = Height of sidewalls of SAF above floor in ft
 L_B = Length of SAF basin (including end sill) in ft
 d_1 = Height of floor and chute blocks above floor of SAF basin in ft
 d_1 = Entrance depth of water without air to SAF basin in ft
 s = Height of transverse end sill above floor of SAF basin in inches
 d_2' = Required height of tailwater above floor of SAF basin in ft
 d_2 = Sequent depth of flow to depth d_1 in ft
 v_1 = Entrance velocity of water to SAF basin in ft/sec
 W = Width of SAF outlet in ft
 Q_r = Design discharge in cfs
 Q_{fr} = Recommended required capacity without freeboard of SAF outlet in cfs
 Q_{mo} = Capacity without freeboard of SAF outlet in cfs
 Q_{so} = Capacity of SAF outlet in cfs
 q_r = Design discharge per foot width in cfs/ft
 q_{mo} = Capacity without freeboard of SAF outlet per foot width in cfs/ft
 s_o = Slope of bottom of channel in the SAF outlet ft/ft
 N = Perpendicular height of sidewalls above channel floor at upstream end of SAF outlet in ft
 g = Acceleration due to gravity--32.16 ft/sec²

DESIGN FORMULAS

$$3 \leq F_1 \leq 300$$

$$1. \quad F_1 = \frac{v_1^2}{gd_1}$$

$$4. \quad L_B = \frac{4.5 d_2}{F_1^{0.38}}$$

$$2. \quad d_2 = \frac{d_1}{2} (-1 + \sqrt{8 F_1 + 1})$$

$$5. \quad J = \frac{d_2}{3} + d_2'$$

$$3. \quad d_2' = 1.4 d_1 F_1^{0.45}$$

$$6. \quad s = 0.07 d_2$$

$$Q_{fr} = (1.20 + 0.003 Z) Q_r$$

The backfill will be limited to one of the following heights, whichever is least:

1. Top of sidewall and wing-wall.
2. $\frac{2}{3}d_2'$ above the floor of the basin,
3. 5 feet above the floor of the basin.

REFERENCE

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
 ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.

ES-86

SHEET 2 OF 8

DATE February 1954

Revised 10/77

CHUTE SPILLWAYS: SAF OUTLETS

Dimensions and Capacities

$$S_o = \frac{1}{3}$$

J = 3.0 to 10.5

J	L _B	N	b _o	d ₁	q _{mo}
3.0	3.0	2.00	2.75	0.3330	6.061
3.5	3.0	2.00	3.00	0.3100	6.913
3.5	3.5	2.00	3.00	0.3800	7.638
3.5	4.0	2.00	3.00	0.4720	8.354
4.0	3.5	2.00	3.50	0.3640	8.518
4.0	4.0	2.00	3.50	0.4410	9.305
4.5	3.5	2.00	4.00	0.3470	9.490
4.5	4.0	2.00	4.00	0.4205	10.323
5.0	3.5	2.00	4.25	0.3315	10.409
5.0	4.0	2.00	4.25	0.4015	11.322
5.0	4.5	2.00	4.25	0.4750	12.160
5.0	5.0	2.00	4.25	0.5550	13.043
5.5	3.5	2.00	4.25	0.3185	11.291
5.5	4.0	2.00	4.25	0.3860	12.273
5.5	4.5	2.00	4.25	0.4560	13.201
5.5	5.0	2.00	4.25	0.5300	14.098
5.5	5.5	2.00	4.25	0.6100	15.036
6.0	3.5	2.00	4.25	0.3085	12.216
6.0	4.0	2.00	4.25	0.3725	13.261
6.0	4.5	2.00	4.25	0.4400	14.256
6.0	5.0	2.00	4.25	0.5100	15.198
6.0	5.5	2.00	4.25	0.5870	16.172
6.0	6.0	2.00	4.25	0.6660	17.116
6.5	3.5	2.00	4.25	0.3000	13.155
6.5	4.0	2.00	4.25	0.3595	14.218
6.5	4.5	2.00	4.25	0.4250	15.300
6.5	5.0	2.00	4.25	0.4925	16.302
6.5	5.5	2.00	4.25	0.5650	17.317
6.5	6.0	2.00	4.25	0.6410	18.333
6.5	6.5	2.00	4.25	0.7240	19.331
6.5	7.0	2.00	4.25	0.8040	20.261
7.0	4.0	2.00	4.25	0.3490	15.120
7.0	4.5	2.00	4.25	0.4125	16.335
7.0	5.0	2.00	4.25	0.4780	17.424
7.0	5.5	2.00	4.25	0.5455	18.438
7.0	6.0	2.00	4.25	0.6200	19.530
7.0	6.5	2.00	4.25	0.6990	20.551
7.0	7.0	2.00	4.25	0.7780	21.551
7.0	7.5	2.00	4.25	0.8615	22.550
7.0	8.0	2.00	4.25	0.9480	23.558
7.5	4.0	2.00	4.25	0.3395	16.177
7.5	4.5	2.00	4.25	0.4000	17.340
7.5	5.0	2.00	4.25	0.4645	18.487
7.5	5.5	2.00	4.25	0.5290	19.626
7.5	6.0	2.00	4.25	0.6013	20.740
7.5	6.5	2.00	4.25	0.6760	21.835
7.5	7.0	2.00	4.25	0.7520	22.898
7.5	7.5	2.00	4.25	0.8350	23.965
7.5	8.0	2.00	4.25	0.9150	24.888
7.5	8.5	2.00	4.25	1.0000	25.970
7.5	8.5	2.25	4.25	1.0000	25.970
7.5	8.5	2.50	4.25	1.0000	25.970
8.0	4.5	2.00	4.25	0.3900	18.408
8.0	5.0	2.00	4.25	0.4525	19.639
8.0	5.5	2.00	4.25	0.5145	20.760
8.0	6.0	2.00	4.25	0.5850	21.967
8.0	6.5	2.00	4.25	0.6570	23.126
8.0	7.0	2.00	4.25	0.7310	24.196
8.0	7.5	2.00	4.25	0.8080	25.250
8.0	8.0	2.00	4.25	0.8850	26.285
8.0	8.5	2.00	4.25	0.9700	27.354
8.0	9.0	2.00	4.25	1.0580	28.460
8.0	9.0	2.25	4.25	1.0580	28.460
8.0	9.0	2.50	4.25	1.0580	28.460
8.0	9.5	2.25	4.25	1.1450	29.541
8.0	9.5	2.50	4.25	1.1450	29.541
8.0	9.5	2.75	4.25	1.1450	29.541
8.0	9.5	3.00	4.25	1.1450	29.541
8.5	5.0	2.00	4.25	0.4410	20.683
8.5	5.5	2.00	4.25	0.5015	21.865
8.5	6.0	2.00	4.25	0.5700	23.142
8.5	6.5	2.00	4.25	0.6390	24.346
8.5	7.0	2.00	4.25	0.7110	25.418
8.5	7.5	2.00	4.25	0.7860	26.567
8.5	8.0	2.00	4.25	0.8620	27.756
8.5	8.5	2.00	4.25	0.9400	28.856
8.5	9.0	2.00	4.25	1.0270	29.937
8.5	9.0	2.25	4.25	1.0270	29.937
8.5	9.5	2.00	4.25	1.1150	30.997
8.5	9.5	2.25	4.25	1.1150	30.997
8.5	9.5	2.50	4.25	1.1150	30.997
8.5	9.5	2.75	4.25	1.1150	30.997
8.5	10.0	2.50	4.25	1.2030	32.060

J	L _B	N	b _o	d ₁	q _{mo}
8.5	10.0	2.75	4.25	1.2030	32.060
8.5	10.0	3.00	4.25	1.2030	32.060
9.0	5.0	2.00	4.25	0.4300	21.737
9.0	5.5	2.00	4.25	0.4910	23.028
9.0	6.0	2.00	4.25	0.5570	24.369
9.0	6.5	2.00	4.25	0.6220	25.595
9.0	7.0	2.00	4.25	0.6930	26.784
9.0	7.5	2.00	4.25	0.7650	27.961
9.0	8.0	2.00	4.25	0.8410	29.099
9.0	8.5	2.00	4.25	0.9170	30.261
9.0	9.0	2.00	4.25	1.0000	31.400
9.0	9.0	2.25	4.25	1.0000	31.400
9.0	9.5	2.00	4.25	1.0840	32.520
9.0	9.5	2.25	4.25	1.0840	32.520
9.0	9.5	2.50	4.25	1.0840	32.520
9.0	10.0	2.25	4.25	1.1700	33.638
9.0	10.0	2.50	4.25	1.1700	33.638
9.0	10.0	2.75	4.25	1.1700	33.638
9.0	10.5	2.50	4.25	1.2600	34.776
9.0	10.5	2.75	4.25	1.2600	34.776
9.0	10.5	3.00	4.25	1.2600	34.776
9.0	11.0	2.75	4.25	1.3500	35.892
9.0	11.0	3.00	4.25	1.3500	35.892
9.0	11.0	3.25	4.25	1.3500	35.892
9.0	11.0	3.50	4.25	1.3500	35.892
9.0	11.0	3.75	4.25	1.3500	35.892
9.5	5.5	2.00	4.25	0.4800	24.240
9.5	6.0	2.00	4.25	0.5450	25.533
9.5	6.5	2.00	4.25	0.6100	26.901
9.5	7.0	2.00	4.25	0.6775	28.116
9.5	7.5	2.00	4.25	0.7470	29.320
9.5	8.0	2.00	4.25	0.8200	30.545
9.5	8.5	2.00	4.25	0.8940	31.692
9.5	9.0	2.00	4.25	0.9760	32.940
9.5	9.5	2.00	4.25	1.0540	34.097
9.5	9.5	2.25	4.25	1.0540	34.097
9.5	10.0	2.00	4.25	1.1390	35.252
9.5	10.0	2.25	4.25	1.1390	35.252
9.5	10.0	2.50	4.25	1.1390	35.252
9.5	10.5	2.25	4.25	1.2220	36.355
9.5	10.5	2.50	4.25	1.2220	36.355
9.5	10.5	2.75	4.25	1.2220	36.355
9.5	11.0	2.50	4.25	1.3100	37.466
9.5	11.0	2.75	4.25	1.3100	37.466
9.5	11.0	3.00	4.25	1.3100	37.466
9.5	11.0	3.25	4.25	1.3100	37.466
9.5	11.5	3.00	4.25	1.4040	38.680
9.5	11.5	3.25	4.25	1.4040	38.680
9.5	11.5	3.50	4.25	1.4040	38.680
9.5	11.5	3.75	4.25	1.4040	38.680
9.5	12.0	3.00	4.25	1.4940	39.815
9.5	12.0	3.25	4.25	1.4940	39.815
9.5	12.0	3.50	4.25	1.4940	39.815
9.5	12.0	3.75	4.25	1.4940	39.815
9.5	12.0	4.00	4.25	1.4940	39.815
10.0	5.5	2.00	4.25	0.4720	25.323
10.0	6.0	2.00	4.25	0.5335	26.782
10.0	6.5	2.00	4.25	0.5970	28.059
10.0	7.0	2.00	4.25	0.6625	29.349
10.0	7.5	2.00	4.25	0.7300	30.660
10.0	8.0	2.00	4.25	0.8010	31.880
10.0	8.5	2.00	4.25	0.8740	33.168
10.0	9.0	2.00	4.25	0.9530	34.451
10.0	9.5	2.00	4.25	1.0300	35.638
10.0	10.0	2.00	4.25	1.1100	36.797
10.0	10.0	2.25	4.25	1.1100	36.797
10.0	10.5	2.00	4.25	1.1930	37.937
10.0	10.5	2.25	4.25	1.1930	37.937
10.0	10.5	2.50	4.25	1.1930	37.937
10.0	11.0	2.50	4.25	1.2750	39.079
10.0	11.0	2.75	4.25	1.2750	39.079
10.0	11.0	3.00	4.25	1.2750	39.079
10.0	11.5	2.75	4.25	1.3650	40.268
10.0	11.5	3.00	4.25	1.3650	40.268
10.0	12.0	3.00	4.25	1.4550	41.540
10.0	12.0	3.25	4.25	1.4550	41.540
10.0	12.0	3.50	4.25	1.4550	41.540
10.0	12.5	3.50	4.25	1.5500	42.703
10.0	12.5	3.75	4.25	1.5500	42.703
10.0	12.5	4.00	4.25	1.5500	42.703
10.5	6.0	2.00	4.25	0.5230	27.902
10.5	6.5	2.00	4.25	0.5850	29.367
10.5	7.0	2.00	4.25	0.6500	30.745
10.5	7.5	2.00	4.25	0.7160	32.041
10.5	8.0	2.00	4.25	0.7870	33.369
10.5	8.5	2.00	4.25	0.8570	34.580
10.5	9.0	2.00	4.25	0.9310	35.882
10.5	9.5	2.00	4.25	1.0050	37.135
10.5	10.0	2.00	4.25	1.0850	38.355
10.5	10.0	2.25	4.25	1.0850	38.355

REFERENCE:

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION- DESIGN SECTION

STANDARD DWG. NO.

ES- 86

SHEET 3 OF 8

DATE 9-8-54

Revised 10/77

CHUTE SPILLWAYS: SAF OUTLETS

Dimensions and Capacities

$$S_0 = \frac{1}{3}$$

J = 10.5 to 13.0

J	L _B	N	b ₀	d ₁	q _{mc}
10.5	10.5	2.00	4.25	1.1650	39.610
10.5	10.5	2.25	4.25	1.1650	39.610
10.5	10.5	2.50	4.25	1.1650	39.610
10.5	11.0	2.25	4.25	1.2460	40.744
10.5	11.0	2.50	4.25	1.2460	40.744
10.5	11.0	2.75	4.25	1.2460	40.744
10.5	11.5	2.50	4.25	1.3300	41.962
10.5	11.5	2.75	4.25	1.3300	41.962
10.5	11.5	3.00	4.25	1.3300	41.962
10.5	12.0	2.75	4.25	1.4160	43.188
10.5	12.0	3.00	4.25	1.4160	43.188
10.5	12.0	3.25	4.25	1.4160	43.188
10.5	12.0	3.50	4.25	1.4160	43.188
10.5	12.5	3.00	4.50	1.5120	44.528
10.5	12.5	3.25	4.50	1.5120	44.528
10.5	12.5	3.50	4.50	1.5120	44.528
10.5	13.0	3.25	4.50	1.6080	45.828
10.5	13.0	3.50	4.50	1.6080	45.828
10.5	13.0	3.75	4.50	1.6080	45.828
10.5	13.5	3.25	4.50	1.7000	46.886
10.5	13.5	3.50	4.50	1.7000	46.886
10.5	13.5	3.75	4.50	1.7000	46.886
10.5	13.5	4.00	4.50	1.7000	46.886
10.5	13.5	4.25	4.50	1.7000	46.886
11.0	6.0	2.00	4.50	0.5140	29.118
11.0	6.5	2.00	4.50	0.5745	30.621
11.0	7.0	2.00	4.50	0.6375	32.003
11.0	7.5	2.00	4.50	0.7010	33.298
11.0	8.0	2.00	4.50	0.7710	34.695
11.0	8.5	2.00	4.50	0.8400	36.036
11.0	9.0	2.00	4.50	0.9110	37.260
11.0	9.5	2.00	4.50	0.9860	38.651
11.0	10.0	2.00	4.50	1.0620	39.879
11.0	10.5	2.00	4.50	1.1400	41.154
11.0	10.5	2.25	4.50	1.1400	41.154
11.0	11.0	2.00	4.50	1.2200	42.456
11.0	11.0	2.25	4.50	1.2200	42.456
11.0	11.0	2.50	4.50	1.2200	42.456
11.0	11.5	2.50	4.75	1.3050	43.783
11.0	11.5	2.75	4.75	1.3050	43.783
11.0	11.5	3.00	4.75	1.3050	43.783
11.0	12.0	2.50	4.75	1.3880	45.041
11.0	12.0	2.75	4.75	1.3880	45.041
11.0	12.0	3.00	4.75	1.3880	45.041
11.0	12.5	3.00	4.75	1.4750	46.168
11.0	12.5	3.25	4.75	1.4750	46.168
11.0	13.0	3.00	4.75	1.5650	47.420
11.0	13.0	3.25	4.75	1.5650	47.420
11.0	13.0	3.50	4.75	1.5650	47.420
11.0	13.0	3.75	4.75	1.5650	47.420
11.0	13.5	3.50	4.75	1.6600	48.638
11.0	13.5	3.75	4.75	1.6600	48.638
11.0	13.5	4.00	4.75	1.6600	48.638
11.0	14.0	4.00	4.75	1.7500	49.700
11.0	14.0	4.25	4.75	1.7500	49.700
11.5	6.5	2.00	4.75	0.5640	31.725
11.5	7.0	2.00	4.75	0.6270	33.231
11.5	7.5	2.00	4.75	0.6900	34.673
11.5	8.0	2.00	4.75	0.7570	36.109
11.5	8.5	2.00	4.75	0.8270	37.587
11.5	9.0	2.00	4.75	0.8930	38.801
11.5	9.5	2.00	4.75	0.9670	40.179
11.5	10.0	2.00	4.75	1.0420	41.522
11.5	10.0	2.25	4.75	1.0402	41.522
11.5	10.5	2.00	4.75	1.1200	42.896
11.5	10.5	2.25	4.75	1.1200	42.896
11.5	11.0	2.25	4.75	1.1920	44.104
11.5	11.0	2.50	4.75	1.1920	44.104
11.5	11.5	2.25	4.75	1.2720	45.347
11.5	11.5	2.50	4.75	1.2720	45.347
11.5	11.5	2.75	4.75	1.2720	45.347
11.5	12.0	2.25	4.75	1.3550	46.613
11.5	12.0	2.50	4.75	1.3550	46.613
11.5	12.0	2.75	4.75	1.3550	46.613
11.5	12.0	3.00	4.75	1.3550	46.613
11.5	12.5	2.75	5.00	1.4400	47.880
11.5	12.5	3.00	5.00	1.4400	47.880
11.5	12.5	3.25	5.00	1.4400	47.880
11.5	13.0	3.00	5.00	1.5280	49.278
11.5	13.0	3.25	5.00	1.5280	49.278
11.5	13.0	3.50	5.00	1.5280	49.278
11.5	13.5	3.25	5.00	1.6180	50.482
11.5	13.5	3.50	5.00	1.6180	50.482
11.5	13.5	3.75	5.00	1.6180	50.482
11.5	13.5	4.00	5.00	1.6180	50.482
11.5	14.0	3.75	5.00	1.7030	51.686
11.5	14.0	4.00	5.00	1.7030	51.686
11.5	14.5	3.75	5.00	1.8120	52.942
11.5	14.5	4.00	5.00	1.8120	52.942
11.5	14.5	4.25	5.00	1.8120	52.942
11.5	14.5	4.50	5.00	1.8120	52.942

J	L _B	N	b ₀	d ₁	q _{mc}
12.0	6.5	2.00	4.75	0.5500	32.835
12.0	7.0	2.00	5.00	0.6170	34.552
12.0	7.5	2.00	5.00	0.6785	35.995
12.0	8.0	2.00	5.00	0.7440	37.498
12.0	8.5	2.00	5.00	0.8120	38.935
12.0	9.0	2.00	5.00	0.8770	40.254
12.0	9.5	2.00	5.00	0.9475	41.595
12.0	9.5	2.25	5.00	0.9475	41.595
12.0	10.0	2.00	5.00	1.0200	42.993
12.0	10.0	2.25	5.00	1.0200	42.993
12.0	10.5	2.25	5.00	1.0960	44.388
12.0	11.0	2.25	5.00	1.1680	45.668
12.0	11.5	2.25	5.00	1.2500	47.063
12.0	11.5	2.50	5.00	1.2500	47.063
12.0	12.0	2.25	5.00	1.3300	48.412
12.0	12.0	2.50	5.00	1.3300	48.412
12.0	12.0	2.75	5.00	1.3300	48.412
12.0	12.5	2.25	5.00	1.4120	49.702
12.0	12.5	2.50	5.00	1.4120	49.702
12.0	12.5	2.75	5.00	1.4120	49.702
12.0	12.5	3.00	5.00	1.4120	49.702
12.0	13.0	2.50	5.00	1.5000	51.075
12.0	13.0	2.75	5.00	1.5000	51.075
12.0	13.0	3.00	5.00	1.5000	51.075
12.0	13.0	3.25	5.00	1.5000	51.075
12.0	13.5	3.00	5.00	1.5850	52.305
12.0	13.5	3.25	5.00	1.5850	52.305
12.0	13.5	3.50	5.00	1.5850	52.305
12.0	13.5	3.75	5.00	1.5850	52.305
12.0	14.0	3.50	5.00	1.6700	53.523
12.0	14.0	3.75	5.00	1.6700	53.523
12.0	14.5	3.50	5.00	1.7630	54.829
12.0	14.5	3.75	5.00	1.7630	54.829
12.0	14.5	4.00	5.00	1.7630	54.829
12.0	14.5	4.25	5.00	1.7630	54.829
12.0	15.0	4.00	5.25	1.8600	56.172
12.0	15.0	4.25	5.25	1.8600	56.172
12.0	15.0	4.50	5.25	1.8600	56.172
12.0	15.0	4.75	5.25	1.8600	56.172
12.5	7.0	2.00	5.00	0.6070	35.813
12.5	7.5	2.00	5.00	0.6670	37.252
12.5	8.0	2.00	5.00	0.7300	38.836
12.5	8.5	2.00	5.00	0.7990	40.389
12.5	9.0	2.00	5.00	0.8610	41.715
12.5	9.0	2.25	5.00	0.8610	41.715
12.5	9.5	2.00	5.25	0.9300	43.152
12.5	9.5	2.25	5.25	0.9300	43.152
12.5	10.0	2.25	5.25	1.0010	44.594
12.5	10.5	2.25	5.25	1.0760	46.000
12.5	11.0	2.25	5.25	1.1480	47.355
12.5	11.0	2.50	5.25	1.1480	47.355
12.5	11.5	2.25	5.25	1.2250	48.692
12.5	11.5	2.50	5.25	1.2250	48.692
12.5	12.0	2.50	5.25	1.3030	50.035
12.5	12.0	2.75	5.25	1.3030	50.035
12.5	12.5	2.50	5.25	1.3830	51.378
12.5	12.5	2.75	5.25	1.3830	51.378
12.5	12.5	3.00	5.25	1.3830	51.378
12.5	13.0	2.50	5.25	1.4650	52.740
12.5	13.0	2.75	5.25	1.4650	52.740
12.5	13.0	3.00	5.25	1.4650	52.740
12.5	13.5	3.00	5.25	1.5550	54.114
12.5	13.5	3.25	5.25	1.5550	54.114
12.5	13.5	3.50	5.25	1.5550	54.114
12.5	14.0	3.00	5.25	1.6370	55.412
12.5	14.0	3.25	5.25	1.6370	55.412
12.5	14.0	3.50	5.25	1.6370	55.412
12.5	14.0	3.75	5.25	1.6370	55.412
12.5	14.5	3.50	5.25	1.7300	56.744
12.5	14.5	3.75	5.25	1.7300	56.744
12.5	14.5	4.00	5.25	1.7300	56.744
12.5	15.0	3.75	5.25	1.8180	57.994
12.5	15.0	4.00	5.25	1.8180	57.994
12.5	15.0	4.25	5.25	1.8180	57.994
12.5	15.0	4.50	5.25	1.8180	57.994
12.5	15.5	4.00	5.50	1.9200	59.328
12.5	15.5	4.25	5.50	1.9200	59.328
12.5	15.5	4.50	5.50	1.9200	59.328
12.5	15.5	4.75	5.50	1.9200	59.328
13.0	7.0	2.00	5.25	0.6000	37.320
13.0	7.5	2.00	5.50	0.6560	38.682
13.0	8.0	2.00	5.50	0.7185	40.236
13.0	8.5	2.00	5.50	0.7850	41.762
13.0	8.5	2.25	5.50	0.7850	41.762
13.0	9.0	2.00	5.50	0.8480	43.248
13.0	9.0	2.25	5.50	0.8480	43.248
13.0	9.5	2.25	5.50	0.9170	44.704
13.0	10.0	2.25	5.50	0.9860	46.145
13.0	10.5	2.25	5.50	1.0570	47.565
13.0	10.5	2.50	5.50	1.0570	47.565
13.0	11.0	2.25	5.50	1.1300	48.966
13.0	11.0	2.50	5.50	1.1300	48.966

REFERENCE:

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION- DESIGN SECTION

STANDARD DWG. NO.

ES-86

SHEET 4 OF 8

DATE 9-8-54

Revised 10/77

CHUTE SPILLWAYS: SAF OUTLETS

Dimensions and Capacities

$$S_0 = \frac{1}{3}$$

J = 13.0 to 15.0

J	L _B	N	b ₀	d ₁	q _{mo}
13.0	11.5	2.50	5.50	1.2040	50.327
13.0	12.0	2.50	5.50	1.2850	51.729
13.0	12.5	2.50	5.50	1.3600	53.176
13.0	12.5	2.75	5.50	1.3600	53.176
13.0	13.0	2.50	5.50	1.4380	54.500
13.0	13.0	2.75	5.50	1.4380	54.500
13.0	13.0	3.00	5.50	1.4380	54.500
13.0	13.5	2.75	5.50	1.5230	55.818
13.0	13.5	3.00	5.50	1.5230	55.818
13.0	13.5	3.25	5.50	1.5230	55.818
13.0	14.0	2.75	5.50	1.6080	57.164
13.0	14.0	3.00	5.50	1.6080	57.164
13.0	14.0	3.25	5.50	1.6080	57.164
13.0	14.0	3.50	5.50	1.6080	57.164
13.0	14.5	3.25	5.50	1.6980	58.581
13.0	14.5	3.50	5.50	1.6980	58.581
13.0	14.5	3.75	5.50	1.6980	58.581
13.0	15.0	3.75	5.50	1.7800	59.897
13.0	15.0	4.00	5.50	1.7800	59.897
13.0	15.5	3.75	5.50	1.8800	61.288
13.0	15.5	4.00	5.50	1.8800	61.288
13.0	15.5	4.25	5.50	1.8800	61.288
13.0	15.5	4.50	5.50	1.8800	61.288
13.0	15.5	4.75	5.50	1.8800	61.288
13.0	16.0	3.75	5.50	1.9700	62.548
13.0	16.0	4.00	5.50	1.9700	62.548
13.0	16.0	4.25	5.50	1.9700	62.548
13.0	16.0	4.50	5.50	1.9700	62.548
13.0	16.0	4.75	5.50	1.9700	62.548
13.5	7.5	2.00	5.50	0.6450	39.990
13.5	8.0	2.00	5.50	0.7070	41.572
13.5	8.0	2.25	5.50	0.7070	41.572
13.5	8.5	2.00	5.50	0.7710	43.137
13.5	8.5	2.25	5.50	0.7710	43.137
13.5	9.0	2.25	5.50	0.8350	44.673
13.5	9.5	2.25	5.50	0.9010	46.267
13.5	10.0	2.25	5.50	0.9700	47.724
13.5	10.0	2.50	5.50	0.9700	47.724
13.5	10.5	2.25	5.50	1.0400	49.140
13.5	10.5	2.50	5.50	1.0400	49.140
13.5	11.0	2.50	5.50	1.1120	50.596
13.5	11.5	2.50	5.50	1.1850	52.140
13.5	12.0	2.50	5.50	1.2600	53.550
13.5	12.0	2.75	5.50	1.2600	53.550
13.5	12.5	2.50	5.50	1.3350	54.935
13.5	12.5	2.75	5.50	1.3350	54.935
13.5	13.0	2.75	5.50	1.4130	56.308
13.5	13.0	3.00	5.50	1.4130	56.308
13.5	13.5	2.75	5.75	1.4970	57.784
13.5	13.5	3.00	5.75	1.4970	57.784
13.5	13.5	3.25	5.75	1.4970	57.784
13.5	14.0	2.75	5.75	1.5800	59.250
13.5	14.0	3.00	5.75	1.5800	59.250
13.5	14.0	3.25	5.75	1.5800	59.250
13.5	14.0	3.50	5.75	1.5800	59.250
13.5	14.5	2.75	5.75	1.6650	60.606
13.5	14.5	3.00	5.75	1.6650	60.606
13.5	14.5	3.25	5.75	1.6650	60.606
13.5	14.5	3.50	5.75	1.6650	60.606
13.5	14.5	3.75	5.75	1.6650	60.606
13.5	15.0	2.75	5.75	1.7500	61.950
13.5	15.0	3.00	5.75	1.7500	61.950
13.5	15.0	3.25	5.75	1.7500	61.950
13.5	15.0	3.50	5.75	1.7500	61.950
13.5	15.0	3.75	5.75	1.7500	61.950
13.5	15.5	3.75	5.75	1.8380	63.227
13.5	15.5	4.00	5.75	1.8380	63.227
13.5	16.0	4.25	5.75	1.9280	64.588
13.5	16.0	4.50	5.75	1.9280	64.588
13.5	16.0	4.75	5.75	1.9280	64.588
14.0	8.0	2.00	5.75	0.6960	42.943
14.0	8.0	2.25	5.75	0.6960	42.943
14.0	8.5	2.25	5.75	0.7600	44.536
14.0	9.0	2.25	5.75	0.8210	46.181
14.0	9.5	2.25	5.75	0.8890	47.828
14.0	9.5	2.50	5.75	0.8890	47.828
14.0	10.0	2.25	5.75	0.9540	49.274
14.0	10.0	2.50	5.75	0.9540	49.274
14.0	10.5	2.50	5.75	1.0240	50.739
14.0	11.0	2.50	5.75	1.0930	52.191
14.0	11.5	2.50	5.75	1.1640	53.660
14.0	11.5	2.75	5.75	1.1640	53.660
14.0	12.0	2.50	5.75	1.2380	55.153
14.0	12.0	2.75	5.75	1.2380	55.153
14.0	12.5	2.75	5.75	1.3130	56.630
14.0	13.0	2.75	5.75	1.3880	58.087
14.0	13.5	2.75	5.75	1.4680	59.527
14.0	13.5	3.00	5.75	1.4680	59.527
14.0	14.0	2.75	5.75	1.5500	61.039
14.0	14.0	3.00	5.75	1.5500	61.039
14.0	14.0	3.25	5.75	1.5500	61.039
14.0	14.5	3.00	5.75	1.6320	62.506
14.0	14.5	3.25	5.75	1.6320	62.506

J	L _B	N	b ₀	d ₁	q _{mo}
14.0	14.5	3.50	5.75	1.6320	62.506
14.0	15.0	3.00	5.75	1.7150	63.884
14.0	15.0	3.25	5.75	1.7150	63.884
14.0	15.0	3.50	5.75	1.7150	63.884
14.0	15.0	3.75	5.75	1.7150	63.884
14.0	15.5	3.00	5.75	1.8020	65.279
14.0	15.5	3.25	5.75	1.8020	65.279
14.0	15.5	3.50	5.75	1.8020	65.279
14.0	15.5	3.75	5.75	1.8020	65.279
14.0	15.5	4.00	5.75	1.8020	65.279
14.0	16.0	3.00	6.00	1.8900	66.623
14.0	16.0	3.25	6.00	1.8900	66.623
14.0	16.0	3.50	6.00	1.8900	66.623
14.0	16.0	3.75	6.00	1.8900	66.623
14.0	16.0	4.00	6.00	1.8900	66.623
14.0	16.0	4.25	6.00	1.8900	66.623
14.0	16.0	4.50	6.00	1.8900	66.623
14.0	16.5	3.25	6.00	1.9820	67.982
14.0	16.5	3.75	6.00	1.9820	67.982
14.0	16.5	4.00	6.00	1.9820	67.982
14.0	16.5	4.25	6.00	1.9820	67.982
14.0	16.5	4.50	6.00	1.9820	67.982
14.0	16.5	4.75	6.00	1.9820	67.982
14.0	16.5	5.00	6.00	1.9820	67.982
14.0	16.5	5.25	6.00	1.9820	67.982
14.5	8.0	2.25	6.00	0.6900	44.367
14.5	8.5	2.25	6.00	0.7490	46.064
14.5	9.0	2.25	6.00	0.8100	47.628
14.5	9.0	2.50	6.00	0.8100	47.628
14.5	9.5	2.25	6.00	0.8760	49.273
14.5	9.5	2.50	6.00	0.8760	49.273
14.5	10.0	2.50	6.00	0.9400	50.901
14.5	10.5	2.50	6.00	1.0080	52.416
14.5	11.0	2.50	6.00	1.0750	53.858
14.5	11.0	2.75	6.00	1.0750	53.858
14.5	11.5	2.50	6.00	1.1460	55.409
14.5	11.5	2.75	6.00	1.1460	55.409
14.5	12.0	2.75	6.00	1.2200	56.974
14.5	12.5	2.75	6.00	1.2940	58.424
14.5	13.0	2.75	6.00	1.3700	60.006
14.5	13.0	3.00	6.00	1.3700	60.006
14.5	13.5	3.00	6.00	1.4500	61.553
14.5	14.0	3.00	6.00	1.5300	63.036
14.5	14.5	3.00	6.00	1.6100	64.480
14.5	14.5	3.25	6.00	1.6100	64.480
14.5	15.0	3.00	6.00	1.6900	65.741
14.5	15.0	3.25	6.00	1.6900	65.741
14.5	15.0	3.50	6.00	1.6900	65.741
14.5	15.5	3.00	6.00	1.7720	67.159
14.5	15.5	3.25	6.00	1.7720	67.159
14.5	15.5	3.50	6.00	1.7720	67.159
14.5	15.5	3.75	6.00	1.7720	67.159
14.5	16.0	3.25	6.00	1.8560	68.579
14.5	16.0	3.50	6.00	1.8560	68.579
14.5	16.0	3.75	6.00	1.8560	68.579
14.5	16.0	4.00	6.00	1.8560	68.579
14.5	16.5	3.25	6.00	1.9500	70.020
14.5	16.5	3.75	6.00	1.9500	70.020
14.5	16.5	4.00	6.00	1.9500	70.020
15.0	8.5	2.25	6.00	0.7375	47.348
15.0	8.5	2.50	6.00	0.7375	47.348
15.0	9.0	2.25	6.00	0.7990	49.099
15.0	9.0	2.50	6.00	0.7990	49.099
15.0	9.5	2.50	6.00	0.8640	50.760
15.0	10.0	2.50	6.00	0.9280	52.432
15.0	10.5	2.50	6.25	0.9940	53.974
15.0	10.5	2.75	6.25	0.9940	53.974
15.0	11.0	2.50	6.25	1.0600	55.491
15.0	11.0	2.75	6.25	1.0600	55.491
15.0	11.5	2.75	6.25	1.1350	57.147
15.0	12.0	2.75	6.25	1.2030	58.646
15.0	12.5	2.75	6.25	1.2750	60.116
15.0	12.5	3.00	6.25	1.2750	60.116
15.0	13.0	2.75	6.25	1.3500	61.628
15.0	13.0	3.00	6.25	1.3500	61.628
15.0	13.5	3.00	6.25	1.4250	63.128
15.0	14.0	3.00	6.25	1.5050	64.640
15.0	14.0	3.25	6.25	1.5050	64.640
15.0	14.5	3.00	6.25	1.5860	66.136
15.0	14.5	3.25	6.25	1.5860	66.136
15.0	15.0	3.00	6.25	1.6640	67.558
15.0	15.0	3.25	6.25	1.6640	67.558
15.0	15.0	3.50	6.25	1.6640	67.558
15.0	15.5	3.25	6.25	1.7470	69.007
15.0	15.5	3.50	6.25	1.7470	69.007
15.0	15.5	3.75	6.25	1.7470	69.007
15.0	16.0	3.25	6.25	1.8250	70.445
15.0	16.0	3.50	6.25	1.8250	70.445
15.0	16.0	3.75	6.25	1.8250	70.445
15.0	16.5	3.25	6.25	1.9170	71.983
15.0	16.5	3.50	6.25	1.9170	71.983
15.0	16.5	3.75	6.25	1.9170	71.983
15.0	16.5	4.00	6.25	1.9170	71.983

REFERENCE:

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ES- 86

SHEET 5 OF 8

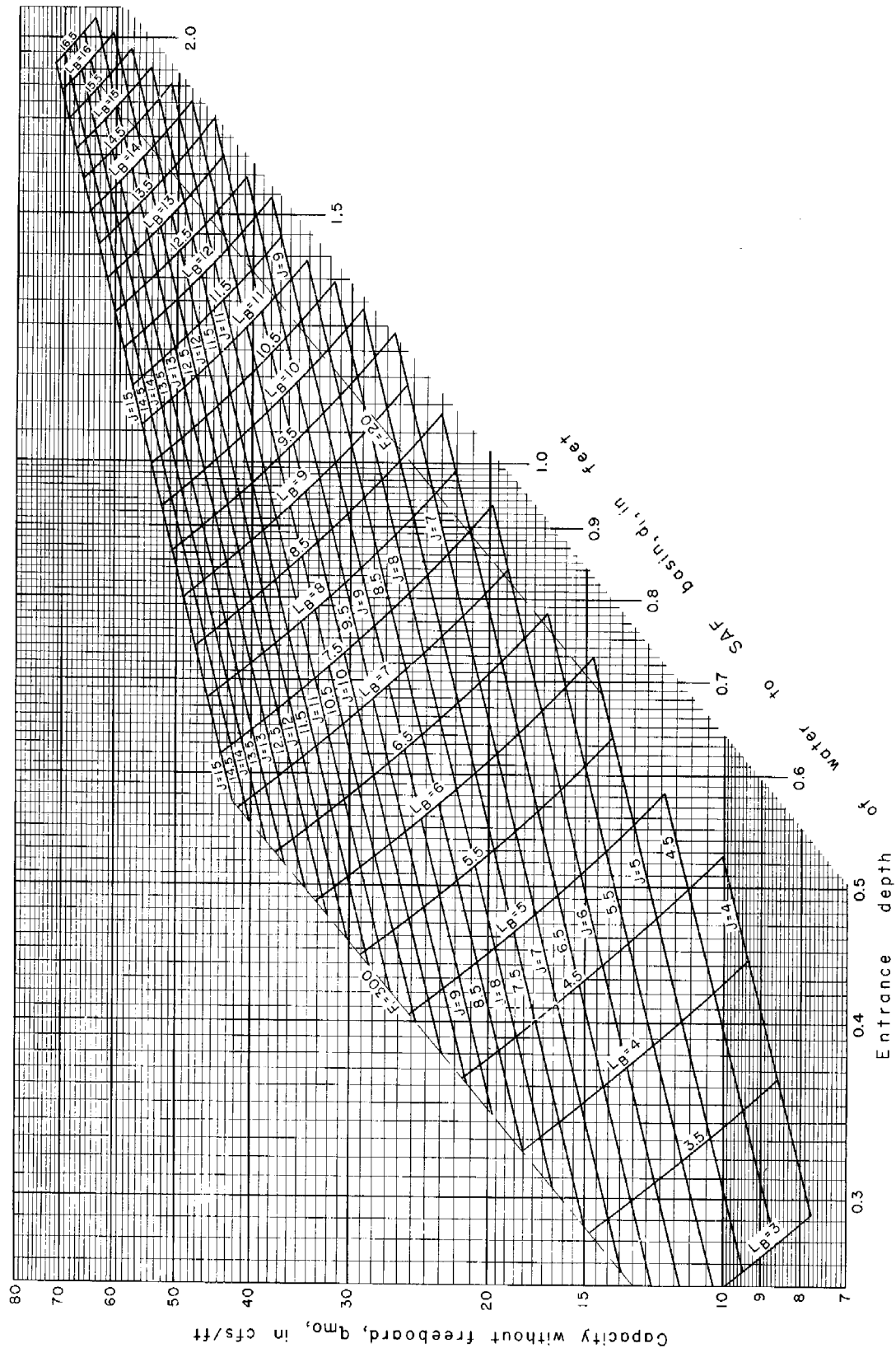
DATE 9-8-54

Revised 10/77

CHUTE SPILLWAYS: SAF OUTLETS

Capacities without freeboard for various dimensions

J in feet

 L_B in feet

REFERENCE

Blaisdell, F.W. "Development And Hydraulic Design, Saint Anthony Falls Stilling Basin." (SAF Stilling Basin)
Trans. A.S.C.E. 113P, 483-561, 1948

This diagram was developed by Paul D. Doubt, Engineering Design Section.

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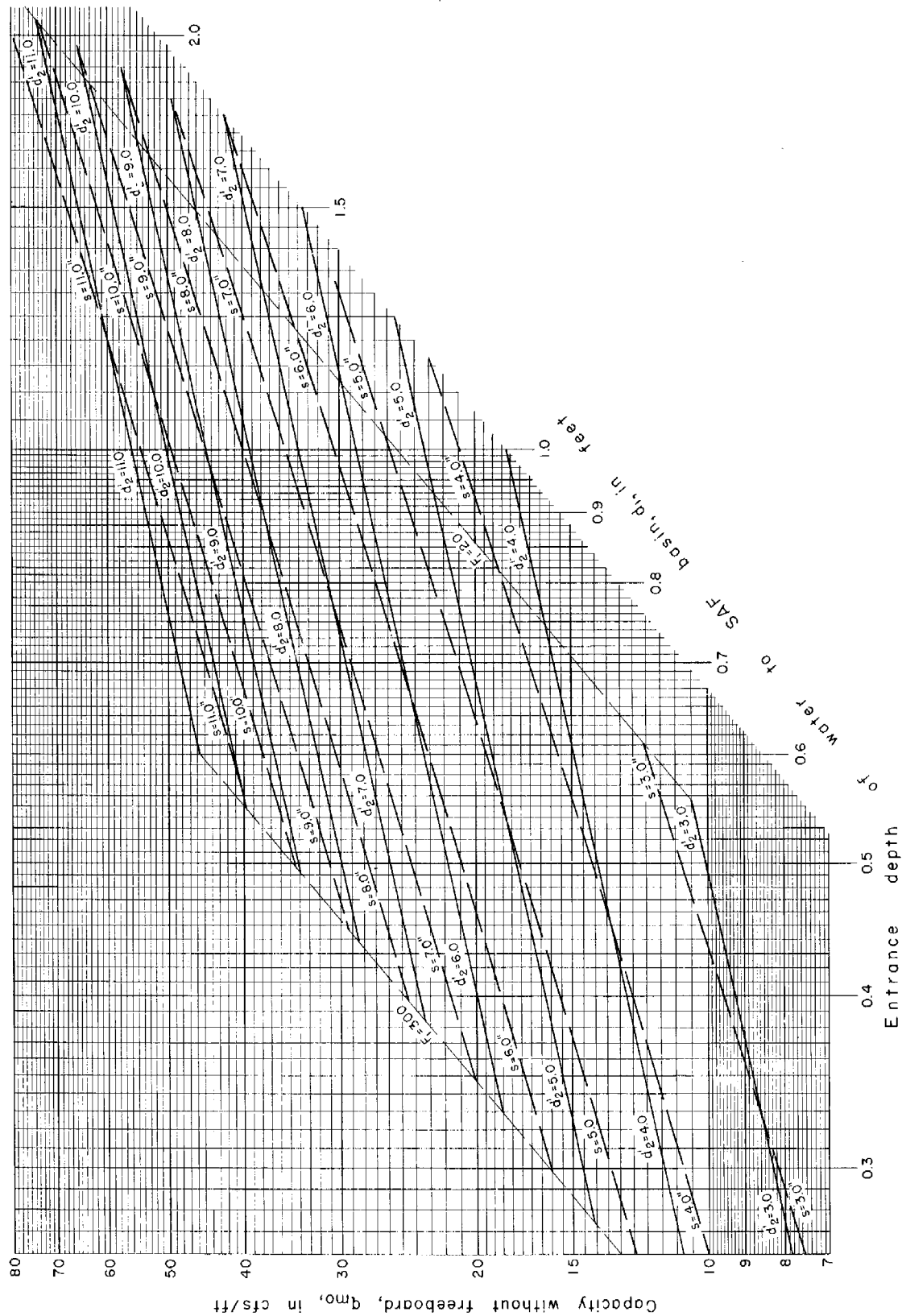
ES-86

SHEET 6 OF
DATE 3-2-54

CHUTE SPILLWAYS: SAF OUTLETS

Tailwater requirement and end sill height.

d_2 in feet
s in inches



REFERENCE

Blaisdell, F. W. "Development And Hydraulic Design, Saint Anthony Falls Stilling Basin." (SAF Stilling Basin)
Trans. ASCE 113P, 483-561, 1948

This diagram was developed by Paul D. Doubt, Engineering Design Section.

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SHEET 7 OF 8

DATE 2-25-54

CHUTE SPILLWAYS: SAF OUTLETS; Example

EXAMPLE

Given: A chute having a straight inlet, a bottom slope of 3 to 1 and a vertical drop of $Z = 50$ ft from the crest of inlet to the floor of the outlet. The design discharge is 200 cfs $W = 8$ ft $J = 8$ ft

- Determine:
1. Required capacity without freeboard.
 2. The height of the channel sidewalls, N , and entrance depth, d_1 , of flow to SAF outlet without air entrainment.
 3. Dimensions of SAF outlet.
 4. Required depth of tailwater.

- Solution:
1. The required capacity without freeboard, Q_{fr} , is

$$Q_{fr} = (1.20 + 0.003 Z) Q_r$$

$$Q_{fr} = [1.20 + (0.003)(50)] 200 = 270 \text{ cfs}$$

$$q_{fr} = \frac{Q_{fr}}{W} = \frac{270}{8} = 33.75 \text{ cfs/ft}$$

2. The required height of channel sidewalls, N , is read from table 3b of ES-88 as

$$N = 2.00 \text{ ft}$$

The entrance depth of flow without air entrainment, d_1 , is obtained from ES-78. Interpolation for this depth between $W = 6$ and $W = 10$ from sheets 9 and 11 obtain

$$d_1 = 0.659 \text{ ft}$$

3. The dimensions of the SAF may be read from ES-73 or ES-86.
 - a. The dimensions of the SAF as given on sheet 6 of ES-86 when $q = 33.75$ cfs/ft and $d_1 = 0.659$ ft is

$$J = 11.5 \text{ ft}; L_B = 7.5 \text{ ft}$$

The height of the end sill as given on sheet 7 of ES-86 when $q = 33.75$ cfs/ft and $d_1 = 0.659$ ft is

$$s = 8 \text{ inches}$$

Since the value of d_1 is known, the size and spacing of floor and chute blocks can be determined from sheet 1 of ES-73.

- b. The dimensions of the SAF outlet may also be determined by ES-73. The entrance velocity to the SAF outlet is determined by the formula

$$v_1 = \frac{q}{d_1} = \frac{33.75}{0.659} = 51.2 \text{ ft/sec}$$

From sheet 2 of ES-73 when $v_1 = 51.2$ ft/sec and $d_1 = 0.659$ ft read the dimensions

$$J = 11.5 \text{ ft}; L_B = 7.5 \text{ ft}$$

The height of the end sill is read from sheet 3 of ES-73 as $s = 8$ inches

4. The SAF outlet will not cause dissipation of the kinetic energy unless it has sufficient tailwater height. Serious erosion will occur in the erodible channel downstream from the SAF outlet whenever sufficient tailwater depth is not present. The required tailwater depth d_2' may be read from sheet 7 of ES-86 or sheet 3 of ES-73.

$$d_2' = 8.1 \text{ ft}$$

REFERENCE

U. S. DEPARTMENT OF AGRICULTURE
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ES-86

SHEET 8 OF 8
DATE February 1954

Revised 10/77