Discussion of

DESIGN
[redacted] OF ALLUVIAL CHANNELS AS
INFLUENCED BY SEDIMENT DISCHARGE

By

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BIBLIOGRAPHY

A. "Practical Design Formulas for Stable Irrigation Channels" C. King. Tech. Report, Central Board of Irrigation, India, 1943, p. 56, Figure 8.

B. "Regime Behaviour of Canals and Rivers". T. Blench. Butter-worths Scientific Publications. London. 1957.

C. Civil Engineering Reference Book. Chapter "Hydraulics of Canals and Rivers of Mobile Boundary". T. Blench. D. Sc. 1961.

D. "Sediment Discharge and Stream Power—A Preliminary Announcement" Ralph A. Bagnold. U. S. Geological Survey Circular 421, Washington D.C. 1960.

E. Discussion on Bib F by D. C. Bondurant. Proc. ASCE. Hy Dn. Hy 6. November 1958.

F. "The Total Sediment Load of Streams". Emmett M. Laursen. Proc. ASCE. Hydraulics Dn. Paper 1530. Hy 1. February 1958.

G. "A study of 1.7 mm Gravel Moving as Bed Load". S K. Bhattacharya. M Sc. Thesis University of Alberts. 1960.

H. "The Behaviour and Control of Rivers and Canals". C.C. Inglis Central W. I. and N. R. Station Poona Research Pbn. No. 13.

I. "The Fourth-root nf Diagram". T. Blanch. Proc. ASCE Hydr. Dn. paper 2340. Hy 1. January 1960 with closure in Hy 2 of February 1961.

J. "Lecture Notes on Sediment Transport and Channel Stability" Report KH-R-I of January 1961. California Institute of Technology.

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The authors made several timely statements pertaining to the application of the regime concepts to the design of alluvial channels. Certainly it is very important, as stated by the authors, to establish design concepts which more effectively consider the role of sediment transport in relation to design, performance, and maintenance of canal and river systems.

New field data were presented by the authors as well as flume data collected by the writer and other engineers interested in and working toward a more fundamental and practical solution to the many problems associated with the mechanics of flow in alluvial channels.

The presentation of the new field data is significant in itself. However, such data would prove even more valuable if greater detail were given; such as the form and dimensions of the bed roughness (probably ripples and/or dunes), the total bed material load, the more significant characteristics of the fine sediment load including its concentration, and water temperat Some of such additional information is both difficult and expensive to obtain. However, new struments such as the sonic sounder reported on by Richardson, Simons and Posakony (6) Karaki (4) simplify one aspect of this problem.

The authors, in the opinion of the writer, correctly point out that the presence of large c centrations of fine sediment (in general smaller than about 0.074 mm) increases the capacity channel to transport bed material sizes. In addition, Simons, Richardson and Haushild (9) h verified that the presence of fine sediment affects resistance to flow. In brief, the writer belie that both the physical grain size and the fall velocity or fall diameter (2) of the bed material sig cantly influence both bed material transport and resistance to flow. Simons and Richardson In brief, the grain size is related to grain roughness and the fall velocity or fall diameter are r ted to form roughness and particle mobility and hence to the transportability of the bed mater In general, the form roughness encountered in stable canals with sand beds and alluvial banks ripples and/or dunes. The spacing and amplitude of the dunes is related to the fall velocity of bed material. For small fall velocities the spacing between dunes is relatively large, the du are less angular, and resistance to flow is relatively small. Considering bed materials with large velocities, the opposite is true --the dunes are more closely spaced, more angular and resistance flow is larger. Recognizing that fall diameter plays a significant role in fluvial mechanics au matically emphasizes that the concentration of fine sediment, $d < 0.074$ mm, is an important va able. Specifically, an increase in the concentration of fine sediment increases the specific grav and the apparent viscosity of the water-fine sediment complex. The increase in apparent viscos is sufficient to radically reduce the fall velocity or fall diameter of the bed material and even ter its effective gradation. It is largely the effect of the fine sediment on viscosity that makes a significant variable. To illustrate these important points, refer to Figs. A and B. Figure shows the effect of fine sediment on apparent viscosity and Fig. B shows the reduction in fall dian ter caused by the slight increase in specific weight of the fluid and the change in viscosity. certain alluvial streams in the Western United States it is not uncommon to find concentratic of fine sediment at flood stage sufficient to reduce the fall velocity and fall diameter of the b material to about half its corresponding clear water values.

In the authors report and in conjunction with the preceding paragraph fall velocity warra still further discussion. In evaluating the fall velocities of sediment the authors refer to and Rubies fall velocity relationships, see Fig. 1b. These relations are in error, particularly for l ger sizes of sediment. The writer suggests the use of the fall velocity information presented Report No. 12 (10) prepared by the Joint Inter-agency Committee on Sedimentation. The ba C_D versus Re relation for sediments of various shape factors from Report 12 is presented Fig. C.

The proposed design procedure recommended by the authors involves the use of their Fi

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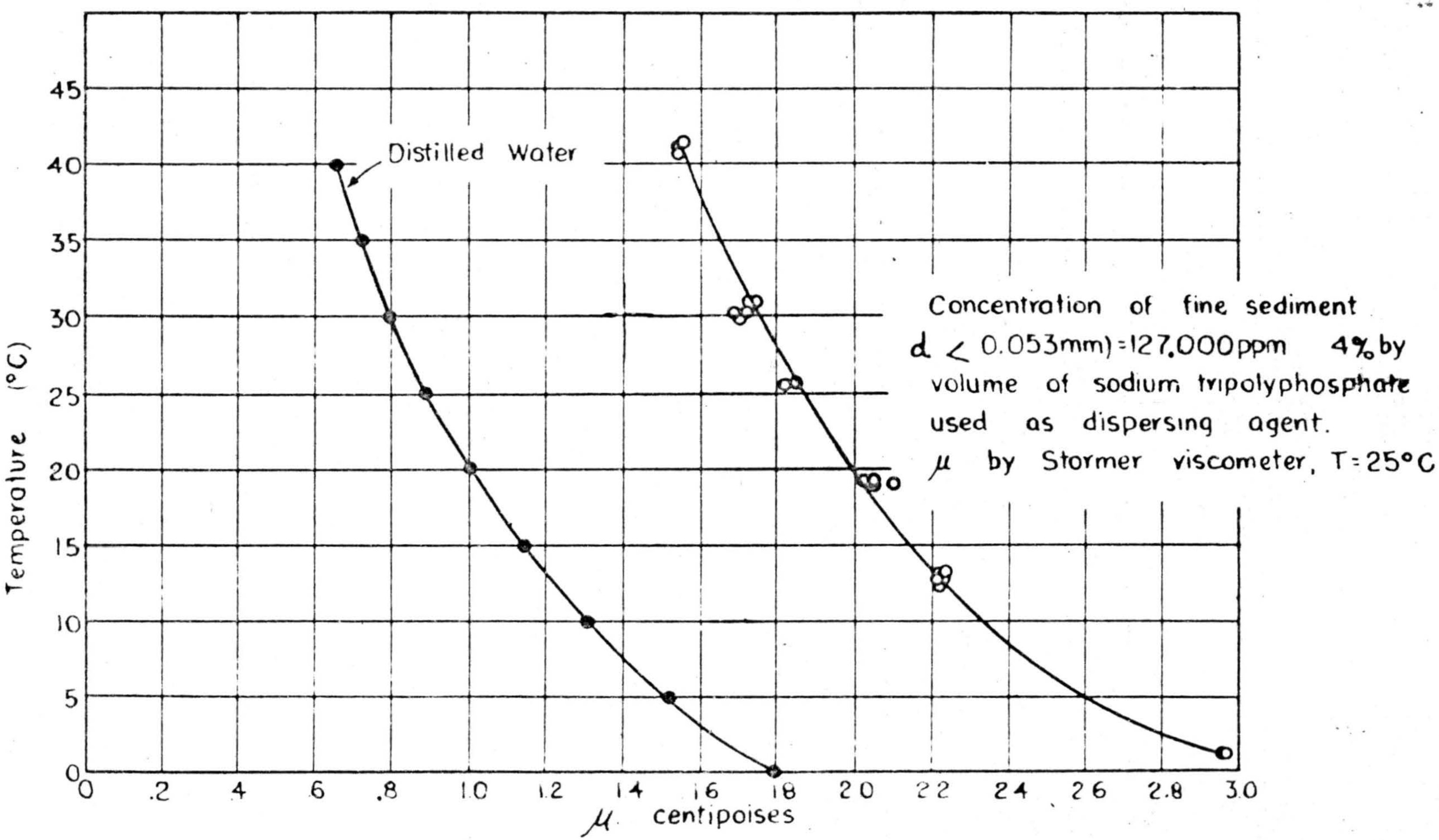
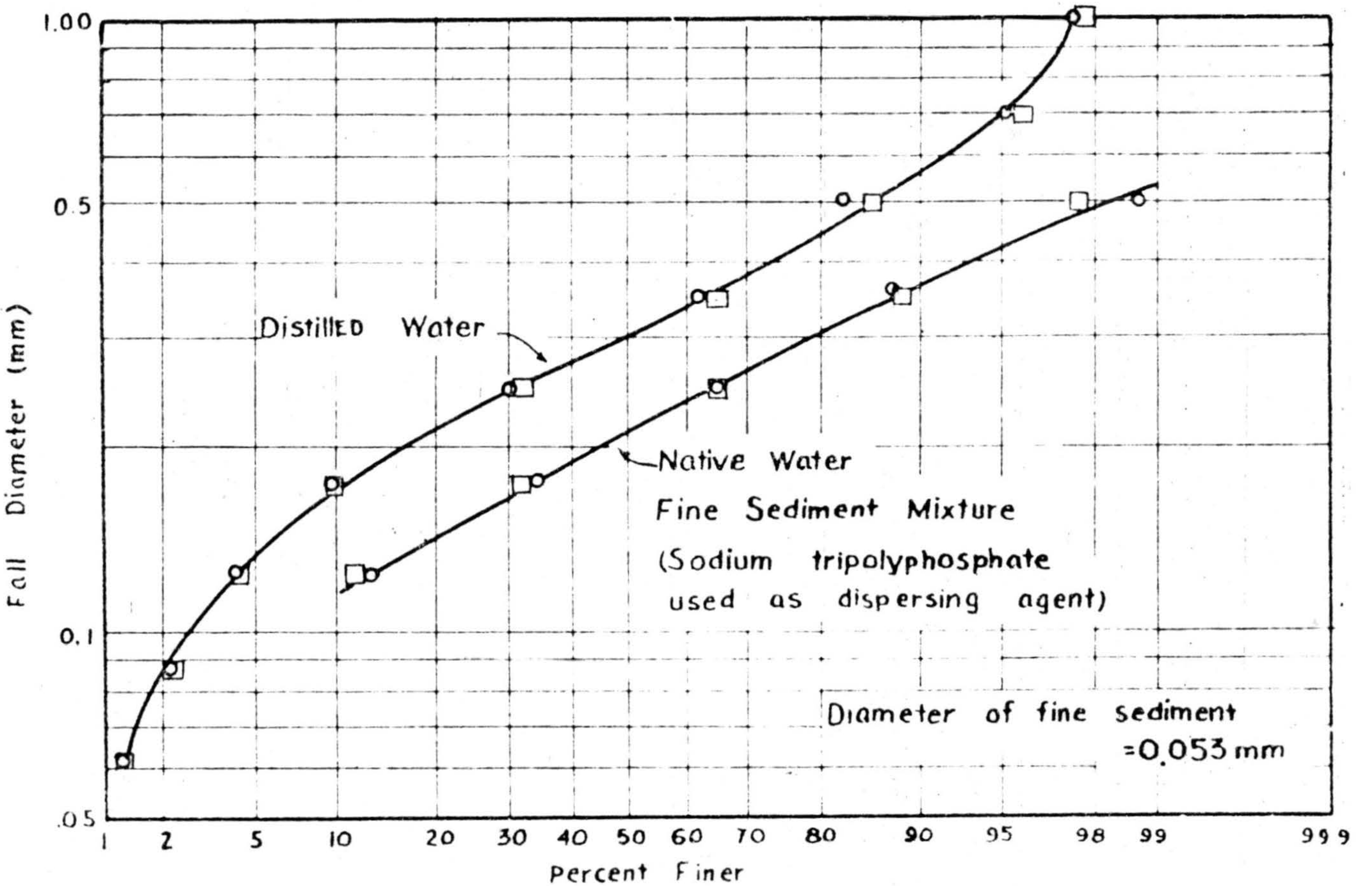
(FIG- A) Variation of Apparent Dynamic Viscosity with Temperature of Water; and Dispersed Fine Sediment in Native Water for Rio Puerco near Bernardo, New Mexico.



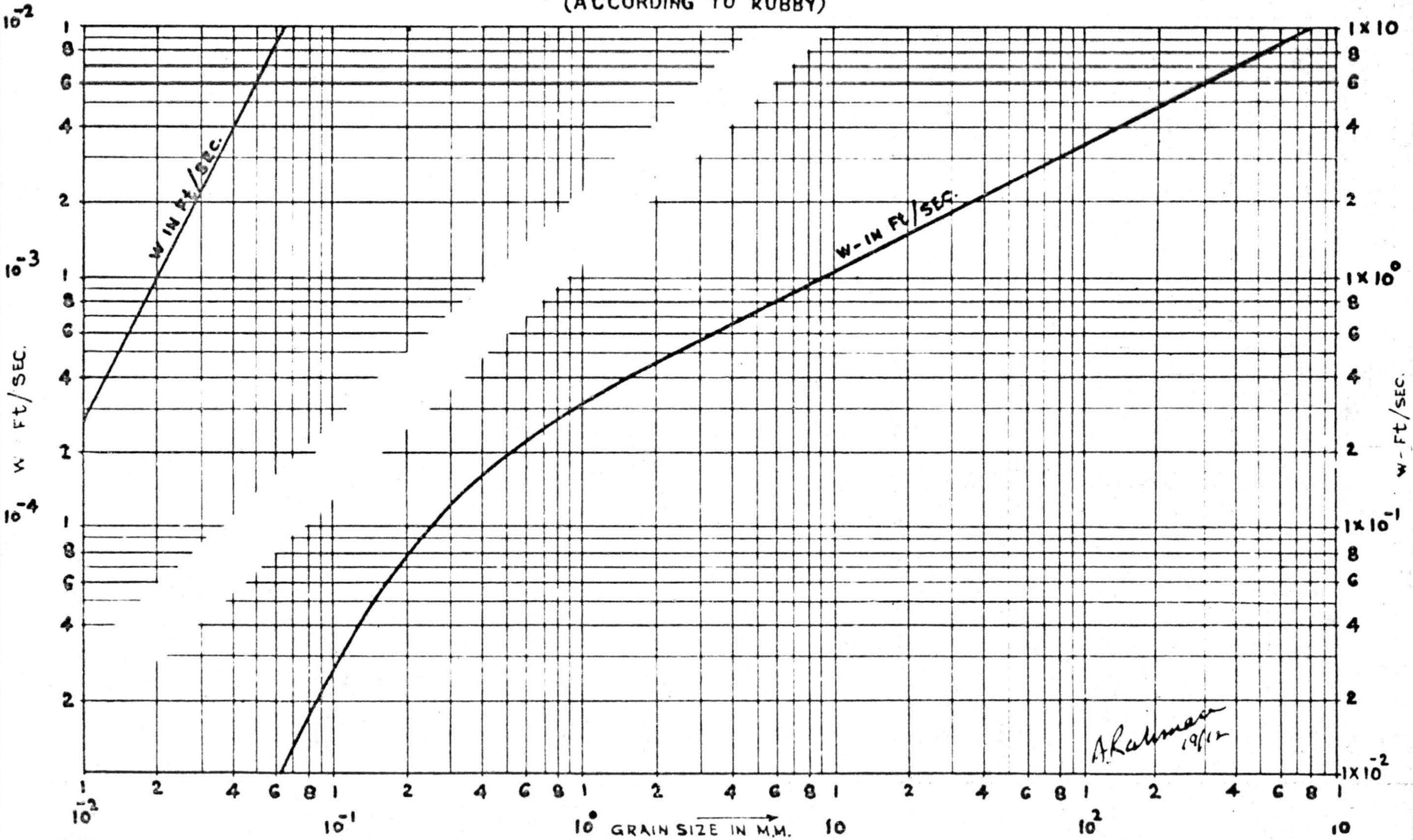


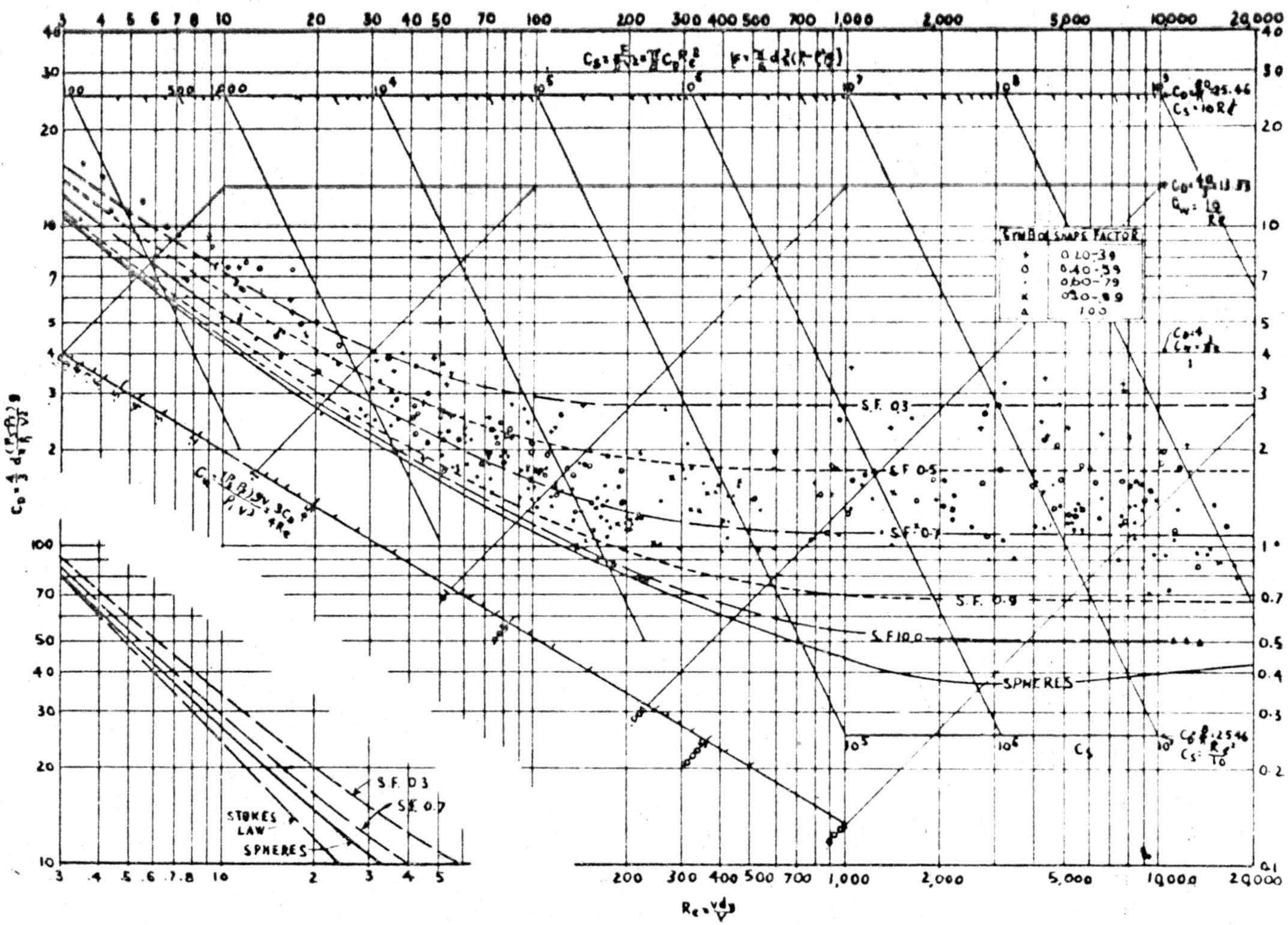
(Figure B) Fall Diameter Size Distribution of the Bed Material of the Rio Puerco near Bernardo, New Mexico in (1) Distilled Water and (2) Native Water - Fine Sediment Mixture.

FIG:- 1 (b)

SETTLING VELOCITY W, FOR VARIOUS SIZES OF GRAINS (QUARTZ)

(ACCORDING TO RUBBY)





(FIG. C) RELATION BETWEEN COEFFICIENT OF DRAG AND REYNOLDS NUMBER FOR NATURALLY WORN SEDIMENT PARTICLES. (TAKEN FROM REPORT 12, INTER-AGENCY COMMITTEE ON WATER RESOUCES SUBCOMMITTEE ON SEDIMENTATION, 1957

5d, 5g, and the regime relation a $q = 0.4 Q^{1/2}$. These two figures have been redrawn including new data as Figs. D and E. Reference is made to these two figures in that it brings out several points of possible interest. To begin with, consider Fig. 5d and the writer's Fig. D.

1. In these figures the silt concentration is the abscissa parameter. Both laboratory and field data were used to develop these figures. Unless the writer is misinterpreting the use of these data, the silt concentration used for the field study is suspended silt larger than 0.05 mm in diameter whereas the silt concentration of the lab data is total bed material load which includes both

TABLE VI A

DATA FROM A STRAIGHT REACH OF THE ELKHORN RIVER AT WATERLOO, NEBRASKA

Meas. No.	Q	S	V	D	W	$\frac{q^{2/3} S}{V W}$	τ_o	$\frac{\tau_o}{(\gamma - \gamma_1) d_{50}}$	Conc.* ppm
628	2830	.392	3.460	2.885	-	-	.0707	.998	3430
630	8960	.380	5.717	5.445	.0994	13.6	.1292	1.632	6260
632	8850	.395	5.750	5.340	.1015	13.92	.1316	1.66	6010
633	7900	.437	5.362	5.150	.0994	14.94	.1404	1.77	5700
634	7860	.440	5.310	5.175	.1015	14.88	.1422	1.795	5010
635	7540	.467	5.175	5.075	.1046	15.35	.1480	1.87	5300
636	6520	.491	4.745	4.775	.1015	15.62	.1465	1.85	4140
637	5610	.431	4.428	4.410	.0994	13.18	.1186	1.495	3780
638	4020	.389	3.610	3.910	.0994	10.64	.0949	1.195	4460
640	2860	.359	3.300	3.020			.0677	.855	1520
642	4100	.374	3.720	3.815	.109	9.89	.0891	1.124	2570
644	2150	.398	2.435	3.070	—	—	.0762	.961	1000
646	1700	.431	2.410	2.480	.1068	8.57	.0667	.843	513
648	1500	.443	2.205	2.400	.1212	7.9	.0663	.836	600
650	1540	.425	2.162	2.480	.1192	7.7	.0658	.83	698
651	5740	.359	4.760	4.187	.1068	10.72	.0939	1.182	813
656	879	.287	1.588	1.960	.132	4.12	.0351	.443	604
657	1820	.368	2.155	2.923	.133	6.7	.0671	.848	3410
658	1890	.287	2.255	2.835	—		.0509	.642	3400
664	2840	.415	2.570	3.760	.1285	8.86	.0971	1.222	3790
666	1150	.463	2.035	2.003	—		.0578	.73	830

*Concentration in ppm of suspended sediment larger than approximately 0.062 mm.

suspended load and bed load. Hence, the silt concentrations for the field data should be increased by an unknown amount equal to the bed load. This would shift these points on Figs. 5d and D to the right and perhaps suggest a change in the position of the recommended design line A-A of Fig. 5d. In general for the dune form of bed roughness the bed load is roughly equal to the suspended bed load for shallow depths of flow.

2. Additional laboratory and field data were used to develop Fig. B. These data include those collected by Simons and Bender (7), U. S. Geological Surevey flume data using 0.19 mm bed material, and Elkhorn River data. The Elkhorn data are presented in Table VI A. The bed roughness in the Simons and Bender canals was ripples superposed on dunes or dunes for the most part and the suspended bed material load was in general less than 100 ppm. The Elkhorn River's bed roughness was dunes and transition when the suspended bed material concentration ranged from 500 to 1000 ppm and was plane when the concentration exceeded 1000 ppm. The 0.19 mm flume data covered the same range of bed material concentrations as the 0.28 mm flume data cited by the authors. The authors recommended design line A-A of Fig. 5d as illustrated in Fig. D is well below the majority of the Simons and Bender canal data and the flume data where silt concentrations are small but serves as an upper limit for the Elkhorn River data. The dashed line on Fig. D is representative of the relation between $\frac{\bar{\tau}}{(\gamma - \gamma_1)d}$ and $\bar{c}$ for the 0.19 mm data which are not plotted but which represent the trend very closely for these data. Summarizing, both the additional field and laboratory data, suggests that the authors' design line should be raised in the range of small silt concentrations - from 0 to 1000 ppm.

3. A careful study of Fig. D indicates that the size of bed material may be a third variable. Perhaps with further study and possible inclusion of additional data the ordinate parameter $\bar{\tau}/(\gamma - \gamma_1)d$ could be modified to do a better job of superposing all data on a common line or the size of bed material and might be retained as a third variable.

The authors' Fig. 5g has been redrawn as Fig. E using the data presented by the authors plus the additional laboratory and field data used to prepare Fig. D. Referring to Fig. D and comparing it with Fig. 5g note that

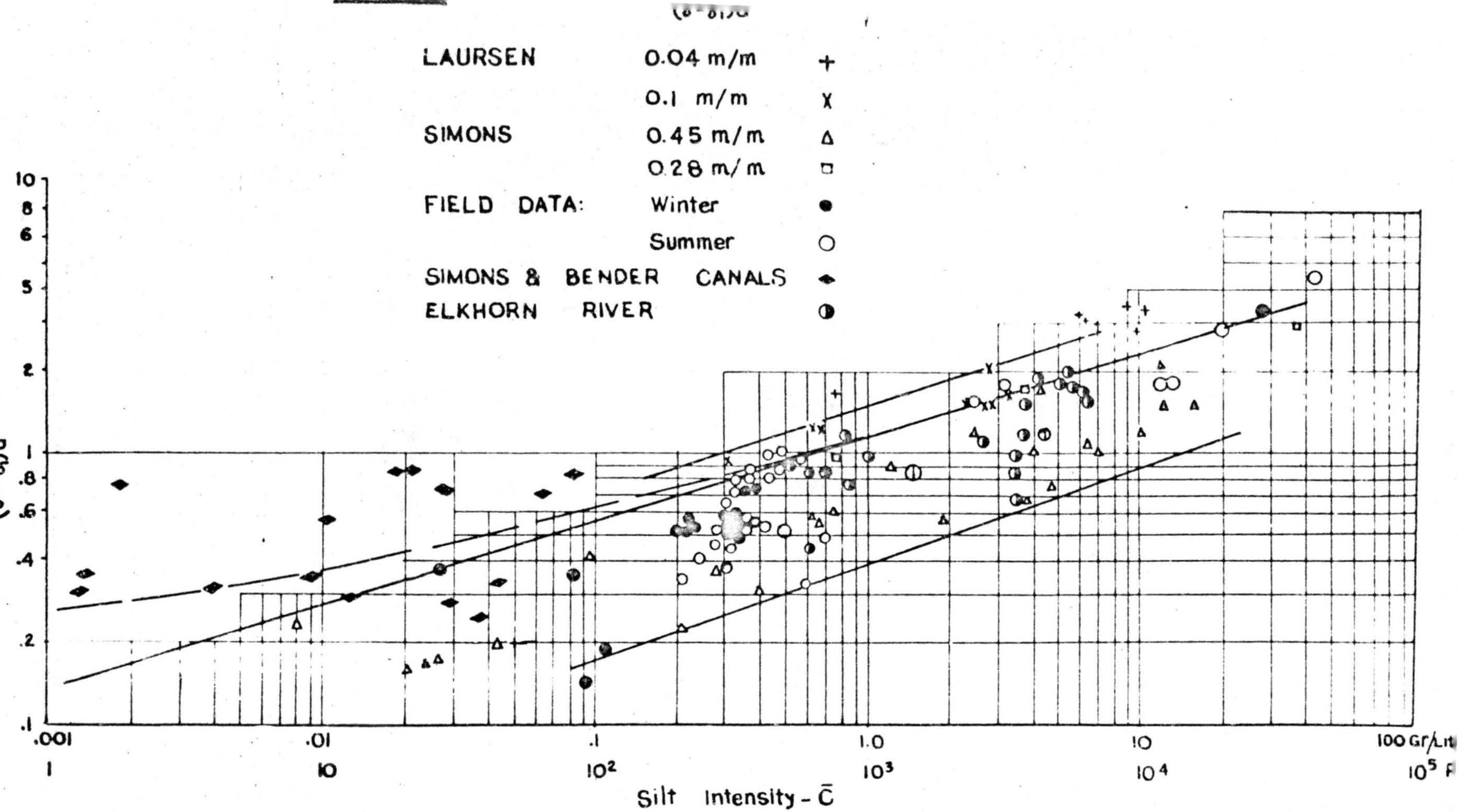
1. The complications of using suspended bed material for the field data and total bed mateiral load for the flume data may exist for Fig. 5 g as for Fig. 5d.

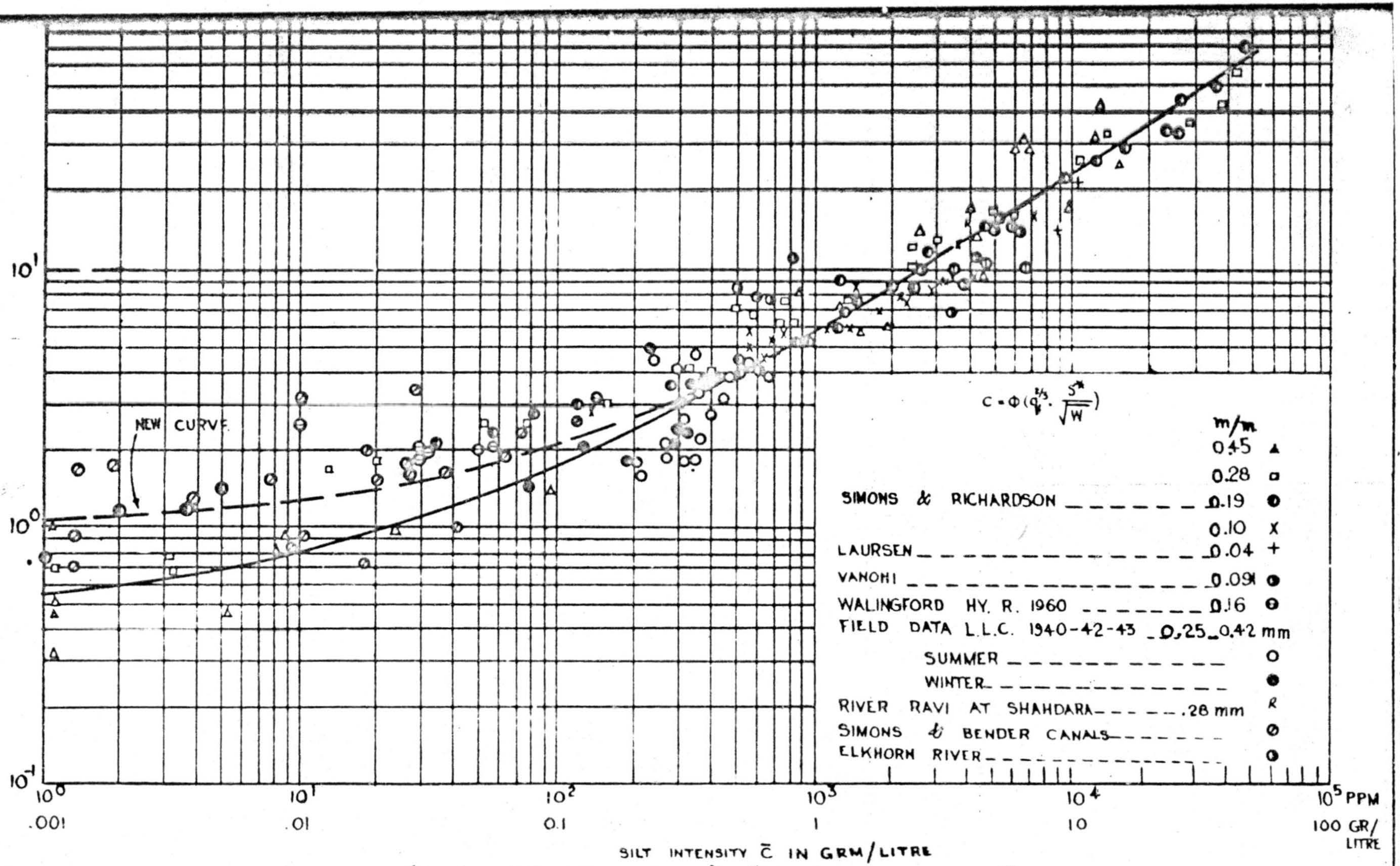
2. There is considerable scatter in the relation for silt intensities ranging from 1 to 1000 ppm.

3. The utilization of the additional laboratory and field data indicates that a design curve different from that of Fig. 5g should be established approximately as indicated by the new curve of Fig. E. The equation of the proposed new curve is

$$\frac{q^{2/3} S^*}{W^{1/2}} = 1 + 5c^{2/3} \quad \text{(A}$$

The authors pointed out that Eq. 21 is very similar to the Meyer-Peter equation. Equation 21 is also very similar to Einstein's bed-load function equation (3) and Bagnold's stream power equa


LAURSEN 0.04 m/m
0.1 m/m
SIMONS 0.45 m/m
0.28 m/m
FIELD DATA: Winter
Summer
SIMONS & BENDER CANALS
ELKHORN RIVER
10
8
6
5
2
1
.8
.6
.4
.2
.1
.001
.01
.1
1.0
10
100 Gr/Lit
1
10
10^2
10^3
10^4
10^5
Silt Intensity - $\bar{C}$



(FIGURE E) RELATION OF $q^{2/3} \frac{S^*}{\sqrt{W}}$ TO SILT INTENSITY $\bar{C}$

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tion (1). In fact, it would be worthwhile and very interesting to try and improve the relations presented in Figs. 5d, 5g, D and F by following some of Einsten's concepts more closely.

The example problems solved by the authors demonstrate that the results obtained by their method are in farily good agreement with those obtained by applying the standard regime concepts within the range of silt intensities where the procedures are comparable. Refer to Table VI B which compares the design dimensions for the Qadirabad-Balloki Link canal arrived at by the writer with dimensions given by the authors in their Table IV.

TABLE VI B

DESIGN DIMENSIONS OF THE QADIRABAD - BALLOKI LINK

	Slope	Depth	Velocity	c in gr litre
Authors ...	0 00011	13.4	4 12	0 59
Simons ...	0 00012	13.6	4.20	0.10

The writers computed value of bed material concentration was determined by the Einstein method (3) using the regime velocity given in the tabulation.

The suggested changes in the authors' Figs. 5d and 5g would alter the design of example 1, which is designed to transport a very small silt concentration.

Referring to design example 3 the writer wishes to emphasize that he doubts that the banks would be stable for conditions cited. It is true that the writer (7) has previously stated that, under special conditions, it may be possible to have stable channels with Froude numbers as large as 0.3, but it is very questionable in this instance. Note the uniform magnitude of the Froude number for the canal data presented by the authors. The average Froude number for those channels is approximately 0.19 Along the same line of thought the writer (7) also indicates that the upper limit of concentration of bed material d $>$0.074 mm, is approximately 500 ppm. The concentration of 1000 ppm cited in example 3 is almost double this arbitrary limit.

In example 4 the interesting problem of designing a canal to carry such a large silt concentration that instability without some type bank stabilization is a certainty, is discussed. The writer has quite successfully applied regime concepts and Lane's (5) tractive force concepts to the design of channels in this category where graded rock or gravel is to be used to stabilize the banks. Lane's tractive force method could also be used very effectively with the authors' design procedure to actually design the pitching required to maintain bank stability.

REFERENCES

1. Bagnold, R.A., Sediment discharge and stream power--a preliminary announcement. U.S. Geological Survey Circular 421, 1960.

2. Colby, B. C., and R. P. Christensen, Visual accumulation tube for size analysis of sand. Am. Soc. Civil Engineers Jour., v. 82, no. HY-3, p. 1004-1-17, 1956.

3. Einstein, H. A., The bed load function for sediment transportation in open channel flows. U. S. Department of Agriculture Tech. Bull. 1026, 70 p. 1950.

4. Karaki, S. S. E. Gray and Jack Collins, Dual Channel stream monitor. Published in ASCE Journal, Hy., Div., October, 1961.

5. Lane, E. W., Design of stable channels. Am. Soc. of Civil Engineers Trans., Vol. 120, p. 1234, 1955.

6. Richardson, E. V., D. B. Simons and G. J. Posakony, Sonic depth sounder for laboratory and field use, U. S. Geological Survey Circular 450, 1961.

7. Simons, D. B., and M. L. Albertson, Uniform water conveyance channels in alluvial materials. Journal of the Hydraulics Division of ASCE, HY5, May, 1960.

8. Simons, D. B. and E. V. Richardson, Form of bed roughness in alluvial channels. Am. Soc. Civil Engineers Jour., v. 87, no. HY3, 1961.

9. Simons, D. B., E. V. Richardson and W. L. Haushild, Studies of roughness in alluvial channels, the effect of fine sediment on the mechanics of flow. U. S. Geol. Survey Water-Supply Paper 1498b, in press, 1960a.

10. U. S. Inter-Agency Report No. 12, Some fundamentals of particle size analysis. U.S. Dept. Army, St. Paul, Minnesota, 1957.