Sediment Deposition in Reservoirs in the United States

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INTRODUCTION

Sedimentation data from known reliable reservoir sedimentation surveys made in the United States through 1960 are summarized in U.S. Department of Agriculture Miscellaneous Publication 964 (10).[2] This publication, along with its unpublished appendix, contains information on storage capacity, drainage area, and sedimentation rates and amounts for 1,069 reservoirs. These data, which were assembled and compiled by the Agricultural Research Service working under the auspices of the Subcommittee on Sedimentation of the Federal Inter-Agency Committee on Water Resources, furnish the basis for this report. The data are further summarized and categorized to afford some insight into the present rate of siltation in the Nation's reservoirs. Mean sedimentation rates and amounts are given by river basins, by reservoir capacity, and by reservoir capacity-drainage area ratios.

DATA USED

Reservoir sedimentation surveys were reported from most of the conterminous United States, except Maine and Florida, and from Puerto Rico. Many of the reservoirs were constructed for a single purpose; others were considered multiple-use structures, and some were constructed for the sole purpose of sediment detention.

The accuracy of the surveys varied considerably, but no attempt was made to classify according to the degree of accuracy, and no attempt was made to check, in detail, the individual data sheets for computational and clerical errors. Surveys ranged from reconnaissance-type measurements of deposited sediments to detailed surveys consisting of closely spaced cross sections or contours.

In selecting the data for this report it was concluded that only those reservoirs with complete information on capacity, total and net drainage area, period of record, and sedimentation rates would be included. After reviewing each data sheet, 968 reservoirs were selected. One, Lake Mead, was purposely omitted because its capacity alone equaled approximately one-half the total capacity of all other reservoirs reported.

Geographic distribution of the selected reservoirs by river basins is shown in figure 1. River basin boundaries and numbers were established by the Subcommittee on Hydrology of the Inter-Agency Committee on Water Resources (11). The selected reservoirs represent virtually every section of the country, with heaviest concentrations in the Midwestern States, Texas, and California. Many of the river basins, however, are not adequately represented.

RESERVOIR STORAGE DEPLETION

A general summary of the data is given in table 1. Total drainage area includes the entire area upstream from the dam, including

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[2] Numbers in parentheses refer to Literature Cited at end of this report.

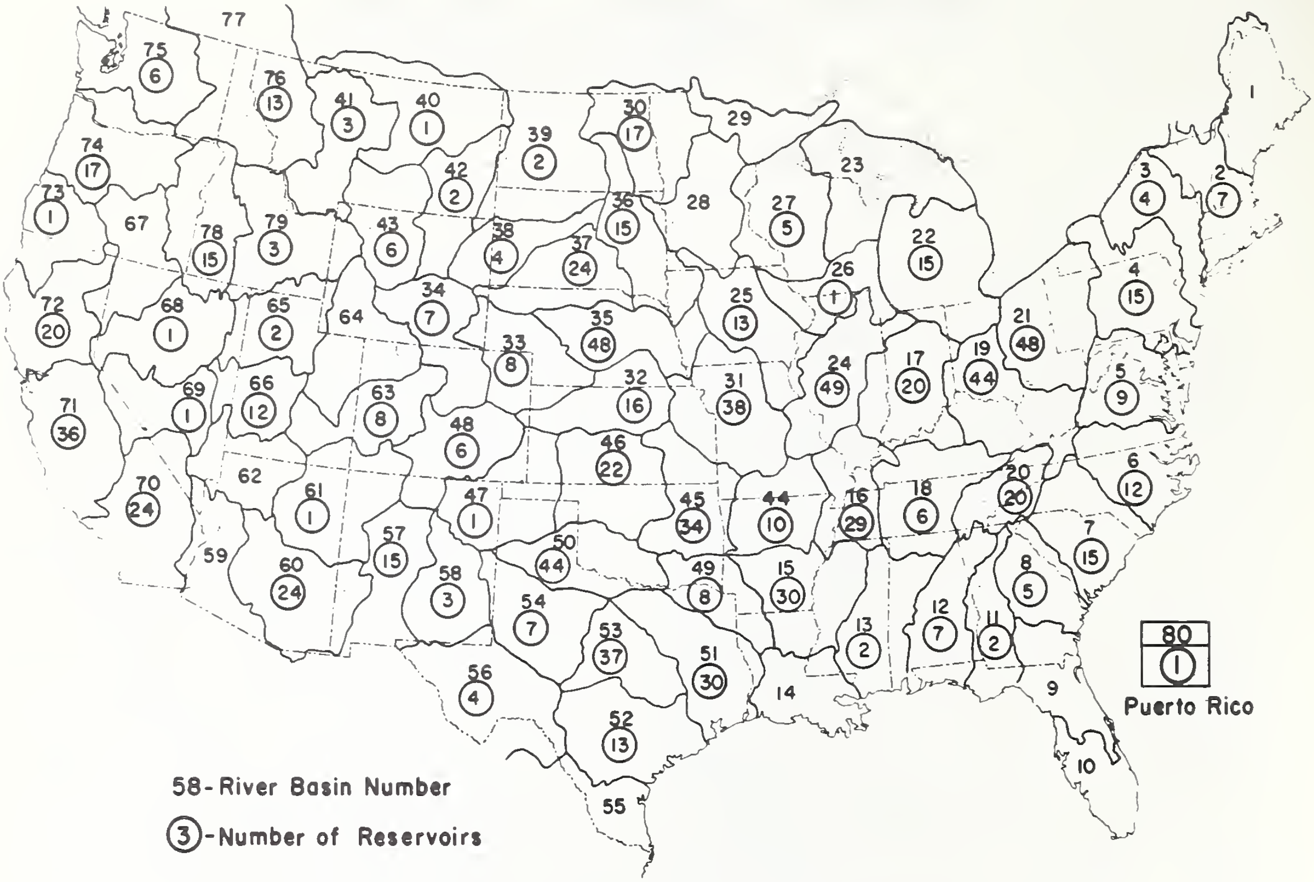

Figure 1.--Geographic distribution of reservoirs.

the reservoir area, but generally excludes non-runoff-contributing drainage areas. Net drainage area is defined as the net sediment-contributing area and generally does not include areas above upstream structures that are effective sediment traps. The maximum value reported was used for the initial reservoir storage capacity and generally represents the storage capacity below the elevation of the crest of an ungated spillway or the top of the gates for gated spillways. Storage depletion is the loss of storage capacity due to sediment deposition. In most instances, the period of record also represents the reservoir age to the date of the latest survey. The capacity-weighted period of record was 16.1 years, slightly less than the average reservoir age.

Average annual storage loss due to sediment accumulation for all reservoirs was about 150,000 acre-feet, which was slightly greater than 0.2 percent of the total original capacity. Although the individual reservoir accumulation rates varied greatly, storage in the smaller reservoirs was depleted at much higher rates, ranging from 2.4 percent annually for the 0 to 10-acre-foot size to 0.2 percent for reservoirs with capacities in excess of 1 million acre-feet. However, 92 percent, or 57 million acre-feet, of the total capacity is contained in only 77 of the larger reservoirs. These reservoirs trapped 82 percent of the total sediment.

Perhaps average annual values of individual reservoir storage depletion rates are a more realistic indicator of the reservoir siltation problem. Average values (table 2) showed the same trend of decreasing percentage of storage depletion as reservoir capacity increased, but at somewhat higher rates. Median rates, although significantly lower than the average, also decreased as capacity increased. For reservoirs having a capacity of 100 acre-feet or less--nearly 40 percent of the total number--the average annual storage loss was 3.3 percent and the median was 1.6 percent. Total percentage storage loss at the time of the latest survey was also much higher in

TABLE 1.--Summary of reservoir storage capacity and storage depletion by capacity ranges

Reservoir capacity range (acre-feet)	Reservoirs	Drainage area		Initial Reservoir storage capacity	Storage depletion		Average period of record
		Total	Net				
	Number	Square Miles	Square Miles	Acre-feet	Acre-feet	Percent	Years
0 - 10	161	153	137	685	180	26.3	11.0
10 - 100	228	425	409	8,199	1,711	20.9	14.7
100 - 1,000	251	4,116	3,502	97,044	16,224	16.7	23.6
1,000 - 10,000	155	12,107	11,372	488,374	51,096	10.5	20.5
10,000 - 100,000	99	109,692	81,311	4,213,330	368,786	8.8	21.4
100,000 - 1,000,000	56	197,560	131,510	18,269,832	634,247	3.5	16.9
Over 1,000,000	18	254,441	139,102	38,161,556	1,338,222	3.5	17.1
Total	968	578,494	367,344	61,239,019	2,410,466	3.9	[1]18.2

[1] Arithmetic average for all reservoirs.

TABLE 2.--Reservoir storage depletion rates

Reservoir capacity range (acre-feet)	Reservoirs	Annual storage depletion rates		Average reservoir storage depletion to date [1]
		Average	Median	
	Number	Percent	Percent	Percent
0 - 10	161	3.41	2.20	25.0
10 - 100	228	3.17	1.32	21.2
100 - 1,000	251	1.02	0.61	17.2
1,000 - 10,000	155	.78	.50	11.0
10,000 - 100,000	99	.45	.26	9.92
100,000 - 1,000,000	56	.26	.13	3.72
Over 1,000,000	18	.16	.10	3.35
Total	968	1.77	.72	16.65

[1] To date of latest survey.

TABLE 3.--Average annual reservoir storage loss by capacity and by capacity-drainage area (c/w) ratio

Reservoir capacity range (acre-feet)	C/w ratio in acre-feet per square mile									
	Less than 1		1 - 10		10 - 100		100 - 1,000		Over 1,000	
	Reservoirs	Storage loss	Reservoirs	Storage loss	Reservoirs	Storage loss	Reservoirs	Storage loss	Reservoirs	Storage loss
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
0 - 10	19	7.18	32	4.08	85	2.22	25	3.72	0	0.0
10 - 100	2	50.48	23	7.22	120	2.37	82	2.08	1	.25
100 - 1,000	1	.44	18	1.81	93	1.45	138	.64	1	.20
1,000 - 10,000	0	0	10	1.59	49	1.23	89	.49	7	.13
10,000 - 100,000	0	0	8	1.03	25	.73	60	.29	6	.10
100,000 - 1,000,000	0	0	0	0	20	.49	32	.15	4	.07
Over 1,000,000	0	0	0	0	5	.13	12	.17	1	.08
Total	22	10.81	91	3.88	397	1.75	438	.96	20	.12

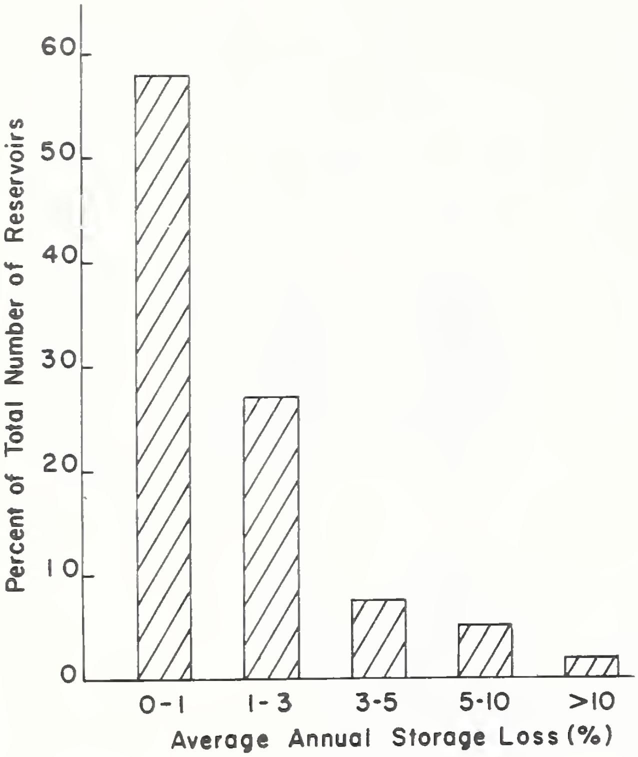

Figure 2.--Reservoir storage depletion rates.

the smaller reservoirs even though they were much younger.

As indicated above, storage depletion rates varied widely, particularly among the smaller reservoirs, ranging from 0 to 100 percent for those with less than 100-acre-foot capacity. On the other hand, annual rates did not exceed 3 percent for any of the reservoirs with capacities of 100,000 acre-feet or more. Further analysis of the data revealed that 58 percent of all reservoirs had annual storage depletion rates of less than 1 percent, 15 percent had rates in excess of 3 percent, and 2 percent had rates in excess of 10 percent (fig. 2). The proportion of reservoirs having relatively low storage depletion rates corresponds closely to that reported by Eakin (3), Happ (6), and Brown (1, 2) approximately 30 years ago based on a much smaller sample.

Normally, the ratio between reservoir capacity and the size of its drainage area (c/w ratio), expressed in acre-feet per square mile of drainage area, is a predominant factor governing storage depletion rates. Although there were wide variations, average depletion rates generally decreased as the c/w ratio increased and as reservoir capacity increased (table 3). Nearly one-half, 43 percent, of all reservoirs with c/w ratios less than 10 had annual storage depletion rates greater than 3 percent, whereas the annual rate did not exceed 0.5 percent for any of the reservoirs with c/w ratios of 1,000 or more.

Average annual values of sediment accumulation per unit of net drainage area in acre-feet per square mile are shown in table 4. On the average, rates were much higher in the smaller reservoirs with high c/w ratios. Although individual reservoir rates varied widely, the average accumulation rate increased as the capacity-area ratio increased and generally decreased as capacity increased. The average rate for the 120 reservoirs in the 10 to 100-acre-foot size category with c/w ratios from 10 to 100 is a readily apparent exception to this trend. A probable explanation is the heavy concentration of reservoirs in this group, about 25 percent of the total number, in river basins 31, 35, and 36 where the average accumulation rate for all reservoirs reported was relatively high.

A complete breakdown of accumulation rates by capacity and capacity-area ratio (table 5) revealed that nearly half of the reservoirs, 46 percent, had an average annual sediment accumulation rate of less than 0.5 acre-feet per square mile, whereas only 4 percent had rates in excess of 5 acre-feet per square mile. The maximum rate reported was 61 acre-feet per square mile for a small reservoir in Iowa.

Storage Depletion and Sediment Accumulation By River Basins

Average annual storage depletion and sediment accumulation rates by river basins ranged from less than 0.1 to 17 percent and from 0.2 to 7.13 acre-feet per square mile (table 6). There were also large variations between reservoirs in the same river basin. For example, in river basin 15, for which most reported reservoirs are in the hills of northern Mississippi, storage depletion rates ranged from 0.04 to 12.9 percent and sediment accumulation from 0.1 to 26 acre-feet per square mile. However, these averages are of limited value for many basins, because too few reservoirs were reported for the data to be representative. In others,

TABLE 4.--Average annual sediment accumulation per unit of net drainage area in acre-feet per square mile by capacity and by capacity-drainage area (c/w) ratio

Reservoir capacity range (Acre-ft.)	C/w Ratio in acre-feet per square mile											
	Less than 1		1 - 10		10 - 100		100 - 1,000		Over 1,000		Total	
	Reser-voirs	Sed. Acc.	Reser-voirs	Sed. Acc.	Reser-voirs	Sed. Acc.	Reser-voirs	Sed. Acc.	Reser-voirs	Sed. Acc.	Reser-voirs	Sed. Acc.
	Number	Acre-ft./mi.²	Number	Acre-ft./mi.²	Number	Acre-ft./mi.²	Number	Acre-ft./mi.²	Number	Acre-ft./mi.²	Number	Acre-ft./mi.²
0 - 10	19	0.06	32	0.24	85	0.84	25	6.58	0	0	161	1.52
10 - 100	2	.56	23	.20	120	1.22	82	3.99	1	3.00	228	2.12
100 - 1,000	1	.03	18	.08	93	.69	138	1.67	1	3.53	251	1.19
1,000 - 10,000	0	0	10	.07	49	.67	89	1.58	7	2.14	155	1.22
10,000 - 100,000	0	0	8	.10	25	.38	60	.75	6	1.64	99	.66
100,000 - 1,000,000......	0	0	0	0	20	.37	32	.55	4	.91	56	.51
Over 1,000,000......	0	0	0	0	5	.36	12	.48	1	.88	18	.47
Total	22	.10	91	.17	397	.84	438	2.12	20	1.79	968	1.36

TABLE 5.--C/w ratio: Sediment accumulation per unit of net drainage area relationship

Capacity-area ratio (Acre-ft. per sq. mile)	Reser-voirs	Average annual sediment accumulation in acre-feet per square mile											
		0 - 0.5		0.5 - 1.0		1.0 - 3.0		3.0 - 5.0		5.0 - 10.0		Over 10.0	
		Reser-voirs	Percent of total	Reser-voirs	Percent of total	Reser-voirs	Percent of total	Reser-voirs	Percent of total	Reser-voirs	Percent of total	Reser-voirs	Percent of total
	Number	Number		Number		Number		Number		Number		Number	
0 - 1	22	20	90.9	1	4.5	1	4.5	--	--	--	--	--	--
1 - 10....................	91	84	92.3	5	5.5	2	2.2	--	--	--	--	--	--
10 - 100	397	216	54.4	89	22.4	74	18.6	12	3.0	5	1.3	1	0.3
100 - 1,000...............	438	120	27.4	82	18.7	159	36.3	44	10.0	19	4.3	14	3.2
Over 1,000..............	20	2	10.0	5	25.0	10	50.0	2	10.0	1	5.0	--	--
Total	968	442	45.7	182	18.8	246	25.4	58	6.0	25	2.6	15	1.5

TABLE 6.--Summary of reservoir sedimentation data by river basins
[Average values except as noted]

River basin no.	Reservoirs	Drainage area		Original reservoir capacity	C/w ratio	Annual sediment accumulation	Annual Storage depletion		Period of Record
		Total	Net				Average	Weighted [1]	
	Number	Square miles	Square miles	Acre-ft.	Acre-ft./sq. mi.	Acre-ft./sq. mi.	Percent	Percent	Years
2	7	6.2	6.2	897.4	379	0.16	0.08	0.05	55
3	4	168.3	141.1	16,430.9	60	.10	.36	.09	80
4	15	56.6	50.8	11,415.5	182	.27	1.12	.13	31
5	9	76.0	75.6	6,370.7	113	.52	1.06	.31	19
6	12	738.8	702.3	252,912.2	144	.55	1.39	.28	12
7	15	630.9	348.3	29,612.7	59	.46	.77	.50	21
8	5	287.2	285.7	23,276.0	196	.98	.55	.52	9
11	2	1.9	1.8	301.2	185	.83	.50	.47	26
12	7	1,307.5	1,305.7	25,590.2	211	1.45	1.17	.49	12
13	2	51.2	50.7	7,304.0	122	.74	.48	.69	25
15	30	133.8	128.7	76,236.2	285	7.13	3.68	.09	11
16	29	55.6	51.4	25,296.3	259	1.20	.68	.06	21
17	20	101.1	100.4	1,431.7	269	1.18	.76	.41	18
18	6	16,525.5	2,226.2	1,417,131.5	156	.58	.24	.10	24
19	44	132.1	131.2	19,888.2	163	.79	1.76	.10	17
20	20	2,337.4	889.0	463,825.0	409	.48	.41	.07	17
21	48	100.0	96.9	31,736.4	185	.51	1.54	.11	20
22	15	188.7	182.9	9,870.4	156	.95	1.08	.24	25
24	49	29.6	29.3	2,338.0	179	.99	1.04	.51	30
25	13	27.5	26.2	1,230.3	83	1.48	2.79	4.02	13
26	1	116.0	116.0	608.0	5	.08	1.52	1.52	15
27	5	1,830.1	170.0	20,531.1	33	.35	.98	.45	35
30	17	305.0	165.8	5,106.0	23	.17	.69	.31	23
31	38	371.3	368.6	55,443.7	185	2.46	2.58	.31	12
32	16	523.7	190.5	28,003.5	61	1.41	2.71	.16	17
33	8	85.0	84.6	11,680.4	55	.72	1.90	.70	10
34	7	5,213.1	3,648.7	320,584.6	68	.16	.49	.14	24
35	48	10.7	1.2	63.8	113	4.71	4.09	2.06	10
36	15	43.6	37.6	945.3	96	3.14	2.66	1.29	9
37	24	1.1	1.1	24.6	37	.56	1.81	.90	10
38	4	0.5	0.5	90.8	100	1.21	1.80	.46	17
39	2	16.5	14.2	104.4	4	.02	.74	.61	27
40	1	55.0	54.0	4,796.0	87	.32	.36	.36	10
41	3	1.2	1.2	26.7	30	.09	.04	.50	45
42	2	872.6	869.8	36,633.0	93	.96	.80	.46	19

43	6	250.8	250.8	76,039.4	80	.56	1.41	.16	15
44	10	472.0	471.4	6,519.7	200	.91	.60	1.45	10
45	34	108.7	107.7	13,074.1	249	.93	.47	.19	18
46	22	807.0	513.3	40,722.1	163	.95	1.98	.43	11
47	1	7,350.0	6,950.0	601,112.0	82	.50	.58	.58	10
48	6	3,316.8	3,006.8	132,988.8	161	.47	1.07	.55	28
49	8	551.9	517.5	466,509.6	575	.67	.49	.00	27
50	44	1,018.0	762.7	150,677.4	230	1.76	1.19	.45	13
51	30	183.0	144.7	55,521.4	361	2.48	.90	.41	21
52	13	2,827.7	2,823.4	100,268.3	123	1.00	1.21	.42	13
53	37	480.3	448.9	25,741.0	210	1.40	1.07	.96	22
54	7	110.8	80.3	16,057.5	136	.50	.47	.26	19
56	4	2.6	1.9	219.2	84	1.31	1.24	1.39	15
57	15	3,850.6	1,882.6	206,839.5	42	1.13	3.41	.42	13
58	3	6,461.0	6,246.3	82,976.7	26	.40	1.16	1.78	26
60	24	1,083.2	1,040.1	137,549.2	69	.31	3.52	.27	15
61	1	9.4	9.4	334.8	36	3.32	9.30	9.30	6
63	8	0.3	0.3	35.2	119	2.77	2.91	1.67	7
65	2	374.8	372.8	37,901.0	54	.28	3.80	.11	13
66	12	760.2	423.5	30,827.8	89	.57	17.30	.30	29
68	1	112.0	111.0	15,300.0	137	.15	.11	.11	15
69	1	2,800.0	2,440.0	13,200.0	5	.02	.42	.42	4
70	24	169.5	131.1	22,917.9	838	1.15	.47	.26	21
71	36	162.4	161.8	53,893.3	215	.23	1.14	.05	23
72	20	62.7	62.1	12,227.9	178	.43	1.84	.33	22
73	1	61.6	61.2	8,300.0	135	.21	.16	.16	27
74	17	71.5	71.0	13,856.3	87	.18	.95	.08	13
75	6	168.6	168.6	14,869.3	16	.03	1.05	.07	9
76	13	0.1	0.1	2.5	115	1.47	1.88	1.56	8
78	15	336.0	319.2	21,986.6	77	.11	.67	.18	16
79	3	582.6	580.9	76,979.8	53	.04	.48	.03	34
80	1	48.9	47.9	50,149.0	1,026	1.29	.12	.12	4

[1] Capacity-weighted.

where the number and size distribution were adequate, the reservoirs were often concentrated in a small area and may represent only a small part of the basin.

Total annual storage loss in each river basin is more accurately reflected by the capacity weighted depletion rates shown in table 6. In most instances the weighted values are considerably lower than the average values, because siltation rates were generally much lower in the larger reservoirs which usually comprised a major portion of the total capacity. A good example is river basin 15, with an average storage depletion rate of 3.68 percent and a weighted rate of only 0.09 percent. On the other hand, all reservoirs in river basins 25 and 35 were relatively small and both the average and weighted depletion rates were high. The phenomenally high average rate for river basin 66 is misleading, because two small reservoirs were completely filled with sediment by single floods.

DISCUSSION

The many complex processes involved in reservoir sedimentation render an overall view of the problem inconclusive. The relative importance of controlling factors varies from region to region and even within a region. Therefore, it is not the intent or purpose of this paper to establish average reservoir sedimentation rates for a given locality or drainage basin. The wide range in deposition rates for reservoirs of similar size and capacity-area ratio, even within a given land resource area, suggests that average rates would be of little value in predicting the useful life of a particular reservoir. Furthermore, the wide range in values strongly indicates that local parameters rather than climatic or geographic factors govern individual reservoir siltation rates.

The data, as compiled, do afford some insight into the magnitude of the Nation's reservoir siltation problem. For example, the relatively low storage depletion rate of only 0.2 percent annually of the total reservoir capacity is probably well within the design requirements of most reservoirs. On the other hand, the smaller upland reservoirs with capacities of 100 acre-feet and less are filling at an average annual rate in excess of 3 percent. The median storage depletion rate of 1.6 percent annually for these small reservoirs suggests that one-half of them will be completely filled with sediment in 62 years. Furthermore, the utility of many of these reservoirs will have been seriously impaired by the time they are half full; thus, indicating a probable useful life of only 31 years.

The quantity of sediment collected in reservoirs does not adequately reflect watershed sediment yields, since it does not include deposits above spillway elevations or sediment transported through the reservoirs. The data in tables 4 and 5 suggest, however, that watershed sediment yield was the predominant factor influencing deposition rates. Even though the trap efficiencies of the reservoirs would normally vary significantly, the average deposition rate per unit area generally decreased as capacity and, correspondingly, drainage area increased for a given capacity-area ratio range. Although not shown in the tables, the average c/w ratio decreased as drainage area increased for reservoirs with drainage areas larger than 10 square miles.

This is in accord with the generally held hypothesis of decreasing sediment delivery with increasing drainage area, and tends to pinpoint most of the reservoir sedimentation problems in the smaller upland reservoirs where watershed sediment yields are highest (4, 5, 8). Again, river basin 15 is a good example. All the reservoirs, except two, were small, primarily farm ponds located in the severely eroded Loess and Coastal Plains soils of northern Mississippi. The average sediment accumulation rate of 8.2 acre-feet per square mile in the small reservoirs was 10 times greater than it was in the two large reservoirs.

It is difficult to ascertain whether these data are truly representative of all reservoirs in the country. Information on the total number of reservoirs, much less the size, distribution, and location, is difficult to obtain. Eakin (3) estimated that there were 10,000 reservoirs in this country in 1939, and in 1963 Martin and Hanson (7) reported 359 million acre-feet of usable reservoir storage in 1,562 reservoirs with individual capacities of 5,000 acre-feet or more. The

Soil Conservation Service has reported 4,050 multiple-purpose and 8,283 flood-water-retarding reservoirs constructed under its various soil and water conservation programs through June 1966. In addition, almost 1.5 million farm ponds were reported as being "on the land" (9).

If one assumes the data to represent a cross section of the Nation's reservoirs, it may be concluded that: (1) the overall depletion rate of 0.2 percent annually of total reservoir capacity is not excessively high; (2) annual storage depletion rates of 3 percent, on the average, are excessive in the smaller upland reservoirs; (3) at present rates, about 20 percent of the Nation's reservoirs will be half filled with sediment and their utility seriously impaired in one generation, or about 30 years; and (4) local factors, such as upstream erosion, watershed sediment yield, and trap efficiency, rather than regional or climatic parameters, govern individual reservoir siltation rates.

LITERATURE CITED

(1) Brown, C. B.
1941. Factors in the Control of Reservoir Silting. Amer. Water Works Assoc. Jour. 33(6): 1022-1040.

(2) ____
1943. The Control of Reservoir Silting. U.S. Dept. Agr. Misc. Pub. 521, 166 pp.

(3) Eakin, H. M. (Rev. by C. B. Brown)
1939. Silting of Reservoirs. U.S. Dept. Agr. Tech. Bul. 524, 168 pp.

(4) Glymph, L. M., Jr.
1954. Studies of Sediment Yields from Watersheds. Internatl. Assoc. Hydrol., IUGG, Tenth Gen. Assembly, Rome, Sept. 1954, pp. 178-191.

(5) Happ, S. C., Rittenhouse, Gordon, and Dobson, G. C.
1940. Some Principles of Accelerated Stream and Valley Sedimentation. U.S. Dept. Agr. Tech. Bul. 695, 134 pp.

(6) ____
1941. Sedimentation in Artificial Lakes. In A Symposium on Hydrobiol., The University of Wisconsin Press: 35-44, illus., Madison.

(7) Martin, R. O. R., and Hanson, R. L.
1966. Reservoirs in the United States. U.S. Geol. Survey Water Supply Paper 1838, 114 pp.

(8) Roehl, J. W.
1962. Sediment Source Areas, Delivery Ratios and Influencing Morphological Factors. Internatl. Assoc. Sci. Hydrol. Pub. 59: 202-213.

(9) Soil Conservation Service.
1967. Soil Conservation in the Changing Landscape - Summary of Activities of the Soil Conservation Service 1966. Soil Conserv. 32(6): 136-141.

(10) Spraberry, J. A. (Compiler for Agricultural Research Service in cooperation with Subcommittee on Sedimentation, Inter-Agency Committee on Water Resources.)
1960. Summary of Reservoir Sediment Deposition Surveys made in the United States through 1960. U.S. Dept. Agr. Misc. Pub. 964, 61 pp.

(11) U.S. Inter-Agency Committee on Water Resources, Subcommittee on Hydrology.
1961. River Basin Maps Showing Hydrologic Stations. Inter-Agency Committee on Water Resources, Subcommittee on Hydrology, Notes on Hydrologic Activities Bul. 11, U.S. Dept. of Commerce, Weather Bureau, 79 pp.