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THE 1967 ALTUS RESERVOIR SEDIMENT SURVEY

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Engineering and Research Center
Bureau of Reclamation

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16. ABSTRACT

Altus Reservoir was surveyed in 1967 to gather the data needed in computing the latest reservoir capacity. The data were also used to compute the quantity of sediments accumulating in the reservoir since the dam was closed in 1940. Capacity of the reservoir is 134,000 acre-ft and the surface area 6,260 acres at spillway crest elevation 1559 ft. Sediments accumulated in the reservoir at an annual rate of 838 acre-ft between 1940 and 1947. Thirty sediment samples of reservoir deposits were collected from 23 reservoir range sites. An average unit weight of 70 lb/cu ft was determined from analyses of samples collected during the 1948, 1953, and 1967 surveys. Particle size analyses of these samples indicated an average breakdown of 29% clay, 32% silt, and 39% sand. Sonic depth recording mechanism was used to run the hydrographic survey. Reservoir capacity was computed based on areas determined by a width ratio method. Sediments have deposited longitudinally to depths of 1 to 9 ft throughout the reservoir length. Depths ranged from 1 to 6 ft for the laterally deposited sediments.

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by
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March 1971

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Engineering and Research Center
Denver, Colorado

UNITED STATES DEPARTMENT OF THE INTERIOR
Rogers C. B. Morton
Secretary

*

BUREAU OF RECLAMATION
Ellis L. Armstrong
Commissioner

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The hydrographic survey was run by Joe M. Lara, Engineering and Research Center, Denver, Colorado. Survey personnel included H. T. Daniel, R. Carey, and W. Vanhosser under the supervision of the Regional Office, Amarillo, Texas. They ran the required land surveys and assisted in running the hydrographic survey and taking the sediment samples. Transcription of the field notes for computer processing was done by R. L. Ochs and W. A. Seth under the supervision of R. Weimer, Regional Office, Amarillo. This report was prepared under the supervision of Ernest L. Pemberton, Head, Sedimentation Section, Engineering and Research Center, Denver, Colorado. Mr. Pemberton also reviewed the report and the data and information used in its preparation.

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GENERAL INFORMATION

Location and Ownership

Altus Dam is located on the North Fork of the Red River about 18 miles north of Altus, Oklahoma. The reservoir is situated in Greer and Kiowa Counties. The dam and reservoir are owned by the U.S. Government and operated by the Bureau of Reclamation, Department of the Interior.

Description of the Dam

Altus Dam is a concrete gravity type, partially curved structure faced with granite masonry on both faces except the downstream face of the overflow section. It rises 110 feet above its foundation and is 1,112 feet long. Incorporated within the dam section are both controlled and uncontrolled overflow-type spillways and an outlet works that delivers water into the project canal system. The spillway capacity is 58,000 cubic feet per second regulated by nine radial gates. A drawing of the general plan and sections is shown in Figure 1.

Description of the Reservoir

The present capacity of the reservoir is 134,549 acre-feet at the spillway crest elevation 1559 feet. This shows a loss of 22,119 acre-feet since the dam was closed in 1940. The present reservoir surface area is 6,260 acres at elevation 1559 feet. The reservoir is 13.1 miles long from the dam to the head of the reservoir. It has an average width of 1 mile. Figures 2 and 3 are plan maps of the reservoir.

The reservoir was designed to provide water for irrigation, flood control, an augmented municipal water supply for the city of Altus, fish and wildlife benefits, and recreational facilities.

Drainage Area Description

The drainage area above Altus Dam is 2,515 square miles of which 399 square miles is probably noncontributing. It originates in the Panhandle of Texas about 15 miles west of Amarillo, Texas, and extends eastwardly into western Oklahoma. The area is drained by the North Fork of the Red River, whose principal tributaries are McClellan and Sweetwater Creeks.

There are no major structures in the watershed that would reduce the sediment contribution to Altus Reservoir. However, the restriction of the lake imposed by the approaches to Granite Bridge and another restriction existing naturally about 3000 feet above the dam do affect the distribution of sediment after it enters the lake.

Further description of the drainage area regarding geology, topography, soils, land use, and other features is given in a Bureau of Reclamation report published in 1949.[1]

Hydrographic Records

Streamflow records of the North Fork of Red River near Carter, Oklahoma, were used to estimate the inflow to Altus Reservoir. These records, adjusted for drainage area, showed an annual average inflow of 104,400 acre-feet for 20 years of record (1944-62, 1964-66). Outflow from the reservoir was based upon records of the river at the gaging station below the dam. These showed an outflow of 36,340 acre-feet per year for a 14-year period (1950-62, 1964-66). The outflow is controlled by releases from the dam. Altus Reservoir operation ranged from a minimum elevation of 1523.20 feet in 1945 to a maximum of 1562.10 feet in 1951.

SURVEYS, SAMPLING, AND EQUIPMENT

Two surveys of Altus Reservoir were previously run in 1948 and 1953 using a combination contour and range method. The range method was used for the 1967 survey that began in February 1967 and completed April 14, 1967. Results of each survey are summarized in Table 2 (pages 12 and 13).

Surveying Methods

Field survey work was begun by locating and flagging all 25 reservoir sedimentation range ends (Figures 2 and 3) that had been permanently monumented during previous surveys. In some cases it was necessary to relocate the range and monuments that had been removed or possibly destroyed for one reason or another. The ranges were profiled across their full length. Standard land surveying procedures and equipment were used to run levels along each range line from the permanent range end monuments down to the water surface from each side of the reservoir. Stations were temporarily established at the terminal land points near water's edge for use in the hydrographic survey.

[1] Seavy, L. M., "Sedimentation survey of Altus Reservoir—W. C. Austin Project, Oklahoma," Bureau of Reclamation, U.S. Department of the Interior, December 1949.

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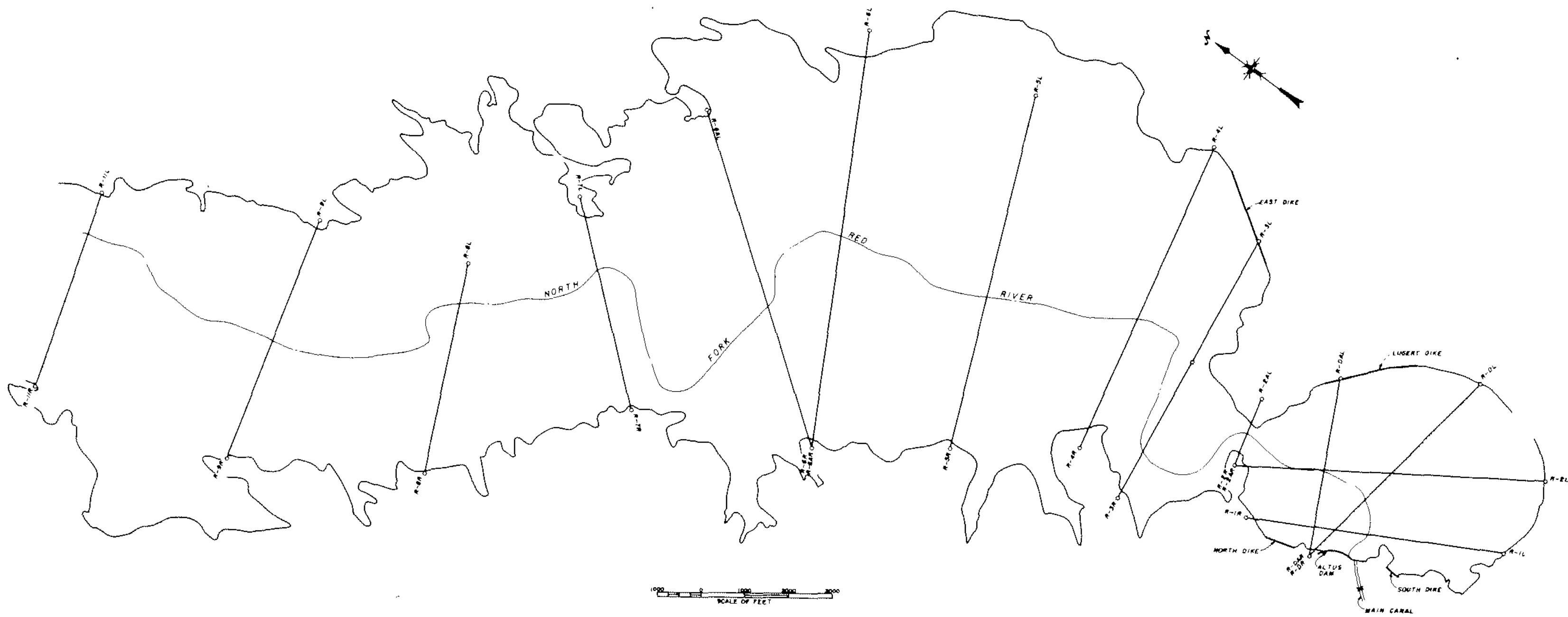

Figure 2. Reservoir sedimentation range system.

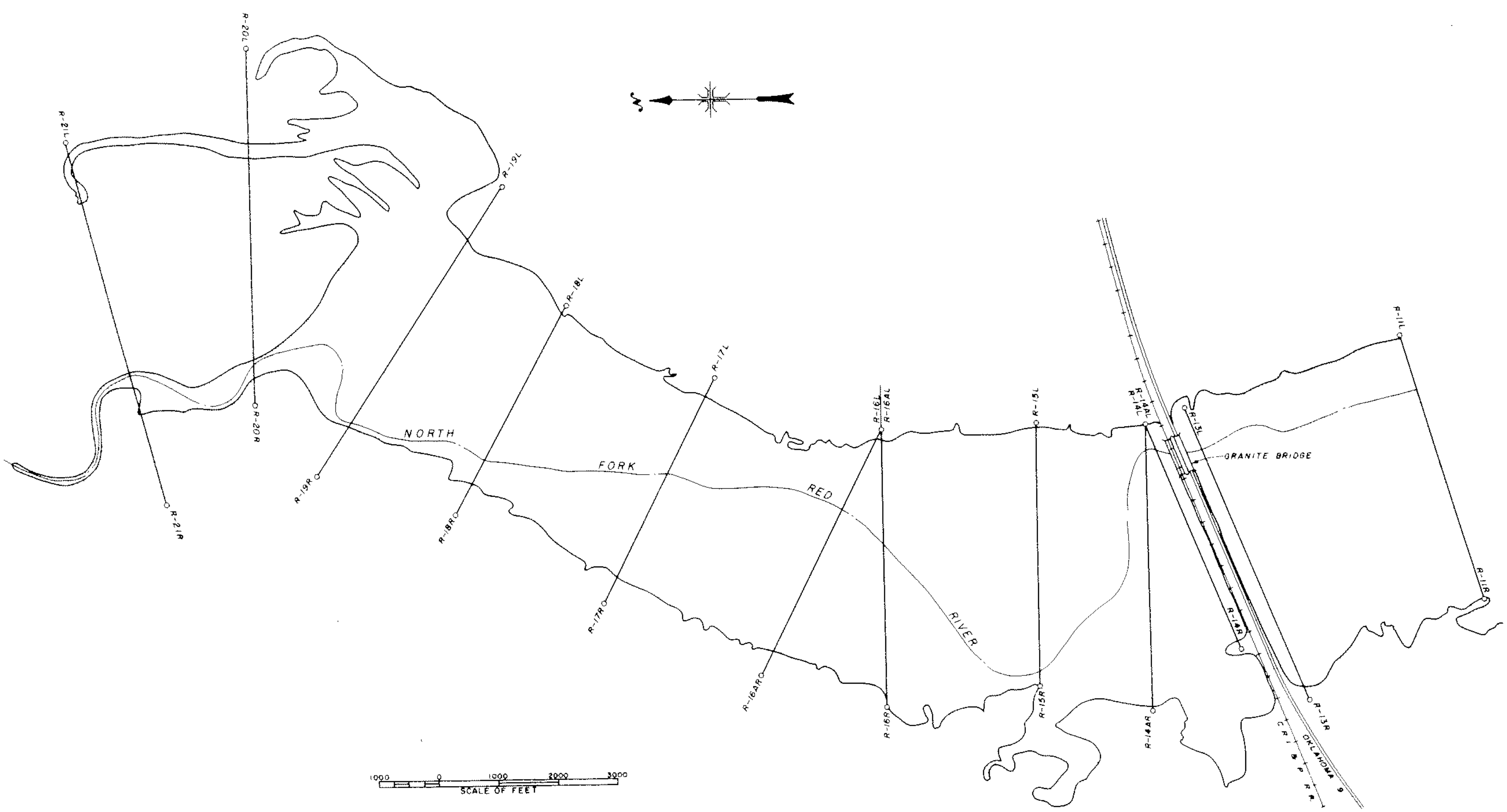

Figure 3. Reservoir sedimentation range system.

The hydrographic survey was run in April 1967 using sonic depth recording equipment (Figure 4) to sound the submerged portion of the ranges. The equipment is installed in a sounding boat as shown in Figure 5. The boat is first positioned on range line as near to the shore as possible. Then the line is profiled from the water's edge station using a level rod and stadia or tape to measure the distance to the center point of the transducer. The depth recorder is started up and the boat is propelled across the range at speeds of about 3 to 5 feet per second (Figure 6). A man on shore keeps the boat on line through radio communication with the boat operator (Figure 7). The distance measuring machine shown in Figure 8 is used to measure horizontal distances across the reservoir. The machine provides a way of noting "fix" lines on the sonar chart that is contained in the recorder cabinet shown in Figure 9. Vertical control was maintained by referencing the recorded soundings to the reservoir water surface indicated by gage at the dam which was read each day of the survey operation.

Figure 4. Sonic depth recording equipment. Transducer is out of water. Photo P258-D-57761

Figure 5. Sounding boat used in the hydrographic survey. Photo P258-D-57701

Sampling Methods and Equipment

Ten samples of the underwater reservoir sediment deposits were collected with a gravity core sampler that is suspended from a frame mounted on a raft (Figure 10). The sampler is operated with a power winch using a 0.25-inch cable. It is allowed to fall free into the sediment deposits to the greatest possible penetration. After the sampler is raised it is brought onto the raft, the cutting shoe at the bottom is removed, and the plastic tube containing the sediment sample is withdrawn. A hacksaw is used to cut that part of the tube holding the sample and each end of the tube is capped and identified for analysis.

Samples were collected from 13 of the upstream ranges using a 2-inch diameter plastic tube that was pounded into the sediment deposits with a rubber mallet (Figure 11).

The field density apparatus was used to take samples at seven of the upstream ranges in the manner prescribed by a Bureau of Reclamation manual.[2] Figure 12 shows one of these samples being taken.

[2] Bureau of Reclamation, *Earth Manual,* U.S. Dept. of the Interior, pp 582-91, 1963.

Figure 6. Sounding Range 1. Photograph was taken from atop the dam looking towards the narrows in the background. Photo P258-D-57705

Figure 7. Transit set up on range point in line with R7L at water's edge. During the sounding operation the man on shore keeps the boat on line through the transit. Radios are used for communication between the transit man and the boat operator. Photo P258-D-57711

Figure 8. Distance measuring machine mounted in back of the boat. Fair lead for piano wire guidance can be seen at right. It has a periscope appearance. Photo P258-D-57703

Figure 9. View of sonic depth recorder cabinet (in right foreground). Photo P258-D-57706

Figure 10. Gravity core sampler shown suspended from a cable and lying on the platform of the raft. Photo P258-D-57699

Figure 11. Sediment sample being taken by pounding a plastic tube into the sediment deposits with a rubber mallet. Photo P258-D-57702

Figure 12. Taking a sediment sample with field density apparatus. Photo P258-D-57697

RESERVOIR SEDIMENT DISTRIBUTION

Longitudinal Distribution

A summary of the sediment distribution computations for Altus Reservoir is contained in Table 1. In Column 6 of the table are the actual accumulated sediment volumes determined from the 1967 survey. Total sediments accumulated in the reservoir since the original survey of 1940 amounted to 22,119 acre-feet at spillway crest elevation 1559 feet. Column 7 lists the volume of sediment accumulated at corresponding reservoir elevations expressed as percentage of the actual total sediment volume, 22,119 acre-feet. To check the theoretical distribution, the Empirical Area-Reduction Method was used to compute the sediment distribution of 22,119 acre-feet in the reservoir. The reservoir depth-capacity relation plotted for the 1940 (original) data in Figure 13 showed the reservoir to be a Type II. A plot of the curves to determine the depth of sediment at the dam is shown in Figure 14. Results of the sediment distribution computations are listed in Columns 8, 9, and 10 of Table 1. The theoretical computations showed the sediment would reach an elevation of 1512.6 feet compared to the actual elevation of 1509 feet. The sediment disposition curves plotted in Figure 15 show a comparison of the actual with the theoretical distribution. The curves graphically show the percentages of reservoir depth plotted against the sediment deposited. Inspecting the curves shows that

Table 1

SUMMARY OF RESERVOIR SEDIMENT DISTRIBUTION COMPUTATIONS

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
							Type II computations		
Elevation (feet)	1940 area (acres)	1940 capacity (acre-feet)	1967 area (acres)	1967 capacity (acre-feet)	Measured sediment volume (acre-feet)	Percent of measured sediment	1967 capacity (acre-feet)	Sediment volume (acre-feet)	Percent
1559	6,772	156,668	6,260	134,549	22,119	100.0	134,557	22,111	100.0
1555	6,007	131,132	5,534	110,963	20,169	91.2	109,653	21,479	97.2
1550	5,302	102,872	4,626	85,565	17,307	78.2	83,236	19,636	88.9
1547	4,777	87,670	4,081	72,504	15,166	68.6	69,353	18,317	82.9
1545	4,279	78,704	3,823	64,167	14,537	65.7	61,324	17,380	78.6
1540	3,720	58,718	3,219	46,560	12,158	55.0	43,811	14,907	67.5
1535	3,103	41,678	2,616	31,972	9,706	43.9	29,359	12,319	55.7
1530	2,510	27,668	2,165	20,276	7,392	33.4	17,967	9,701	43.9
1525	1,991	16,302	1,645	10,752	5,550	25.1	9,179	7,123	32.2
1520	1,445	7,732	1,103	3,844	3,888	17.6	3,087	4,645	21.0
1517.5	1,073	4,608	643	1,663	2,945	13.3	1,144	3,464	15.7
1515	678	2,448	182	632	1,816	8.2	114	2,334	10.6
1510	135	586	59	30	586	2.7	**0	0	2.7
1505	58	116	*0	0	116	0.5	–	–	0.5
1500	1	2	–	–	2	0	–	–	0
1496.7	0	0	–	–	0	0	–	–	0

*El. 1509

**El. 1512.6

EXPLANATION OF COLUMNS

(1) Elevation of reservoir.
(2) Original reservoir surface area surveyed in 1940.
(3) Original reservoir capacity from 1940 survey.
(4) Reservoir surface area surveyed in 1967.
(5) Reservoir capacity from 1967 survey.
(6) Accumulated sediment volume = Column (3) minus Column (5).
(7) Measured sediment expressed as percentage of total sediment (22,119 acre-feet).
(8) Computed 1967 reservoir capacity using Emperical Area-Reduction Method.
(9) Computed sediment volume to date = Column (3) minus Column (8).
(10) Computed sediment expressed as percentage of total sediment (22,111 acre-feet).

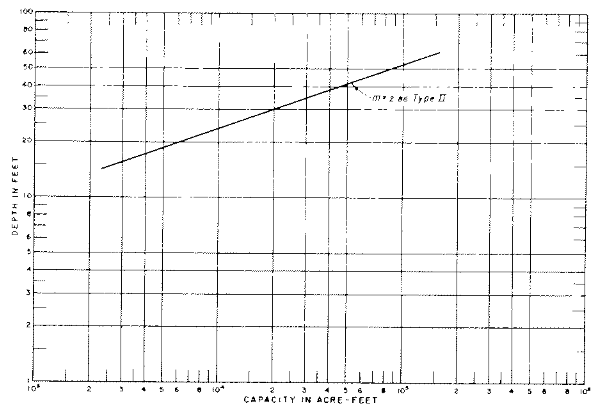

Figure 13. Reservoir depth-capacity relation.

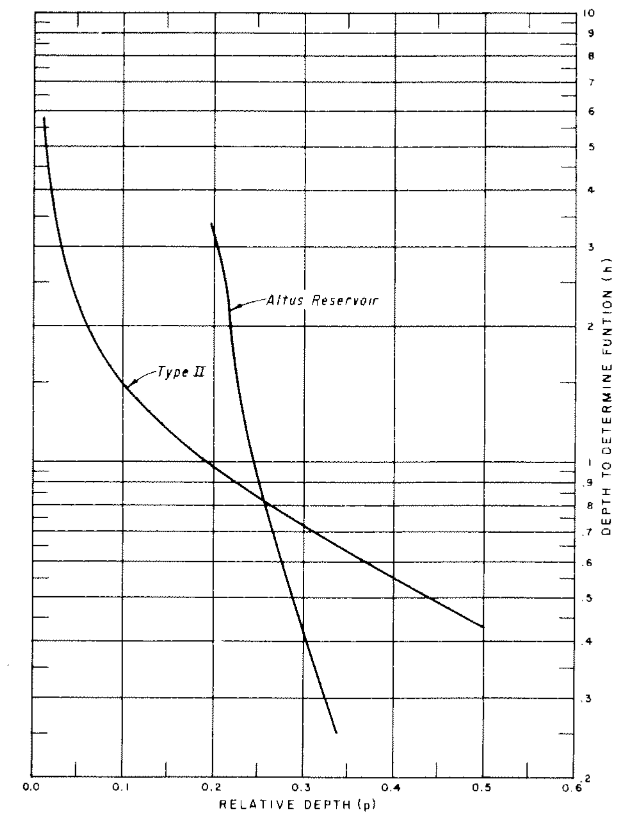

Figure 14. Curves to determine depth of sediment at dam.

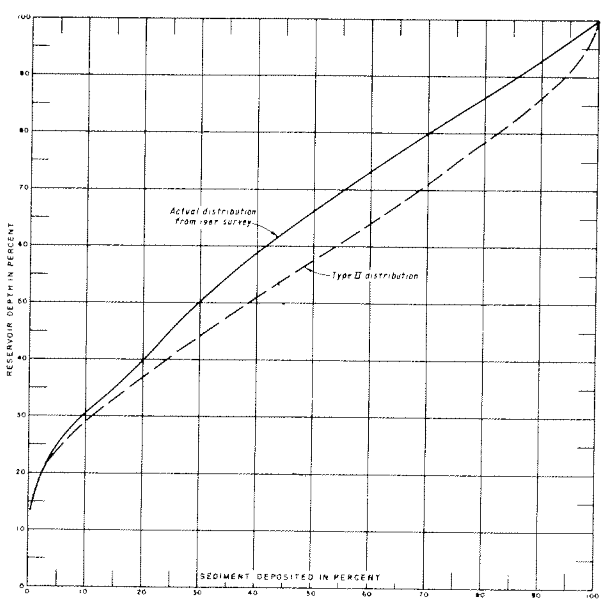

Figure 15. Sediment disposition curves.

the actual and Type II distribution compare favorably throughout the depth range. Deviations of the sediment deposited do not exceed 13 percent for reservoir depths ranging from 60 to 80 percent. In an actual project planning study, results of the Type II computations would have been used which show about a 3-1/2-foot difference in the elevation of sediment at the dam when compared to the observed data. A sediment accumulation curve covering the 1940-67 period is plotted in Figure 16 using the values in Columns 1 and 6 of Table 1.

A further idea of how the sediment was distributed longitudinally through the reservoir can be obtained by studying the profiles in Figure 17. The points plotted to define these profiles are not, in every case, the valley thalweg; i.e., the minimum point of the range line cross section. The thalweg elevation of the old floodplain

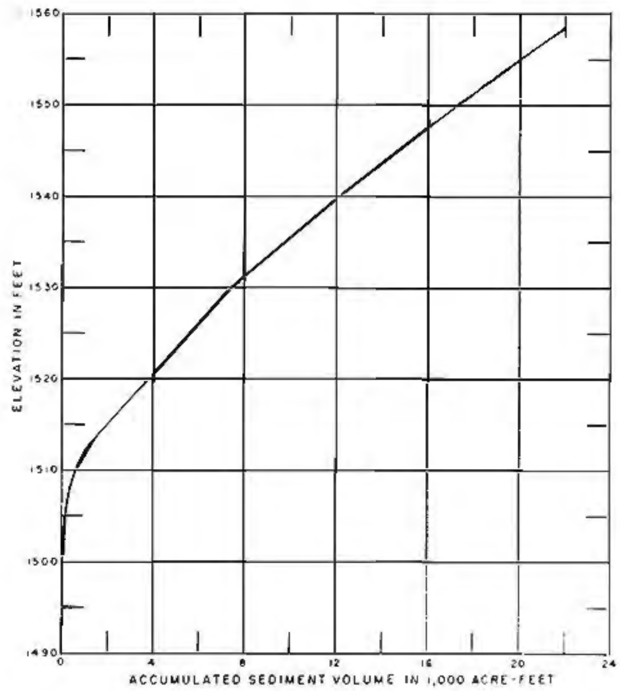

Figure 16. Sediment accumulation curve.

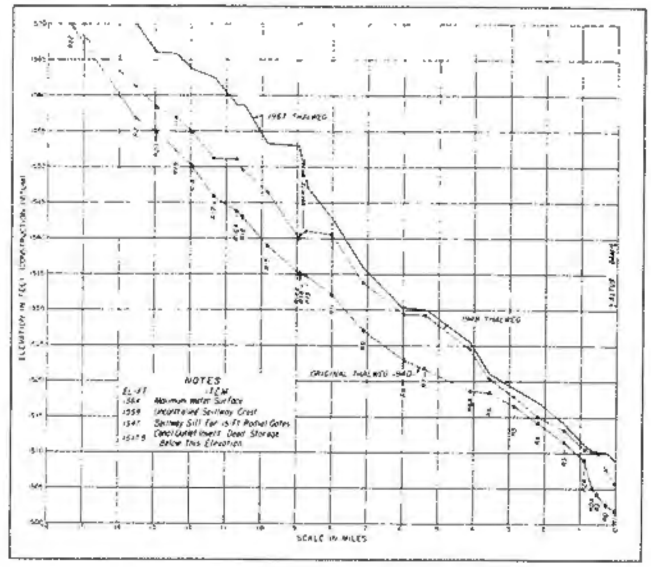

Figure 17. Longitudinal profiles.

was plotted in some instances. The table below summarizes the depths to which the sediments had accumulated between the 1940-67 and 1948-67 periods.

Distance above dam (miles)	Depth of sediment (feet)	
	Between 1940-67 survey	Between 1948-67 survey
0-8		range <1 to 2
8-12		8.5 average*
0-1	6.5 average	
1-3.5	2.5 average	
3.5-7	7.5 average	
7-12	14 average**	

*Excludes maximum of 13 feet at Range 14A.
**Excludes maximum of 18 feet at Range 14A.

The extreme rise in the depths of sediment at Range 14A results from the influence of Granite Bridge downstream. However, the narrows area occurring naturally at Range 2A had little influence on the sediment depositional pattern immediately upstream (Range 3).

Lateral Distribution

Profiles of all 25 sedimentation ranges surveyed in 1948 and 1967 were plotted in Figures 28 through 52 in the appendix. These profiles show generally how sediments were laterally distributed in the reservoir. Sediments are shown depositing laterally to depths of 1 to 4 feet from sedimentation Ranges 1 to 11, 8 miles above the dam. From sedimentation Range 13 on upstream to Range 19, the laterally deposited sediments averaged about 6 feet except at Range 15 that showed an average depth of about 11 feet. The cross sectional plottings show that Ranges 20 and 21 were essentially filled laterally with sediment to maximum water surface, 1564 feet.

SEDIMENT ANALYSES

Sediment Accumulations

The total volume of sediments that has accumulated in Altus Reservoir amounted to 22,120 acre-feet at spillway crest elevation 1559 feet (Item 38a, Table 2) as computed by subtracting the 1967 from the 1940 capacity. An average annual sediment accumulation rate of 838 acre-feet was determined for the 26.4 years since the dam was built. Sediments deposited at a rate of 0.398 acre-foot per square mile per year for this period.

Reservoir Sedimentation Summary

Table 2 gives a comprehensive summary of the reservoir sediment data relative to each survey that has been run. The data include tabulating incremental sediment inflow volumes as well as sediment yield rates computed for periods between surveys. Both of these values are considered important for practical and research use.

Unit Weight Analyses

During the 1948, 1953, and 1967 surveys, 69 physical samples of the reservoir sediment deposits were collected. A summary of the results of each sample taken during these surveys is contained in Table 3. Unit weights, median diameters, and percentages of clay, silt, and sand are tabulated.

Analyses were made of the sample data collected to determine a unit weight for the inflowing deposited sediments. A weighting process was used to do this by computing the unit weight averages of the sediments sampled within individual segmented reservoir areas. These averages were multiplied by the incremental sediment volumes and the resulting products summed. The sum was divided by the total sediment volume giving a weighted unit weight of 70.2 pounds per cubic foot. This compares with unit weights of 66.9 and 52.3 pounds per cubic foot determined for the 1953 and 1948 surveys, respectively.

An empirical method[3] was used to compute the unit weight applying the representative clay, silt, and sand size gradations subsequently described. Assuming a Type II reservoir operation,[4] an initial unit weight of 70.5 pounds per cubic foot was computed which compares favorably with the 70.2 weighted value described above. However, by considering a compaction correction using the method of Miller,[5] a unit weight of 73.4 pounds per cubic foot was determined for a 26-year period.

Particle Size Analyses

A study was made of the particle size analysis tests run on 62 of the samples collected in the 1948, 1953, and 1967 surveys. The graphs in Figures 18 through 24 contain the particle size analysis curves for each sample. Representative particle sizes in the clay, silt, and sand ranges were determined by the weighting process as was used in the unit weight analyses. The data in Figures 18 through 24 were used to determine the percentages of clay, silt, and sand of each range sample taken within the same segmented areas used in the unit weight analyses. The representative size was computed to be 29 percent clay, 32 percent silt, and 39 percent sand.

Estimated Sediment Inflow to Reservoir

An attempt was made to estimate the sediment inflow to the reservoir for comparison with the inflow determined from the 1967 survey. The estimate is based on a sediment rating curve that was developed from records available for the period March 1, 1948 to September 30, 1953, shown in Figure 25. Records of the North Fork Red River near Carter, Oklahoma, were used. The sediment rating curve was used in conjunction with the flow duration curve (Figure 26) for the period covering water years 1941-1965. The results of this analysis in Table 4 show an average total sediment discharge of 1,475,000 tons per year assuming 15 percent for the bedload discharge. This value was adjusted further to take into account the drainage area (149 square miles) between the Carter gaging station and Altus Dam. Assuming an annual sediment yield rate of 0.4 acre-foot per square mile for this area and assuming a unit weight of 70.2 pounds per cubic foot as determined by the 1967 survey, a sediment discharge of 91,100 tons per year was computed. Adding this to the total in Table 4 (1,475,000) gives an estimated 1,566,100 tons per year total sediment inflow to the reservoir. This compares to the total sediment inflow of 1,430,720 tons per year measured by the 1967 survey. A difference of about 9.5 percent is indicated between estimated and measured sediment inflow rates. This indicates a reasonable check from a practical standpoint. However, it should be pointed out that several factors have been determined by judgment in the course of the computations. Included in these are the major factors of the assumption for bedload (15 percent) the assumed annual sediment yield rate of 0.4 acre-foot per square mile as well as the assumed unit weight of 70 pounds per cubic foot.

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[3] Lara, J. M., and Pemberton, E. L., "Initial Unit Weight of Deposited Sediments," Paper No. 82, Proc. of the Federal Inter-Agency Sedimentation Conference, Misc. Publ. No. 970, U.S. Department of Agriculture, 1963.
[4] Ibid, p 845.
[5] Miller, C. R., "Determination of the Unit Weight of Sediment for Use in Sediment Volume Computations," U.S. Dept. of the Interior, Bureau of Reclamation, Feb. 1953.

Table 2

RESERVOIR SEDIMENT
DATA SUMMARY

Altus Reservoir
NAME OF RESERVOIR

DATA SHEET NO.

DAM	1. OWNER U.S. Dept. of Int., Bur. of Recl.	2. STREAM North Fork, Red River	3. STATE Oklahoma
	4. SEC. 22 TWP. 5N RANGE 20W	5. NEAREST P.O. Altus 18NE	6. COUNTY Greer-Kiowa
	7. LAT. 34 ° 53 ′ ″ LONG. 99 ° 18 ′ ″	8. TOP OF DAM ELEVATION 1567	9. SPILLWAY CREST ELEV. [1]1559

RESERVOIR	10. STORAGE ALLOCATION	11. ELEVATION TOP OF POOL	12. ORIGINAL SURFACE AREA, ACRES	13. ORIGINAL CAPACITY, ACRE-FEET	14. GROSS STORAGE, ACRE-FEET	15. DATE STORAGE BEGAN
	a. FLOOD CONTROL					
	b. MULTIPLE USE	[2]1564	7,705	36,174	[4]192,842	Dec 1940[5]
	c. POWER					
	d. WATER SUPPLY					16. DATE NORMAL OPER. BEGAN
	e. IRRIGATION	1559	6,772	[3]152,060	156,668	
	f. CONSERVATION					
	g. INACTIVE	1517.5	1,073	4,608	4,608	June 19, 1946
	17. LENGTH OF RESERVOIR 13.1 MILES			AV. WIDTH OF RESERVOIR 1 MILES		

WATERSHED			
	18. TOTAL DRAINAGE AREA 2,515 SQ. MI.		22. MEAN ANNUAL PRECIPITATION 24.2 (14-39) INCHES
	19. NET SEDIMENT CONTRIBUTING AREA 2,104 SQ. MI.		23. MEAN ANNUAL RUNOFF 0.78 INCHES
	20. LENGTH 146.5 MILES	AV. WIDTH 17.2 MILES	24. MEAN ANNUAL RUNOFF [6]104,400 AC.-FT.
	21. MAX. ELEV. 3,500+	MIN. ELEV. 1496.7	25. ANNUAL TEMP.: MEAN 63.1 RANGE 65.9-62.3

SURVEY DATA

26. DATE OF SURVEY	27. PERIOD YEARS	28. ACCL. YEARS	29. TYPE OF SURVEY	30. NO. OF RANGES OR CONTOUR INT.	31. SURFACE AREA, ACRES	32. CAPACITY, ACRE-FEET	33. C/I. RATIO, AC.-FT. PER AC.-FT.
Dec 1940			Contour	2 to 5 ft	6,772	156,668 [7](192,842)	
Jun 1948	7.5	7.5	Contour and range (S)	26 (R) 5 ft (CI)	6,793	148,640 (185,035)	
Jul 1953	5.1	12.6	Contour and range (S)	25 (R) 5 ft (CI)	6,575	142,862 (178,610)	1.74
Apr 14, 1967	13.8	26.4	Range (R)	25 (R)	6,260	134,549 (168,117)	1.61

26. DATE OF SURVEY	34. PERIOD ANNUAL PRECIPITATION	35. PERIOD WATER INFLOW, ACRE-FEET a. MEAN ANNUAL	b. MAX. ANNUAL	c. PERIOD TOTAL	36. WATER INFL. TO DATE, AC.-FT. a. MEAN ANNUAL	b. TOTAL TO DATE
Dec 1940						
Jun 1948	[8]27.0	126,980	256,700	952,320	126,980	952,320
Jul 1953	[8]20.3	107,940	213,400	550,473	119,270	1,502,793
Apr 14, 1967	[9]24.4	89,000	188,800	1,227,897	103,440	2,730,690

26. DATE OF SURVEY	37. PERIOD CAPACITY LOSS, ACRE-FEET a. PERIOD TOTAL	b. AV. ANNUAL	c. PER SQ. MI.-YEAR	38. TOTAL SED. DEPOSITS TO DATE, ACRE-FEET a. TOTAL TO DATE	b. AV. ANNUAL	c. PER SQ. MI.-YEAR
Dec 1940						
Jun 1948	8,028 [7](7,807)	1,070 [7](1,041)	0.506 [7](0.495)	8,028 [7](7,807)	1,070 [7](1,041)	0.509 [7](0.495)
Jul 1953	5,778 (6,425)	1,133 (1,260)	0.535 (0.599)	13,806 (14,232)	1,096 (1,130)	0.521 (0.537)
Apr 14, 1967	8,313 (10,493)	602 (760)	0.286 (0.361)	22,119 (24,725)	838 (937)	0.398 (0.445)

26. DATE OF SURVEY	39. AV. DRY WGT., LBS. PER CU. FT.	40. SED. DEP., TONS PER SQ. MI.-YR. a. PERIOD	b. TOTAL TO DATE	41. STORAGE LOSS, PCT. a. AV. ANN.	b. TOT. TO DATE	42. SED. INFLOW, PPM a. PERIOD	b. TOT. TO DATE
Dec 1940							
Jun 1948	52.3	580 [7](564)	580 [7](564)	0.683 [7](0.540)	5.12 [7](4.05)	7,072 [7](6,877)	7,065 [7](6,871)
Jul 1953	66.9	1,023 (1,104)	759 (782)	0.700 (0.586)	8.81 (7.38)	14,673 (15,835)	9,849 (10,153)
Apr 14, 1967	70.2	472 (588)	609 (680)	0.535 (0.486)	14.12 (12.82)	8,213 (10,231)	9,113 (10,187)

Table 2—Continued

26. DATE OF SURVEY	43. DEPTH DESIGNATION RANGE IN FEET BELOW, AND ABOVE, CREST ELEVATION											
	62.3-60	60-50	50-40	40-30	30-20	20-10	10-C	C-5				
	PERCENT OF TOTAL SEDIMENT LOCATED WITHIN DEPTH DESIGNATION											
Dec 1940												
Jun 1948	0.01	5.26	8.22	28.31	25.96	22.62	12.44	−2.83				
Jul 1953	0.01	3.24	16.48	26.61	16.47	14.85	19.35	2.99				
Apr 14, 1967	0.01	1.99	13.54	13.71	18.92	20.62	20.67	10.54				

26. DATE OF SURVEY	44. REACH DESIGNATION PERCENT OF TOTAL ORIGINAL LENGTH OF RESERVOIR														
	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	-105	-110	-115	-120	-125
	PERCENT OF TOTAL SEDIMENT LOCATED WITHIN REACH DESIGNATION														
Dec 1940															
Jun 1948	14.26	4.48	11.83	11.10	14.42	12.31	7.97	11.93	7.93	3.78					
Jul 1953	Not computed														
Apr 14, 1967	6.07	3.03	6.67	8.50	11.12	12.74	25.88	4.05	7.28	7.68	4.86	2.12			

45. RANGE IN RESERVOIR OPERATION

WATER YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AC.-FT.	WATER YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AC.-FT.
1940-44	–	–	–	1956	1544.99	1525.80	49,620
1945	1536.90	1523.20	[10]59,000	1957	1559.53	1525.02	122,900
1946	1531.20	1526.90	12,920	1958	1557.93	1549.43	64,190
1947	1550.50	1528.23	160,200	1959	1559.85	1548.62	120,600
1948	1548.01	1541.95	51,180	1960	1560.04	1552.47	136,700
1949	1560.20	1540.80	139,900	1961	1561.96	1552.69	188,800
1950	1560.39	1553.47	158,600	1962	1560.06	1551.83	122,800
1951	1562.10	1551.59	213,400	1963	1559.31	1554.06	62,800
1952	1551.82	1530.82	22,960	1964	1548.24	1529.30	31,300
1953	1531.40	1525.63	15,750	1965	1547.70	1528.48	79,660
1954	1549.63	1525.60	99,630	1966	1551.70	1537.65	68,740
1955	1543.90	1525.60	57,150	1967	1542.02	1530.03	42,340

46. ELEVATION-AREA-CAPACITY DATA

ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY
	1940 Survey		1540	3,720	58,718	1517.5	643	1,663
1496.7	0	0	1545	4,279	78,704	1520	1,103	3,844
1500	1	2	1550	5,302	102,872	1525	1,645	10,752
1505	58	116	1555	6,007	131,132	1530	2,165	20,276
1510	135	586	1559	6,772	156,668	1535	2,616	31,972
1515	678	2,448	1564	7,705	192,842	1540	3,219	46,560
1517.5	1,073	4,608				1545	3,823	64,167
1520	1,445	7,732		1967 Survey		1550	4,626	85,565
1525	1,991	16,302	1509	0	0	1555	5,534	110,963
1530	2,510	27,668	1510	59	30	1559	6,260	134,549
1535	3,103	41,678	1515	182	632	1564	7,168	168,117

47. REMARKS AND REFERENCES

[1]Uncontrolled spillway crest.
[2]Maximum water surface–includes surcharge.
[3]Includes 4,800 acre-feet of storage for municipal use.
[4]Includes flood control between elevations 1559 and 1562 and surcharge between elevations 1562 and 1564.
[5]Date of original survey for new dam over deposits placed behind old dam.
[6]North Fork Red River near Carter, Oklahoma, 20-year average adjusted for drainage area.
[7]Values in parentheses are for maximum water surface elevation 1564 feet.
[8]Recorded at Sayre and Erick, Oklahoma.
[9]Record at Altus Dam.
[10]From records at Carter gage except 1963 and 1964 are from Project records.

48. AGENCY MAKING SURVEY Bureau of Reclamation
49. AGENCY SUPPLYING DATA Bureau of Reclamation
50. DATE January 29, 1971

April 1966

Table 3

SUMMARY OF SEDIMENT SAMPLE DATA ANALYSES

1948-49 Survey Data

Range location	Sample No.	In percent Clay	Silt	Sand	Unit weight pcf	Median diameter (D_{50}) mm
			Gravity Core Samples			
1	6	21	64	15	26.3	0.0245
2	8	27	59	14	53.6	.0215
D	1	43	55	2	26.7	.0054
DA	4	39	50	11	36.5	.0120
2A	11	22	19	59	91.6	.1490
3	A1	1	11	88	106.6	.1270
5	A3	40	59	1	45.8	.0058
6	A6	3	47	50	65.4	.0610
6A	12	24	42	34	80.8	.0355
7	10	55	42	3	54.3	.0032
8	A4	22	55	23	57.9	.0250
9	A2	33	51	16	32.8	.0072
11	A10	51	47	2	39.6	.0037
13	3	50	47	3	43.1	.0036
14	A8	55	44	1	49.3	.0034

1953 Survey Data

D	384	44	53	3	36.1	0.0056
DA	385	18	51	31	58.6	.0395
1	386	16	65	19	51.9	.0440
2	388	27	45	28	56.3	.0348
2A	389	18	70	12	38.3	.0322
3	390	21	36	43	49.8	.0440
4	391	53	43	4	19.9	.0033
5	392	47	46	7	19.3	.0045
6	393	6	49	45	79.8	.0560
6A	394	37	24	39	62.2	.0320
7	395	9	62	29	82.6	.0430
8	397	17	17	66	63.2	.1400
9	398	15	30	55	88.1	.0770
11	399	53	41	6	c63.5	.0035
13	400	59	35	6	61.5	.0027
14A	401	4	15	81	101.7	.1550
14	404	36	51	13	69.9	.0104
15	407	32	36	32	78.4	.0320
16	410	51	37	12	82.3	.0039
16A	412	13	14	73	97.8	.1390
17	415	0	3	97	95.1	.1520
18	416	13	35	52	82.3	.0650
19	417	4	20	76	88.5	.1270
20	418	6	19	75	88.5	.6200

Table 3—Continued

1967 Survey Data

Range location	Sample No.	In percent Clay	Silt	Sand	Unit weight pcf	Median diameter (D_{50}) mm
		Gravity Core Samples*				
1	16	9	25	66	–	0.1050
2	15	3	95	2	–	.0019
D	24	2	95	3	–	.0020
DA	14	34	45	21	–	.0190
2A	20	41	53	6	–	.0081
3	19	13	43	44	–	.0520
4	26	71	27	2	–	.0013
5	11	65	24	11	–	.0016
6/6A	18	56	43	1	–	.0027
7	23	14	59	27	–	.0410
		Plastic Tube Samples*				
8	21	53	40	7	–	0.0032
8/9	22	63	30	7	–	.0020
11	33	18	27	55	–	.0850
13	12	41	45	14	–	.0044
14	29	28	32	40	–	.0310
14	30	0	1	99	–	.2400
14A	27	43	38	19	–	.0076
14A	28	0	1	99	–	.1570
15	17	19	10	71	–	.2000
16A	31	37	25	38	–	.0240
16A	32	0	1	99	–	.1900
17	10	55	42	3	–	.0028
19	13	18	18	64	–	.0950
20	9	6	24	70	–	.1200
21	25	0	1	99	–	.2140
22	34	0	1	99	–	.2690
		Field Density Samples**				
13	1	–	–	–	49.6	–
14	2	–	–	–	96.2	–
14A	3	–	–	–	88.4	–
16A	4	–	–	–	77.9	–
19	5	–	–	–	90.4	–
20	6	–	–	–	87.9	–
21	7	–	–	–	121.5	–

*Unit weights not determined for gravity core and plastic tube samples.
**Gradation tests not run for field density samples.

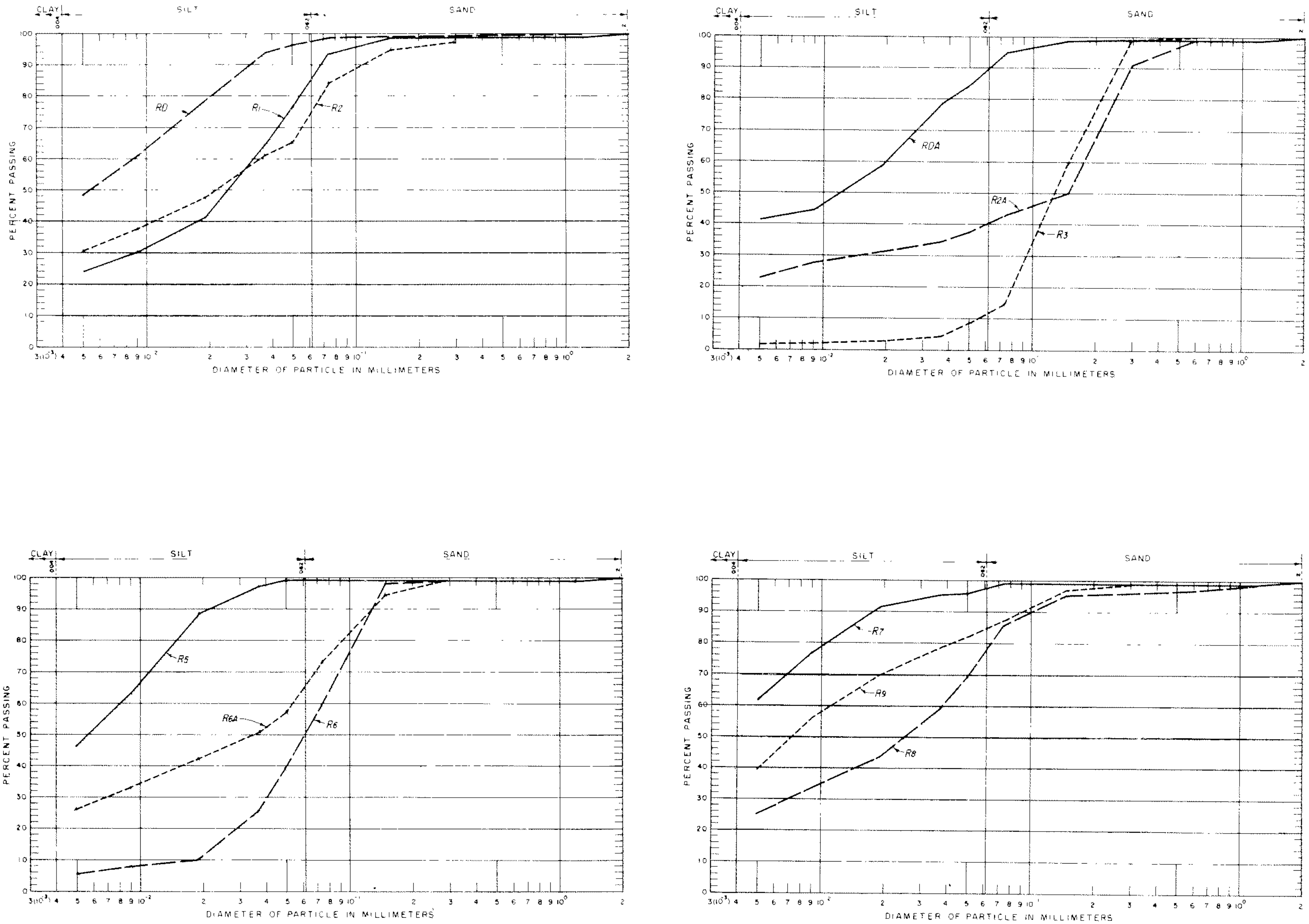


Figure 18. Particle size analysis curves. Ranges 1, D, 2, DA, 2A, 3, 5, 6, 6A, 7, 8, and 9—1948 survey.

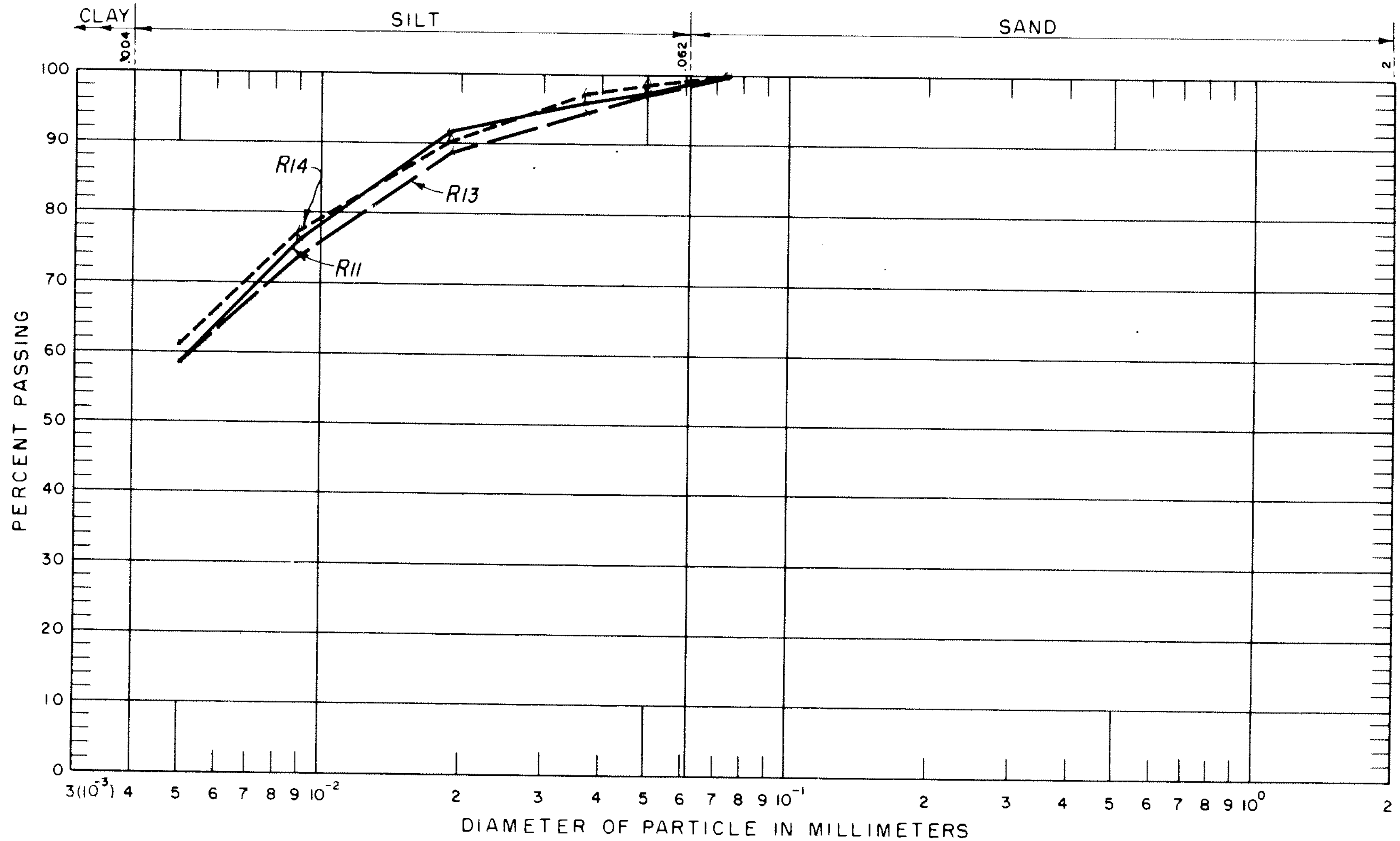


Figure 19. Particle size analysis curves. Ranges 11, 13, and 14—1948 survey.

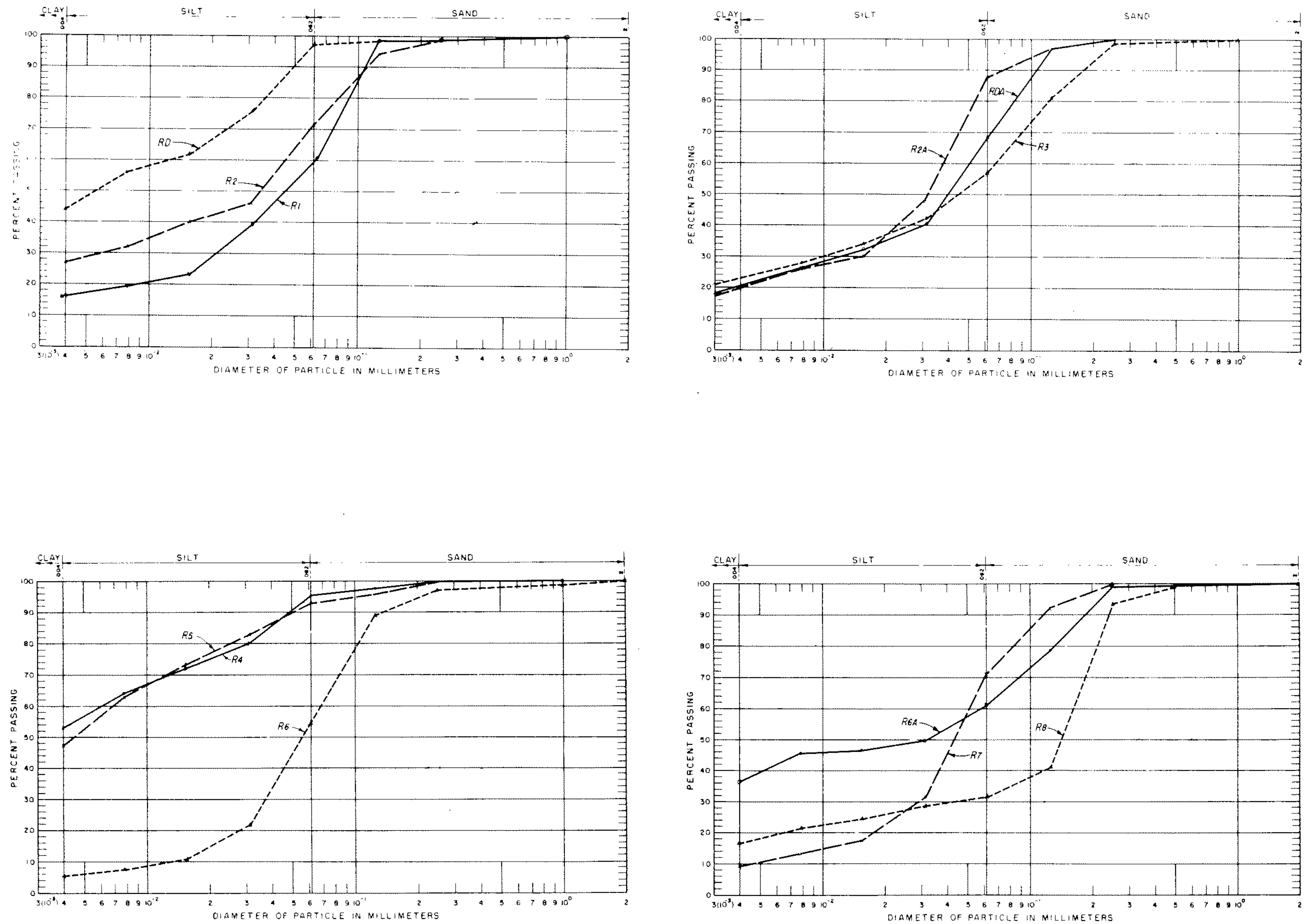


Figure 20. Particle size analysis curves. Ranges 1, D, 2, DA, 2A, 3, 4, 5, 6, 6A, 7, and 8—1953 survey.

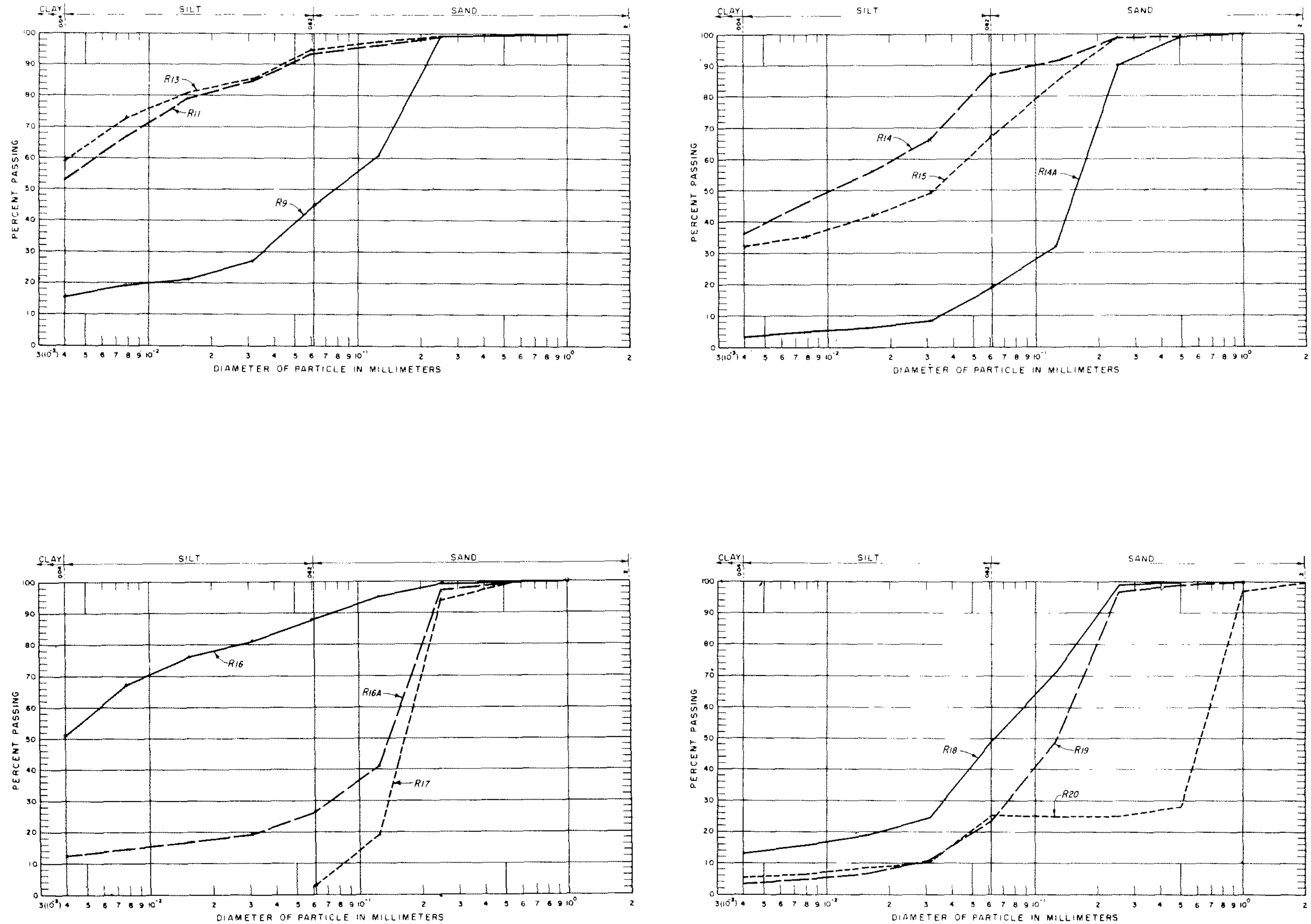


Figure 21. Particle size analysis curves. Ranges 9, 11, 13, 14, 14A, 15, 16, 17, 18, 19, and 20—1953 survey.

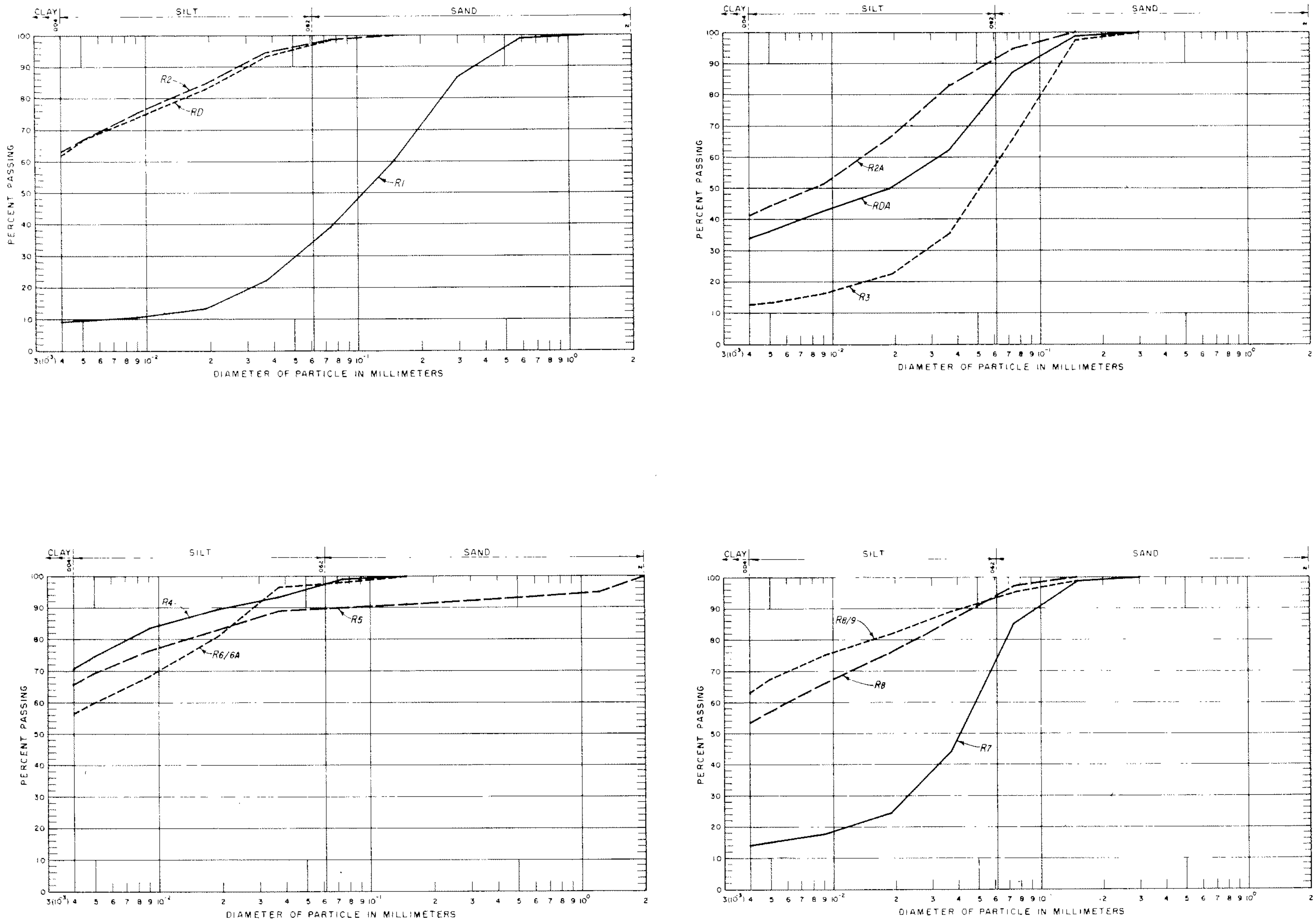


Figure 22. Particle size analysis curves. Ranges 1, D, 2, DA, 2A, 3, 4, 5, 6/6A, 7, 8, and 8/9—1967 survey.

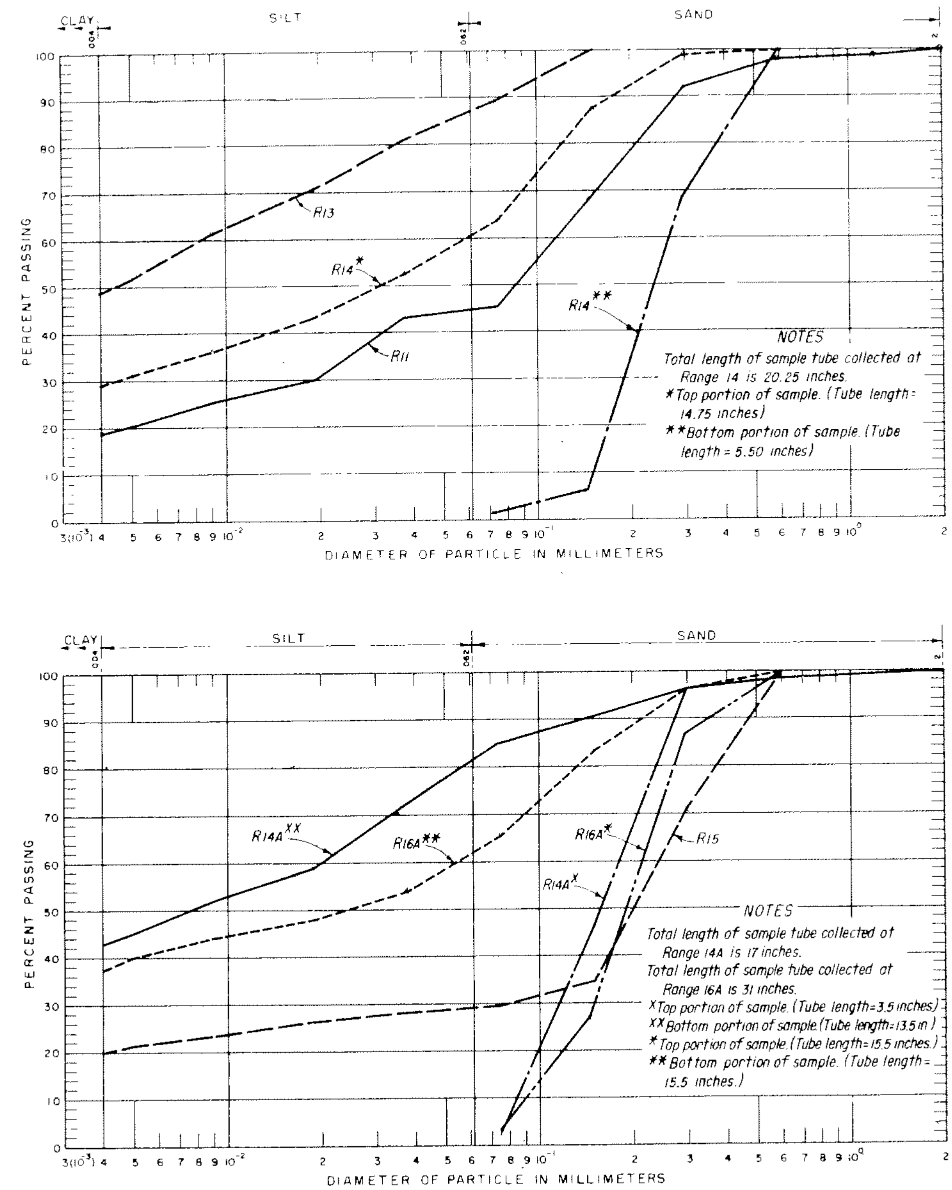


Figure 23. Particle size analysis curves. Ranges 11, 13, 14, 14A, 15, and 16A--1967 survey.

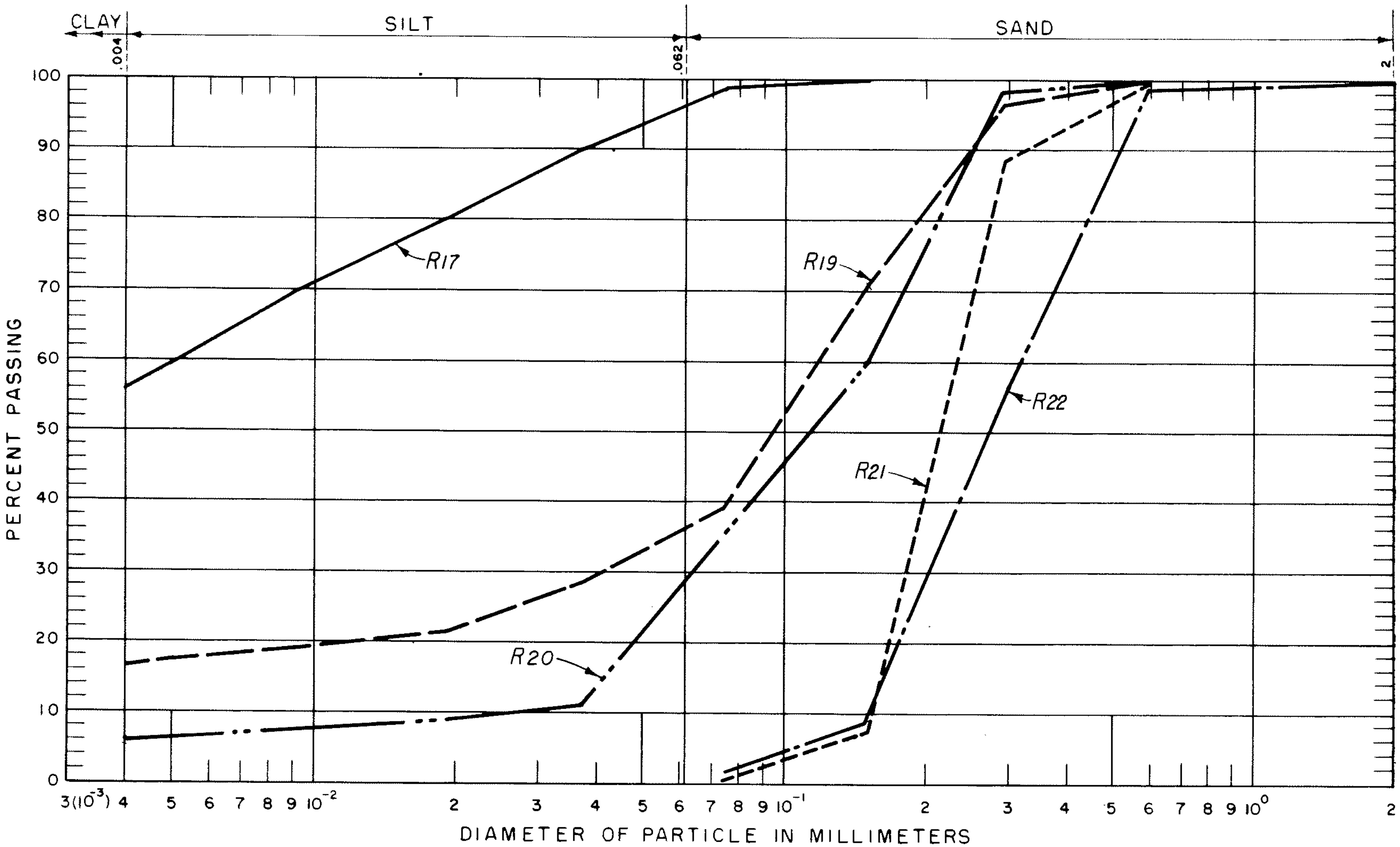


Figure 24. Particle size analysis curves. Ranges 17, 19, 21, and 22—1967 survey.

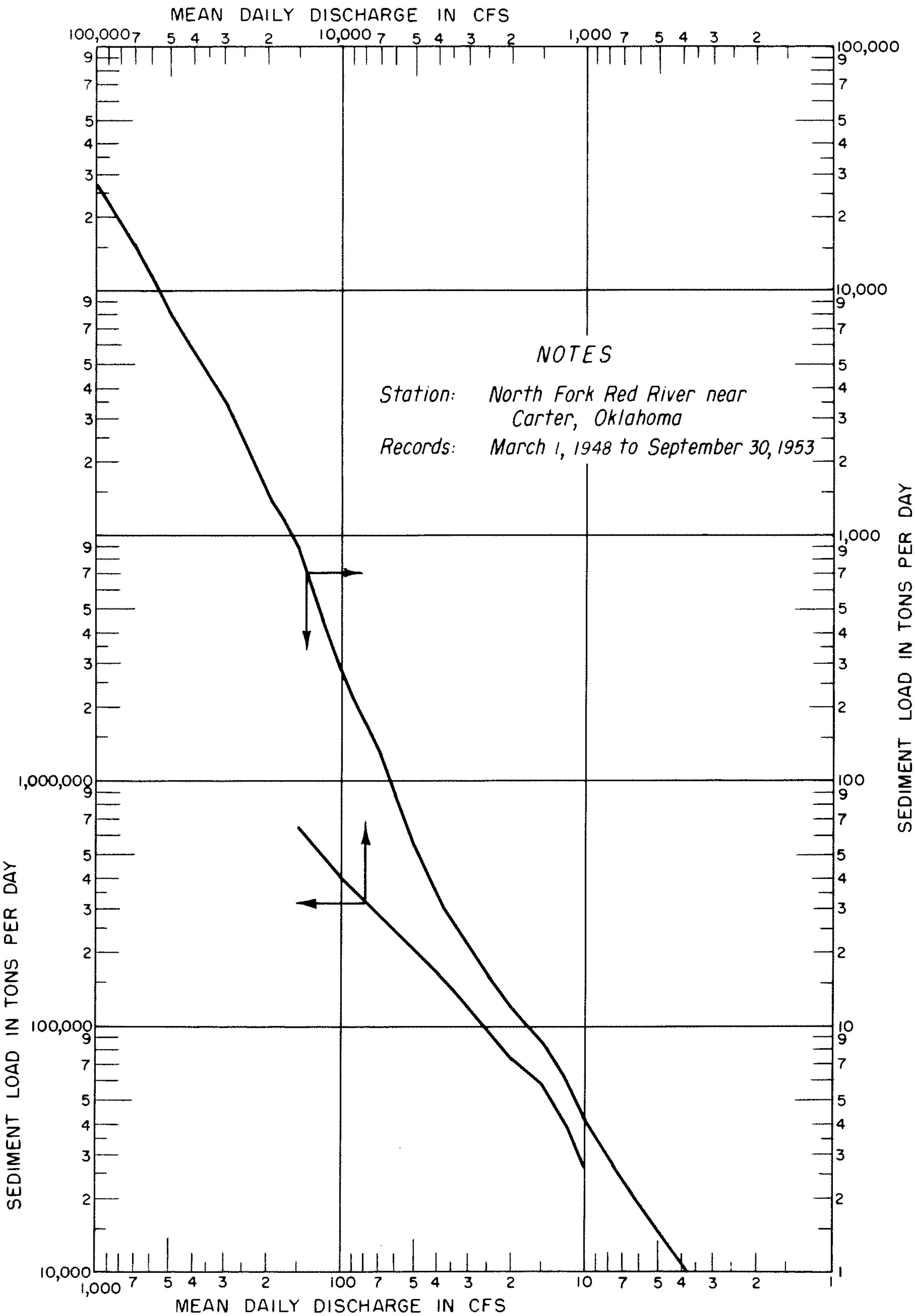


Figure 25. Sediment rating curve.

Table 4

TOTAL SEDIMENT DISCHARGE COMPUTATIONS

SECTION	PERIOD	RIVER
Near Carter, Oklahoma	WY 1941–1965	North Fork Red River
COMPUTED BY	CHECKED BY	DATE
JML		5-5-70

1	2	3	4	5	6	7
% LIMITS	% INTERVAL	% MID. ORD.	Qw	Qs	2x4 Qw. DISCH.	2x5 Qs. DISCH.
0.00–0.02	0.02	0.01	17,500	750,000	3.5	150
0.02–0.1	0.08	0.06	10,000	420,000	8.0	336
0.1 –0.5	0.4	0.3	6,000	250,000	24.0	1,000
0.5 –1.5	1.0	1.0	2,500	96,000	25.0	960
1.5 –5.0	3.5	3.25	860	21,000	30.1	735
5–15	10	10	260	2,600	26.0	260
15–25	10	20	127	520	12.7	52
25–35	10	30	75	150	7.5	15
35–45	10	40	41.5	37.5	4.2	3.8
45–55	10	50	22	13.5	2.2	1.4
55–65	10	60	8.7	3.2	0.9	0.3
65–75	10	70	0.5	–		
75–85	10	80				
85–95	10	90				
95–98.5	3.5	96.75				
98.5–99.5	1.0	99.0				
99.5–99.9	0.4	99.7				
99.9–99.98	0.08	99.94				
99.98–100	0.02	99.99				
				TOTAL	144.1	3,513.5

Qw.A.D. = 144 D.D.x365x1.9835 = 104,253 (AF)/yr.

Qs.A.D. = 3,514 D.D.x365 = 1,282,610 Tons/yr.

15 Percent Correction for Bedload = 192,391 Tons/yr.

Total Sediment Discharge = 1,475,001 Tons/yr.

Sediment

A.D. = ______ Tons/yr. / Tons/(AF) ______ = (AF)/yr.

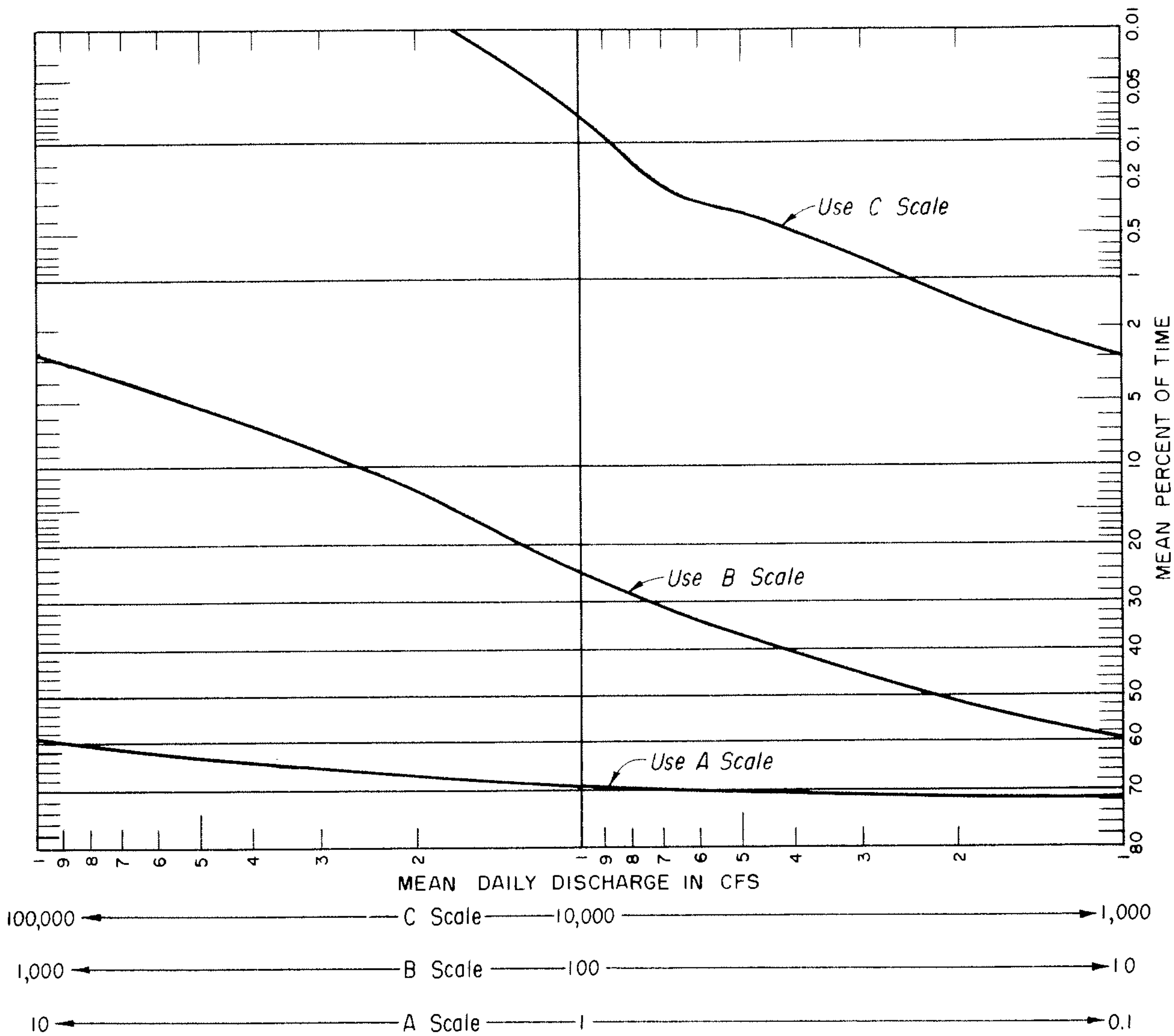
Yield = ______ Tons/yr. / Tons/(AF)xD.A. ______ = (AF)/sq.mi.

Concentration = 1,282,610 x 100 / 104,253 x 1,361 = Qs A.D.x100 / Qw A.D.x1361 = 0.904 Percent

Runoff

Rate = ______ Qw A.D. / D.A. ______ = (AF)/sq.mi.

D.D. = Daily Discharge
A.D. = Annual Discharge
D.A. = Drainage Area
67.5 = lbs./cubic foot
1,470 = Tons/ acre foot



NOTES

Station: North Fork Red River
near Carter, Oklahoma.

Records: Water Years 1941 to 1965

Figure 26. Flow duration curve.

RESERVOIR AND AREA AND CAPACITY

The 1967 Altus Reservoir surface areas were determined by a method using reservoir sedimentation range width ratios. Briefly, this method entails comparing the 1967 range widths with the 1948 widths at corresponding elevation intervals. The results are tabulated in the ratio form 1967/1948. To facilitate the computations the reservoir is divided into segments using the sedimentation range lines to delineate the segmental boundaries. The 1948 reservoir topographic maps were used to planimeter the surface areas at 5-foot contour intervals. For corresponding elevations, these areas were multiplied by the width ratios obtained and the 1967 surface areas were determined.

The 1967 surface areas were the control parameters for computing the reservoir capacities with the electronic computer. The computer program computes 1-foot area increments by linear interpolation between the 5-foot contour intervals. Respective capacities and capacity equations are then obtained by integration of the area equations. The initial capacity equation is tested over successive intervals to check whether it fits within an allowable error limit (0.01). This one equation is then used over the whole range that fits within the allowable error limit. For the next interval beginning at the elevation where the initial allowable error limit has been exceeded, a new capacity equation (integrated from the basic area equation over that interval) begins testing the fit until it too exceeds the error limit. Thus, the capacity curve is defined by a series of curves, each falling within a specific elevation interval as constrained by the limiting error. The final area equations are subsequently derived by differentiation of the capacity equations. Capacity equations are of second order polynominal form, $y = a_1 + a_2x + a_3x^2$, where y is the capacity, x is the elevation above an elevation base, a_1 is the intercept, and a_2 and a_3 are coefficients. Results of the 1967 reservoir area and capacity computations are listed in Columns 4 and 5 of Table 1 (page 8). Listed also in this table in Columns 2 and 3 are the original area and capacity values for comparison purposes. Both the original and 1967 area and capacity curves are plotted in Figure 27. At elevation 1559 feet (uncontrollable spillway crest), the present capacity of Altus Reservoir is 134,550 acre-feet and the surface area is 6,260 acres.

SUMMARY AND CONCLUSIONS

The 1967 sediment survey report of Altus Reservoir briefly describes the field surveying and sediment sampling procedures and equipment. Also discussed are the analytical methods used to measure and study the nearly 26.5 years of reservoir sediment accumulation. The survey was primarily run to gather the necessary data for use in computing the latest capacity of Altus Reservoir.

Standard land surveying methods were used to run levels from the permanent range end monuments to stations that were temporarily established at the reservoir water's edge. The hydrographic survey was run using sonic depth recording equipment operated from a boat. This system continuously recorded reservoir depths on charts as the boat was propelled across the range line. Five men were required to run the hydrographic survey. A distance measuring machine was used to maintain horizontal control and the water surface elevations determined from the gage at the dam were used as a reference for vertical control.

Ten sediment samples of the reservoir deposits were collected with a gravity core sampler and 13 more using a 2-inch diameter plastic tube driven by hand into the deposits with a rubber mallet. Field density apparatus was used to take seven additional samples at upstream range locations. Analyzing these samples and others collected during the 1948 and 1953 surveys resulted in determining a unit weight of 70.2 pounds per cubic foot and a representative size of 29 percent clay, 32 percent silt, and 39 percent sand.

The longitudinal and lateral deposition of sediments in the reservoir generally followed the usual pattern. Longitudinally, the sediments deposited between the 1940 and 1967 surveys to average depths of 6.5 feet for a distance from the dam to a mile above the dam, 2.5 feet from 1 to 3-1/2 miles above the dam, 7.5 feet from 3-1/2 to 7 miles above dam, and 14 feet from 7 to 12 miles above the dam. Between the 1948 and 1967 surveys, these deposited depths varied from less than 1 to 2 feet for a distance from the dam to 8 miles above the dam and averaged about 8.5 feet from 8 to 12 miles above the dam. Laterally, the reservoir range cross sectional profiles for the 1948 and 1967 surveys show sediments deposited to depths of 1 to 4 feet for the area 8 miles above the dam. For the area from 8 to 12 miles above the dam the laterally deposited sediments averaged about 6 feet with the greatest average depth of about 11 feet at 10 miles above the dam. For all practical purposes sediments have essentially deposited to maximum water surface, 1564 feet, in the reservoir area beginning at 12 miles above the dam.

The capacity of Altus Reservoir as determined by the 1967 survey is 134,550 acre-feet and the surface area 6,260 acres at spillway crest elevation 1559 feet (see

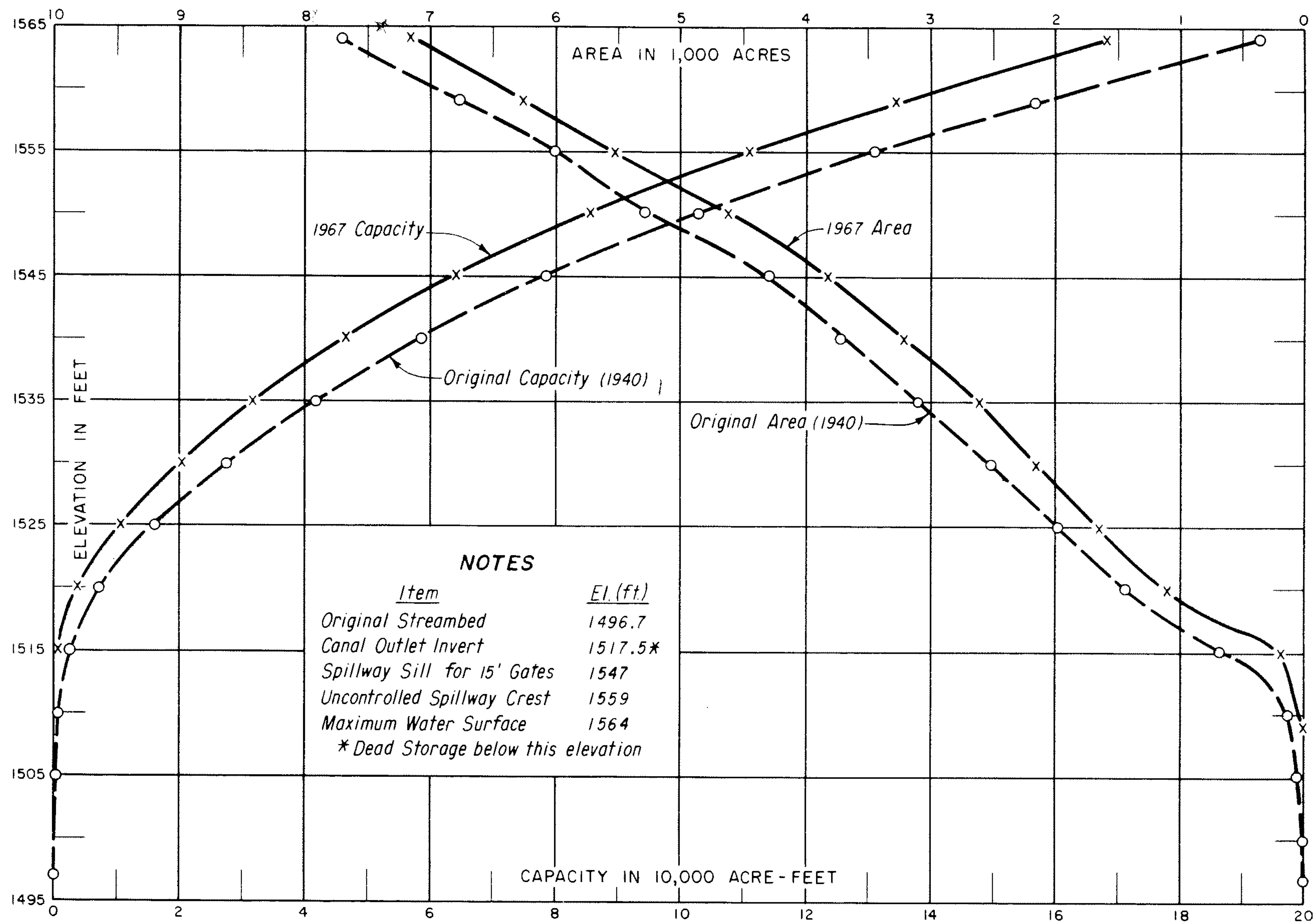


Figure 27. Reservoir area-capacity curves.

area-capacity curves in Figure 27). The 1967 reservoir surface areas were determined by a width ratio method described on page 26. The electronic computer was used to compute areas at 1-foot increments by linear interpolation. The computer was also used to compute the reservoir capacity which is defined by a series of curves obtained by integrating the area equations over an elevation interval within a restricted error limit. The capacity data were also compiled at 1-foot intervals.

A comprehensive summary of the reservoir sediment data for the 1967 survey is contained in Table 2. Sediments have accumulated to a volume of 22,120 acre-feet at elevation 1559 feet since the dam was closed in 1940. This indicates a loss in reservoir capacity of about 14 percent. The average annual sediment accumulation rate of 838 acre-feet was found for the 1940-67 period. Sediments deposited at a rate of 0.398 acre-feet per square mile annually during this period.

APPENDIX

Profiles run for the 25 sedimentation ranges surveyed in 1948 and 1967 are plotted in Figures 28 through 52.

NOTE (applicable to Figures 28 through 52)

1948 profile

1967 profile

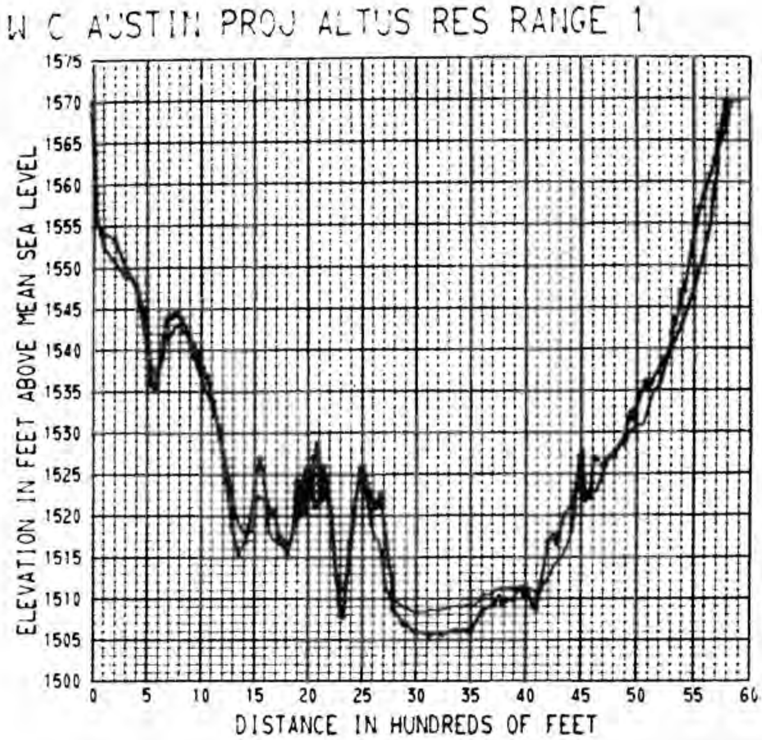


Figure 28. 1948 and 1967 sedimentation range profiles—Range 1.

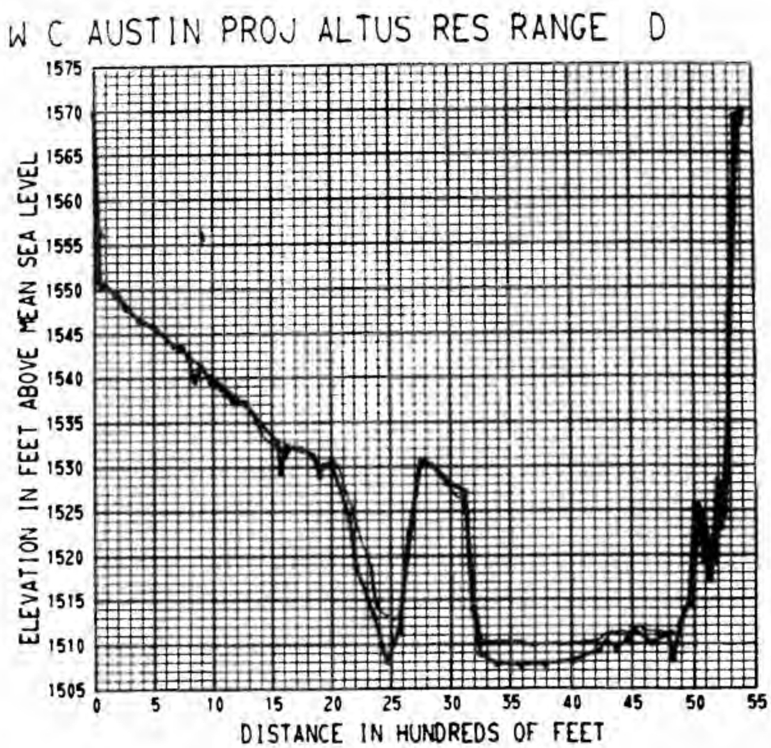


Figure 29. 1948 and 1967 sedimentation range profiles—Range D.

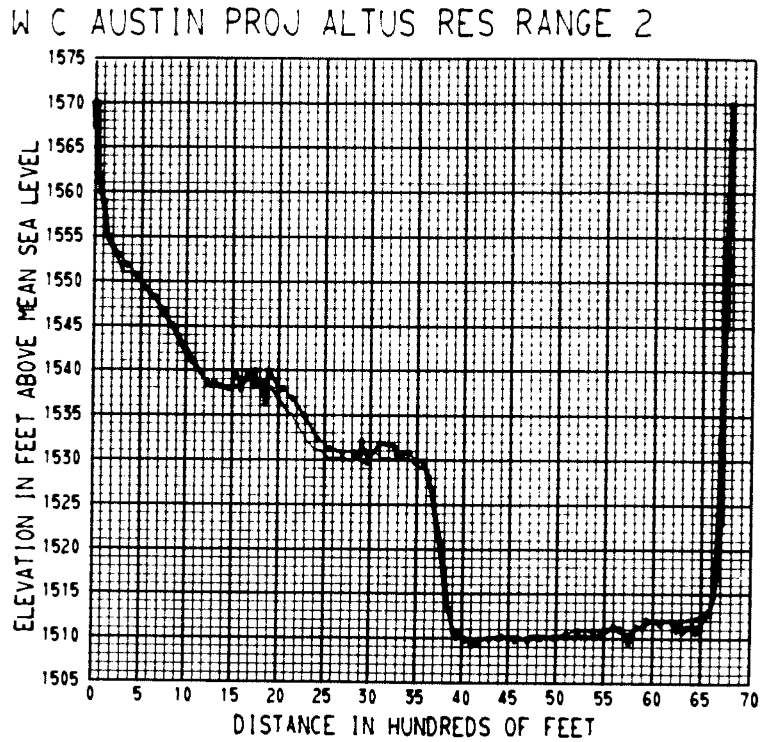


Figure 30. 1948 and 1967 sedimentation range profiles—Range 2.

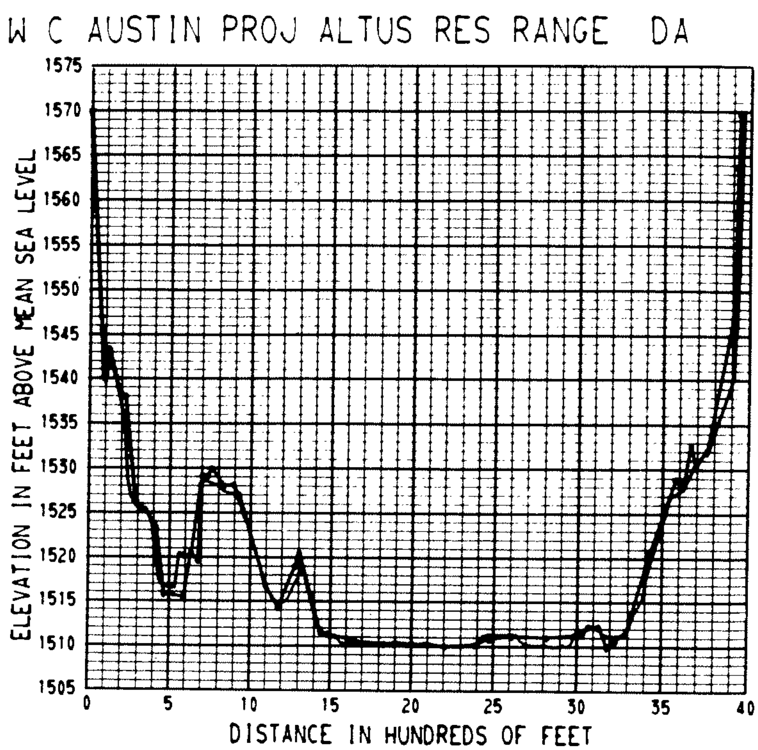


Figure 31. 1948 and 1967 sedimentation range profiles—Range DA.

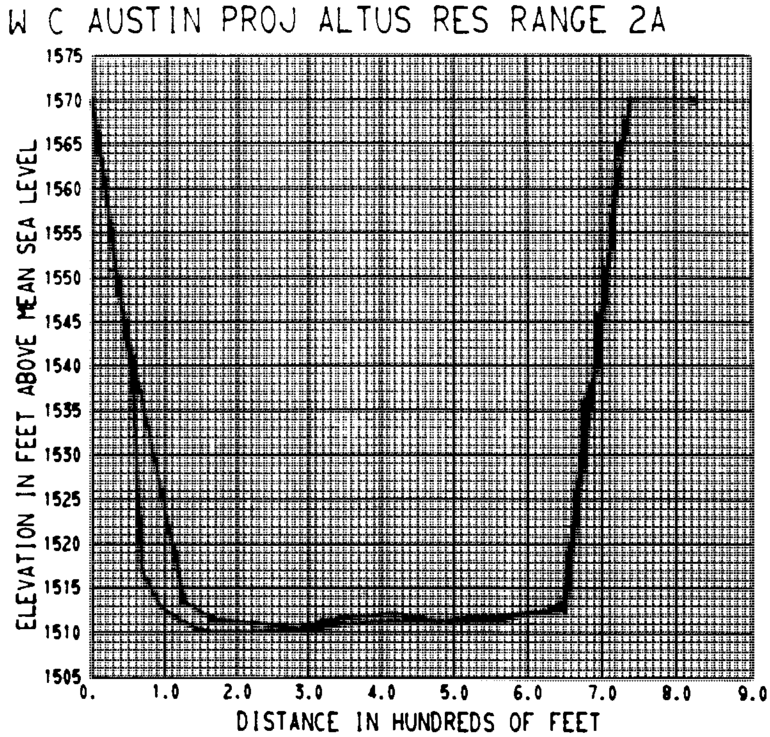


Figure 32. 1948 and 1967 sedimentation range profiles—Range 2A.

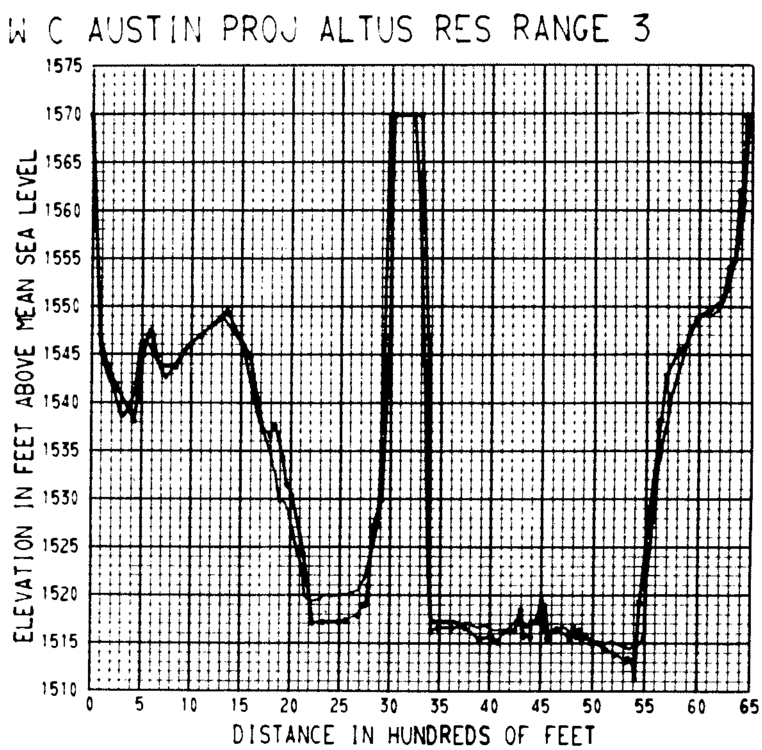


Figure 33. 1948 and 1967 sedimentation range profiles—Range 3.

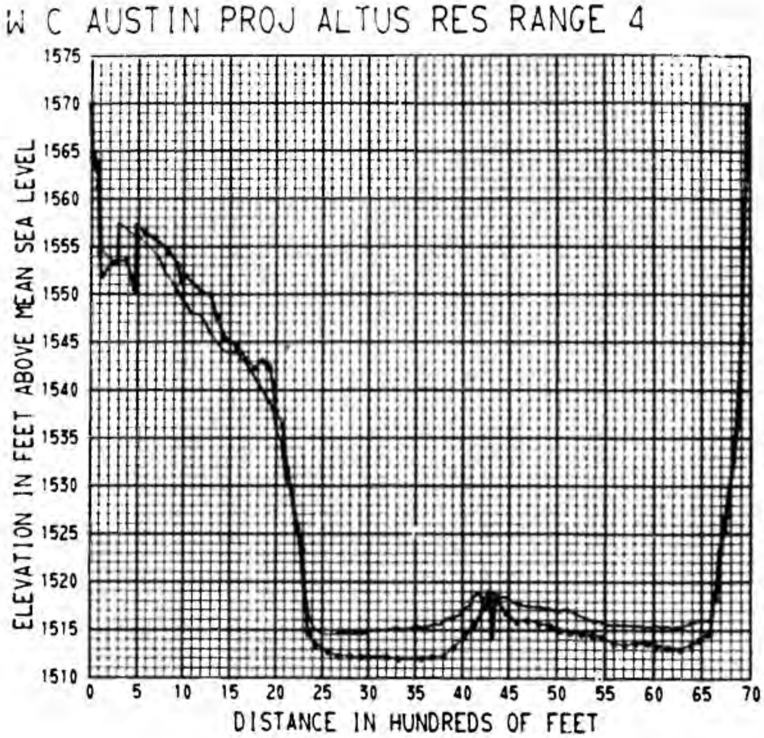


Figure 34. 1948 and 1967 sedimentation range profiles—Range 4.

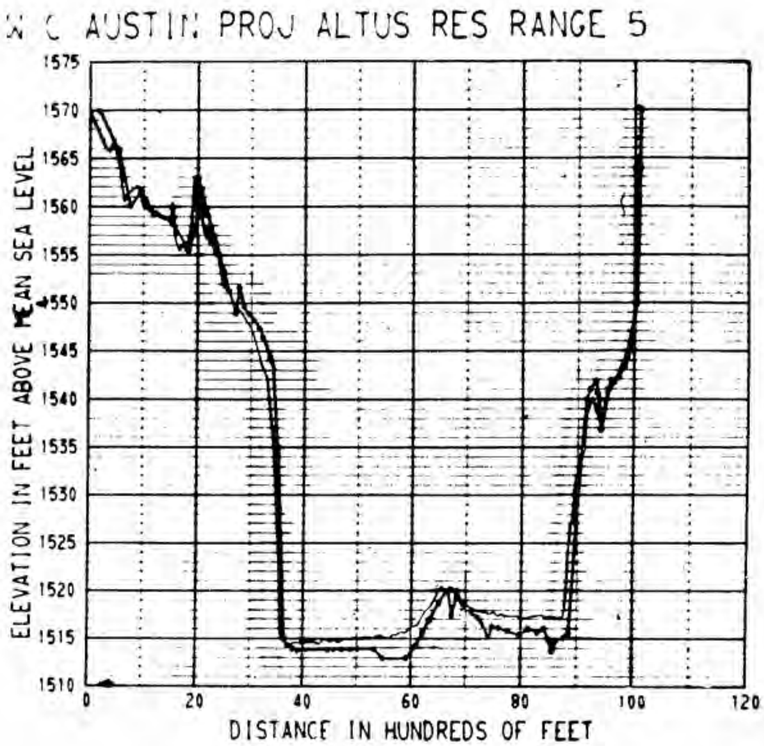


Figure 35. 1948 and 1967 sedimentation range profiles—Range 5.

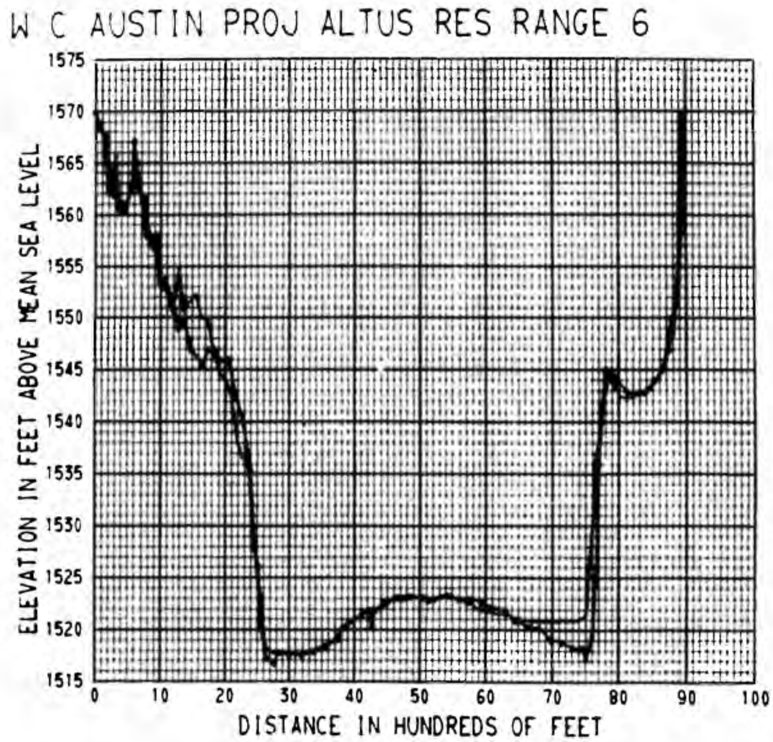


Figure 36. 1948 and 1967 sedimentation range profiles—Range 6.

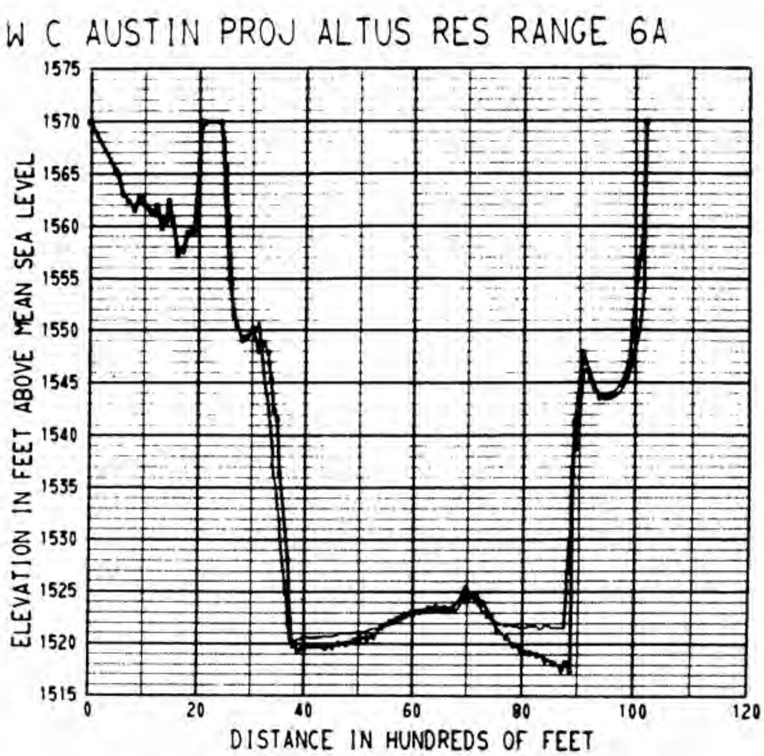


Figure 37. 1948 and 1967 sedimentation range profiles—Range 6A.

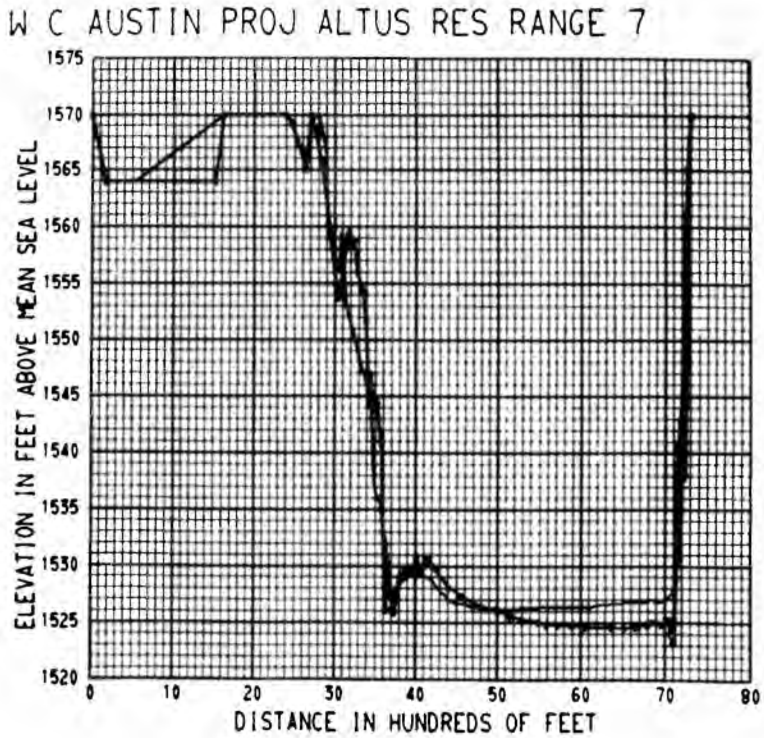


Figure 38. 1948 and 1967 sedimentation range profiles—Range 7.

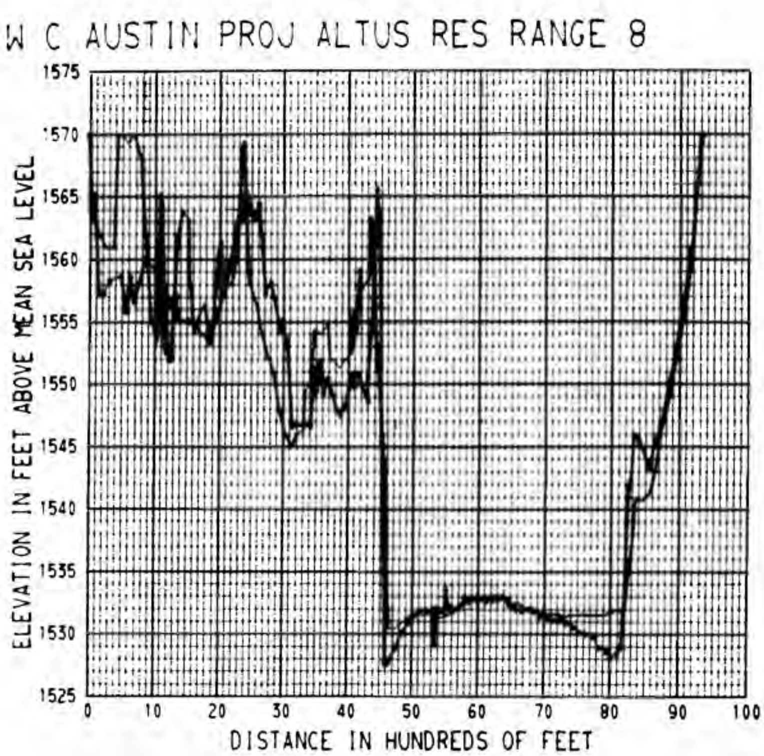


Figure 39. 1948 and 1967 sedimentation range profiles—Range 8.

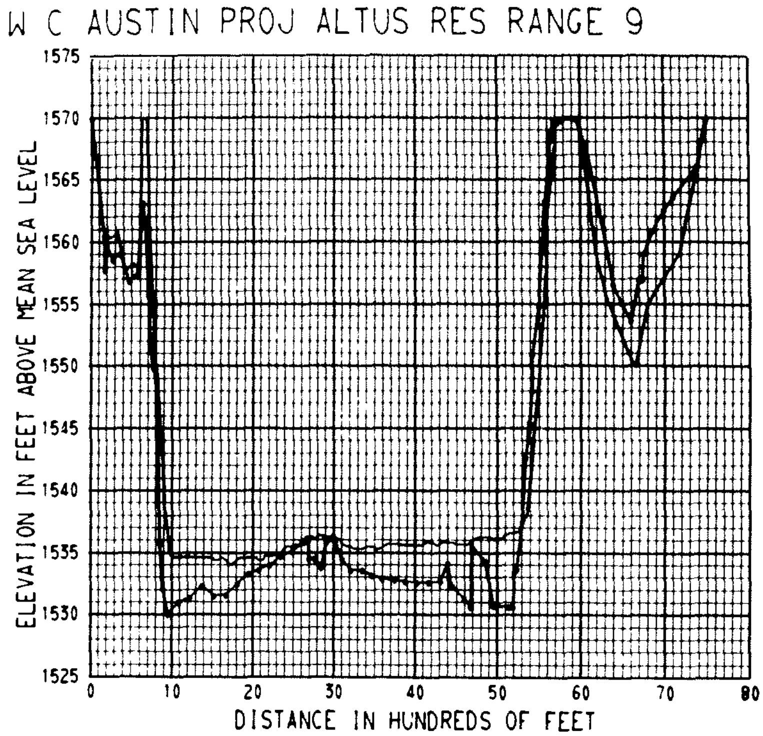


Figure 40. 1948 and 1967 sedimentation range profiles—Range 9.

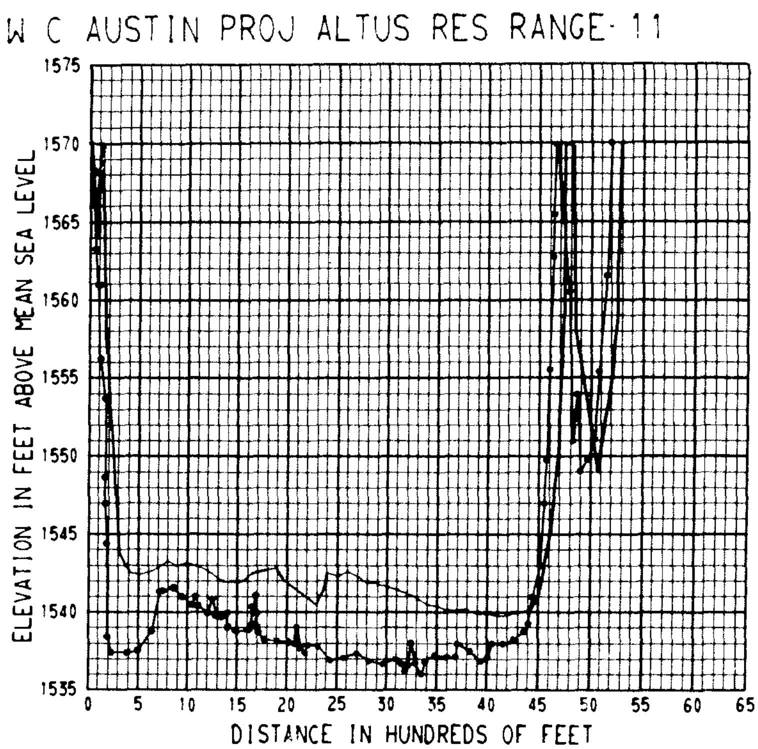


Figure 41. 1948 and 1967 sedimentation range profiles—Range 11.

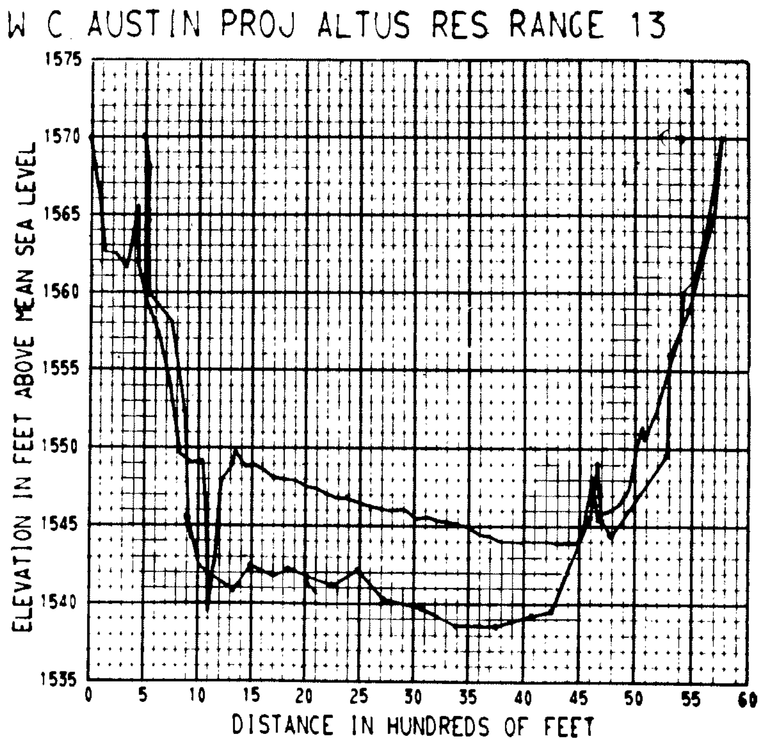


Figure 42. 1948 and 1967 sedimentation range profiles—Range 13.

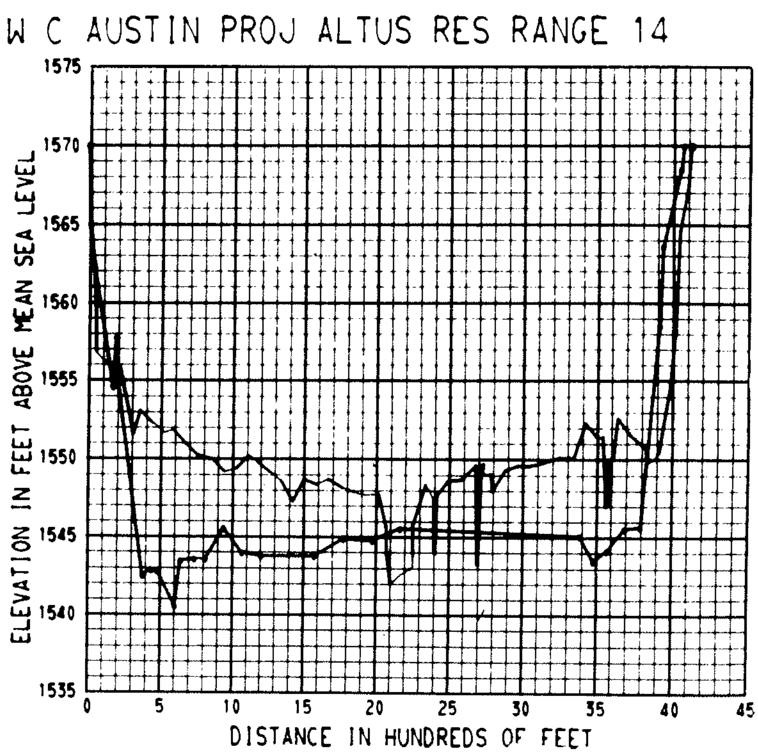


Figure 43. 1948 and 1967 sedimentation range profiles—Range 14.

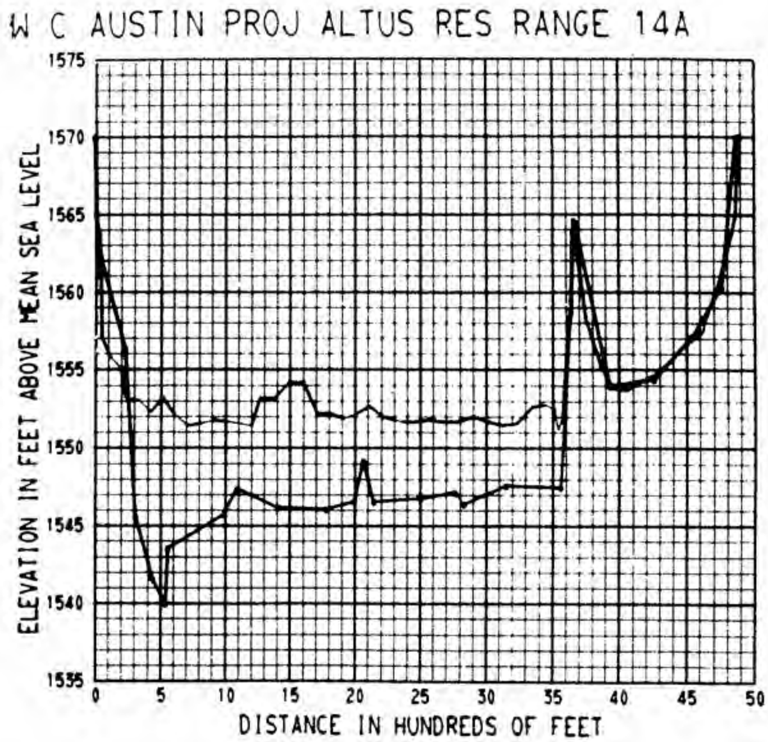


Figure 44. 1948 and 1967 sedimentation range profiles—Range 14A.

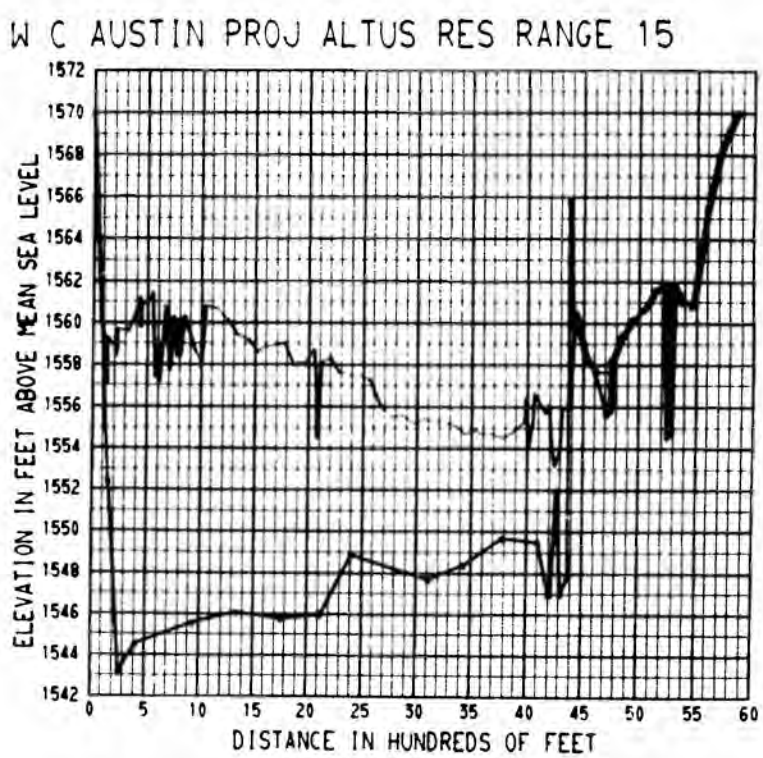


Figure 45. 1948 and 1967 sedimentation range profiles—Range 15.

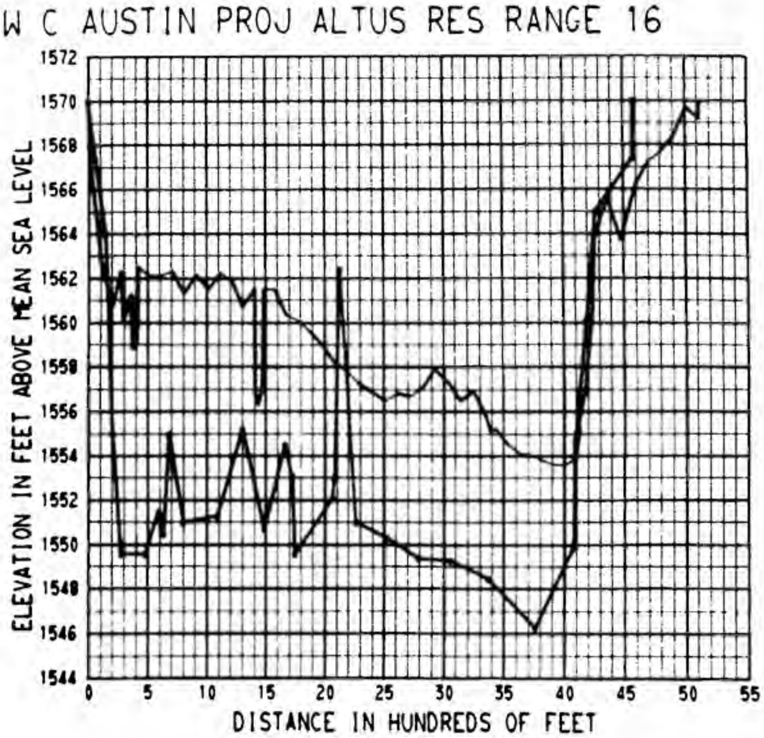


Figure 46. 1948 and 1967 sedimentation range profiles—Range 16.

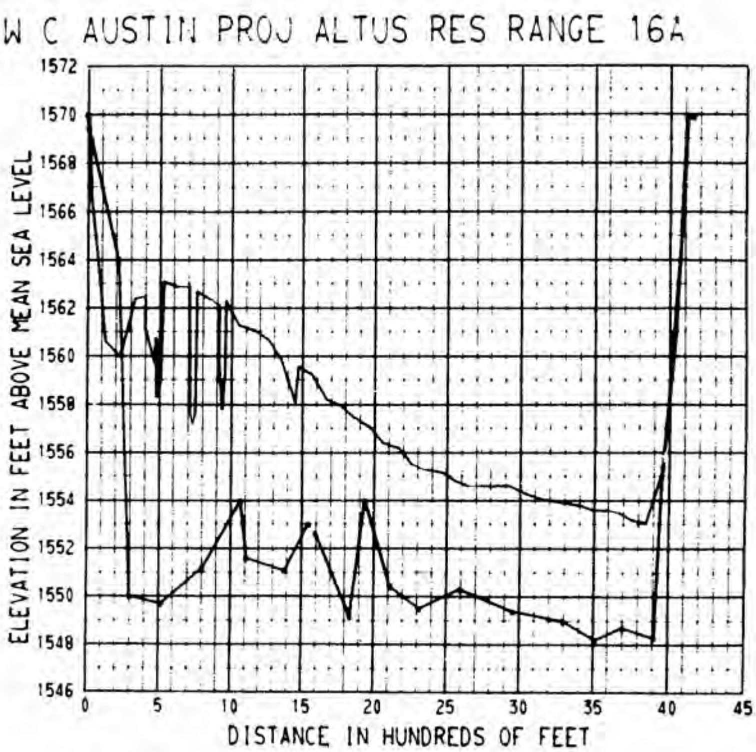


Figure 47. 1948 and 1967 sedimentation range profiles—Range 16A.

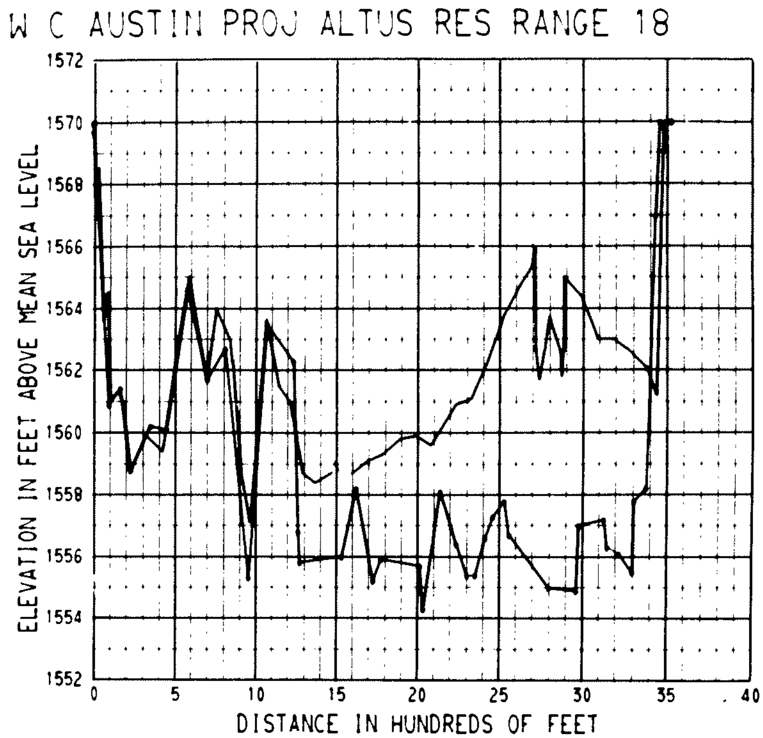


Figure 48. 1948 and 1967 sedimentation range profiles—Range 17.

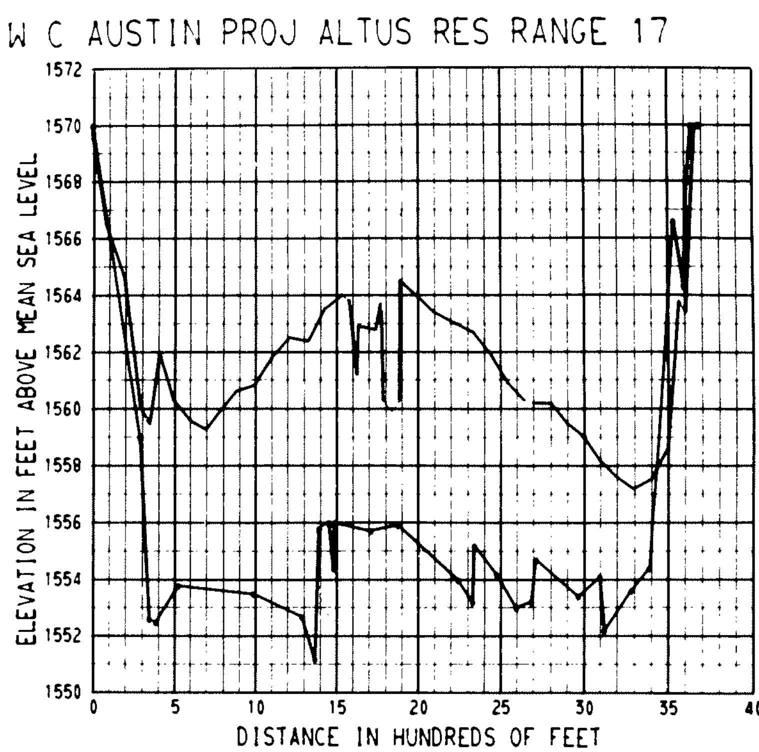


Figure 49. 1948 and 1967 sedimentation range profiles—Range 18.

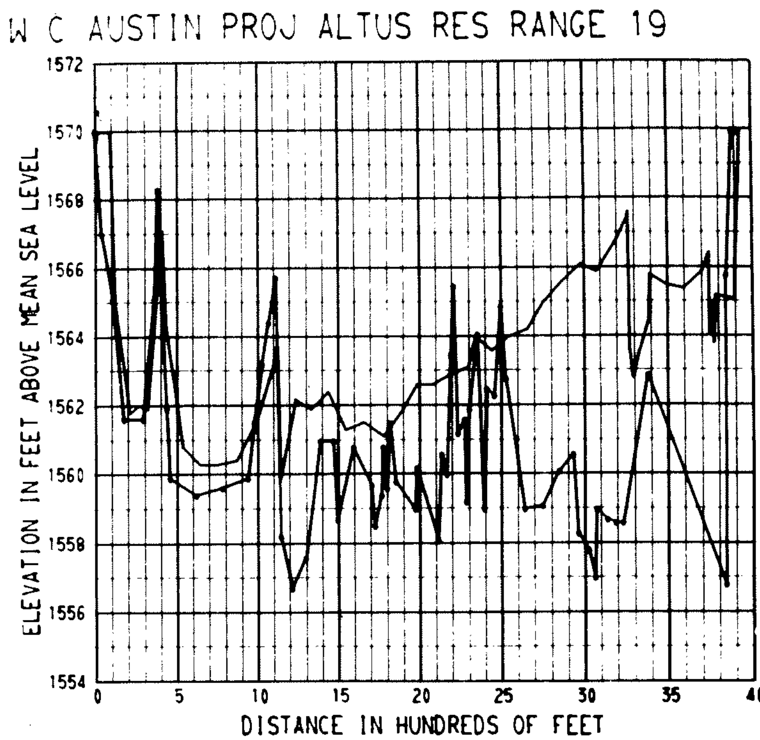


Figure 50. 1948 and 1967 sedimentation range profiles—Range 19.

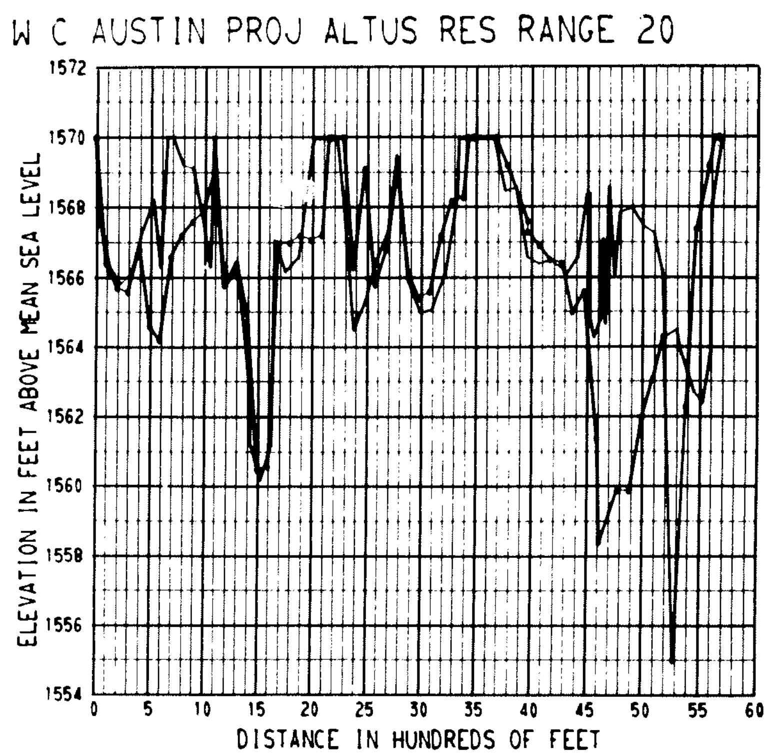


Figure 51. 1948 and 1967 sedimentation range profiles—Range 20.

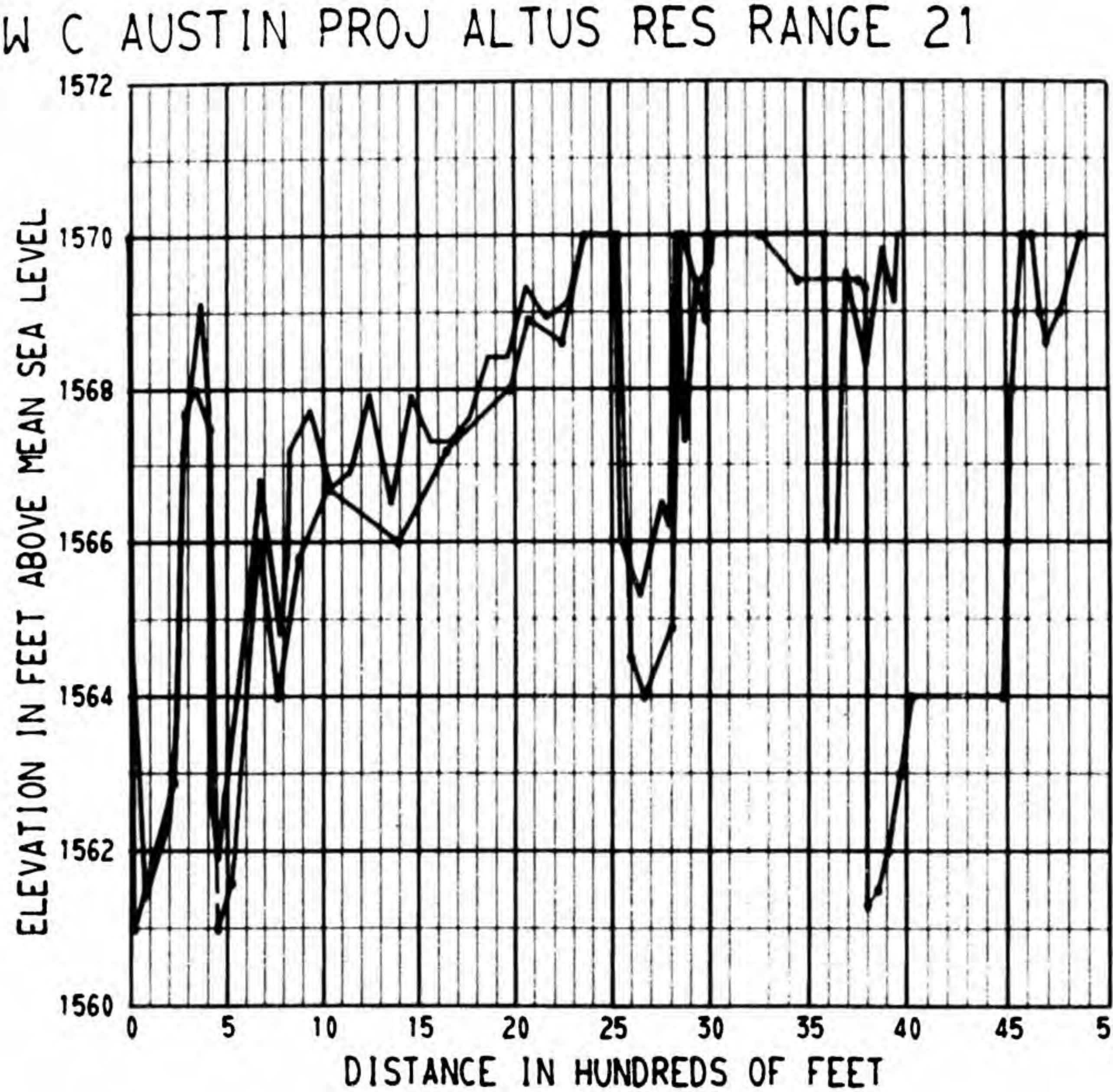


Figure 52. 1948 and 1967 sedimentation range profiles—Range 21.

CONVERSION FACTORS—BRITISH TO METRIC UNITS OF MEASUREMENT

The following conversion factors adopted by the Bureau of Reclamation are those published by the American Society for Testing and Materials (ASTM Metric Practice Guide, E 380-68) except that additional factors (*) commonly used in the Bureau have been added. Further discussion of definitions of quantities and units is given in the ASTM Metric Practice Guide.

The metric units and conversion factors adopted by the ASTM are based on the "International System of Units" (designated SI for Systeme International d'Unites), fixed by the International Committee for Weights and Measures; this system is also known as the Giorgi or MKSA (meter-kilogram (mass)-second-ampere) system. This system has been adopted by the International Organization for Standardization in ISO Recommendation R-31.

The metric technical unit of force is the kilogram-force; this is the force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 9.80665 m/sec/sec, the standard acceleration of free fall toward the earth's center for sea level at 45 deg latitude. The metric unit of force in SI units is the newton (N), which is defined as that force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 1 m/sec/sec. These units must be distinguished from the (inconstant) local weight of a body having a mass of 1 kg, that is, the weight of a body is that force with which a body is attracted to the earth and is equal to the mass of a body multiplied by the acceleration due to gravity. However, because it is general practice to use "pound" rather than the technically correct term "pound-force," the term "kilogram" (or derived mass unit) has been used in this guide instead of "kilogram-force" in expressing the conversion factors for forces. The newton unit of force will find increasing use, and is essential in SI units.

Where approximate or nominal English units are used to express a value or range of values, the converted metric units in parentheses are also approximate or nominal. Where precise English units are used, the converted metric units are expressed as equally significant values.

Table I

QUANTITIES AND UNITS OF SPACE

Multiply	By	To obtain
	LENGTH	
Mil	25.4 (exactly)	Micron
Inches	25.4 (exactly)	Millimeters
Inches	2.54 (exactly)*	Centimeters
Feet	30.48 (exactly)	Centimeters
Feet	0.3048 (exactly)*	Meters
Feet	0.0003048 (exactly)*	Kilometers
Yards	0.9144 (exactly)	Meters
Miles (statute)	1,609.344 (exactly)*	Meters
Miles	1.609344 (exactly)	Kilometers
	AREA	
Square inches	6.4516 (exactly)	Square centimeters
Square feet	*929.03	Square centimeters
Square feet	0.092903	Square meters
Square yards	0.836127	Square meters
Acres	*0.40469	Hectares
Acres	*4,046.9	Square meters
Acres	*0.0040469	Square kilometers
Square miles	2.58999	Square kilometers
	VOLUME	
Cubic inches	16.3871	Cubic centimeters
Cubic feet	0.0283168	Cubic meters
Cubic yards	0.764555	Cubic meters
	CAPACITY	
Fluid ounces (U.S.)	29.5737	Cubic centimeters
Fluid ounces (U.S.)	29.5729	Milliliters
Liquid pints (U.S.)	0.473179	Cubic decimeters
Liquid pints (U.S.)	0.473166	Liters
Quarts (U.S.)	*946.358	Cubic centimeters
Quarts (U.S.)	*0.946331	Liters
Gallons (U.S.)	*3,785.43	Cubic centimeters
Gallons (U.S.)	3.78543	Cubic decimeters
Gallons (U.S.)	3.78533	Liters
Gallons (U.S.)	*0.00378543	Cubic meters
Gallons (U.K.)	4.54609	Cubic decimeters
Gallons (U.K.)	4.54596	Liters
Cubic feet	28.3160	Liters
Cubic yards	*764.55	Liters
Acre-feet	*1,233.5	Cubic meters
Acre-feet	*1,233,500	Liters

Table II

QUANTITIES AND UNITS OF MECHANICS

Multiply	By	To obtain
	MASS	
Grains (1/7,000 lb)	64.79891 (exactly)	Milligrams
Troy ounces (480 grains)	31.1035	Grams
Ounces (avdp)	28.3495	Grams
Pounds (avdp)	0.45359237 (exactly)	Kilograms
Short tons (2,000 lb)	907.185	Kilograms
Short tons (2,000 lb)	0.907185	Metric tons
Long tons (2,240 lb)	1,016.05	Kilograms
	FORCE/AREA	
Pounds per square inch	0.070307	Kilograms per square centimeter
Pounds per square inch	0.689476	Newtons per square centimeter
Pounds per square foot	4.88243	Kilograms per square meter
Pounds per square foot	47.8803	Newtons per square meter
	MASS/VOLUME (DENSITY)	
Ounces per cubic inch	1.72999	Grams per cubic centimeter
Pounds per cubic foot	16.0185	Kilograms per cubic meter
Pounds per cubic foot	0.0160185	Grams per cubic centimeter
Tons (long) per cubic yard	1.32894	Grams per cubic centimeter
	MASS/CAPACITY	
Ounces per gallon (U.S.)	7.4893	Grams per liter
Ounces per gallon (U.K.)	6.2362	Grams per liter
Pounds per gallon (U.S.)	119.829	Grams per liter
Pounds per gallon (U.K.)	99.779	Grams per liter
	BENDING MOMENT OR TORQUE	
Inch-pounds	0.011521	Meter-kilograms
Inch-pounds	1.12985×10^6	Centimeter-dynes
Foot-pounds	0.138255	Meter-kilograms
Foot-pounds	1.35582×10^7	Centimeter-dynes
Foot-pounds per inch	5.4431	Centimeter-kilograms per centimeter
Ounce-inches	72.008	Gram-centimeters
	VELOCITY	
Feet per second	30.48 (exactly)	Centimeters per second
Feet per second	0.3048 (exactly)*	Meters per second
Feet per year	*0.965873×10^{-6}	Centimeters per second
Miles per hour	1.609344 (exactly)	Kilometers per hour
Miles per hour	0.44704 (exactly)	Meters per second
	ACCELERATION*	
Feet per second^2	*0.3048	Meters per second^2
	FLOW	
Cubic feet per second (second-feet)	*0.028317	Cubic meters per second
Cubic feet per minute	0.4719	Liters per second
Gallons (U.S.) per minute	0.06309	Liters per second
	FORCE*	
Pounds	*0.453592	Kilograms
Pounds	*4.4482	Newtons
Pounds	*4.4482×10^5	Dynes

Table II–Continued

Multiply	By	To obtain
	WORK AND ENERGY*	
British thermal units (Btu)	*0.252	Kilogram calories
British thermal units (Btu)	1,055.06	Joules
Btu per pound	2.326 (exactly)	Joules per gram
Foot-pounds	*1.35582	Joules
	POWER	
Horsepower	745.700	Watts
Btu per hour	0.293071	Watts
Foot-pounds per second	1.35582	Watts
	HEAT TRANSFER	
Btu in./hr ft^2 degree F (k, thermal conductivity)	1.442	Milliwatts/cm degree C
Btu in./hr ft^2 degree F (k, thermal conductivity)	0.1240	Kg cal/hr m degree C
Btu ft/hr ft^2 degree F	*1.4880	Kg cal m/hr m^2 degree C
Btu/hr ft^2 degree F (C, thermal conductance)	0.568	Milliwatts/cm^2 degree C
Btu/hr ft^2 degree F (C, thermal conductance)	4.882	Kg cal/hr m^2 degree C
Degree F hr ft^2/Btu (R, thermal resistance)	1.761	Degree C cm^2/milliwatt
Btu/lb degree F (c, heat capacity)	4.1868	J/g degree C
Btu/lb degree F	*1.000	Cal/gram degree C
Ft^2/hr (thermal diffusivity)	0.2581	Cm^2/sec
Ft^2/hr (thermal diffusivity)	*0.09290	M^2/hr
	WATER VAPOR TRANSMISSION	
Grains/hr ft^2 (water vapor) transmission)	16.7	Grams/24 hr m^2
Perms (permeance)	0.659	Metric perms
Perm-inches (permeability)	1.67	Metric perm-centimeters

Table III

OTHER QUANTITIES AND UNITS

Multiply	By	To obtain
Cubic feet per square foot per day (seepage)	*304.8	Liters per square meter per day
Pound-seconds per square foot (viscosity)	*4.8824	Kilogram second per square meter
Square feet per second (viscosity)	*0.092903	Square meters per second
Fahrenheit degrees (change)*	5/9 exactly	Celsius or Kelvin degrees (change)*
Volts per mil	0.03937	Kilovolts per millimeter
Lumens per square foot (foot-candles)	10.764	Lumens per square meter
Ohm-circular mils per foot	0.001662	Ohm-square millimeters per meter
Millicuries per cubic foot	*35.3147	Millicuries per cubic meter
Milliamps per square foot	*10.7639	Milliamps per square meter
Gallons per square yard	*4.527219	Liters per square meter
Pounds per inch	*0.17858	Kilograms per centimeter

GPO 835-947

ABSTRACT

Altus Reservoir was surveyed in 1967 to gather the data needed in computing the latest reservoir capacity. The data were also used to compute the quantity of sediments accumulating in the reservoir since the dam was closed in 1940. Capacity of the reservoir is 134,000 acre-ft and the surface area 6,260 acres at spillway crest elevation 1559 ft. Sediments accumulated in the reservoir at an annual rate of 838 acre-ft between 1940 and 1947. Thirty sediment samples of reservoir deposits were collected from 23 reservoir range sites. An average unit weight of 70 lb/cu ft was determined from analyses of samples collected during the 1948, 1953, and 1967 surveys. Particle size analyses of these samples indicated an average breakdown of 29% clay, 32% silt, and 39% sand. Sonic depth recording mechanism was used to run the hydrographic survey. Reservoir capacity was computed based on areas determined by a width ratio method. Sediments have deposited longitudinally to depths of 1 to 9 ft throughout the reservoir length. Depths ranged from 1 to 6 ft for the laterally deposited sediments.

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REC-ERC-71-21
Lara, Joe M.
THE 1967 ALTUS RESERVOIR SEDIMENT SURVEY
Bur Reclam Rep REC-ERC-71-21, March 1971. Bureau of Reclamation, Denver, 41 p, 52 fig, 4 tab, 5 ref

DESCRIPTORS— /*reservoir silting/ sedimentation/ *reservoir surveys/ sediment distribution/ range lines/ Oklahoma/ contours/ deltas/ fluvial hydraulics/ sediment production/ sonar/ *sediment sampling/ field investigations/ sediment transport/ unit weight/ *aggradation/ deposition (sediments)/ sediment yield
IDENTIFIERS—/*reservoir capacity/ Altus Reservoir, Okla/ width ratio method

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