Sedimentation Investigations Technical Guide Series

Section E. Intake Works and Desilting Basins
Part 2. Settling Basins

A PROCEDURE TO DETERMINE SEDIMENT DEPOSITION IN A SETTLING BASIN

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The Sedimentation Investigations Technical Guide Series describes techniques and procedures for the technical guidance of sedimentation investigations in the Bureau of Reclamation. The series is divided into the following major sections, each in a specific field of subject matter:

A	Physical Properties and Sediment Movement
B	Natural Channels
C	(Unassigned)
D	Reservoir Sedimentation
E	Intake Works and Desilting Basins
F	Channel Improvement and Design
G	(Unassigned)
H	Conservation Practices
I	(Unassigned)
J	(Unassigned)
K	Economics of Sedimentation
L	Pumping Plants and Turbines
M	Wind Erosion
N	Instruments and Equipment
O	(Unassigned)
P	Estuaries and Harbors

Sectionalization facilitates distribution of particular procedural techniques for use by those engineers whose specialty includes one or more of the fields of sedimentation investigations covered in the series. The sections are periodically revised as necessary to reflect experience in use or to include advancements in knowledge, techniques, or equipment. Application of the procedures by other sedimentation investigators in basic or applied research is welcomed. Comments and suggestions resulting from the use of the materials in the series may be directed to: Bureau of Reclamation, Engineering and Research Center, Building 67, Denver Federal Center, Denver, Colorado 80225, Attention: Code 753.

PREFACE

Part 2 of Section E presents a procedure to determine sediment deposition in a settling basin. The procedure is based on the methodology contained in a study made by Dr. H. A. Einstein, Professor, University of California, Berkeley, California. A brief discussion of the theoretical background of the procedure is included. An example is given on a practical application of the procedure.

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INTRODUCTION

Einstein 1/ has studied the behavior of fine sediments carried by flows in suspension over gravel beds. His study, performed under contract with the Bureau of Reclamation, provides useful information for the design of artificial spawning grounds for salmon. Natural spawning grounds in various California river systems have been lost owing to changes in the flow regimen caused by river diversions.

This technical guide applies the procedure developed by Einstein. The dimensions of settling basins, the quantity of sediments deposited in the basins, and trap efficiencies may be determined by application of the procedure. Einstein's theoretical development is briefly discussed herein; the comprehensive development of the theory is contained in his report. An example of the application also is included. Comparison of the results with the Vetter 2/ method is made through graphical relationships.

THEORY

The first three equations listed below are taken from the Einstein study:

$$T = 0.657 \frac{d}{V_s \eta} \qquad (1)$$

Where

T = halflife time or time for concentration to be reduced one-half in seconds

0.657 = an empirical coefficient determined from laboratory test runs

d = water depth in feet

V_s = settling velocity of sediment particle in feet per second

η = efficiency of the flume assuming the value of unity in a long canal or river with continuous gravel bed

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1/ Einstein, H. A., "Final Report Spawning Grounds," U. of California, Hydr. Eng. Lab., 16 p, 2 tables, 10 figs, 1965

2/ Vetter, C. P., "Technical Aspects of the Silt Problem on the Colorado River," Civil Engineering, Vol 10, pp 698-701, November 1940

$$L = VT/5{,}280 \qquad (2)$$

Where

L = length of channel in miles over which one-half the particles are deposited

V = average flow velocity in feet per second

$$p = 1 - e^{-0.693\, \ell/L} \qquad (3)$$

Where

p = fraction of material deposited over total basin length

ℓ = basin length in miles

0.693 = value numerically predicted for the halflife, T, determined theoretically in the Einstein study

The three Einstein equations above can be converted to one equation in terms of P letting ℓ = basin length in feet.

$$P = \left(1 - \frac{1}{e^X}\right)100 \qquad (4)$$

Where

P = material deposited over total basin length expressed in percent

Where

$$X = \frac{(0.693)(5280)\ \ell V_s}{(0.657)(5280)\ Vd}$$

$$= \frac{1.055\ \ell V_s}{Vd}$$

Substituting in Equation (4)

$$P = \left[1 - \frac{1}{e^{\left(\frac{1.055\ \ell V_s}{Vd}\right)}}\right]100 \qquad (5)$$

Equation (5) can be used to determine the sediment deposition in a settling basin.

EXAMPLE

Statement:

Determine the dimensions of a settling basin, the quantity of sediment that will deposit in the basin, and trap efficiency using the Einstein procedure and check the results by Vetter's formula.

Assume a water discharge, Q_w = 230 cfs; sediment discharge, Q_s = 16 ac-ft/yr; a size distribution (Figure 3); a velocity of 0.5 ft/sec; and a water temperature = 68° F.

Try d = 10 ft and ℓ = 1,000 ft

$$X = \frac{1.055\ \ell V_s}{Vd} = \frac{(1.055)(1{,}000)\ V_s}{(0.5)(10)}$$

$$= 211\ V_s$$

$$P = \left[1 - \frac{1}{e^{(211 V_s)}}\right]100$$

Compute the values for each particle size shown below.

D (mm)	V_s*	211 V_s	$e^{(211V_s)}$	P	Avg P	Sediment Inflow in ac-ft (from size anal)	Sediment Deposit in ac-ft
0.5	0.203	42.9	>20,000	100			
					100	0.3	0.3
0.25	0.10	21.1	>20,000	100			
					99.98	2.4	2.4
0.125	0.038	8.02	3,000	99.97			
					95.82	5.9	5.6
0.062	0.0118	2.49	12	91.67			
					68.7	2.1	1.4
0.031	0.0029	0.612	1.84	45.7			
					30.4	1.8	0.6
0.016	0.00077	0.162	1.176	15			
					9.5	1.4	0.1
0.008	0.00019	0.04	1.0408	4			
					2.5	1.0	-
0.004	0.000048	0.0101	1.0101	1			
					0.5	1.1	-
					Totals	16.0	10.4

* Read from Figure 2

If the settling basin is to be of a size to accommodate a 1-year sediment depositional volume, an average width can be determined as follows:

$$W_{avg} = \frac{(10.4 \text{ ac-ft})}{(10 \text{ ft})(1{,}000 \text{ ft})} \times \frac{(43{,}560 \text{ cu ft})}{(\text{ac-ft})}$$

$$= \underline{45 \text{ ft}}$$

Assuming the channel is to be trapezoidal with side slopes of 2:1 and a bottom width of 25 ft, the top width would be 65 ft to satisfy the dimensional requirements set forth in the example. Quantity of sediment deposited in the settling basin = 10.4 ac-ft. Trap efficiency = (10.4/16)100 = 65 percent.

Further trials can be made of the settling basin dimensions and similar computations carried out. For example, assuming a basin length of 500 ft, a depth of 10 ft, and velocity of 0.5 ft/sec, the computations showed the total deposition to be 9.1 ac-ft/yr. Again, assuming a trapezoidal channel with 2:1 side slopes and a 25-foot bottom width, the top width would compute to 55 ft. Quantity of sediment deposited in settling basin = 9.1 ac-ft. Trap efficiency = (9.1/16)100 = 57 percent.

In the foregoing example it is noted that the computations are based upon a specific breakdown of the particle sizes shown in the first column. In other applications a different breakdown can be used should the sediments be analyzed to finer gradations. For instance in the example it may have been desirable to run the gradation analysis to include a finer breakdown between the 0.062- and 0.125-mm sizes since a substantial percentage difference (37 percent - refer to Figure 3) is indicated in this size range.

A final judgment for determining the appropriate settling basin dimensions for actual design purposes can be made depending upon the usual controlling factors among which could include cost, location with possible physical limitations, sediment sizes to be removed, etc.

A comparison of the first trial results (Einstein procedure - average width = 45 feet) was made with the results obtained by using the Vetter formula. A family of curves in Figure 1 relating the ℓ/q ratio to percent removed was developed from Vetter's formula for individual particle sizes. The term q is the discharge per foot width of basin. These curves are for conditions where the temperature is 68° F. The ℓ/q in the example is 1000/(230/45) = 200. Entering Figure 1 with this value and the percentages computed for each corresponding particle size shows very close checks with the graphical results. These are shown as an "x" for each particle size.

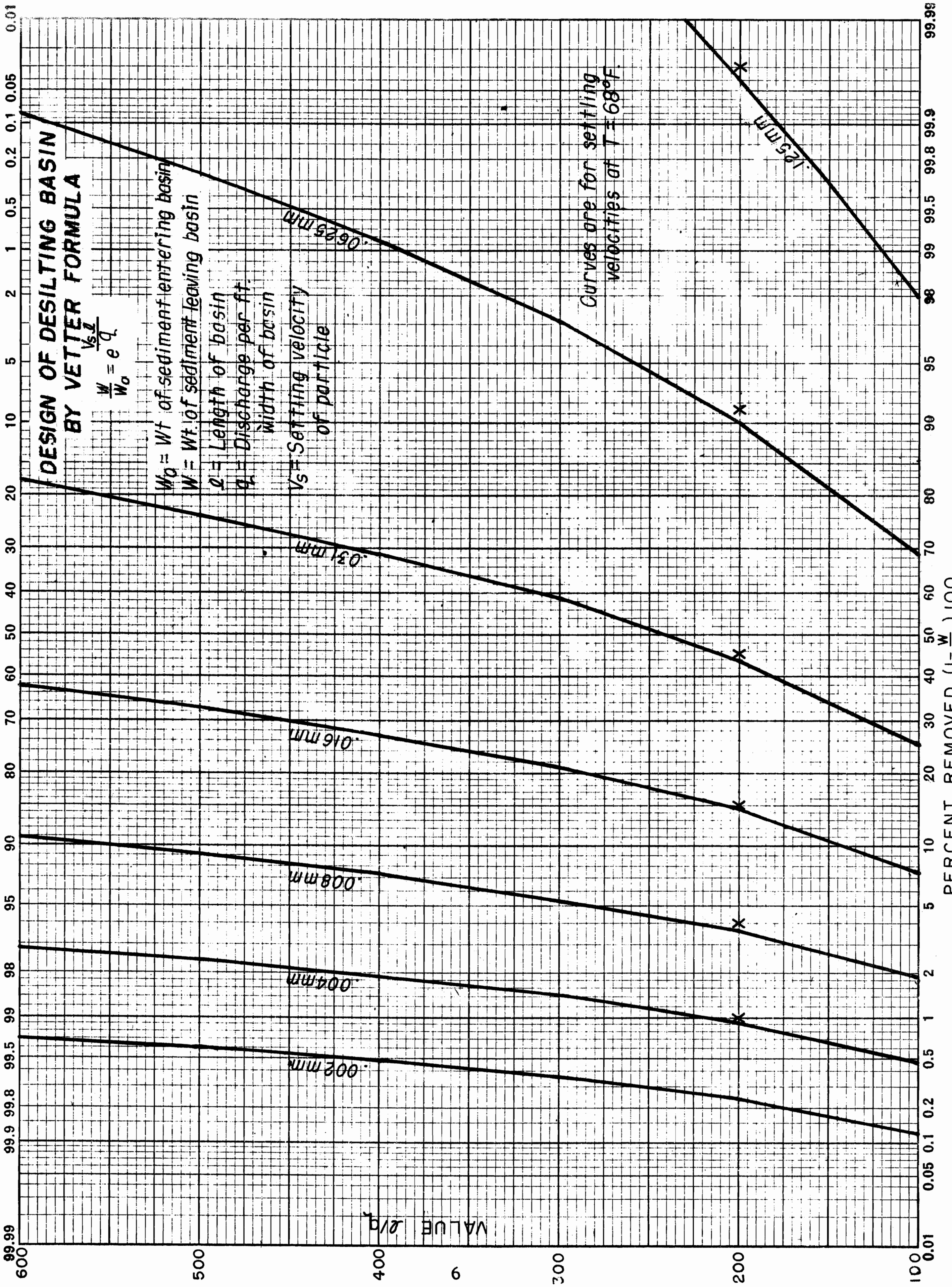
DESIGN OF DESILTING BASIN
BY VETTER FORMULA
$\frac{W}{W_o} = e^{\frac{V_s l}{q}}$
W_o = Wt of sediment entering basin
W = Wt. of sediment leaving basin
l = Length of basin
q = Discharge per ft. width of basin
V_s = Settling velocity of particle
Curves are for settling velocities at T = 68°F.
.125mm
.0625mm
.031mm
.016mm
.008mm
.004mm
.002mm
PERCENT REMOVED $(1-\frac{W}{W_o})$ 100
VALUE l/q

FIGURE I

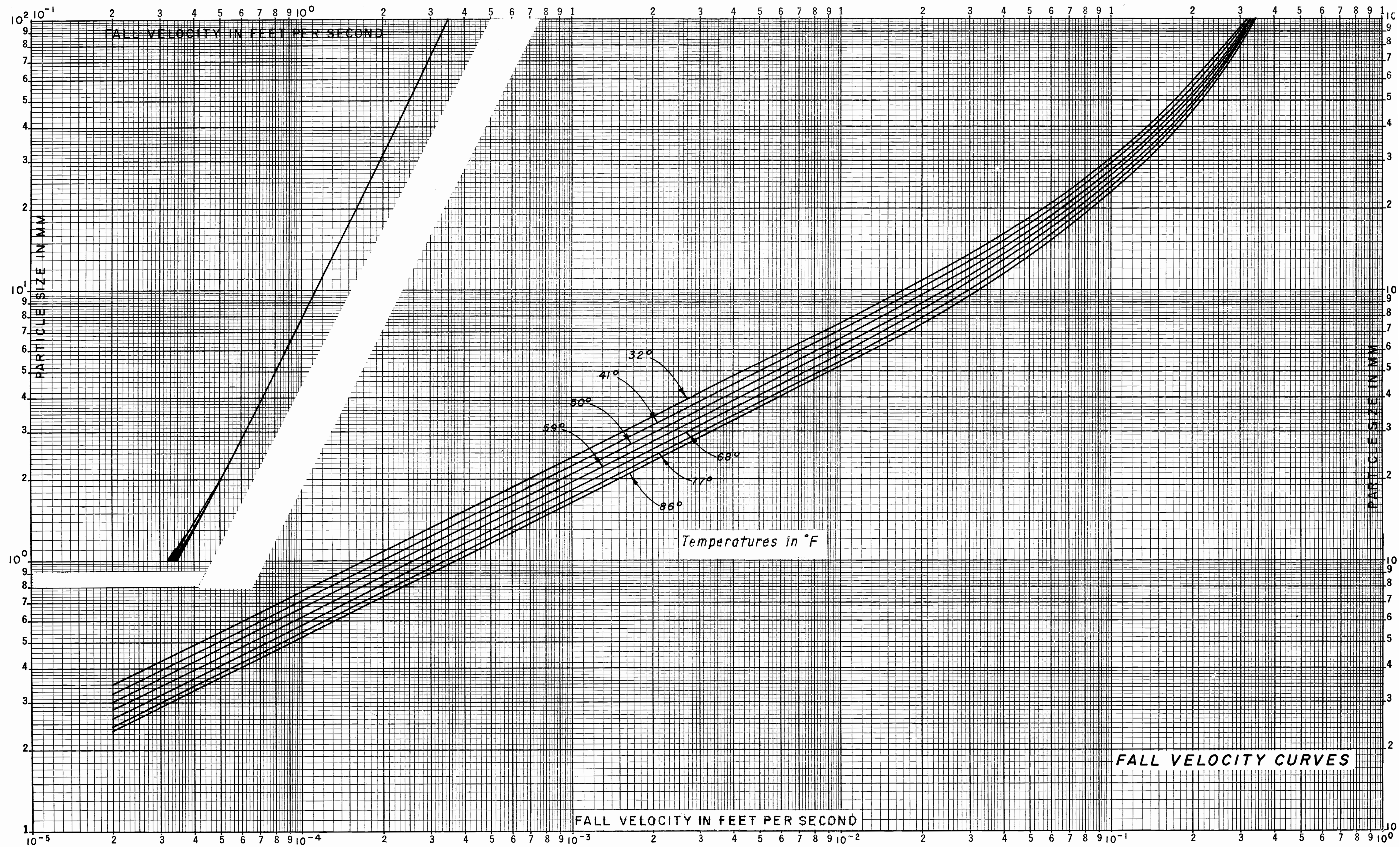
FALL VELOCITY IN FEET PER SECOND
PARTICLE SIZE IN MM
Temperatures in °F
32°
41°
50°
59°
68°
77°
86°
FALL VELOCITY CURVES

FIGURE 2

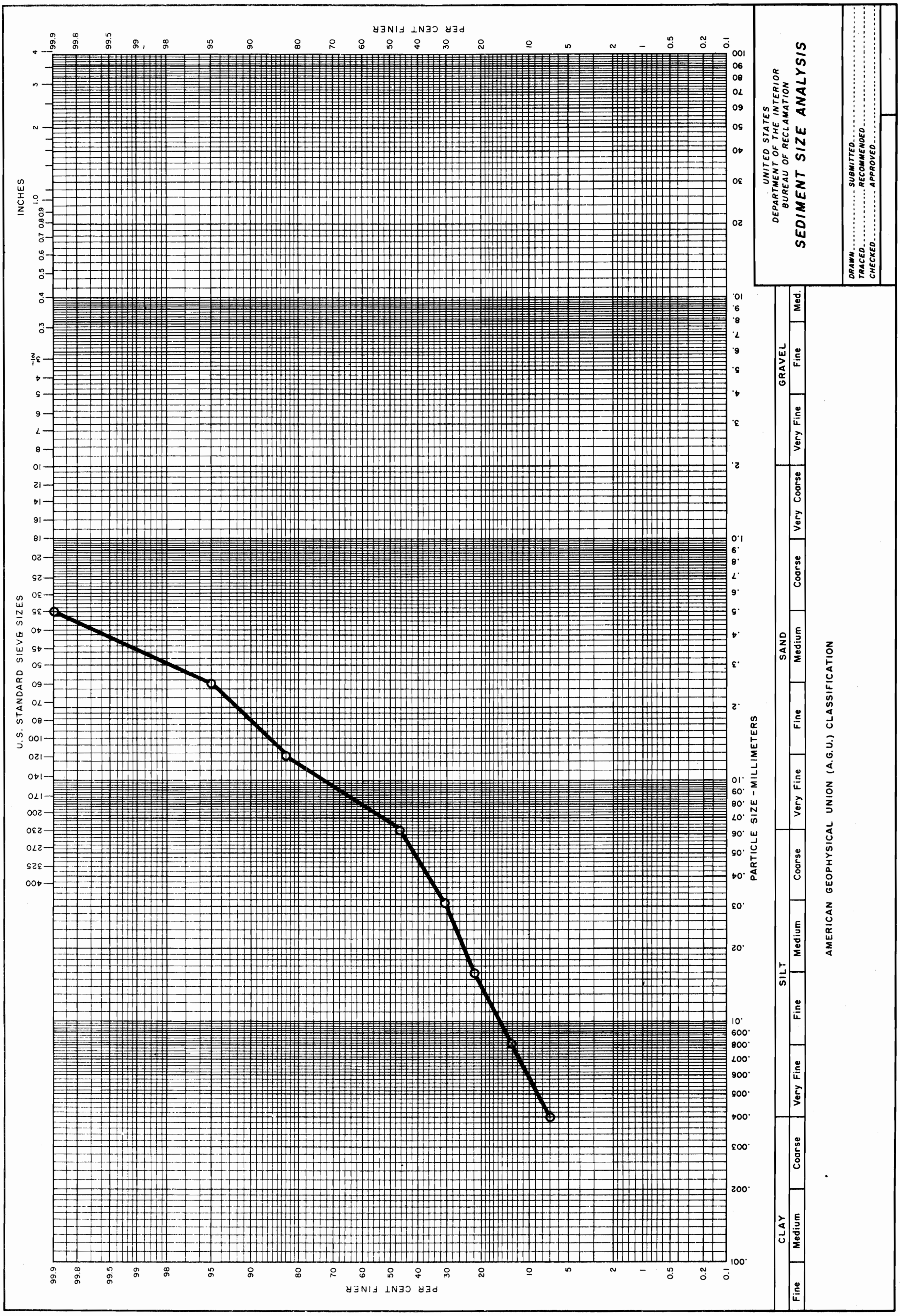
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
SEDIMENT SIZE ANALYSIS
DRAWN
TRACED
CHECKED
SUBMITTED
RECOMMENDED
APPROVED
GPO 837-101
INCHES
U.S. STANDARD SIEVE SIZES
PER CENT FINER
PARTICLE SIZE - MILLIMETERS
CLAY
SILT
SAND
GRAVEL
Fine
Medium
Coarse
Very Fine
Very Coarse
Med.
AMERICAN GEOPHYSICAL UNION (A.G.U.) CLASSIFICATION

FIGURE 3