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RESEARCH REPORT NO. 343

USING THE RADIOISOTOPE SEDIMENT DENSITOMETER ON SABETHA LAKE IN KANSAS

by

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INTRODUCTION

The radioisotope sediment densitometer (RSD) is an instrument for determining the dry density of saturated submerged sediments. It works on the principle that gamma rays are scattered by electrons in the sediment and water, and this scattering is related to the density.

Gamma rays are emitted by the source (cobalt 60), and scattered by electrons in the sediment and water. Some of the gamma rays are bounced back to a detector, where they are measured. The intensity of the radiation scattering is dependent upon the electron density of the surrounding substance. The density of sediments is also proportional to the electron density, and, therefore, the radiation scattered to the detector is a function of the wet density of the saturated sediment. This is explained more fully by Timblin.2/

The wet density of saturated sediment is determined by the relative proportions of water and sediment. If the specific gravity of these two materials is known, the dry density of the sediment can be determined. This relationship is shown in the equation

$$D = \frac{G(W-62.4)}{(G-1)}$$

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2/ Timblin, L. O., Jr., "Density Measurement of Saturated Submersed Sediment by Gamma Ray Scattering", Bureau of Reclamation, Chemical Engineering Laboratory Report No. SI-11, dated March 25, 1957.

where D is the dry density

G is the specific gravity of the sediment

W is the wet density as determined with the RSD

The instrument used in obtaining the density consists of a probe, into which the source of radiation (cobalt 60) and the detector are set--separated by a column of lead. The purpose of the lead is to assure very little direct radiation from the source to the detector. See Figure 1. Starting at the bottom, the probe (about an inch in diameter) is fabricated with about two and one-half inches of lead, the source (60 mc of Co-60), a 10-inch column of lead, a detecting device, and then a micarta tube for holding the measuring instrument in place and also used in removing it as necessary to obtain readings. The probe can slide through the lead working shield which provides protection from radiation and weight to sink it into sediment. This working tool is pictured and explained more fully by Timblin.[2/]

This radioisotope sediment densitometer was developed by the Denver office of the Bureau of Reclamation, Department of the Interior, during 1956 and 1957. The development project was sponsored by the Sedimentation Subcommittee of the Federal Inter-Agency Committee on Water Resources. Various federal agencies contributed funds to help finance the research program.

The RSD was the first instrument of its kind employing radioactive principles to determine densities of underwater saturated sediments. It was a big step forward in the study of reservoir sedimentation, and was instrumental in the development of the sediment density probe for the Beach Erosion Board, Corps of Engineers.

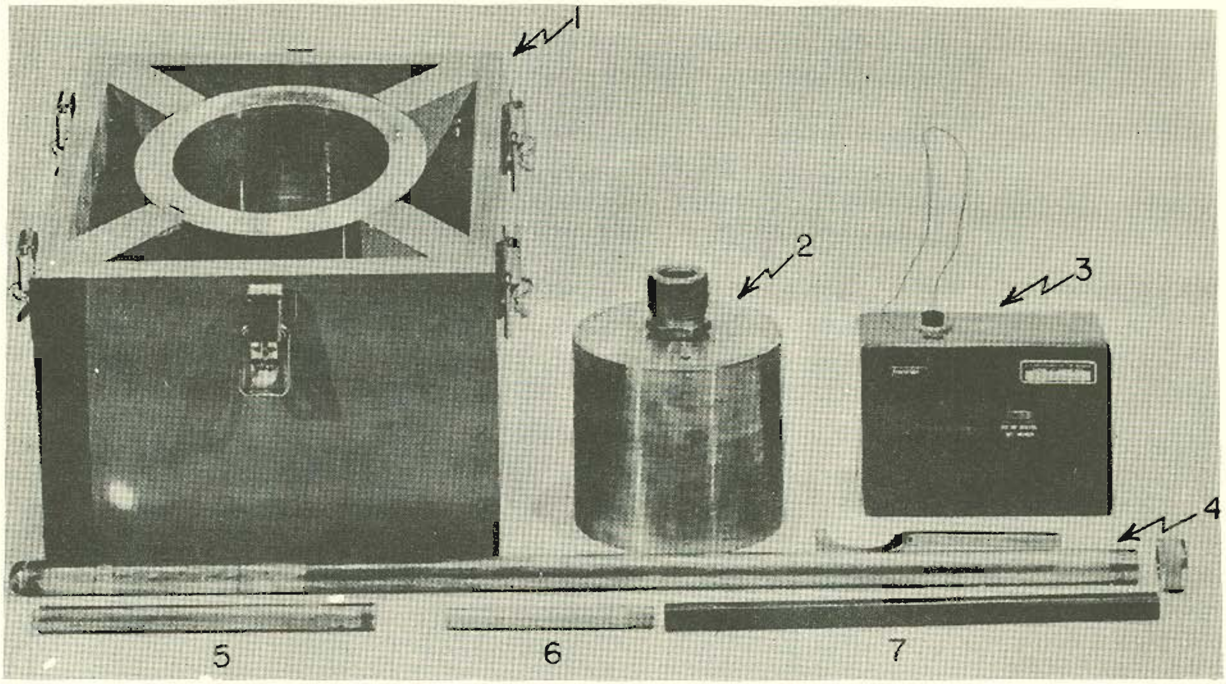


Figure 1

RADIOISOTOPE SEDIMENT DENSITOMETER

Figure 1 shows the major components of the RSD: (1) storage shield, (2) working shield, (3) dosimeter charger, (4) probe shell, (5) lead column to separate source and detector, (6) dosimeter, and (7) dosimeter holder.

Photo by U. S. Bur. of Reclamation

OBJECTIVES OF THIS STUDY

The objectives of this study of the RSD were as follows:

(1) To become more familiar with the instrument, and evaluate it.

(2) To compare the results with the Agricultural Research Service 2-7/8" piston type standard sampler.

(3) To provide an opportunity for the Sabetha Lake Project Cooperators, the Soil Conservation Service and others, to become acquainted with this new working tool.

BACKGROUND

Sabetha Lake in Kansas was chosen for testing this instrument because of the wide range in densities and particle sizes of the reservoir sediment. Sabetha Lake has been surveyed in 1951, 1952, 1953, 1955, 1956 and 1958, and a complete history of the lake is available. Range ends are permanently located and can be found easily.

The densitometer was used at some of the same locations at which sediment density samples were obtained during the 1956 sedimentation survey. The laboratory analyses results of the 1956 sediment samples (giving density, specific gravity, and particle size distribution) were available during this study. Permission to conduct this study was obtained from the Kansas State Board of Health, Division of Sanitation; City of Sabetha, Kansas; and the Radiological Safety Officer of the Agricultural Research Service.

INSTRUCTION

Before using the RSD, the writer observed the Bureau of Reclamation engineer's procedure for obtaining sediment densities. These observations were made on the John Martin Reservoir in Colorado. Additional instruction was also provided in regard to the operation of this device and the necessary safety precautions to observe, by Mr. L. O. Timblin, Jr., and Mr. Q. L. Flory of the Bureau of Reclamation Engineering Laboratory in Denver, Colorado. Reference 2 was also studied.

EQUIPMENT

The following equipment is necessary in order to use the RSD on a lake:

Radioisotope sediment densitometer (RSD)

Encapsulated Co-60 source - 60 mc

Dosimeter charger

Spanner wrench

A B-reel and cable for lifting the densitometer and for recording depth

Personnel dosimeters

Extractor for removing the dosimeter from the probe

Stop watch

Computation forms

Large boat (18' long x 6-1/2' wide) and motor

Anchors and rope

"A"-frame for the boat

Wrenches

Sounding bell

Pointed pliers

Brush for cleaning mud off densitometer

Rags for keeping the dosimeter dry

FIELD OPERATION OF EQUIPMENT

A typical sediment density determination would be made as follows: the radioisotope sediment densitometer with the probe in the retracted position is lowered over the side of the boat until only a couple of inches of the working shield are above water. The probe is then pushed through the working shield until it is in the extended position. The cap of the probe is removed. The dosimeter is removed from the probe, charged on the dosimeter charger, read, and placed back into the probe. At the moment the dosimeter is placed into the probe, the stop watch is started. The probe is now capped and the RSD lowered into water or sediment -- depending upon the substance for which a dosimeter reading is desired. When the RSD enters the sediment, the time is recorded as "Time into sediment". The device is left in the substance for a 10-minute period and accurate stop watch readings are taken to measure the length of time in the sediment because the density is derived from the ratio of RSD readings in sediment to RSD readings in water. (For this reason, several readings for comparative purposes are obtained with the instrument in water.) After the required test time has elapsed, the RSD is raised. At the instant it leaves the sediment, the time is read and recorded as "Time out of sediment". When the original position alongside the boat is reached, the probe is uncapped, the dosimeter removed and read. The instant the dosimeter leaves the probe, the stop watch is stopped and the time recorded as "Stop time".

The weight of the lead shield provides the impetus for getting the instrument into sediment. Final penetration is controlled by the resistance of sediment to the above force and also by the depth setting on the "B" reel. The RSD was designed to measure the density of sediment with a minimum thickness of two feet. In shallower sediment the determination would include the density of other material and give an erroneous result.

Figure 2 shows a sample data sheet for the density determinations. The calculations outlined thereon are followed.

During this study (October 1957), two readings were first obtained for comparative purposes with the instrument in water at a location on Range 8 (585 ft. from R8R) where samples were obtained in 1956. The location is shown on Figure 3. This was followed by two separate densitometer measurements of the top two feet of sediment. A sediment core was then taken at the same point with the Agricultural Research Service standard sampler (2-7/8" I.D.). From this core, 4" samples were taken at 7"-11" and at 16"-20" from the top of the sediment.

The next readings were made 807 ft. from R4R on Range R4R - R4L. Here, also, two separate readings were taken of the top two feet of sediment. A core was also taken at this location with the Agricultural Research Service standard sampler and samples taken at 3-3/4" to 7-3/4" and at 12-1/2" to 16-1/2" below the top of sediment.

The next readings were taken on this same range but at 1241 ft. from R4R. Three readings were obtained at this location because there was a difference of about 40 percent between the dry densities from the first two readings. A sample was also taken at the same point with the standard

Sheet ___ of ___

Sample Data Sheet

SEDIMENT DENSITY MEASUREMENT WITH
RADIOISOTOPES SEDIMENT DENSITOMETER

Date __________

Project __________

Location __________

____

Surface elevation __________

Depth to top of sediment __________

Depth of measurement __________

Personnel __________

____

____

____

Dosimeter number __________

Dosimeter readings:

Final __________

Initial __________

(1) Difference __________

Time:

(2) Into sediment __________

(3) Out of sediment __________

(4) Stop time __________

(5) Time in sediment =(3)-(2)= __________

(6) Transit time =(4)-(5)= __________

(7) Water rate __________

(8) Water correction =(6)x(7)= __________

(9) Sediment reading =(1)-(8)= __________

(10) Sediment rate =(9)/(5)= __________

(11) Intensity ratio, R=(10)/(7)= __________

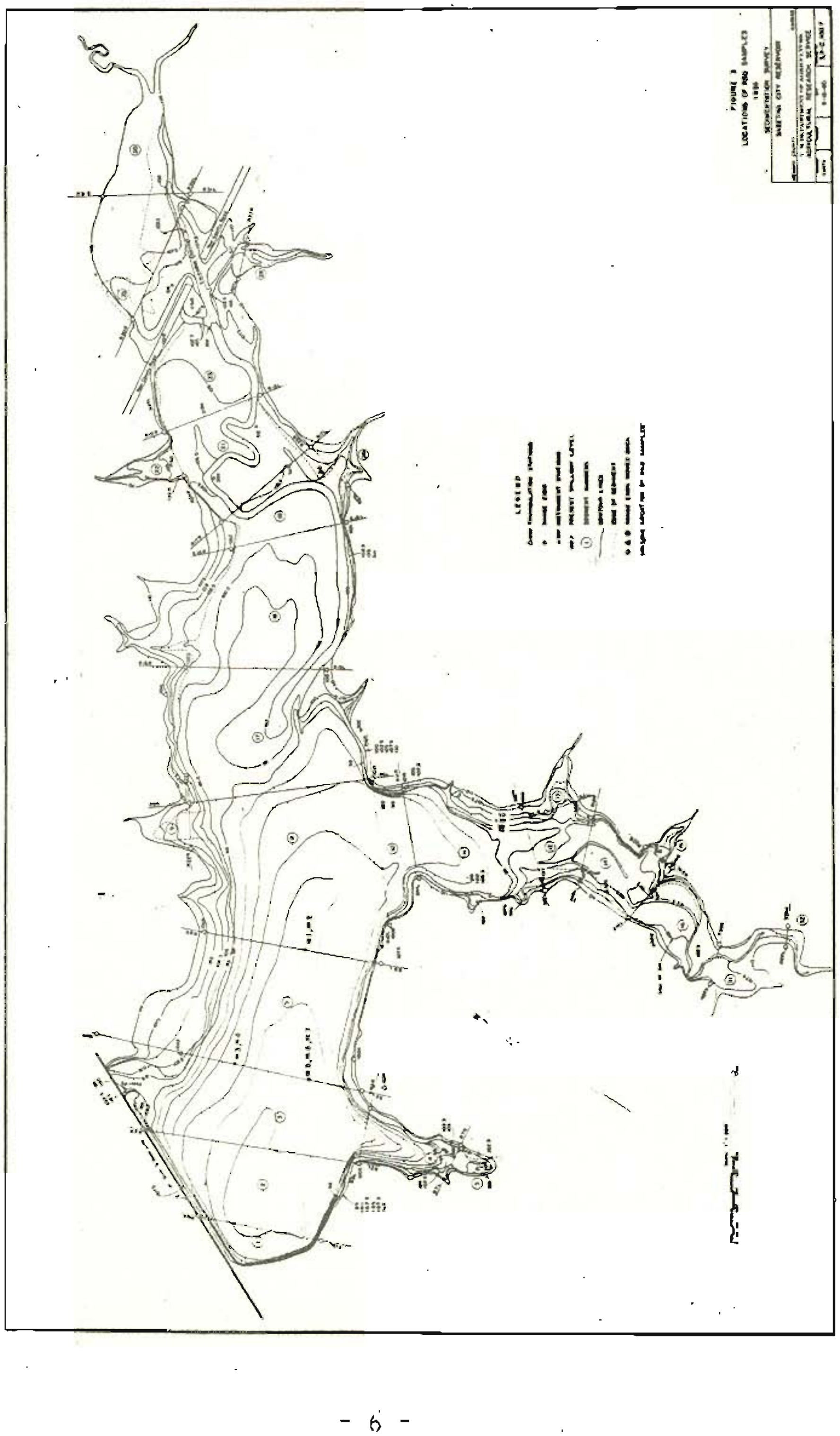
Wet density __________

Specific gravity __________

Dry density __________

Remarks: __________

Figure 2
U.S. Bur. of Recl. Form



sampler. This was at a depth of 6" to 10" below the top of sediment.

DATA AND RESULTS

A total of 17 people observed the field tests. None of the participants or observers received an overdose of radiation. The maximum was 25 milliroentgens (mr) of gamma rays received by the writer. The allowable dosage rate for radiation workers at the time of the field work was 300 milliroentgens per week, but this constantly being revised downward -- especially for young people.

All calculations were made in accordance with pages 15, 16 and 27 of reference 2, previously referred to, and also the calculation form developed for use with the RSD. Figure 2 is a sample of this calculation form. The results of these studies are given in Table 1. The information in columns headed "1956 Sed. Samples" and "1957 Sed. Samples" pertains to samples taken with the Agricultural Research Service standard vacuum type sampler.

COMPARISON AND DISCUSSION OF RESULTS

The results of this study, shown in Table 1, provide an interesting comparison. The densities which were determined in 1956, by using the Agricultural Research Service standard sampler, as well as the RSD densities, are all closely bunched except for the first reading with the RSD at station 1241 ft. from R4R. There is also a considerable difference in the dry densities between the first two 1957 sediment samples, which were obtained by using the Agricultural Research Service standard sampler. There was as much spread between RSD densities as between the standard sampler densities. The big difference, however, is that when an appreciable difference develops between the RSD densities at a given point, a person is still at the location

TABLE 1. -- Lake Sabetha, Kansas -- Comparisons of dry densities from RSD, and 1956 and 1957 sediment samples

Range No.	Dist. from range end	1956 Sed. Samples: Sample No.	1956 Sed. Samples: Specific gravity	1956 Sed. Samples: Dry density Lb/cu ft	Oct. 1957 RSD: Trial No.	Oct. 1957 RSD: Specific gravity	Oct. 1957 RSD: Dry density Lb/cu ft	Oct. 1957 Sed. Samples: Sample No.	Oct. 1957 Sed. Samples: Specific gravity	Oct. 1957 Sed. Samples: Dry density Lb/cu ft
8	585 ft.	16		47.19	1	2.68	37.65	1	2.692	55.95
	from R8R	17	2.68	53.98	2	2.68	36.05	2	2.668	43.77
		18		52.53						
			Avg.	= 51.23		Avg.	= 36.85	Avg.	2.68	49.86
4	807 ft.	13	2.68	43.28	1	2.70	31.92	3	2.71	40.47
	from R4R	14		43.62	2	2.70	34.31	4	2.689	43.36
		15	2.68	45.49						
			Avg.	= 44.13		Avg.	= 33.12	Avg.	2.70	41.92
4	1241 ft.	9	2.72	26.01	1	2.72	31.79	5	2.72	29.07
	from R4R	10		23.01	2	2.72	22.93			
		11	2.72	19.32	3	2.72	19.92			
			Avg.	= 22.78		Avg.	= 24.88			
					Avg.	2 & 3	= 21.43			

and, therefore, can make additional determinations. This is not the case when using the standard sampler, as disagreements are not exposed until the samples are analyzed.

The dry densities determined by using the RSD are considerably less than those obtained from the sediment sampling of 1956 and 1957. The RSD densities are as much as 35 percent lower than those obtained from the samples. When these RSD dry densities are plotted versus the sampler dry densities for 1957, the points fall in a pattern very similar to those experienced by the Bureau of Reclamation. Figure 4 shows a comparison of results of sampling methods from field tests. It shows the results of the Bureau of Reclamation field tests and also the results of this work on Sabetha Lake. The seven Sabetha Lake points show the relationship between individual RSD densities and the average density at a location as determined from the October 1957 sediment samples. Figure 4 points up the need for additional calibration efforts for either one or both of the techniques used, to determine the accurate volume weight of reservoir sediment.

It would seem as though the densities determined by using the RSD would be more accurate than the densities obtained by using standard sampler methods. Friction is developed inside standard piston type samplers as sediment rises inside the sampler, thereby compacting the sediment and forming a friction ball. Part of this is pushed ahead of such a sampler as it moves deeper into sediment, and additional compaction takes place. Such friction should not be developed with the RSD.

The sensitivity of the dry densities to the dosimeter readings was noticed, as was the fact that the dosimeter cannot be read closer than plus or minus

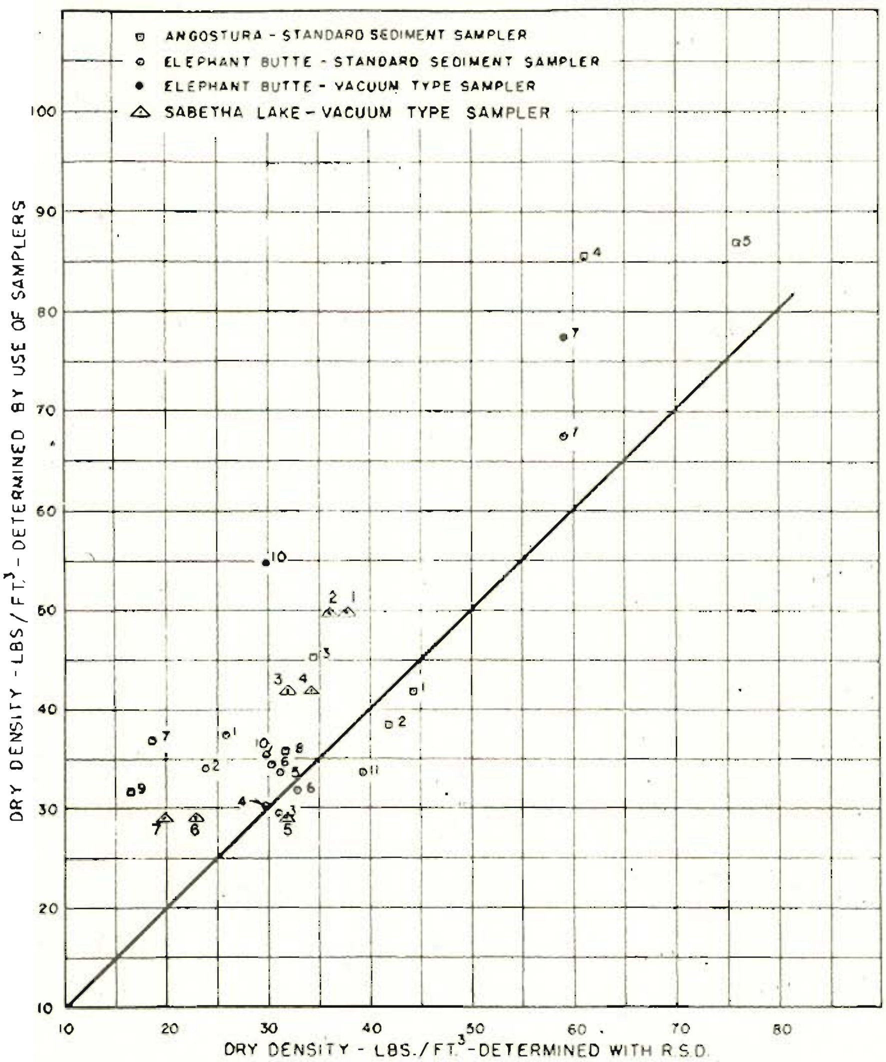


FIGURE 4 - COMPARISON OF SAMPLING METHODS FROM FIELD TESTS

U.S. Bureau of Reclamation Figure

0.1 or 0.2 milliroentgens. This can result in appreciable differences as shown in Table 2. This shows that variations between readings 0.1 high and those 0.1 low caused differences in dry density values of from 9 to 15 percent. This may be within the realm of necessary accuracy, but this fact should be recognized as a possible source of error.

ADVANTAGES

The radioisotope sediment densitometer has a number of advantages over other methods for determining the density of sediment. Some of these are:

(1) There is a minimum amount of instrument compaction when obtaining the density of the top several feet of sediment, and, therefore, the accuracy here should be greater.

(2) Radioisotope measurements are direct and densities can be determined in the field. If large differences in densities occur, additional readings can be made immediately.

(3) This instrument requires less physical exertion.

DISADVANTAGES

The radioisotope sediment densitometer also has a number of disadvantages over other devices. Some of these are:

(1) The present instrument fulfills its design requirements; however, an instrument is needed for obtaining densities also at greater depths. The extension device for determing densities at greater depths is too fragile and easily bent. When this occurs, it prevents the operator from bringing the radioactive source back into the safety shield. Nor is it

TABLE 2. -- Lake Sabetha, Kansas -- Comparison of dry densities obtained by changing dosimeter readings by 0.1

Range No.	Dist. from range end	Recorded: Dosimeter reading (mr)	Recorded: Dry density (Lb/cu ft)	High: Dosimeter reading (mr)	High: Dry density (Lb/cu ft)	Low: Dosimeter reading (mr)	Low: Dry density (Lb/cu ft)	Differences in densities (Lb/cu ft)	Differences (Percent)
8	585' from	14.3	37.65	14.4	35.89	14.2	39.24	3.35	9.3
	R8R	14.3	36.05	14.4	34.13	14.2	37.64	3.51	10.3
4	807' from	13.5	31.92	13.6	30.97	13.4	33.98	3.01	9.7
	R4R	13.5	34.31	13.6	31.76	13.4	35.73	3.97	12.5
4	1241' from	13.5	31.79	13.6	30.83	13.4	33.83	3.00	9.7
	R4R	14.7	22.93	14.8	21.19	14.6	24.35	3.16	14.9
		14.2	19.92	14.3	19.92	14.1	22.77	2.85	14.3

believed satisfactory to plunge this instrument into deeper sediment because the working shield compacts lower sediments, resulting in erroneous answers. Chances also are that during such a plunge, the lead working shield will penetrate the sediment first, and the probe containing the source of radiation and the dosimeter will trail the heavier, more compact shield into sediment. This means, then, that the density one obtains is not of undisturbed sediment but a density which is strongly modified by water and the softer sediments that fill the hole left by the plunging instrument.

(2) The RSD method of obtaining density is more time consuming in the field.

(3) A possible radiation hazard exists.

(4) More costly equipment is necessary.

(5) The RSD and shielding box (about 200 pounds) are awkward to handle.

(6) For the lakes in which the Department of Agriculture is interested, one would need a large low draft boat or a large boat and a small one working together. Large boats often cannot get close enough to shore so that workers can disembark easily.

(7) Only carefully trained personnel should operate this instrument.

(8) Supplemental equipment such as the "B" reel hoist, "A" frame, a pocket dosimeter per person, power pack, etc., are essential

in the use of the densitometer.

(9) The scale on the present dosimeter prevents the operator from making readings more accurate than ± 0.2 milli-roentgens. This can cause a considerable variation in the dry density value.

(10) This instrument cannot be used to obtain the density of sediment which is less than about two feet in thickness.

(11) Another factor is that a standard sampler still has to be used to get material from which to obtain specific gravity and the particle size distribution.

CONCLUSIONS

The Bureau of Reclamation has made a very noteworthy contribution toward a better way of obtaining the density of reservoir sediments by developing the radioisotope sediment densitometer. They are to be commended. The theory behind the use of this method is well grounded. The RSD was a big factor in the development of the sediment density probe by Technical Operations, Incorporated, for the Corps of Engineers, Beach Erosion Board.

The present RSD has several outstanding advantages over standard samplers. Instrument compaction is certainly at a minimum when the apparatus is operated within its designed limits, and, therefore, accuracy should be greater. The fact that samples need not be obtained for later analysis, and the discrepancies are uncovered at the time in the field are also very desirable features. Although the RSD is more costly, requires more field time, and constitutes a source of danger, the primary disadvantage is that it should only be used to obtain the density of submerged sediments between two and about four feet of sediment depth. This deficiency is being overcome, however, by the Technical Operations, Incorporated, instrument. Radioactive density instruments show great promise and further development should be planned.

The stated objectives for this study were satisfied, even though many readings were not made, nor the instrument operated over a variety of conditions. A plotting of the data obtained during the study shows that these points fall among the scattering of points experienced by the Bureau of Reclamation on other lakes.

The loan of this instrument and the other necessary equipment by the Bureau of Reclamation was appreciated. It is hoped that additional development is contemplated for this type of instrument.