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# THE 1969 ELEPHANT BUTTE RESERVOIR SEDIMENT SURVEY

Joe M. Lara
Engineering and Research Center
Bureau of Reclamation

March 1972

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16. ABSTRACT
The Elephant Butte Reservoir was surveyed in 1969 to gather data needed in computing the present reservoir capacity. The data were also used to compute the volume of sediments that accumulated in the reservoir since the dam was closed in 1915. Reservoir capacity is 2,137,200 acre-feet and the surface area 36,600 acres at spillway crest elevation 4407 feet. Sediments accumulated at an annual rate of 9,164 acre-feet between 1915 and 1969. Seventeen sediment samples of reservoir deposits were collected from sites of the reservoir ranges immediately above the dam during the 1969 survey. An average unit weight of 62 lb/cu ft was determined from analyses of samples collected during 1952, 1957, and 1969. Particle size analyses of these samples indicated an average breakdown of 60 percent clay, 31 percent silt, and 9 percent sand. Sonic depth recording apparatus 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 8 to 42 feet throughout the reservoir length. Depths ranged from 10 to 44 feet for the laterally deposited sediments.

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# THE 1969 ELEPHANT BUTTE RESERVOIR SEDIMENT SURVEY

by

Joe M. Lara

March 1972

Hydrology Branch
Division of Planning Coordination
Engineering and Research Center
Denver, Colorado

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UNITED STATES DEPARTMENT OF THE INTERIOR * BUREAU OF RECLAMATION
Rogers C. B. Morton, Secretary
Ellis L. Armstrong, Commissioner

## ACKNOWLEDGMENT

The hydrographic survey was run by Joe M. Lara, Hydraulic Engineer, Engineering and Research Center, Denver, Colorado. Survey personnel included Mike Tracy and Emery Goertz on detail from the Navajo Indian Irrigation Project Office, Farmington, New Mexico, and H. T. Daniel and other members of the Power Field Branch Office, Elephant Butte, New Mexico. 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 Sam Bock and others under the supervision of James W. Kirby, Project Superintendent, El Paso, Texas. 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

Elephant Butte Reservoir is in Sierra and Socorro Counties of New Mexico. The dam is on the Rio Grande about 4 miles east of Truth or Consequences, New Mexico, and 125 miles north of El Paso, Texas. The dam and reservoir are owned and operated by the Bureau of Reclamation, U.S. Department of the Interior.

### Description of the Dam

Elephant Butte was originally named Engle Dam. It is a gravity dam (Figure 1), 301 feet (ft) high and 1,674 ft long including the spillway. A drawing of the general plan and sections of the dam is shown in Figure 2. The dam was completed in 1916, but storage operation began in 1915.

The power system consists of the 24,300-kilowatt (kw) hydroelectric powerplant at the dam, 490 miles of 115-kilovolt (kv) transmission lines radiating from it, and 11 substations totaling 81,750 kilovolt-amperes (kva) in transformer capacity. More details on the description of the dam are contained in two previously published Bureau of Reclamation reports.[1] [2]

### Description of the Reservoir

The original (1915) surface area of Elephant Butte Reservoir was 40,060 acres at spillway crest elevation (el) 4407 ft. This compares to a surface of area of 36,600 acres at the same elevation determined from the 1969 survey. The present capacity at this elevation is 2,137,200 acre-feet (acre-ft) showing a loss of 497,600 acre-ft since the dam was originally built. The length of the reservoir is about 41 miles and its average width is 1.39 miles.

### Drainage Area Description

The drainage area of the Rio Grande above Elephant Butte Dam is 25,923 square miles of which 25,866 square miles is considered as the net sediment contributing area.

The Rio Grande rises in the San Juan Mountains of Colorado and flows between the Conejos Mountains and La Garita Hills. Water surface slopes are steep in the mountainous headwater regions. Most of the rocks in these regions are igneous or metamorphic and are not easily eroded. Just above the New Mexico state line the river enters a deep canyon flowing through a stretch of low sediment contribution until it enters Espanola Valley near the confluence with Rio Chama. Upon leaving this valley, it enters White Rock Canyon in the vicinity of Otowi Bridge. The unconsolidated sediments of the Santa Fe formation (Miocene and Pliocene continental deposits) have been eroded to form the valley of the Rio Grande from the lower end of White Rock Canyon near Cochiti Diversion Dam to near San Acacia. The flood plains and terraces of the valley are composed of alluvium that is available for transport and contributes substantial quantities of sediment to the Rio Grande. From the mouth of Rio Salado, just upstream from San Acacia, to the headwaters of Elephant Butte Reservoir, the Palomas formation of the Quaternary period has been eroded to form the river valley. The major geologic formations of the Rio Grande Valley are of the Cenozoic Era.

The topography of the drainage area is varied. In the extreme upper portion it is mountainous and rugged. South of Santa Fe, New Mexico, the topography is less rugged consisting of isolated mountains separated by desert plains and the Rio Grande Valley. The ranges of the drainage area elevation vary from 12,000 ft mean sea level (msl) at the Continental Divide in the upper portion to 4,450 ft msl in the Elephant Butte Reservoir headwaters area.

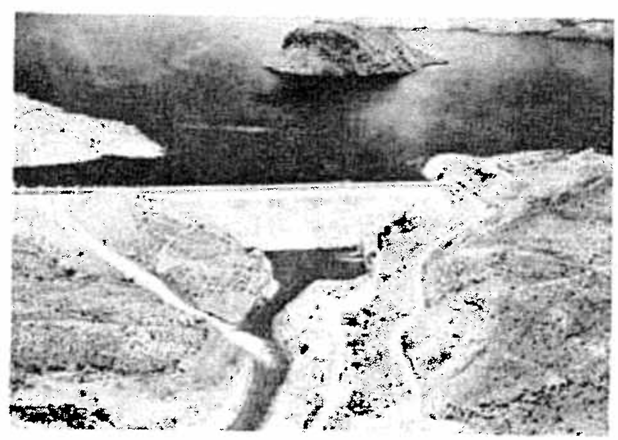

Figure 1. Elephant Butte Dam. Photo P24-D-24996

[1] Seavy, L. M., "Sedimentation Surveys of Elephant Butte Reservoir," Bureau of Reclamation, U.S. Department of the Interior, Denver, Colorado, February 1949.

[2] Lara, J. M., "The 1957 Sedimentation Survey of Elephant Butte Reservoir," Bureau of Reclamation, U.S. Department of the Interior, Denver, Colorado, November 1960.

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The higher elevations are forested with pine and fir trees and the slopes are sprinkled with cedars along the foothills. Natural cover of the plains consists chiefly of creosote bush, sagebrush, greasewood, cactus, and natural grasses. Thick stands of salt cedars, willows, and cottonwoods grow along the riverbanks above the reservoir.

The previously cited reports[1 2] contain further descriptions of the drainage area.

### Datum

All elevations quoted in this report are based on the project datum. To adjust these elevations to mean-sea-level datum, 43.3 ft should be added.

### Hydrographic Records

Records of the inflow to Elephant Butte Reservoir show an average of 866,000 acre-ft per year for 53 years (1915-1968, no record in 1957). The 11-year average (1958-1968), covering about the period since the last survey (1957), is 603,000 acre-ft per year. This 11-year average is about 70 percent of the average computed for 53 years.

Based on 53 years of record (1915-1968), the average annual discharge of the Rio Grande below Elephant Butte Dam is 732,700 acre-ft giving an indication of the outflow.

Elephant Butte Reservoir operation ranged from a minimum elevation of 4258.03 ft in 1954 to a maximum of 4409.15 ft in 1942.

## SURVEYS, SAMPLING, AND EQUIPMENT

Seven surveys of varying degrees of accuracy have been previously run, beginning in 1916. Results of these surveys are documented later in the report. All surveys, except the one in 1947, were run using the contour method. The 1947 and 1969 surveys were run using the range method. Fieldwork for the last survey began February 3 and ended April 1, 1969.

### Surveying Methods

Field survey work consisted initially of locating 60 of the reservoir sediment range ends permanently monumented during previous surveys. Ranges 90 to 65 were profiled across their full length. Above Range 65, only the main channel section was profiled; for the remainder of the range line in the floodway on each side of the main channel, the 1957 profile data were used. This was done for each range in the upper reservoir area because the water had never reached floodway levels since the 1957 survey. Standard land surveying procedures and equipment were used to run levels on each range line. For those ranges that are partly submerged underwater, levels were run on line down to water's edge from both sides of the reservoir. Stations were established at the edge of the water for the hydrographic survey.

The hydrographic survey was run in March and April 1969 using sonic depth recording equipment (Figures 3 and 4) to sound the submerged portion of the ranges. The equipment was installed on the deck of a pontoon boat as shown in Figure 5. First, the boat was positioned on range line near to the shore as possible. Then the line was profiled from the station at water's edge using stadia or tape to measure the distance to the center point of the transducer. The depth recorder was turned on and the boat was propelled (Figure 6) across the range at speeds of about 3 to 5 feet per second (fps). A man on shore (Figure 7) kept the boat on line through radio communication with the boat operator. A distance measuring machine was used to measure horizontal distances across the reservoir. The machine provided a way of marking the "fix" lines on the sonar

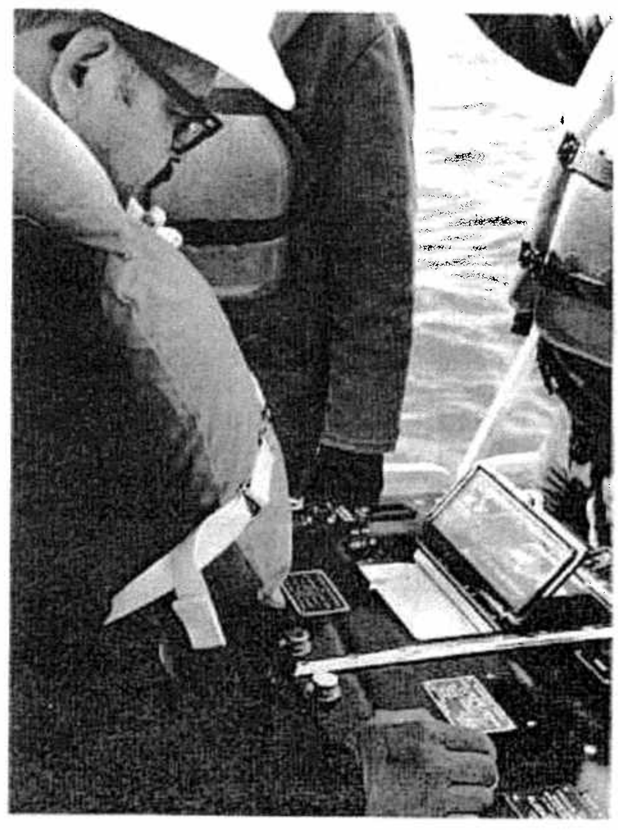

Figure 3. Recorder for sonic charting. Photo P24-500-1246 NA

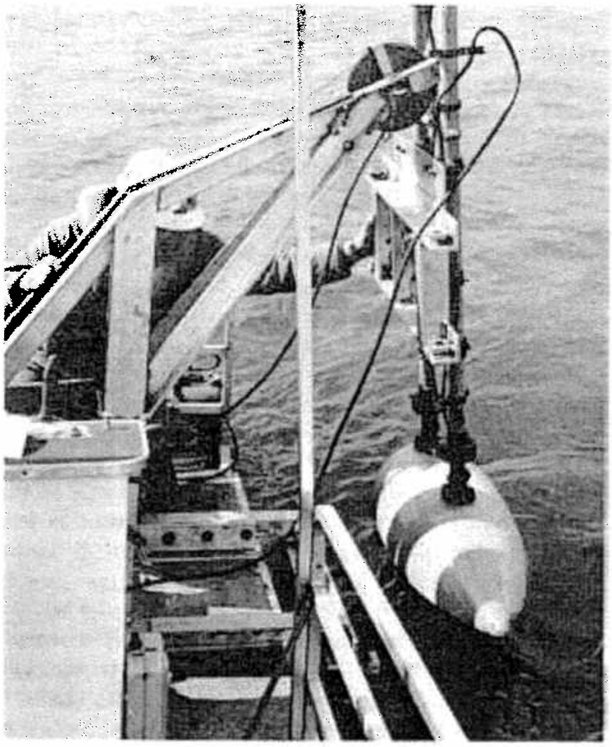

Figure 4. Transducer being readied for operation.

Figure 6. Launching the boat to sound a range line. Photo P24-500-1244 NA

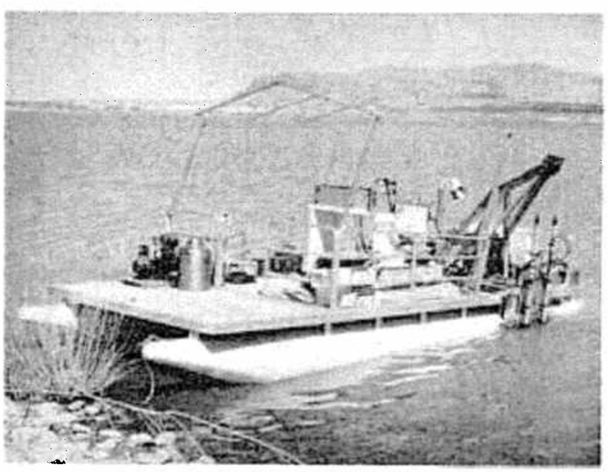

Figure 5. Equipment installed on deck of pontoon boat to run hydrographic survey.

Figure 7. Man on shore keeps boat on line through radio communication with boat operator. Photo P24-500-1247 NA

chart. Vertical control was maintained by referencing the recorded soundings to the reservoir water surface indicated by the gage at the dam which was read each day of the survey operation.

A graphical reproduction of a sonar chart is shown in Figure 8 for the west portion of Range 90. The chart shows it was necessary to change the depth scale from the 0- to 60-ft scale to the 60- to 120-ft scale between 50 and 100 ft from the beginning station. Then, the scale was changed back to the 0- to 60-ft range just after passing a distance of 650 ft from the beginning station.

**Sampling Method and Equipment**

A gravity core sampler (Figure 9) was used to take 17 samples of the underwater reservoir sediment deposits. The sampler was suspended over the side of the boat from a 0.25-inch (in.) cable reeled off a power-operated winch. It was allowed to fall free into the sediment deposits to maximum possible penetration. When the sampler was retrieved on the boat deck, the cutterhead at the bottom was removed and the plastic liner containing the sediment sample was withdrawn from the coring pipe (Figure 10). A hacksaw was used to cut that part of the liner holding the sample. Plastic caps were put on each end of the liner which was identified for analysis.

## RESERVOIR SEDIMENT DISTRIBUTION

**Longitudinal Distribution**

A study of how sediments were distributed in the reservoir can be made by plotting a longitudinal profile as shown in Figure 11. The thalweg elevation or lowest point on the range line is used to plot the profiles for the 1915 and 1969 conditions. The shaded area represents the sediment encroachment into the reservoir since the dam was closed in 1915. However, beginning about 28 miles above the dam, the conveyance channel (a manmade channel) thalweg was plotted indicating depths of the sediment deposits less than those that would be indicated by the main channel thalweg. The table below lists the depths to which sediments had longitudinally accumulated between the 1915 and 1969 period.

| Interval distances above dam (miles) | Average depth of sediment (ft) |
|---|---|
| 0 to 3 | 27 |
| 3 to 6 | 20 |
| 6 to 11 | 29 |
| 11 to 12 | 37 |
| 12 to 16 | 42 |
| 16 to 21 | 34 |
| 21 to 24 | 26 |
| 24 to 27 | 24 |
| 27 to 31 | 18 |
| 31 to 36 | 14 |
| 36 to 40 | 8 |

The greatest depths of longitudinal sediment deposits occur between 11 and 21 miles above the dam. It is likely that "The Narrows" area between 15 and 19.5 miles above the dam may have influenced the depositional pattern in this region of the reservoir. Another factor influencing the pattern is the lack of water inflow that was evidenced by a severe drought period since 1950. Average annual inflow for the 1950-1968 period (18 years) was 501,000 acre-ft or only 58 percent of the long-term annual average of 866,000 acre-ft for 1915-1968 (53 years).

Table 1 contains a summary of the sediment distribution computations for Elephant Butte Reservoir. Tabulated in column (6) are the accumulated sediment volumes as determined from the 1969 survey results. Total sediments accumulated in the reservoir (see top of column (6)) since the 1915 survey amounted to 497,581 acre-ft. Column (7) lists the volumes expressed in percentage of the total measured sediment volume.

As a matter of further practical interest, a theoretical distribution of the sediment was computed using the Empirical Area-Reduction Method. It was assumed that the sediment inflow volume to be distributed would be 497,600 acre-ft (equal to that measured by the 1969 survey). A plotting of the depth-capacity (Figure 12) relationship using the original (1915) data indicated the reservoir to be a Type II. The Elephant Butte Reservoir data are plotted in Figure 13 which shows it crossing the Type II curve to determine the depth of sediment at the dam. Results of the sediment distribution computations are listed in columns (8),

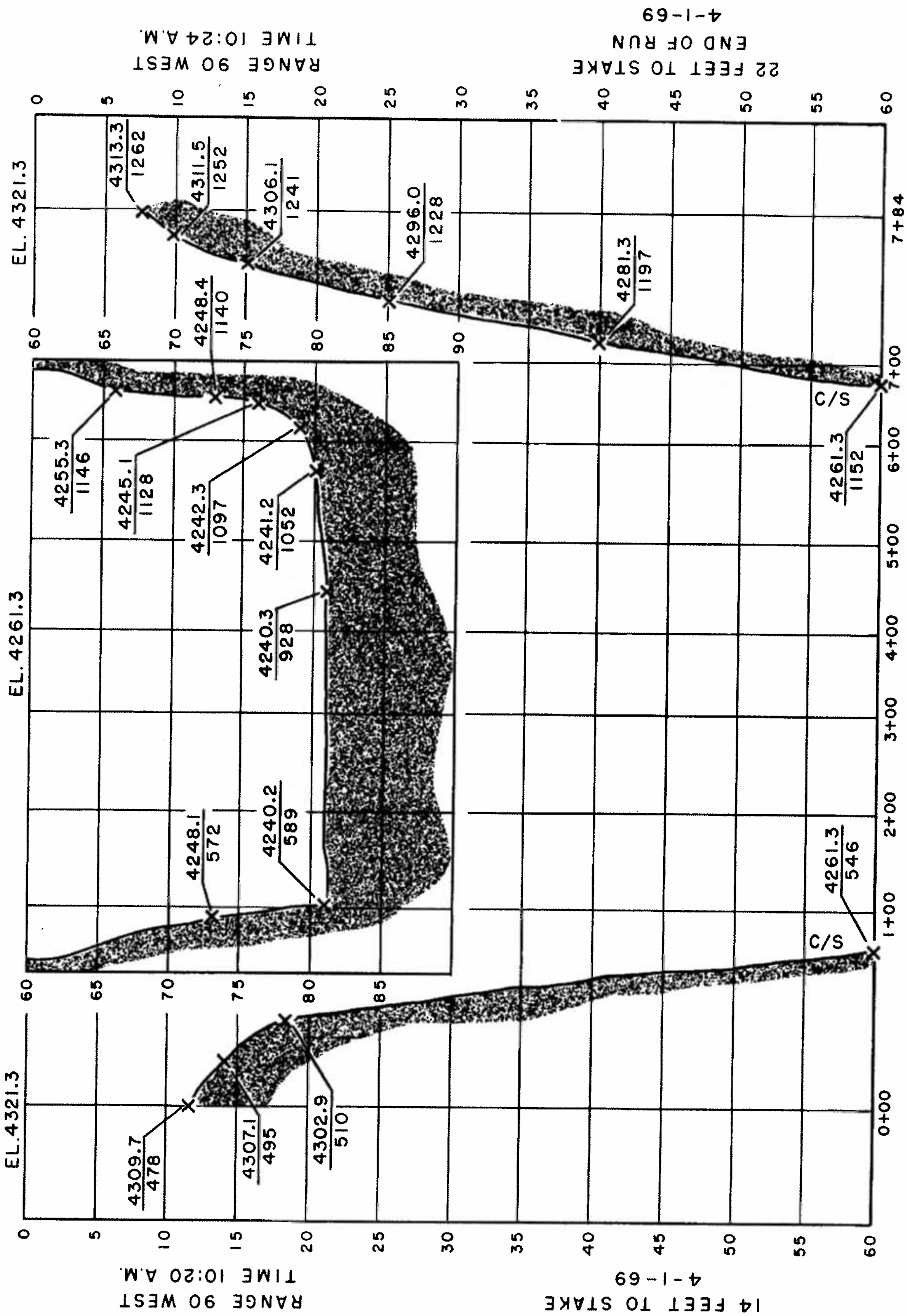


Figure 8. Example of a sonar chart for Range 90 (west portion).

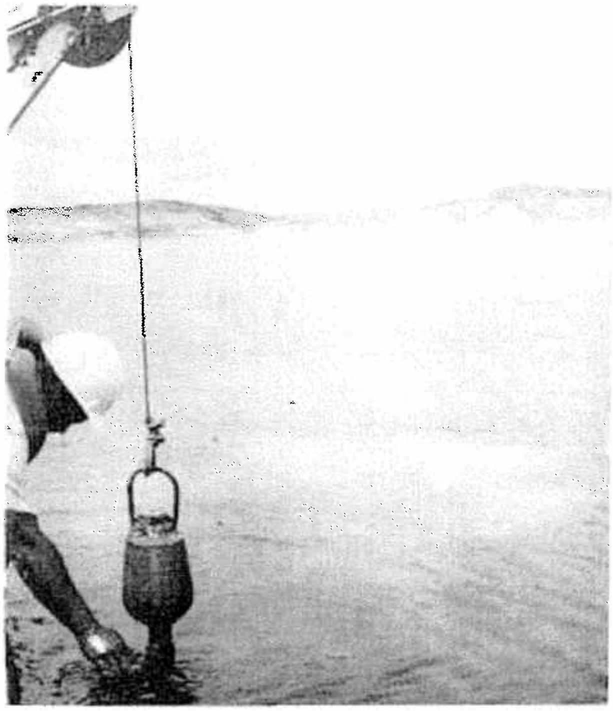

Figure 9. Gravity core sampler (only the head can be seen above water).

(9), and (10) of Table 1. These computations show the sediment would reach an elevation of 4257.5 ft compared to the elevation of 4240 ft determined in the 1969 survey after 54 years of operation. The sediment disposition curves plotted in Figure 14 show how the actual distribution compared with the one from the Type II computations. The curves show the percentages of reservoir depth plotted against the sediment deposited. Examining the curves discloses that the actual and Type II distributions compare reasonably well throughout the depth range. For the most part, the sediment was actually distributed at lesser quantities than those computed throughout the reservoir depth. A maximum deviation of about 13 percent occurs at the 70-percent reservoir depth between the two curves in relation to the percentage of sediment deposited.

Assuming for project planning purposes the conditions of an estimated sediment inflow volume of 497,600 acre-ft for a 54-year period, present day techniques using the Empirical Area-Reduction Method would have resulted in the Type II computations in columns (8), (9), and (10) of Table 1. As previously mentioned, these computations predicted the sediments would reach an elevation of 4257.5 ft or 17.5 ft higher than the elevation (4240 ft) determined in the 1969 survey. A probable explanation for existing sediment accumulating to a lower elevation than the one computed is that the lower outlet (valve centerline at el 4234 ft, see Figure 2) may have had a sluicing effect on the inflowing sediments. Such an effect could not be accounted for when applying the empirically developed technique for computing the depth.

A sediment accumulation curve covering the 1951-1969 period is plotted in Figure 15 using the values in columns (1) and (6) of Table 1. Also plotted as an inset in this figure is a bar diagram representing the sediment that accumulated within the 10-ft elevation intervals. About half of the total sediments had accumulated between el 4350 and 4400 ft for this period.

**Lateral Distribution**

Profiles of the 59 reservoir sedimentation ranges surveyed in 1969 and those transcribed from the 1915 topographic map are plotted in Figures 20 through 78 in the Appendix. The profiles show generally how

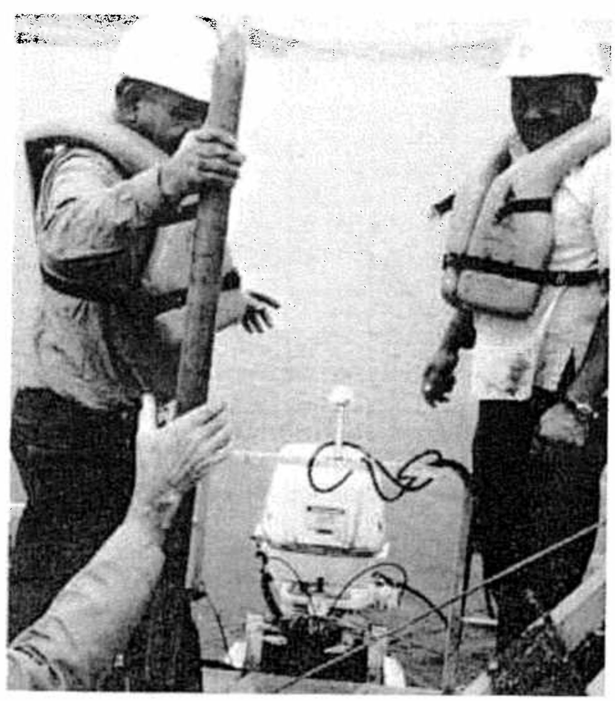

Figure 10. Plastic liner containing sediment sample.

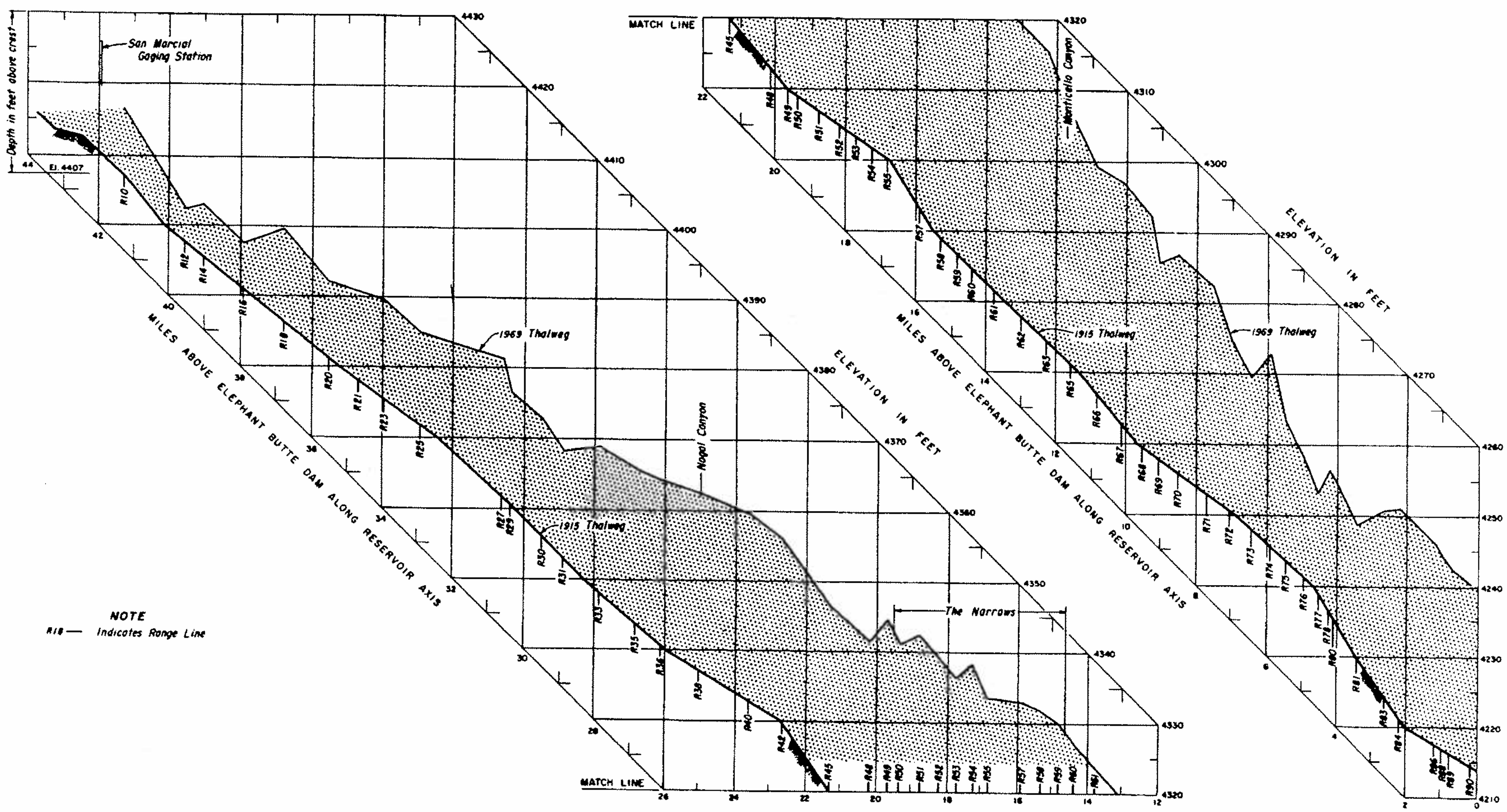


Figure 11. Longitudinal profiles.

Table 1

SUMMARY OF 1969 SURVEY RESULTS AND SEDIMENT DISTRIBUTION COMPUTATIONS

| (1) Elevation (ft) | (2) 1915 area (acres) | (3) 1915 capacity (acre-ft) | (4) 1969 area (acres) | (5) 1969 capacity (acre-ft) | (6) Measured sediment volume (acre-ft) | (7) Percent of measured sediment | (8) 1969 capacity (acre-ft) | (9) Sediment volume (acre-ft) | (10) Percent |
|---|---|---|---|---|---|---|---|---|---|
| 4407 | 40,060 | 2,634,800 | 36,569 | 2,137,219 | 497,581 | 100.0 | 2,137,200 | 497,600 | 100.0 |
| 4400 | 37,328 | 2,363,900 | 34,064 | 1,890,005 | 473,895 | 95.2 | 1,872,143 | 491,757 | 98.8 |
| 4390 | 33,451 | 2,010,300 | 28,744 | 1,575,965 | 434,335 | 87.3 | 1,539,403 | 444,367 | 89.3 |
| 4380 | 30,191 | 1,692,800 | 25,257 | 1,305,960 | 386,840 | 77.7 | 1,248,433 | 414,292 | 83.2 |
| 4370 | 26,620 | 1,408,000 | 21,328 | 1,073,035 | 334,965 | 67.3 | 993,708 | 381,802 | 76.7 |
| 4360 | 22,563 | 1,162,100 | 18,422 | 874,434 | 286,666 | 57.6 | 780,298 | 347,612 | 69.9 |
| 4350 | 19,194 | 954,400 | 16,122 | 701,715 | 252,685 | 50.8 | 606,788 | 312,287 | 62.8 |
| 4340 | 16,595 | 775,600 | 13,799 | 552,040 | 223,560 | 44.9 | 463,313 | 276,252 | 55.5 |
| 4330 | 14,240 | 621,400 | 12,162 | 422,235 | 199,165 | 40.0 | 345,148 | 239,932 | 48.2 |
| 4320 | 11,894 | 490,800 | 10,010 | 311,375 | 179,425 | 36.1 | 250,868 | 203,897 | 41.0 |
| 4310 | 10,202 | 380,800 | 8,241 | 220,120 | 160,680 | 32.3 | 176,903 | 168,572 | 33.9 |
| 4300 | 8,923 | 285,400 | 6,271 | 147,560 | 137,840 | 27.7 | 116,828 | 134,097 | 26.9 |
| 4290 | 7,715 | 202,100 | 4,679 | 92,810 | 109,290 | 22.0 | 68,003 | 100,757 | 20.2 |
| 4280 | 6,145 | 132,800 | 3,050 | 54,165 | 78,635 | 15.8 | 32,043 | 69,117 | 13.9 |
| 4270 | 4,691 | 78,600 | 2,197 | 27,930 | 50,670 | 10.2 | 9,483 | 39,607 | 8.0 |
| 4260 | 3,157 | 39,700 | 1,510 | 9,395 | 30,305 | 6.1 | 93 | 32,574 | 6.5 |
| 4250 | 1,684 | 15,800 | 369 | 0 | 15,800 | 3.2 | *0 | 15,800 | 3.2 |
| 4240 | 671 | 4,660 | | | 4,660 | 0.9 | | 4,660 | 0.9 |
| 4230 | 376 | 2,960 | | | 2,960 | 0.6 | | 2,960 | 0.6 |
| 4220 | 98 | 490 | | | 490 | 0.1 | | 490 | 0.1 |
| 4210 | 0 | 0 | | | 0 | 0 | | 0 | 0 |

*El. 4257.5

## EXPLANATION OF COLUMNS

(1) Elevation of reservoir water surface.
(2) Original reservoir surface area surveyed in 1915.
(3) Original reservoir capacity from 1915 survey.
(4) Reservoir surface area determined from 1969 survey.
(5) Reservoir capacity from 1969 survey.
(6) Accumulated sediment volume = column (3) minus column (5).
(7) Measured sediment expressed as percentage of total sediment (497,581 acre-ft).
(8) Computed 1969 reservoir capacity using Empirical Area—Reduction method.
(9) Computed sediment volume to date = column (3) minus column (8).
(10) Computed sediment expressed as percentage of total sediment (497,600 acre-ft).

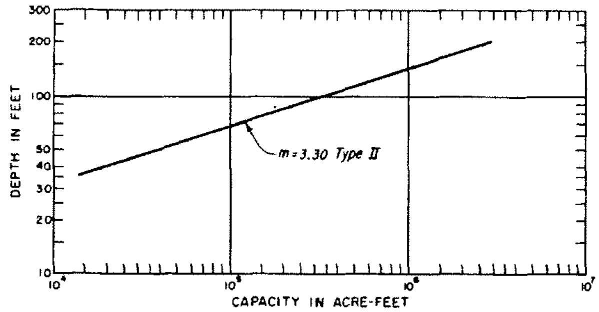


Figure 12. Reservoir depth-capacity relation.

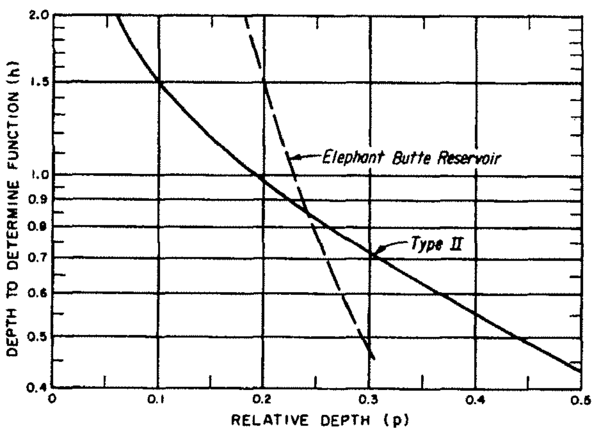


Figure 13. Curves to determine depth of sediment at dam.

sediments were laterally distributed in the reservoir. Sediments are shown depositing laterally to depths ranging from 10 to 44 ft in the following pattern:

| From | To | Range in depths (ft) |
|---|---|---|
| (in miles above dam) | | |
| Dam | 3 | 20 to 27 |
| 3 | 5 | 10 to 20 |
| 5 | 9 | 20 to 30 |
| 9 | 15 | 28 to 39 |
| 15 | 17 | 36 to 44 |
| 17 | 20 | 29 to 37 |
| 20 | 28 | 23 to 32 |
| 28 | 36 | 16 to 25 |

It will be noted that the lateral sediment depths are similar to the longitudinal depths (listed on page 5 ) for the reservoir area about 27 miles above dam. Above this point, the lateral depths substantially exceed the longitudinal ones. The differences are due to the fact that the conveyance channel thalweg in this upper reach was used as the reference base to measure the longitudinal depths instead of the river thalweg as was used for all lateral depth determinations.

Cross sectional plottings of the reservoir ranges located in the reservoir area 26 miles above the dam show these ranges, for all practical purposes, were filled with sediment to the spillway crest el 4407 ft. Sediment accumulated to higher elevations at some of these ranges but this is not apparent from the cross-sectional plottings because the computer input data were limited to display only the range cross-sectional areas below el 4407 ft.

## SEDIMENT ANALYSES

### Sediment Accumulations

Sediments have accumulated in Elephant Butte Reservoir to a total volume of 497,600 acre-ft at spillway crest el 4407 ft since the dam was built over 54 years ago. An average annual sediment accumulation rate of 9,164 acre-ft was computed for the 54-year period.

### Reservoir Sedimentation Summary

Tables 2 and 3 contain summaries of the reservoir sediment data with respect to each survey that has been run. The data include a tabulation of incremental sediment inflow volumes as well as sediment accumulation rates computed for periods between surveys. Both types of data are valuable for practical and research use.

### Unit Weight Analyses

A total of 131 physical samples of the reservoir sediment deposits were collected in 1952, 1957, and 1969. A summary of the results of each sample taken in 1969 is contained in Table 4. Unit weights, percentages of clay, silt, and sand and sample location are tabulated.

Analyses were made of the sample data collected to determine a unit weight for the inflowing sediments that have deposited. 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 sediment volumes of the reservoir segments and the resulting products summed. The sum was divided by the total sediment volume giving a weighted unit weight of 62 pounds per cubic foot (pcf). This compares to the unit weight of 60 pcf determined for the 1957 survey.

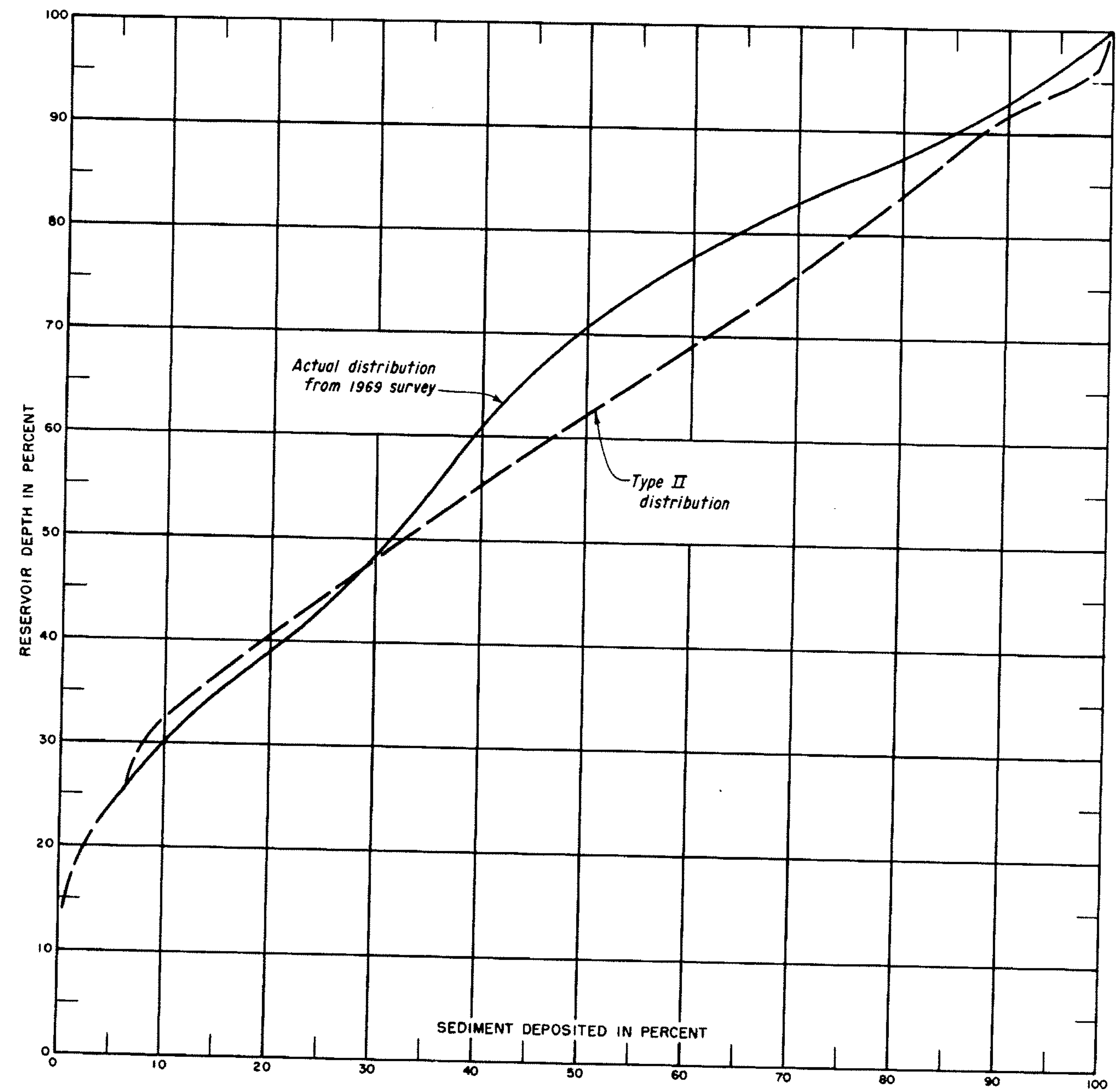


Figure 14. Sediment disposition curves.

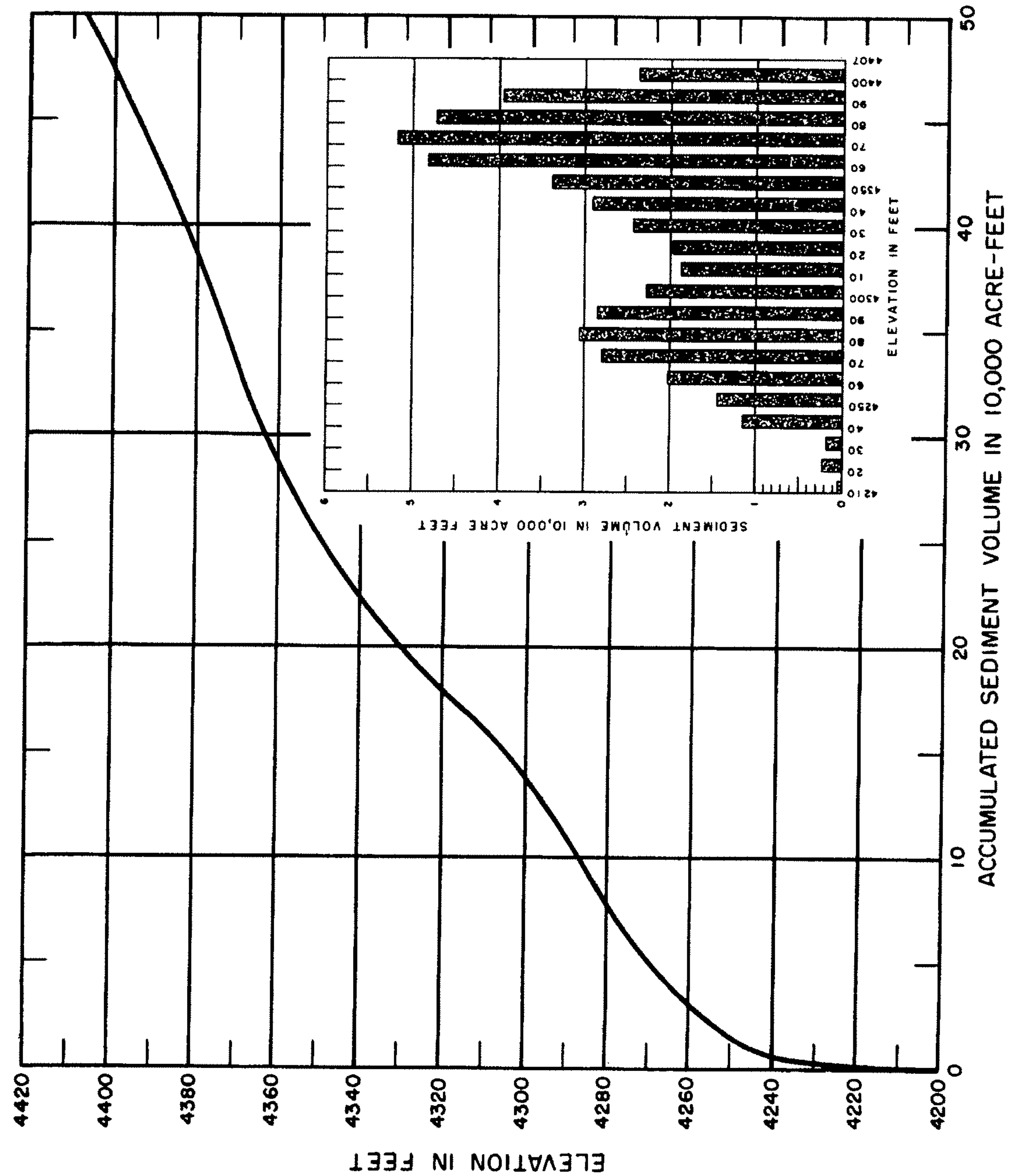


Figure 15. Sediment accumulation curve and diagram.

RESERVOIR SEDIMENT DATA SUMMARY

Table 2

Elephant Butte
NAME OF RESERVOIR

DATA SHEET NO.

**DAM**

| | | |
|---|---|---|
| 1. OWNER U. S. Dept. of Int., Bur. of Recl. | 2. STREAM Rio Grande | 3. STATE New Mexico |
| 4. SEC. 30 TWP. 13S RANGE [1] 3W | 5. NEAREST P. O. Elephant Butte, N. Mex. 0.6NW | 6. COUNTY Sierra |
| 7. LAT. 33° 9′ 16″ LONG. 107° 11′ 29″ | 8. TOP OF DAM ELEVATION [2] 4414 | 9. SPILLWAY CREST ELEV. 4407 |

**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[3] | 4407 | 40,064 | 2,631,585 | 2,634,800 | Jan. 6, 1915 |
| c. POWER | | | | | |
| d. WATER SUPPLY | | | | | 16. DATE NORMAL OPER. BEGAN |
| e. IRRIGATION | | | | | |
| f. CONSERVATION | | | | | |
| g. INACTIVE | 4231.5 | [4] 420 | 3,215 | 3,215 | 1915 |

17. LENGTH OF RESERVOIR 41 MILES | AV. WIDTH OF RESERVOIR 1.39 MILES

**WATERSHED**

| | |
|---|---|
| 18. TOTAL DRAINAGE AREA 25,923 SQ. MI. | 22. MEAN ANNUAL PRECIPITATION 15.1 (8-22) INCHES |
| 19. NET SEDIMENT CONTRIBUTING AREA 25,866 SQ. MI. | 23. MEAN ANNUAL RUNOFF 0.67 INCHES |
| 20. LENGTH 305 MILES; AV. WIDTH 85 MILES | 24. MEAN ANNUAL RUNOFF [5] 923,430 (73) AC.-FT. |
| 21. MAX. ELEV. 12,000; MIN. ELEV. 4210 | 25. ANNUAL TEMP.: MEAN 52.3 RANGE 38.8-61.2 |

**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. |
|---|---|---|---|---|---|---|---|
| Jan. 6, 1915 | | | Contour (D) | 10 ft (CI) | 40,064 | 2,634,800 | |
| Feb. 12, 1957[6] | – | 42.1 | Range (D) | 73 (R) 10 ft (CI) | 36,584 | 2,206,780 | 2.20 |
| Apr. 1, 1969 | 12.2 | 54.3 | Range (D) | 60 (R) | 36,569 | 2,137,219 | 2.31 |

| 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 |
|---|---|---|---|---|---|---|
| Jan. 6, 1915 | | | | | | |
| Feb. 12, 1957 | | 918,439 | 2,440,000 | 38,647,900 | 918,439 | 38,647,900 |
| Apr. 1, 1969 | | 537,075 | 1,391,000 | 6,552,317 | 832,416 | 45,200,217 |

| 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 |
|---|---|---|---|---|---|---|
| Jan. 6, 1915 | | | | | | |
| Feb. 12, 1957 | 7 | – | – | 428,000 | 10,200 | 0.390 |
| Apr. 1, 1969 | 69,561 [8] (69,925) | 5,702 (5,732) | 0.220 (0.222) | 497,581 (508,065) | 9,164 (9,357) | 0.354 (0.362) |

| 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 |
|---|---|---|---|---|---|---|---|
| Jan. 6, 1915 | | | | | | | |
| Feb. 12, 1957 | 60 | – | | 0.463 | 19.4 | – | – |
| Apr. 1, 1969 | 62 | 357 (402) | 478 (489) | 0.348 (0.339) | 18.9 (18.4) | 12,650 (14,250) | 10,940 (11,170) |

Table 2—Continued

| 26. DATE OF SURVEY | 43. DEPTH DESIGNATION RANGE IN FEET BELOW, AND ABOVE, CREST ELEVATION | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 193-175.5 | 175.5-167 | 167-147 | 147-127 | 127-107 | 107-87 | 87-67 | 67-47 | 47-27 | 27-11 | 11-Cr. | Cr. +3 |
| | PERCENT OF TOTAL SEDIMENT LOCATED WITHIN DEPTH DESIGNATION | | | | | | | | | | | |
| Apr. 1, 1969 | 0.6 | 0.3 | 5.1 | 9.5 | 11.6 | 8.2 | 8.7 | 12.6 | 19.5 | 14.4 | 7.4 | 2.1 |

| 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 | | | | | | | | | | | | | | |
| Apr. 1, 1969 | 0.8 | 4.1 | 8.3 | 13.1 | 8.3 | 8.8 | 10.0 | 16.6 | 22.4 | 7.6 | | | | | |

45. RANGE IN RESERVOIR OPERATION

| WATER YEAR | MAX. ELEV. | MIN. ELEV. | INFLOW, AC.-FT. | WATER YEAR | MAX. ELEV. | MIN. ELEV. | INFLOW, AC.-FT. |
|---|---|---|---|---|---|---|---|
| [9]1915 | 4321.81 | | 1,302,250 | 1930 | 4384.5 | 4372.27 | 930,000 |
| 1916 | 4346.85 | 4306.6 | 1,421,000 | 1931 | 4374.17 | 4349.74 | 418,000 |
| 1917 | 4353.8 | 4331.8 | 1,305,000 | 1932 | 4384.5 | 4351.75 | 1,440,000 |
| 1918 | 4337.0 | 4290.30 | 379,100 | 1933 | 4377.9 | 4365.02 | 717,000 |
| 1919 | 4358.8 | 4285.5 | 1,527,000 | 1934 | 4367.8 | 4325.00 | 298,300 |
| 1920 | 4393.87 | 4350.9 | 1,970,000 | 1935 | 4342.2 | 4322.80 | 917,600 |
| 1921 | 4392.5 | 4377.5 | 1,470,000 | 1936 | 4354.90 | 4331.83 | 872,900 |
| 1922 | 4389.5 | 4370.7 | 1,044,000 | 1937 | 4380.7 | 4333.87 | 1,597,000 |
| 1923 | 4377.4 | 4366.5 | 964,000 | 1938 | 4377.1 | 4365.6 | 1,004,000 |
| 1924 | 4395.8 | 4368.9 | 1,662,000 | 1939 | 4378.4 | 4351.20 | 615,700 |
| 1925 | 4382.1 | 4354.7 | 321,000 | 1940 | 4357.04 | 4323.2 | 333,100 |
| 1926 | 4378.10 | 4354.6 | 1,120,000 | 1941 | 4399.2 | 4324.3 | 2,440,000 |
| 1927 | 4373.95 | 4363.02 | 1,180,000 | 1942 | 4409.15 | 4397.00 | 2,322,000 |
| 1928 | 4379.10 | 4359.70 | 773,000 | 1943 | 4398.96 | 4380.82 | 441,600 |
| 1929 | 4374.80 | 4353.70 | 1,240,000 | 1944 | 4385.68 | 4369.16 | 982,500 |

46. ELEVATION–AREA–CAPACITY DATA

| ELEVATION | AREA | CAPACITY | ELEVATION | AREA | CAPACITY | ELEVATION | AREA | CAPACITY |
|---|---|---|---|---|---|---|---|---|
| 1915 Survey | | | 4300 | 8,923 | 285,400 | 4400 | 37,328 | 2,363,900 |
| 4210 | 0 | 0 | 4310 | 10,202 | 380,800 | 4407 | 40,060 | 2,634,800 |
| 4220 | 98 | 490 | 4320 | 11,894 | 490,800 | 4410 | 41,283 | 2,756,600 |
| 4230 | 376 | 2,960 | 4330 | 14,240 | 621,400 | | | |
| 4240 | 671 | 4,660 | 4340 | 16,595 | 775,600 | 1969 Survey | | |
| 4250 | 1,684 | 15,800 | 4350 | 19,194 | 954,400 | 4250 | 369 | 0 |
| 4260 | 3,157 | 39,700 | 4360 | 22,563 | 1,162,100 | 4260 | 1,510 | 9,395 |
| 4270 | 4,691 | 78,600 | 4370 | 26,620 | 1,408,000 | 4270 | 2,197 | 27,930 |
| 4280 | 6,145 | 132,800 | 4380 | 30,191 | 1,692,800 | 4280 | 3,050 | 54,165 |
| 4290 | 7,715 | 202,100 | 4390 | 33,451 | 2,010,300 | 4290 | 4,679 | 92,810 |

47. REMARKS AND REFERENCES

[1]Sections projected. Dam located in Pedro Armendariz Grant No. 33 which is unsurveyed.

[2]All elevations listed are based on project datum. Add 43.3 feet to adjust elevations to msl.

[3]Irrigation and power.

[4]Estimated by interpolation.

[5]Rio Grande at San Marcial, New Mexico.

[6]For intermediate surveys see Data Sheets 57-1 and 57-1a.

[7]Total storage showed gain of 9,180 acre-feet since 1947 survey.

[8]Values in parentheses at elevation 4410.

[9]From January 1915 through September 1915.

48. AGENCY MAKING SURVEY U.S. Dept. of the Interior, Bureau of Reclamation, Rio Grande Project, New Mexico-Texas.

49. AGENCY SUPPLYING DATA Bureau of Reclamation, U.S. Dept. of the Interior 50. DATE October 15, 1971

April 1966

Table 2—Continued

| 45. RANGE IN RESERVOIR OPERATION | | | | | | | |
|---|---|---|---|---|---|---|---|
| WATER YEAR | MAX. ELEV. | MIN. ELEV. | INFLOW, AC.-FT. | WATER YEAR | MAX. ELEV. | MIN. ELEV. | INFLOW, AC.-FT. |
| 1945 | 4385.60 | 4372.28 | 851,500 | 1957 | 4337.12 | 4269.10 | |
| 1946 | 4375.66 | 4339.52 | 224,900 | 1958 | | 4336.20 | 1,391,000 |
| 1947 | 4339.36 | 4311.94 | 419,200 | 1959 | 4362.80 | 4334.46 | 341,900 |
| 1948 | 4349.22 | 4313.08 | 1,036,000 | 1960 | 4339.04 | 4322.40 | 563,400 |
| 1949 | 4351.30 | 4329.69 | 1,031,000 | 1961 | 4329.10 | 4301.99 | 437,700 |
| 1950 | 4346.01 | 4315.46 | 364,100 | 1962 | 4329.80 | 4304.38 | 748,100 |
| 1951 | 4315.79 | 4262.30 | 132,900 | 1963 | 4327.52 | 4282.07 | 405,500 |
| 1952 | 4324.59 | 4261.64 | 967,000 | 1964 | 4299.23 | 4275.51 | 164,200 |
| 1953 | 4320.49 | 4283.19 | 286,800 | 1965 | 4323.01 | 4277.46 | 821,700 |
| 1954 | 4297.30 | 4258.03 | 198,500 | 1966 | 4338.30 | 4311.03 | 725,340 |
| 1955 | 4295.46 | 4276.58 | 257,900 | 1967 | 4321.84 | 4293.03 | 391,600 |
| 1956 | 4304.40 | 4268.44 | 174,800 | 1968 | 4319.70 | 4295.09 | 646,230 |

| 46. ELEVATION-AREA-CAPACITY DATA | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ELEVATION | AREA | CAPACITY | ELEVATION | AREA | CAPACITY | ELEVATION | AREA | CAPACITY |
| 4300 | 6,271 | 147,560 | 4400 | 34,064 | 1,890,005 | | | |
| 4310 | 8,241 | 220,120 | 4407 | 36,569 | 2,137,219 | | | |
| 4320 | 10,010 | 311,375 | 4410 | 37,642 | 2,248,535 | | | |
| 4330 | 12,162 | 422,235 | | | | | | |
| 4340 | 13,799 | 552,040 | | | | | | |
| 4350 | 16,122 | 701,715 | | | | | | |
| 4360 | 18,422 | 874,434 | | | | | | |
| 4370 | 21,328 | 1,073,035 | | | | | | |
| 4380 | 25,257 | 1,305,960 | | | | | | |
| 4390 | 28,744 | 1,575,965 | | | | | | |

UNITED STATES
DEPARTMENT OF THE INTERIOR

Table 3

BUREAU OF RECLAMATION

# RESERVOIR SEDIMENTATION DATA SUMMARY

NAME OF RESERVOIR: Elephant Butte

DATA SHEET NO.: 57-

**DAM**

| | | |
|---|---|---|
| 1. OWNER Bureau of Reclamation | 2. RIVER Rio Grande | 3. STATE New Mexico[1] |
| 4. SEC. 2 TWP. 135 RANGE 4W | 5. NEAREST TOWN Truth or Consequences | 6. COUNTY Sierra |
| 7. STREAM BED ELEV. | 8. TOP OF DAM ELEV. | 9. SPILLWAY CREST ELEV. 4407 |

**RESERVOIR**

| 10. STORAGE ALLOCATION | 11. ELEVATION TOP OF POOL | 12. SURFACE AREA ACRES | 13. STORAGE ACRE-FEET | 14. ACCUMULATED ACRE-FEET | 15. DATE STORAGE BEGAN / 16. DATE NORMAL OPER. BEGAN |
|---|---|---|---|---|---|
| a. FLOOD CONTROL | 4407 | 36,584 | | 2,206,780 | |
| b. POWER | | | | | Jan. 6, 1915 |
| c. WATER SUPPLY | | | | | 16. DATE NORMAL OPER. BEGAN |
| d. IRRIGATION | | | | | |
| e. CONSERVATION | | | | | |
| f. INACTIVE | 4231.5 | Negligible | Negligible | | 1915 |

17. LENGTH OF RESERVOIR 41 MILES | AV. WIDTH OF RESERVOIR 1.69 MILES

**WATERSHED**

| | |
|---|---|
| 18. TOTAL DRAINAGE AREA 25,923 SQ. MI. | 22. MEAN ANNUAL PRECIPITATION 10 to 15 INCHES |
| 19. NET SEDIMENT CONTRIBUTING AREA 25,866 SQ. MI. | 23. MEAN ANNUAL RUNOFF INCHES |
| 20. LENGTH 305 MILES AV. WIDTH 85 MILES | 24. MEAN ANNUAL RUNOFF 1,004,000 (60) AC.-FT. |
| 21. MAX. ELEV. 12,000 MIN. ELEV. 4407 | 25. CLIMATIC CLASSIFICATION Semi-arid |

**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/W RATIO AC.-FT. PER SQ. MI. |
|---|---|---|---|---|---|---|---|
| Jan. 6, 1915 | 0 | 0 | Contour | 10 feet | 40,060 | 2,634,800 | 102 |
| Dec. 1916 | 1.9 | 1.9 | | | | 2,584,865 | 100 |
| Aug. 1920 | 3.7 | 5.6 | | | | 2,498,850 | 96 |
| Aug. 1925 | 5.0 | 10.6 | Contour | | 39,406 | 2,389,380 | 92 |
| April 1935 | 9.7 | 20.3 | Contour | 5 feet | 38,140 | 2,270,300 | 88 |
| Oct. 1940 | 5.5 | 25.8 | Contour | | 37,670 | 2,219,000 | 86 |

| 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 |
|---|---|---|---|---|---|---|
| Jan. 6, 1915 | | | | | | |
| Dec. 1916 | | 1,573,665 | | 3,005,700 | 1,573,665 | 3,005,700 |
| Aug. 1920 | | 1,413,845 | 2,250,100 | 5,188,810 | 1,463,305 | 8,194,510 |
| Aug. 1925 | | 1,130,348 | 1,690,900 | 5,651,742 | 1,306,250 | 13,846,252 |
| April 1935 | | 853,428 | 1,444,200 | 8,252,648 | 1,088,616 | 22,098,900 |
| Oct. 1940 | | 945,761 | 1,597,000 | 5,201,730 | 1,058,164 | 27,300,630 |

| 26. DATE OF SURVEY | 37. PERIOD SEDIMENT DEPOSITS 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 |
|---|---|---|---|---|---|---|
| Jan. 6, 1915 | | | | | | |
| Dec. 1916 | 49,900 | 26,300 | 1.02 | 49,900 | 26,300 | 1.02 |
| Aug. 1920 | 86,000 | 23,200 | 0.899 | 136,000 | 24,300 | 0.939 |
| Aug. 1925 | 109,000 | 21,900 | 0.846 | 245,000 | 23,200 | 0.895 |
| April 1935 | 119,000<br>(125,000) | 12,300<br>(12,900) | 0.475<br>(0.498) | 365,000<br>(370,000) | 18,000<br>(18,200) | 0.694<br>(0.705) |

| 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. ANNUAL | b. TOT. TO DATE | 42. SED. INFLOW PPM: a. PERIOD | b. TOT. TO DATE |
|---|---|---|---|---|---|---|---|
| Jan. 6, 1915 | | | | | | | |
| Dec. 1916 | | | | 0.998 | 1.89 | | |
| Aug. 1920 | | | | 0.922 | 5.16 | | |
| Aug. 1925 | | | | 0.881 | 9.30 | | |
| April 1935 | 60 (est ) | 621<br>(651) | 907<br>(921) | 0.683 | 13.9 | 13,900<br>(14,600) | 15,900<br>(16,100) |

| 26. DATE OF SURVEY | 43. DEPTH DESIGNATION RANGE IN FEET ABOVE, AND BELOW, CREST ELEVATION | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 193-175.5 | 175.5-167 | 167-147 | 147-127 | 127-107 | 107-87 | 87-67 | 67-47 | 47-27 | 27-11 | 11-Cr. | Cr.-3 |
| | PERCENT OF TOTAL SEDIMENT LOCATED WITHIN DEPTH DESIGNATION | | | | | | | | | | | |
| Aug. 1925 | 1.26 | –0.057 | 7.18 | 11.1 | 9.03 | 5.86 | 9.19 | 14.3 | 25.1 | 8.99 | 4.53 | |
| April 1935 | 0.869 | 0.380 | 5.70 | 8.38 | 7.22 | 4.81 | 8.14 | 16.4 | 27.1 | 12.9 | 6.54 | 1.46 |
| Oct. 1940 | 0.760 | 0.330 | 5.10 | 7.45 | 6.83 | 5.06 | 8.32 | 15.4 | 26.1 | 16.3 | 6.69 | 1.70 |
| Apr. 28, 1947 | 0.719 | 0.321 | 4.75 | 7.07 | 6.53 | 5.64 | 8.66 | 15.0 | 24.9 | 16.0 | 8.14 | 2.21 |
| Feb. 12, 1957 | 0.734 | 0.325 | 6.04 | 10.0 | 7.64 | 5.42 | 7.83 | 13.1 | 22.5 | 15.6 | 8.40 | 2.31 |

| 26. DATE OF SURVEY | 44. REACH DESIGNATION PERCENT OF TOTAL ORIGINAL LENGH 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 | | | | | | | | | | | | | | |
| | Data not available due to contour method of sediment computation. | | | | | | | | | | | | | | |

45. RANGE IN RESERVOIR OPERATION

| WATER YEAR | MAX. ELEV. | MIN. ELEV. | INFLOW AC.–FT. | WATER YEAR | MAX. ELEV. | MIN. ELEV. | INFLOW AC.–FT. |
|---|---|---|---|---|---|---|---|
| 1915 | 4321.81 | | 1,443,900 | 1923 | 4374.20* | 4368.3* | 964,500 |
| 1916 | 4346.85 | 4307.29* | 1,420,900 | 1924 | 4395.80 | 4370.4* | 1,690,900 |
| 1917 | 4354.0 | 4331.0* | 1,310,600 | 1925 | 4379.20 | 4354.7* | 320,800 |
| 1918 | 4326.28 | 4290.30* | 379,100 | 1926 | 4378.10 | 4355.68* | 1,120,900 |
| 1919 | 4364.0 | 4267.70* | 1,527,000 | 1927 | 4371.96* | 4363.02* | 1,178,400 |
| 1920 | 4393.87 | 4351.5* | 2,250,100 | 1928 | 4379.10 | 4359.70* | 772,700 |
| 1921 | 4392.5 | 4378.2* | 1,607,300 | 1929 | 4374.80 | 4354.00* | 1,238,900 |
| 1922 | 4389.50* | 4377.5* | 1,069,100 | 1930 | 4384.5 | 4372.27* | 930,200 |

46. ELEVATION–AREA–CAPACITY DATA

| ELEVATION | AREA | CAPACITY | ELEVATION | AREA | CAPACITY | ELEVATION | AREA | CAPACITY |
|---|---|---|---|---|---|---|---|---|
| 4220 | 1 | 1 | 4310 | 8,993 | 259,940 | 4390 | 29,226 | 1,642,790 |
| 4240 | 4 | 22 | 20 | 10,804 | 358,450 | 4396 | 32,140 | 1,826,570 |
| 50 | 312 | 1,298 | 30 | 12,556 | 475,150 | 4400 | 34,117 | 1,959,060 |
| 60 | 1,220 | 8,590 | 40 | 14,290 | 608,930 | 07 | 36,584 | 2,206,780 |
| 70 | 2,343 | 26,253 | 4350 | 16,506 | 762,940 | 4410 | 37,884 | 2,318,460 |
| 80 | 4,004 | 57,680 | 60 | 18,504 | 937,850 | | | |
| 90 | 6,005 | 107,730 | 70 | 21,328 | 1,135,660 | | | |
| 4300 | 7,698 | 176,810 | 80 | 25,455 | 1,369,870 | | | |

47. REMARKS AND REFERENCES

[1] Headquarters for operation of dam located at El Paso, Texas.
[2] Sections not determined–Located in Amendariz Grant No. 33.
*Mean monthly elevations.

48. AGENCY SUPPLYING DATA Bureau of Reclamation

49. DATE January 8, 1959

UNITED STATES
DEPARTMENT OF THE INTERIOR

Table 3—Continued

BUREAU OF RECLAMATION

RESERVOIR SEDIMENTATION DATA SUMMARY

Elephant Butte—Continued
NAME OF RESERVOIR

DATA SHEET NO.

| DAM | | | |
|---|---|---|---|
| DAM | 1. OWNER | 2. RIVER | 3. STATE |
| | 4. SEC. TWP. RANGE | 5. NEAREST TOWN | 6. COUNTY |
| | 7. STREAM BED ELEV. | 8. TOP OF DAM ELEV. | 9. SPILLWAY CREST ELEV. |

| RESERVOIR | 10. STORAGE ALLOCATION | 11. ELEVATION TOP OF POOL | 12. SURFACE AREA ACRES | 13. STORAGE ACRE-FEET | 14. ACCUMULATED ACRE-FEET | 15. DATE STORAGE BEGAN |
|---|---|---|---|---|---|---|
| | a. FLOOD CONTROL | | | | | |
| | b. POWER | | | | | |
| | c. WATER SUPPLY | | | | | 16. DATE NORMAL OPER. BEGAN |
| | d. IRRIGATION | | | | | |
| | e. CONSERVATION | | | | | |
| | f. INACTIVE | | | | | |
| | 17. LENGTH OF RESERVOIR MILES | | | AV. WIDTH OF RESERVOIR MILES | | |

| WATERSHED | | |
|---|---|---|
| WATERSHED | 18. TOTAL DRAINAGE AREA SQ. MI. | 22. MEAN ANNUAL PRECIPITATION INCHES |
| | 19. NET SEDIMENT CONTRIBUTING AREA SQ. MI. | 23. MEAN ANNUAL RUNOFF INCHES |
| | 20. LENGTH MILES; AV. WIDTH MILES | 24. MEAN ANNUAL RUNOFF AC.-FT. |
| | 21. MAX. ELEV.; MIN. ELEV. | 25. CLIMATIC CLASSIFICATION |

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/W RATIO AC.-FT. PER SQ. MI. |
|---|---|---|---|---|---|---|---|
| Apr. 28, 1947 | 6.5 | 32.3 | Range | 90 feet | 36,772 | 2,197,600 | 85 |
| Feb. 12, 1957 | 9.75 | 42.1 | Contour | 10 feet | 36,584 | 2,206,780 | 85 |

| 26. DATE OF SURVEY | 34. PERIOD ANNUAL PRECIPITATION | 35. PERIOD WATER INFLOW ACRE-FEET | | | 36. WATER INFL. TO DATE AC-FT. | |
|---|---|---|---|---|---|---|
| | | a. MEAN ANNUAL | b. MAX. ANNUAL | c. PERIOD TOTAL | a. MEAN ANNUAL | b. TOTAL TO DATE |
| Apr. 28, 1947 | | 1,154,862 | 2,440,000 | 7,506,600 | 1,077,623 | 34,807,230 |
| Feb. 12, 1957 | | 441,776 | 1,036,000 | 4,307,318 | 930,191 | 39,114,548 |

| 26. DATE OF SURVEY | 37. PERIOD SEDIMENT DEPOSITS ACRE-FEET | | | 38. TOTAL SED. DEPOSITS TO DATE ACRE-FEET | | |
|---|---|---|---|---|---|---|
| | a. PERIOD TOTAL | b. AV. ANNUAL | c. PER SQ. MI.-YEAR | a. TOTAL TO DATE | b. AV. ANNUAL | c. PER SQ. MI.-YEAR |
| Oct. 1940 | 51,300 | 9,330 | 0.361 | 416,000 | 16,100 | 0.623 |
| Apr. 28, 1947 | 21,400 | 3,290 | 0.127 | 437,000 | 13,500 | 0.523 |
| | (43,000)[3] | (6,620) | (0.256) | (465,000) | (14,400) | (0.556) |
| Feb. 12, 1957 | | | | 428,000 | 10,200 | 0.390 |

| 26. DATE OF SURVEY | 39. AV. DRY WGT. LBS. PER CU. FT. | 40. SED. DEP. TONS PER SQ. MI.-YR. | | 41. STORAGE LOSS PCT. | | 42. SED. INFLOW PPM | |
|---|---|---|---|---|---|---|---|
| | | a. PERIOD | b. TOTAL TO DATE | a. AV. ANNUAL | b. TOT. TO DATE | a. PERIOD | b. TOT. TO DATE |
| Oct. 1940 | | | | 0.611 | 15.8 | | |
| Apr. 28, 1947 | 65.9 (est) | 182 | 751 | 0.512 | 16.6 | 3,010 | 13,300 |
| | | (367)[3] | (798) | | | (6,050) | (14,100) |
| Feb. 12, 1957 | 60.0 | | | 0.463 | 19.4 | | |

Table 3—Continued

| 28. DATE OF SURVEY | 43. DEPTH DESIGNATION RANGE IN FEET ABOVE, AND BELOW, CREST ELEVATION | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | |
| | PERCENT OF TOTAL SEDIMENT LOCATED WITHIN DEPTH DESIGNATION | | | | | | | | | | | |
| | | | | | | | | | | | | |

| 26. DATE OF SURVEY | 44. REACH DESIGNATION PERCENT OF TOTAL ORIGINAL LENGH 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 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |

45. RANGE IN RESERVOIR OPERATION

| WATER YEAR | MAX. ELEV. | MIN. ELEV. | INFLOW AC.-FT. | WATER YEAR | MAX. ELEV. | MIN. ELEV. | INFLOW AC.-FT. |
|---|---|---|---|---|---|---|---|
| 1931 | 4374.17 | 4351.66* | 417,900 | 1948 | 4349.22 | 4313.08 | 1,036,000 |
| 1932 | 4384.5 | 4353.26* | 1,444,200 | 1949 | 4351.30 | 4329.69 | 1,031,000 |
| 1933 | 4377.9 | 4365.01* | 716,800 | 1950 | 4346.02* | 4315.46 | 364,100 |
| 1934 | 4367.2 | 4325.00* | 298,300 | 1951 | 4315.79 | 4262.30 | 132,900 |
| 1935 | 4342.2 | 4324.50* | 917,700 | 1952 | 4324.59 | 4261.64 | 487,500 |
| 1936 | 4354.90 | 4331.83 | 872,800 | 1953 | 4320.49 | 4283.19 | 286,800 |
| 1937 | 4380.7 | 4336.48* | 1,597,400 | 1954 | 4297.30 | 4258.03 | 198,500 |
| 1938 | 4377.1 | 4365.6 | 1,003,500 | 1955 | 4295.46 | 4276.58 | 257,900 |
| 1939 | 4378.4 | 4348.6 | 615,700 | 1956 | 4304.40 | 4268.44 | 174,830 |
| 1940 | 4357.04 | 4323.2 | 333,100 | | | | |
| 1941 | 4399.2 | 4324.3 | 2,440,500 | | | | |
| 1942 | 4409.15 | 4397.00 | 2,322,000 | | | | |
| 1943 | 4398.96 | 4380.82 | 441,600 | | | | |
| 1944 | 4385.68 | 4369.16 | 982,500 | | | | |
| 1945 | 4385.60 | 4372.28 | 851,500 | | | | |
| 1946 | 4375.66 | 4339.52 | 224,900 | | | | |
| 1947 | 4339.36 | 4311.94 | 419,200 | | | | |

47. REMARKS AND REFERENCES

Values listed in parentheses include above crest deposits.

[3]Total storage shows a gain of 9,180 acre-feet since 1947 survey attributable primarily to compaction.

USDA Technical Bulletin No. 524, August 1939, "Silting of Reservoirs."

Bureau of Reclamation, February 1949, "Sedimentation Surveys of Elephant Butte Reservoir." Only the upper two-thirds of the reservoir was surveyed in 1925 and 1940. Curves from these data were extended over the remaining lower one-third of the reservoir.

48. AGENCY SUPPLYING DATA

49. DATE____________

Table 3—Continued

| Depth below crest | CAPACITY | | | | | | SEDIMENT VOLUME | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Original | 1925 | 1935 | 1940 | 1947 | 1957 | 1925 | 1935 | 1940 | 1947 | 1957 | 1925 | 1935 | 1940 | 1947 | 1957 |
| 193 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | | | | |
| | 3,215 | 0 | 0 | 0 | 0 | 0 | 3,215 | 3,215 | 3,215 | 3,215 | 3,215 | 1.26 | 0.869 | 0.760 | 0.719 | 0.734 |
| 175.5 | 3,215 | 0 | 0 | 0 | 0 | 1 | | | | | | | | | | |
| | 1,445 | 1,590 | 40 | 50 | 10 | 21 | -145 | 1,405 | 1,395 | 1,435 | 1,424 | 0.057 | 0.380 | 0.330 | 0.321 | 0.325 |
| 167 | 4,660 | 1,590 | 40 | 50 | 10 | 22 | | | | | | | | | | |
| | 35,040 | 16,760 | 13,960 | 13,450 | 13,790 | 8,568 | 18,280 | 21,080 | 21,590 | 21,250 | 26,472 | 7.18 | 5.70 | 5.10 | 4.75 | 6.04 |
| 147 | 39,700 | 18,350 | 14,000 | 13,500 | 13,800 | 8,590 | | | | | | | | | | |
| | 93,100 | 64,950 | 62,100 | 61,600 | 61,500 | 49,090 | 28,150 | 31,000 | 31,500 | 31,600 | 44,010 | 11.1 | 8.38 | 7.45 | 7.07 | 10.0 |
| 127 | 132,800 | 83,300 | 76,100 | 75,100 | 75,300 | 57,680 | | | | | | | | | | |
| | 152,600 | 129,620 | 125,900 | 123,700 | 123,400 | 119,130 | 22,980 | 26,700 | 28,900 | 29,200 | 33,470 | 9.03 | 7.22 | 6.83 | 6.53 | 7.64 |
| 107 | 285,400 | 212,920 | 202,000 | 198,800 | 198,700 | 176,810 | | | | | | | | | | |
| | 205,400 | 190,490 | 187,600 | 184,000 | 180,200 | 181,640 | 14,910 | 17,800 | 21,400 | 25,200 | 23,760 | 5.86 | 4.81 | 5.06 | 5.64 | 5.42 |
| 87 | 490,800 | 403,410 | 389,600 | 382,800 | 378,900 | 358,450 | | | | | | | | | | |
| | 284,800 | 261,410 | 254,700 | 249,600 | 246,100 | 250,480 | 23,390 | 30,100 | 35,200 | 38,700 | 34,320 | 9.19 | 8.14 | 8.32 | 8.66 | 7.83 |
| 67 | 775,600 | 664,820 | 644,300 | 632,400 | 625,000 | 608,930 | | | | | | | | | | |
| | 386,500 | 350,060 | 325,700 | 321,400 | 319,500 | 328,920 | 36,440 | 60,800 | 65,100 | 67,000 | 57,580 | 14.3 | 16.4 | 15.4 | 15.0 | 13.1 |
| 47 | 1,162,100 | 1,014,880 | 970,000 | 953,800 | 944,500 | 937,850 | | | | | | | | | | |
| | 530,700 | 466,890 | 430,400 | 420,400 | 419,200 | 432,020 | 63,810 | 100,300 | 110,300 | 111,500 | 98,680 | 25.1 | 27.1 | 26.1 | 24.9 | 22.5 |
| 27 | 1,692,800 | 1,481,770 | 1,400,400 | 1,374,200 | 1,363,700 | 1,369,870 | | | | | | | | | | |
| | 525,000 | 502,130 | 477,100 | 456,100 | 453,300 | 456,700 | 22,870 | 47,900 | 68,900 | 71,700 | 68,300 | 8.99 | 12.9 | 16.3 | 16.0 | 15.6 |
| 11 | 2,217,800 | 1,983,900 | 1,877,500 | 1,830,300 | 1,817,000 | 1,826,570 | | | | | | | | | | |
| | 417,000 | 405,480 | 392,800 | 388,700 | 380,600 | 380,210 | 11,520 | 24,200 | 28,300 | 36,400 | 26,790 | 4.53 | 6.54 | 6.69 | 8.14 | 8.40 |
| Crest | 2,634,800 | 2,389,380 | 2,270,300 | 2,219,000 | 2,197,600 | 2,206,780 | 254,420 | | | | | | | | | |
| | 121,800 | | 116,400 | 114,600 | 111,900 | 111,680 | | 5,400 | 7,200 | 9,900 | 10,120 | | 1.46 | 1.70 | 2.21 | 2.31 |
| 3 | 2,756,600 | | 2,386,700 | 2,333,600 | 2,309,500 | 2,318,460 | | 369,900 | 423,000 | 447,100 | 438,140 | | | | | |

Table 4

SUMMARY OF SEDIMENT DATA ANALYSES–1969 SURVEY

| Range location | Sample No. | In percent | | | Unit weight pcf |
|---|---|---|---|---|---|
| | | Clay | Silt | Sand | |
| 90 | 24 | 68.4 | 28.4 | 3.2 | 34.3 |
| 89 | 23 | 76.9 | 20.1 | 3.0 | 31.8 |
| 88 | 22 | 84.3 | 15.7 | 0 | 30.9 |
| 87 | 20 | 85.6 | 14.4 | 0 | 29.0 |
| 86 | 18 | 85.6 | 14.4 | 0 | 29.4 |
| 85 | 16 | 88.1 | 11.9 | 0 | 29.4 |
| 84 | 14 | 85.1 | 14.9 | 0 | 33.1 |
| 83 | 12 | 79.3 | 17.7 | 3.0 | 40.6 |
| 82 | 11 | 85.3 | 14.7 | 0 | 35.0 |
| 81 | 10 | 73.1 | 26.9 | 0 | 36.2 |
| 80 | 9 | 86.3 | 13.7 | 0 | 31.2 |
| 79 | 8 | 85.6 | 14.4 | 0 | 33.7 |
| 78 | 7 | 86.4 | 13.6 | 0 | 33.1 |
| 76 | 5 | 86.7 | 13.3 | 0 | 33.1 |
| 75 | 4 | 82.4 | 17.6 | 0 | 35.0 |
| 74 | 3 | 84.3 | 15.7 | 0 | 35.0 |
| 73 | 1 | 81.3 | 18.7 | 0 | 35.0 |

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 52 pcf was computed. By considering a compaction correction, using the method of Miller,[5] a unit weight of 59 pcf was computed for a 54-year period (age of the dam). This computed value compared favorably with the 62 pcf, the weighted unit weight described above.

A factor having substantial influence in determining the unit weight on a weighted basis may be questioned as to how reliable is the assumption that the samples collected at the ranges are representative of conditions in the reservoir reach (or segment) between ranges. This may be questioned in that possibly more collected samples would give a better picture of the situation. The sites selected for taking samples and the depths of the sediment deposits sampled are two other factors that influence unit weight determinations. In computing the unit weight, the size gradation values of the deposited samples are used. A question can be posed regarding the use of these values—are they reliable representations of the actual inflowing sediment particles? An answer to this question and resolving the other factors mentioned await further research study. Also, in this connection, improvement in sampling methods, analyses, and equipment must continually be sought.

**Particle Size Analyses**

A study was made of the particle size analyses tests run on the 131 samples collected in 1952, 1957, and 1969. The graphs in Figures 16, 17, and 18 contain the particle size analyses curves for only the samples collected in 1969. Representative particle sizes in the clay, silt, and sand ranges were determined in a similar weighting fashion as was done in the unit weight analyses. The representative size was computed to be 60 percent clay, 31 percent silt, and 9 percent sand.

[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. Department of the Interior, Bureau of Reclamation, February 1953.

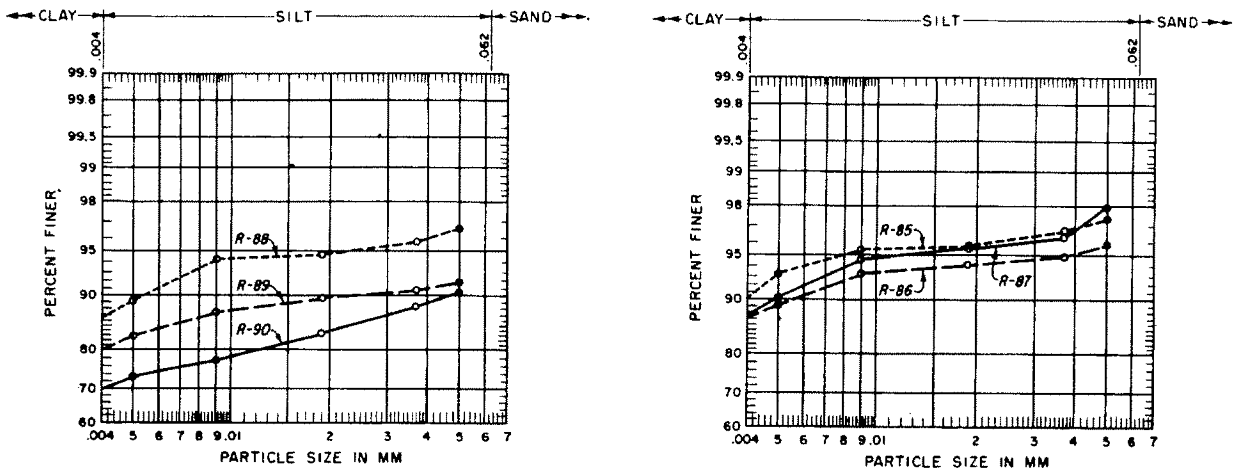


Figure 16. Particle size analyses curves.

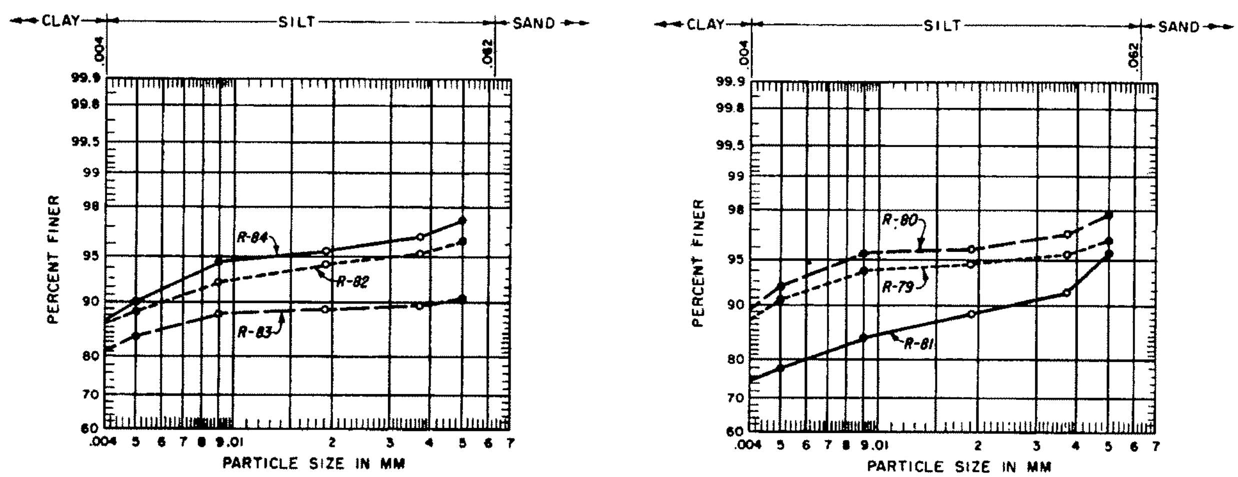


Figure 17. Particle size analyses curves.

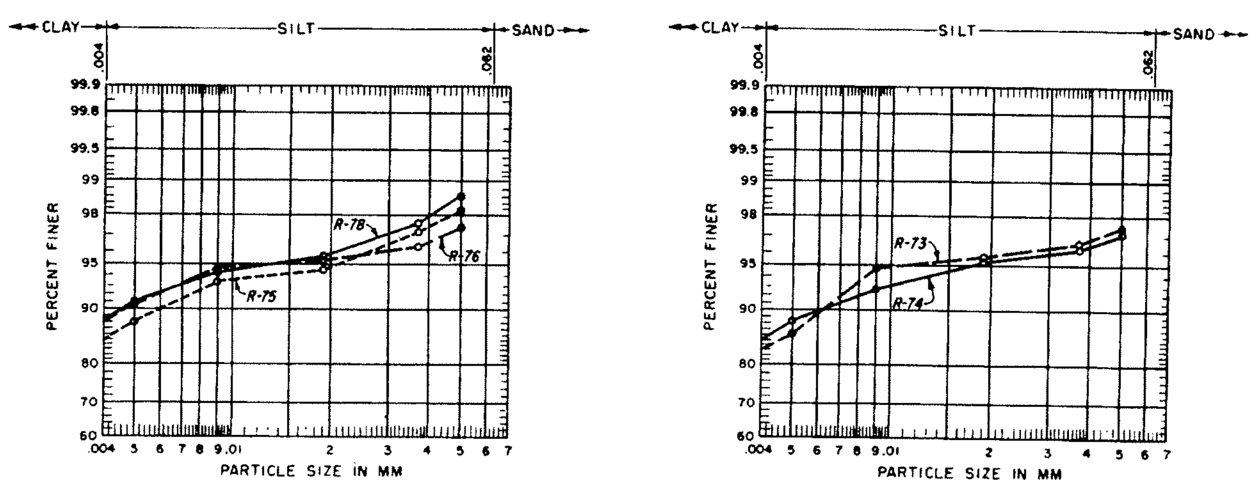


Figure 18. Particle size analyses curves.

## RESERVOIR AREA AND CAPACITY

The 1969 Elephant Butte Reservoir surface areas were determined by a method using reservoir sedimentation range width ratios. Briefly, this method entailed comparing the 1969 range widths with the 1915 widths at corresponding elevations. The results are tabulated in the ratio form 1969 width/1915 width. Computations are made easier by dividing the reservoir into segments using the sedimentation range lines as segmental boundaries. The 1915 reservoir topographic maps were used to planimeter the surface areas at 10-ft contour intervals. For given elevations, these areas were multiplied by the width ratios and the 1969 surface areas resulted.

The 1969 surface areas were the control parameters for computing the reservoir capacities by the electronic computer. The program was written to compute 1-ft area increments by linear interpolation between the 10-ft contour intervals. Respective capacities and capacity equations are then obtained by integration of the area equations. The progressive computational procedure begins by testing the initial capacity equation over successive intervals to check whether it fits within an allowable error limit (set at 0.01 in this case). This one equation is 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 was 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 polynomial form,

$$y = a_1 + a_2 x + a_3 x^2,$$

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 1969 Elephant Butte Reservoir area and capacity computations are listed in columns (4) and (5) of Table 1 (page 9). Also listed in columns (2) and (3) of the table are the original area and capacity values for comparison purposes. Both the original and 1969 area and capacity curves are plotted in Figure 19. At spillway crest el 4407 ft, the present capacity of Elephant Butte Reservoir is 2,137,200 acre-ft and the surface area is 36,570 acres.

## SUMMARY AND CONCLUSIONS

The 1969 sediment survey report of Elephant Butte Reservoir includes a discussion of the methods used to measure and study the nearly 54.5 years of reservoir sediment accumulation. It also briefly describes the field surveying and sediment sampling procedures and equipment. The survey was primarily run to gather the necessary data for use in computing the present capacity of Elephant Butte 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 across the range line. The water surface elevations read at the gage of the dam were used as bases to obtain the bottom elevations at selected points on the cross sectional profile traced by the sonic sounder chart.

Seventeen sediment samples of the reservoir deposits were collected with a gravity core sampler. Analyzing these samples along with others collected during 1952 and 1957 resulted in determining a unit weight of 62 pcf and a representative size of 60 percent clay, 31 percent silt, and 9 percent sand.

Longitudinally, the sediments were deposited between the 1915 and 1969 surveys to average depths ranging from 8 to 42 ft (see page 5). Laterally, the reservoir range cross sectional profiles for the 1915 and 1969 surveys showed sediments deposited to depths from 10 to 44 ft (see page 10). For all practical purposes sediments have deposited to at least the spillway crest el 4407 ft in the reservoir area beginning at 37 miles above the dam.

The capacity of Elephant Butte Reservoir as determined from the 1969 survey is 2,137,000 acre-ft and the surface area 36,570 acres at spillway crest elevation (see area-capacity curves in Figure 19). The 1969 reservoir surface areas were determined by a width-ratio method described on page 23. The electronic computer was used to compute areas at 1-ft

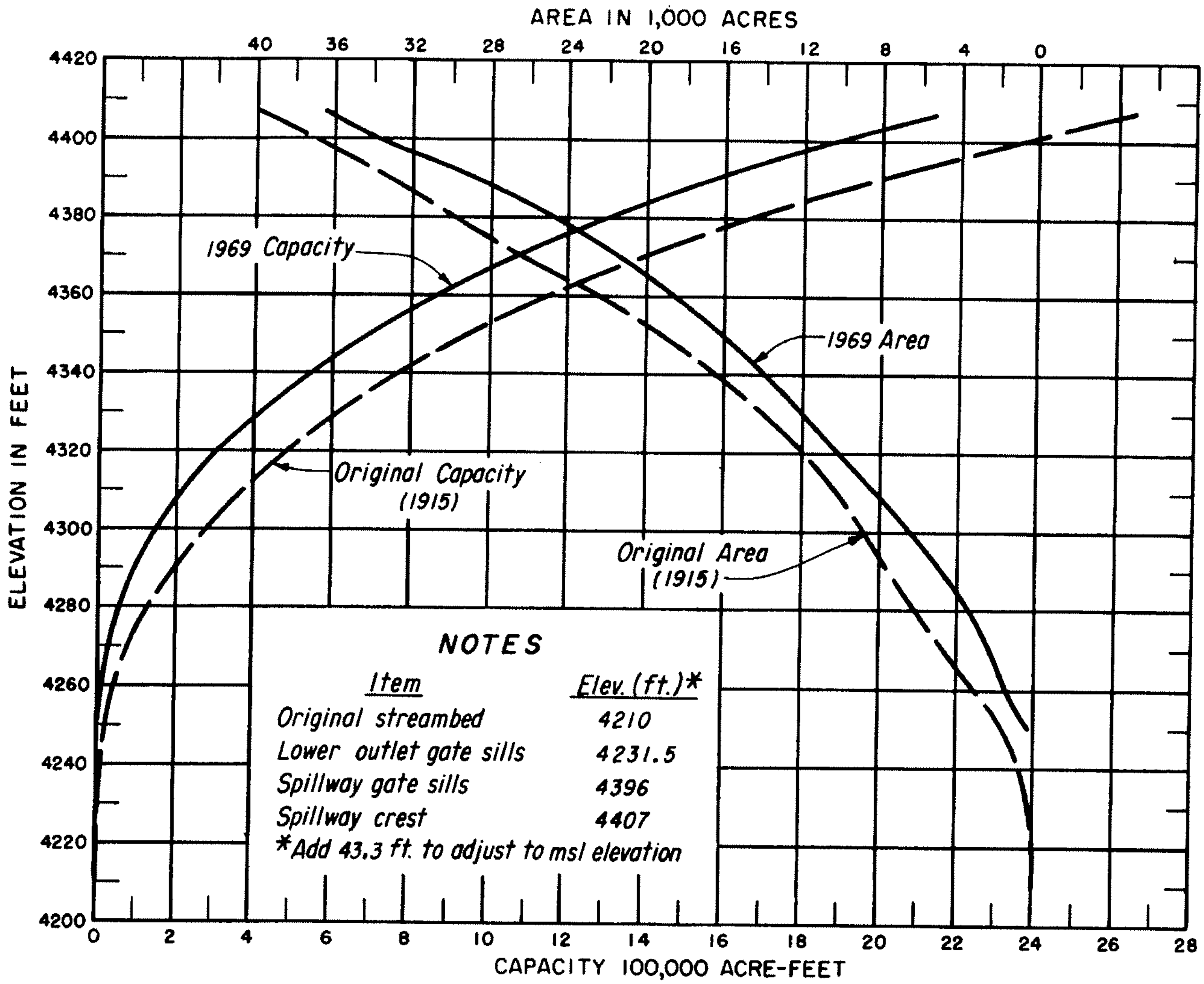


Figure 19. Reservoir area-capacity curves.

increments by linear interpolation. The reservoir capacity was computed 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-ft intervals.

A comprehensive summary of the reservoir sediment data for the 1969 survey is contained in Table 2. Volume of the sediments that have accumulated in the dam since 1915 amounted to 497,600 acre-ft at el 4407 ft. This indicates a loss in reservoir capacity of about 19 percent. An average annual sediment accumulation rate of 9,160 acre-ft was found for the 1915 to 1969 period. Sediments deposited at a rate of 0.354 acre-ft per square mile annually during this same period.

## APPENDIX

Profiles run for the 59 reservoir sedimentation ranges surveyed in 1915 and 1969—plotted in Figures 20 through 78.

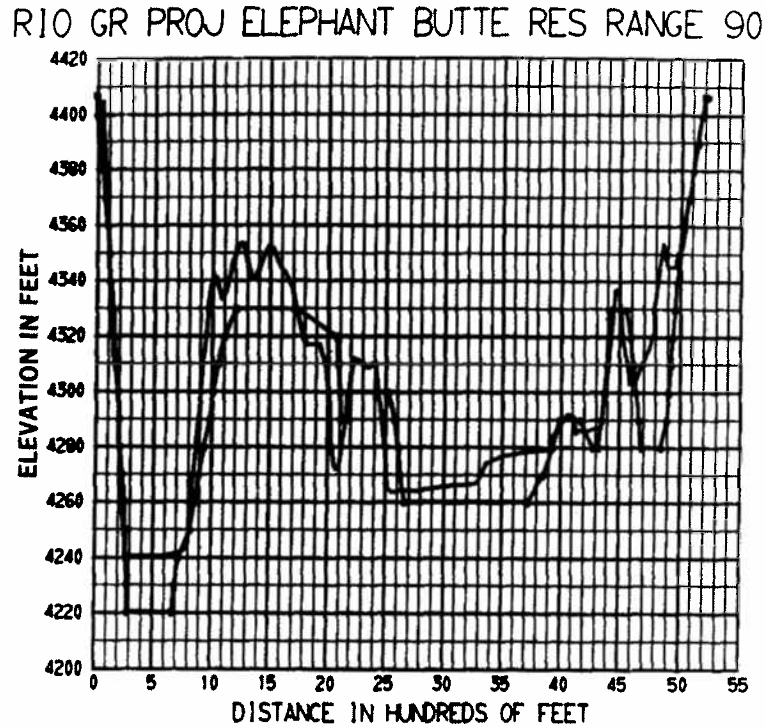


Figure 20. 1915 and 1969 sedimentation range profiles—Range 90.

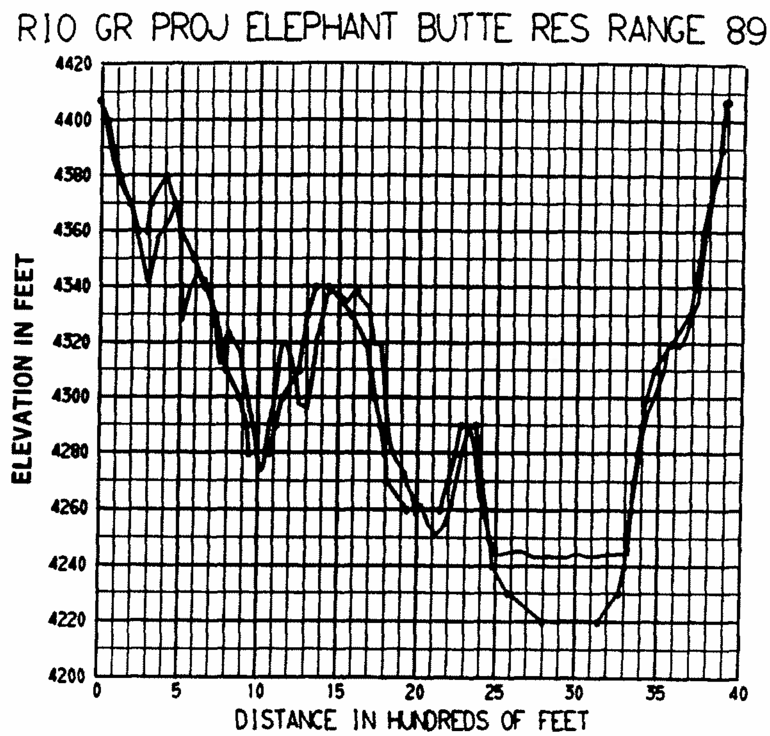


Figure 21. 1915 and 1969 sedimentation range profiles—Range 89.

NOTE (applicable to Figures 20 through 78)

●—●—●—●—●—●—● 1915 profile

———————— 1969 profile

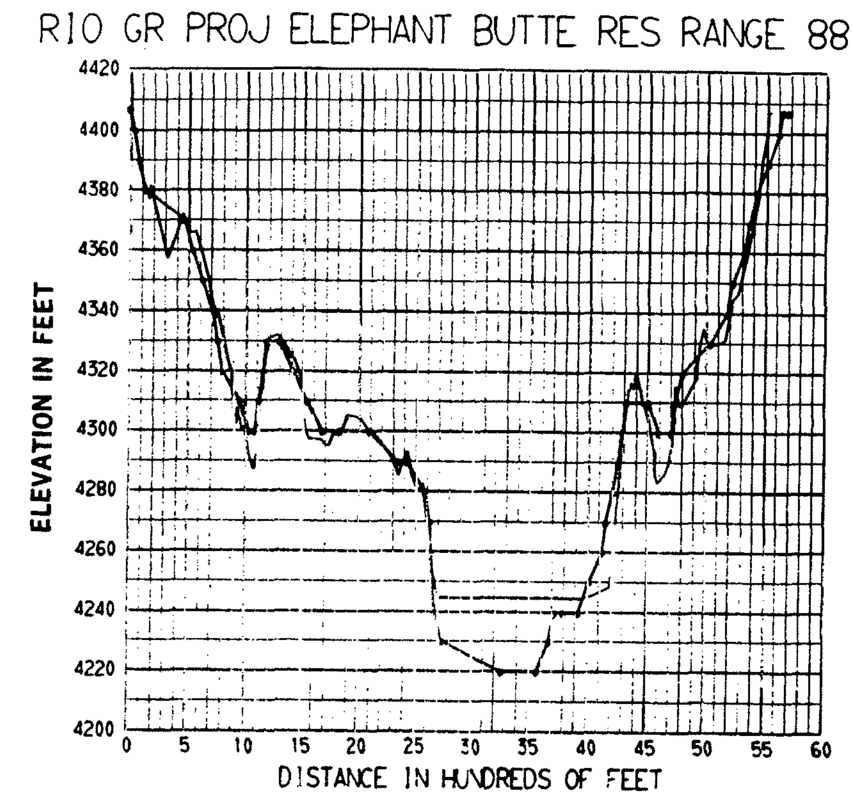


Figure 22. 1915 and 1969 sedimentation range profiles—Range 88.

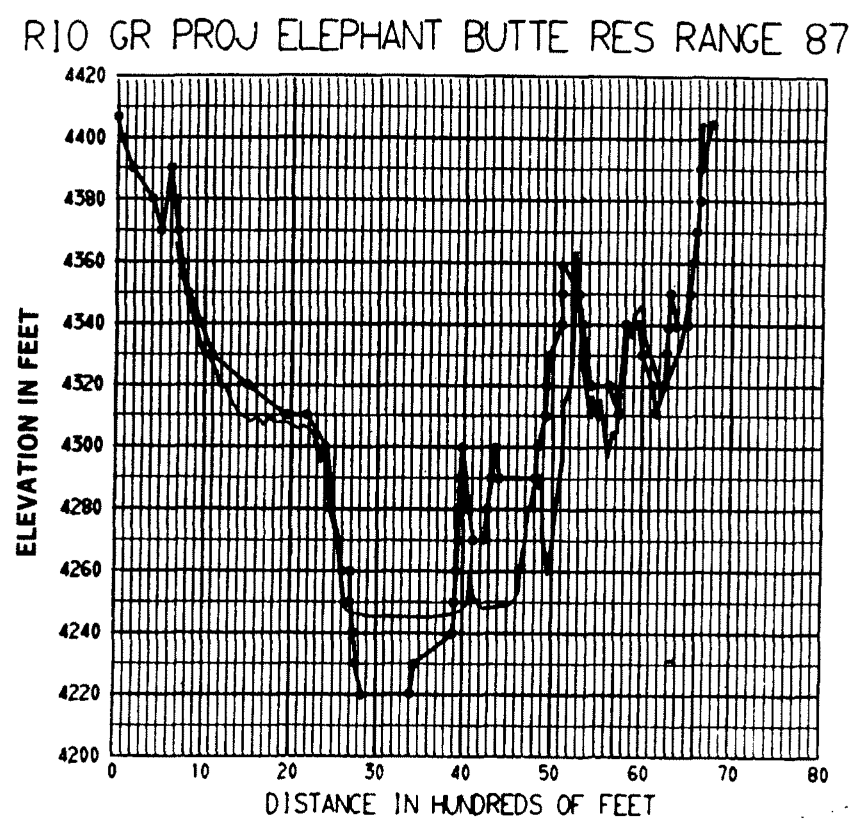


Figure 23. 1915 and 1969 sedimentation range profiles—Range 87.

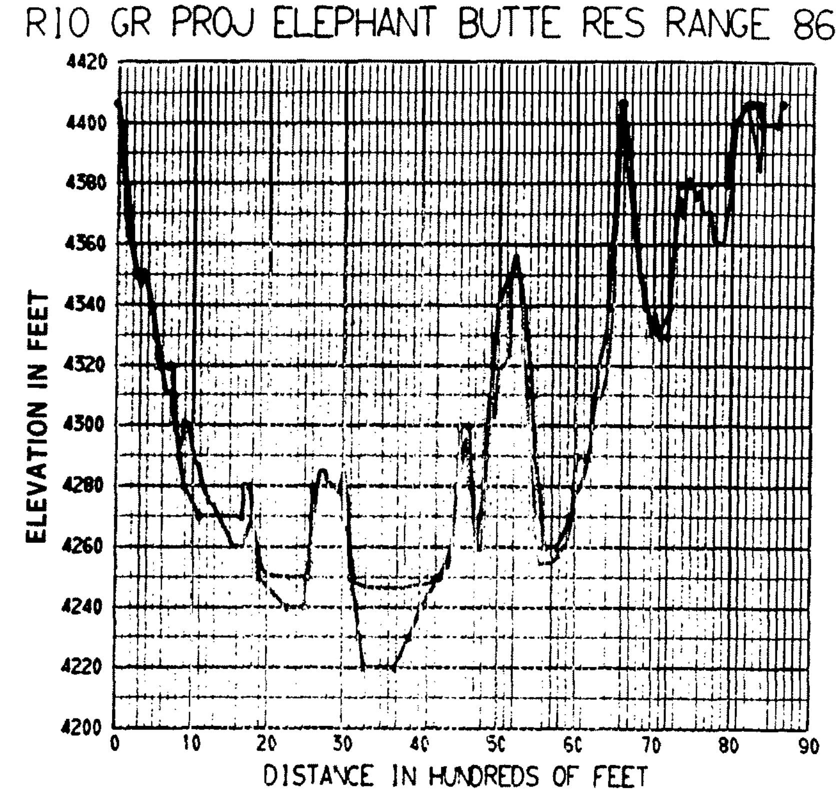


Figure 24. 1915 and 1969 sedimentation range profiles—Range 86.

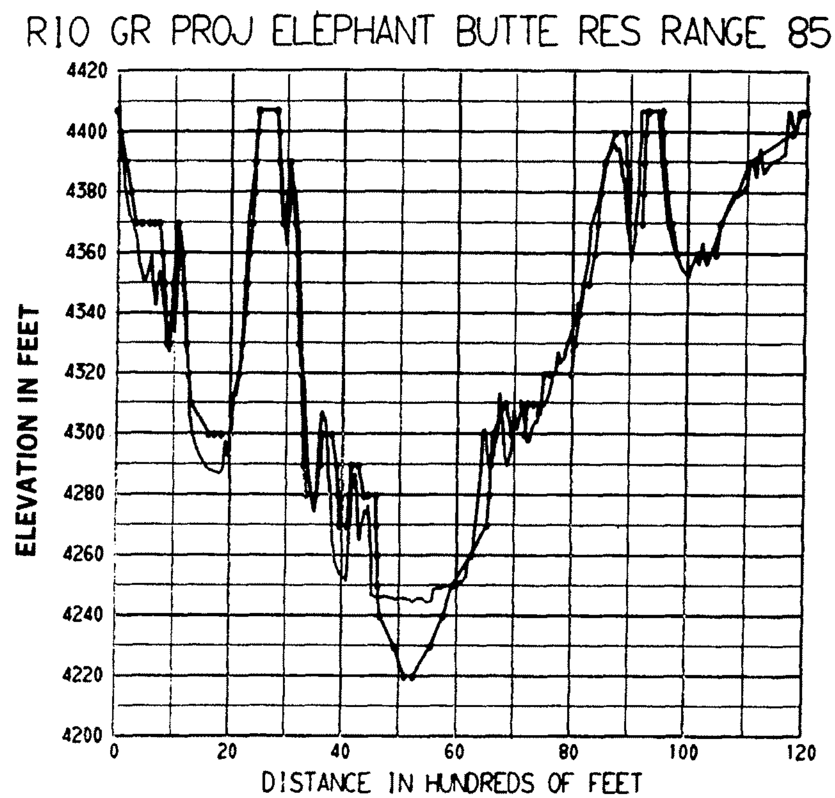


Figure 25. 1915 and 1969 sedimentation range profiles—Range 85.

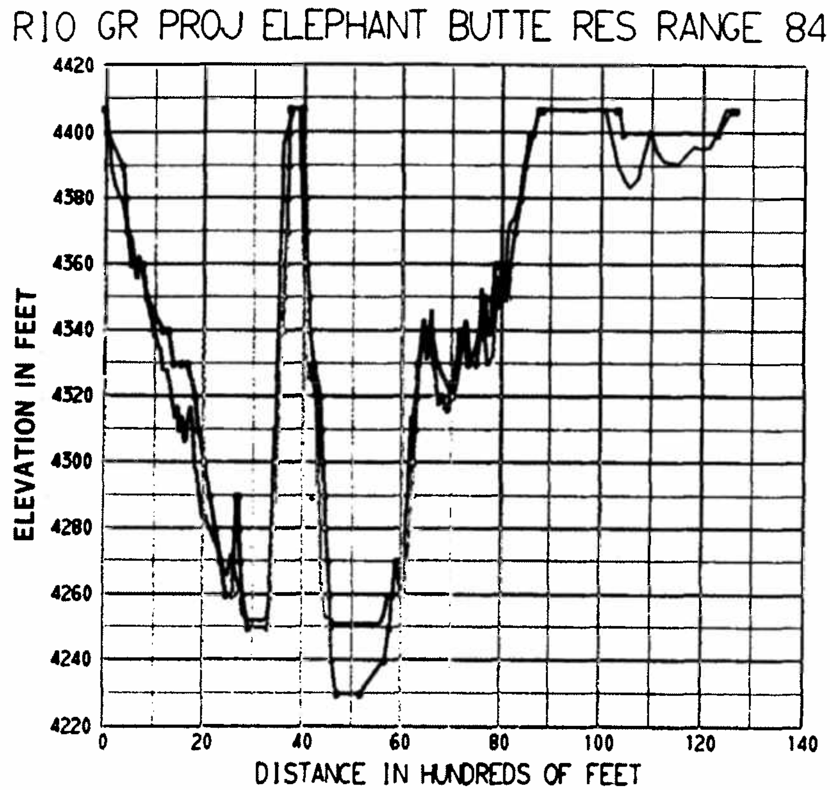


Figure 26. 1915 and 1969 sedimentation range profiles—Range 84.

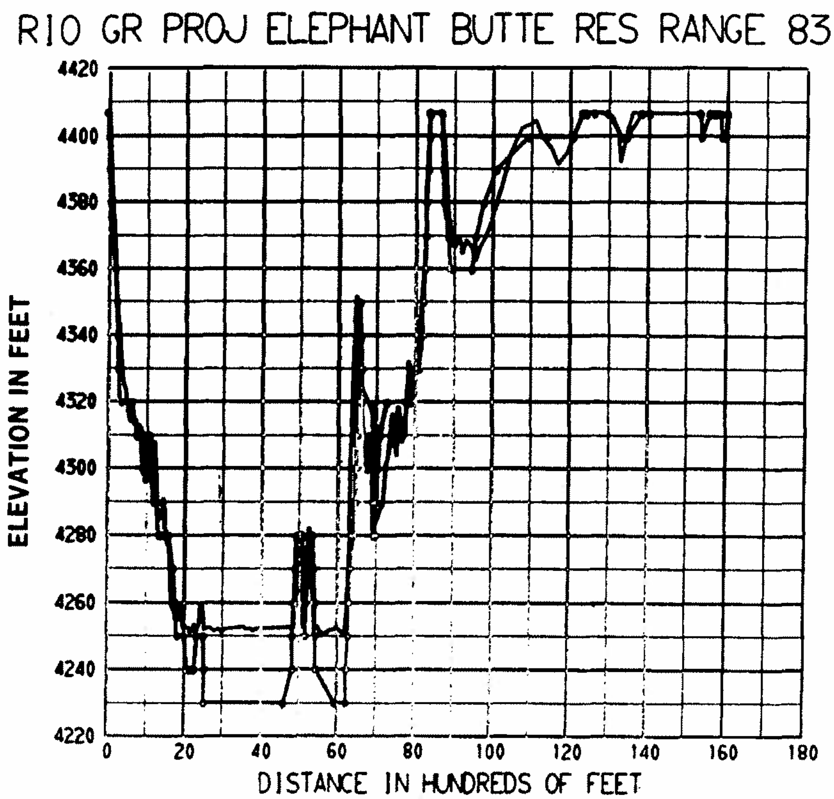


Figure 27. 1915 and 1969 sedimentation range profiles—Range 83.

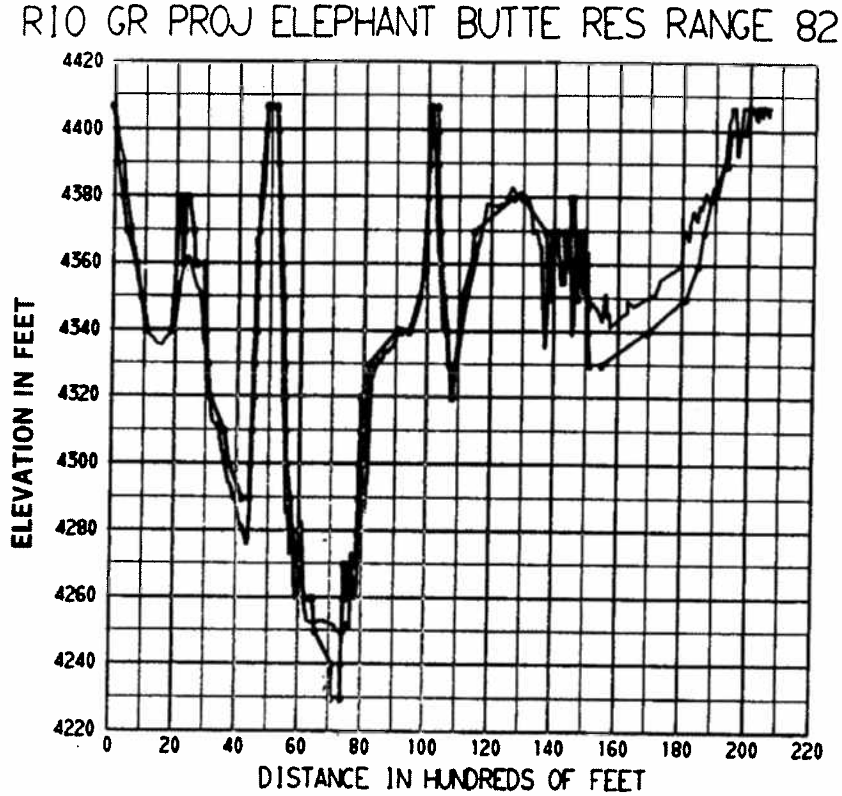


Figure 28. 1915 and 1969 sedimentation range profiles—Range 82.

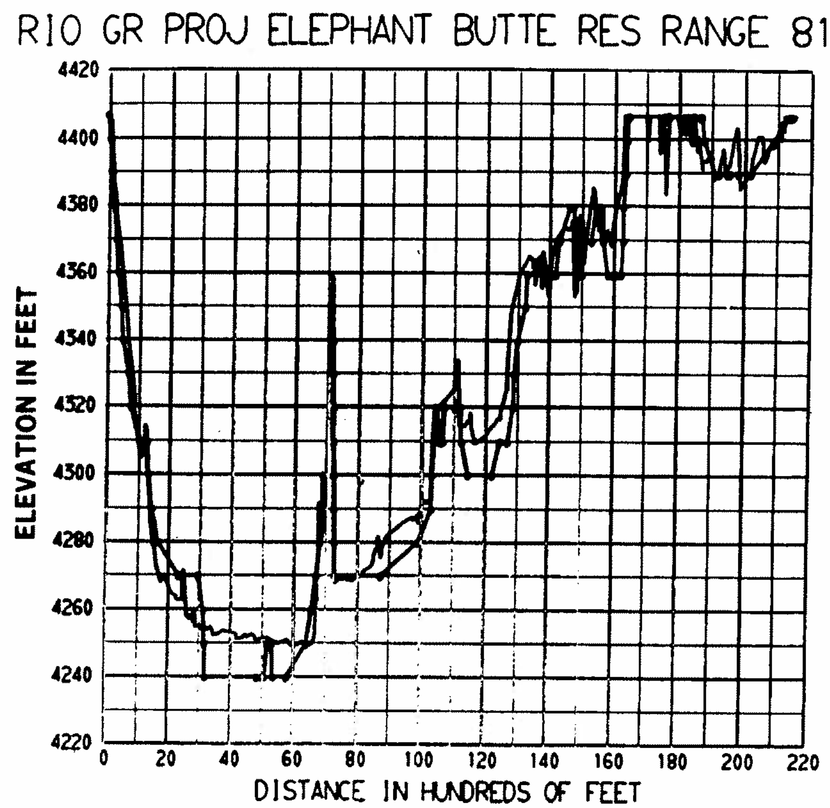


Figure 29. 1915 and 1969 sedimentation range profiles—Range 81.

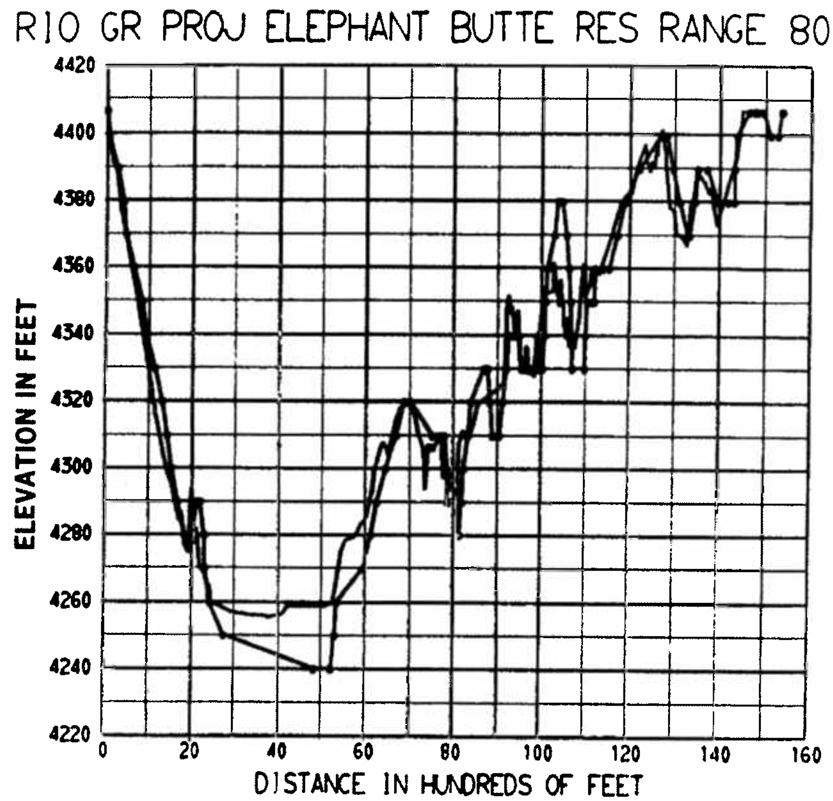


Figure 30. 1915 and 1969 sedimentation range profiles—Range 80.

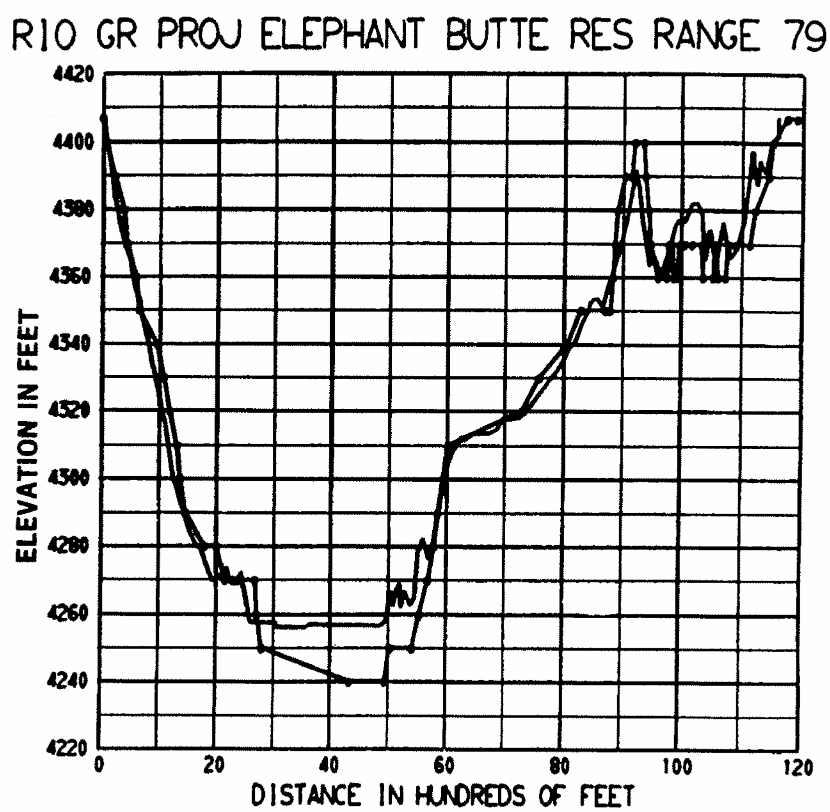


Figure 31. 1915 and 1969 sedimentation range profiles—Range 79.

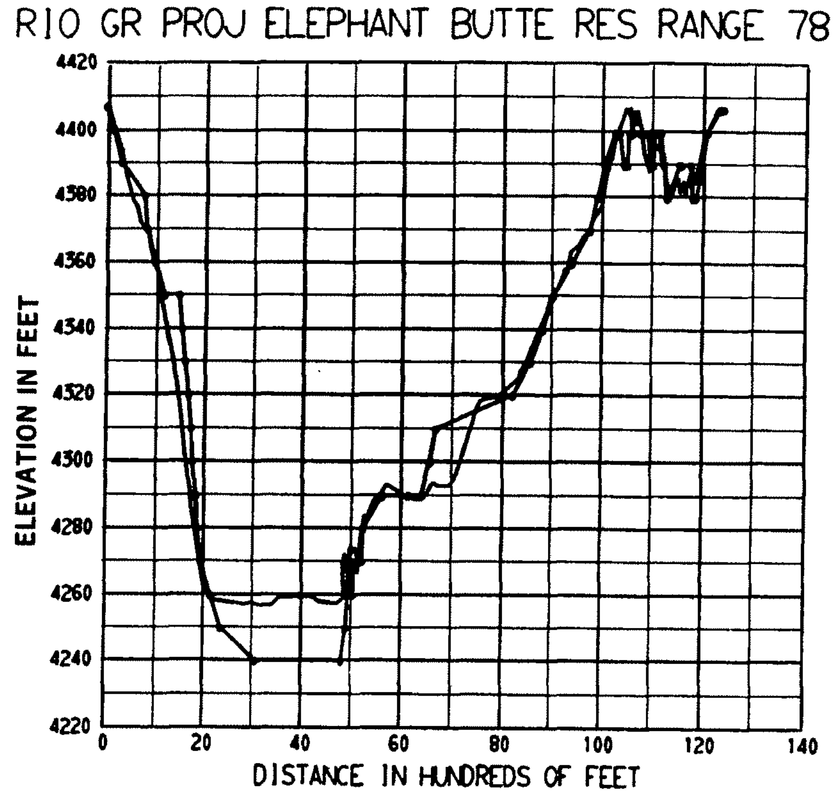


Figure 32. 1915 and 1969 sedimentation range profiles–Range 78.

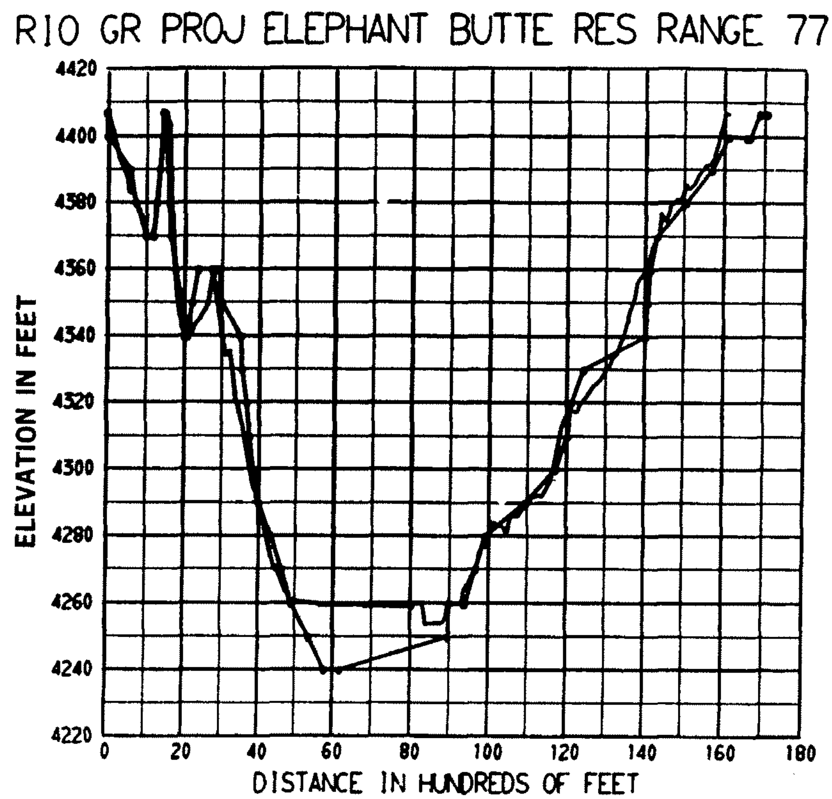


Figure 33. 1915 and 1969 sedimentation range profiles–Range 77.

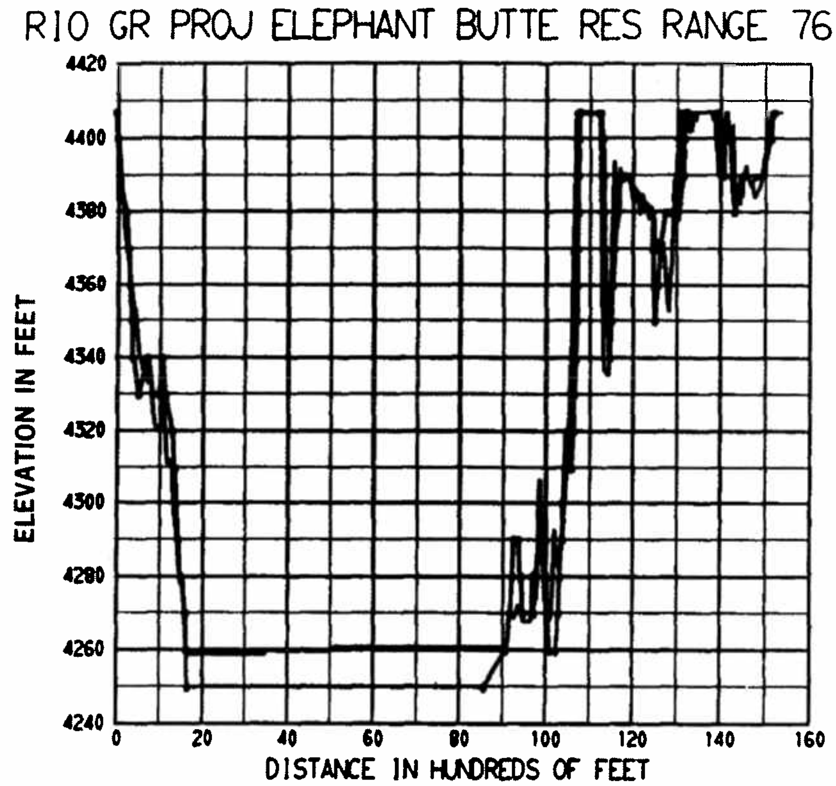


Figure 34. 1915 and 1969 sedimentation range profiles—Range 76.

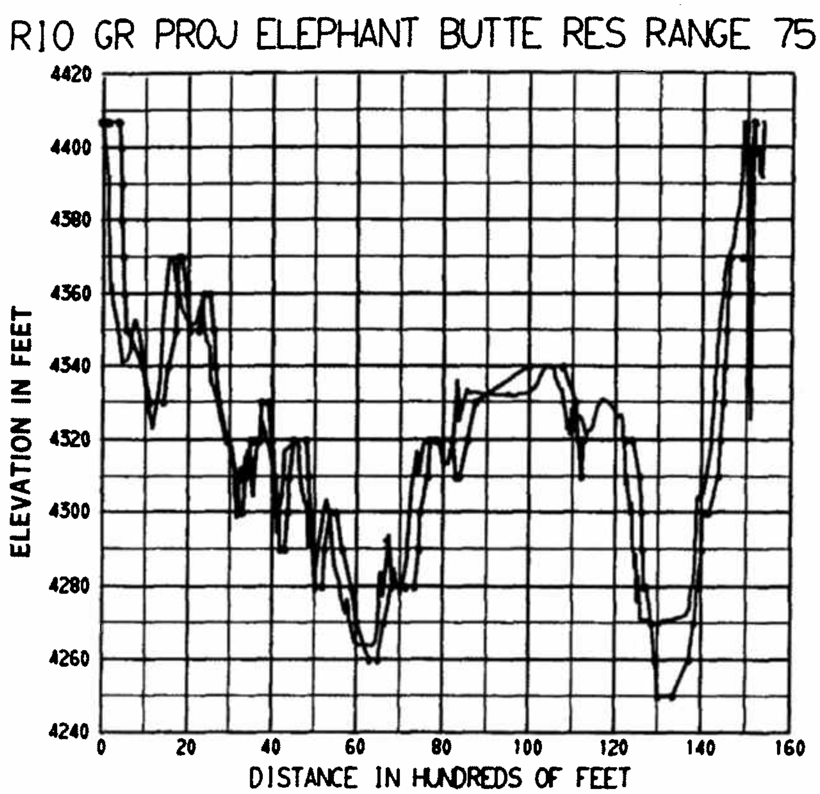


Figure 35. 1915 and 1969 sedimentation range profiles—Range 75.

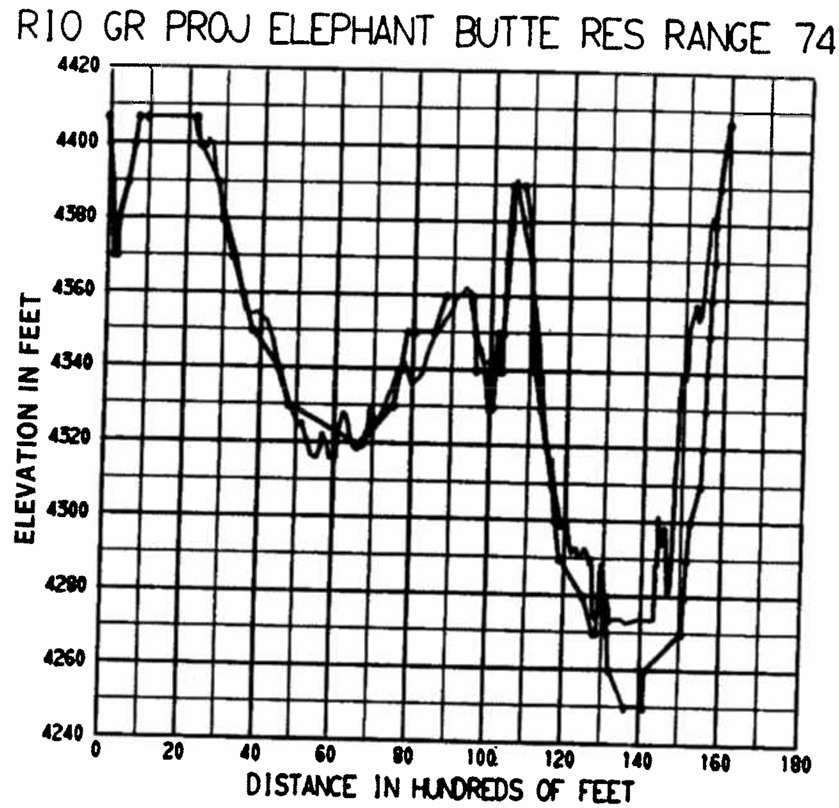


Figure 36. 1915 and 1969 sedimentation range profiles—Range 74.

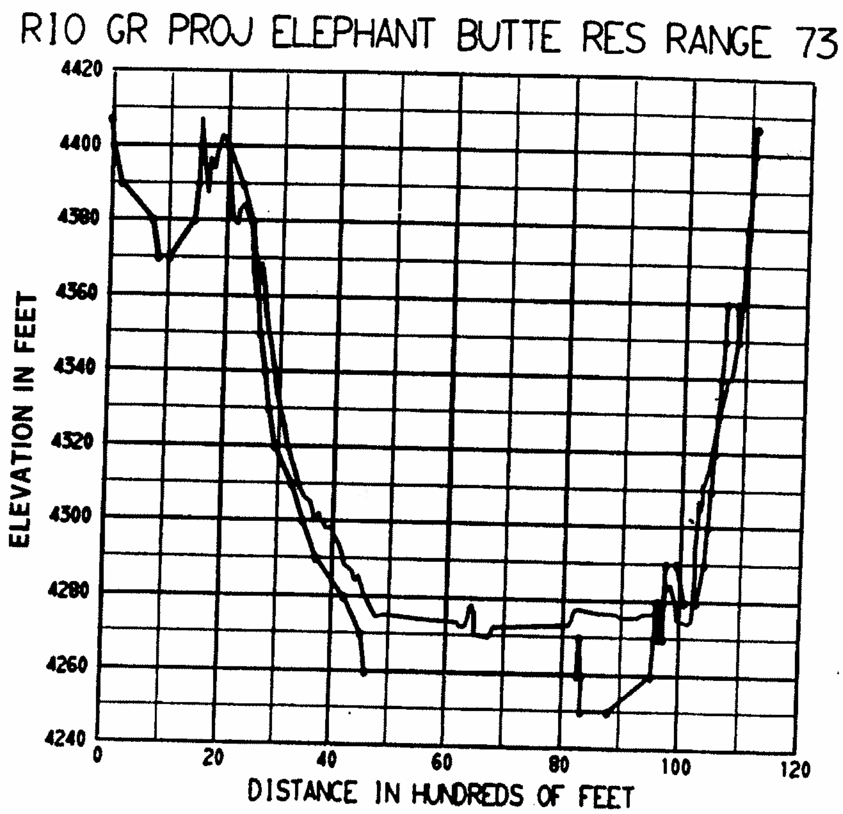


Figure 37. 1915 and 1969 sedimentation range profiles—Range 73.

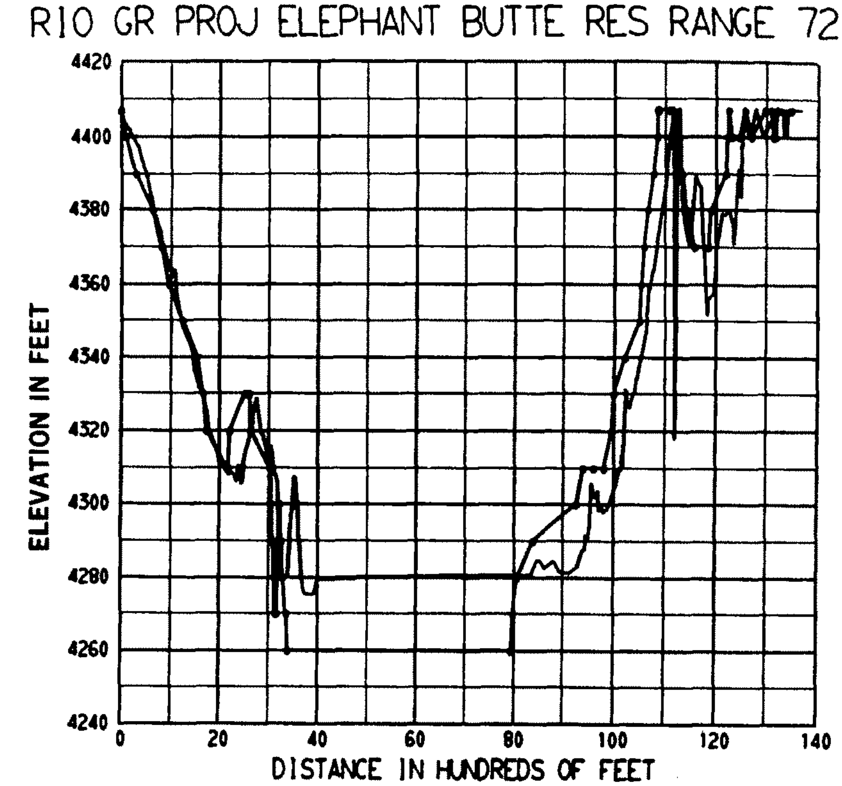


Figure 38. 1915 and 1969 sedimentation range profiles—Range 72.

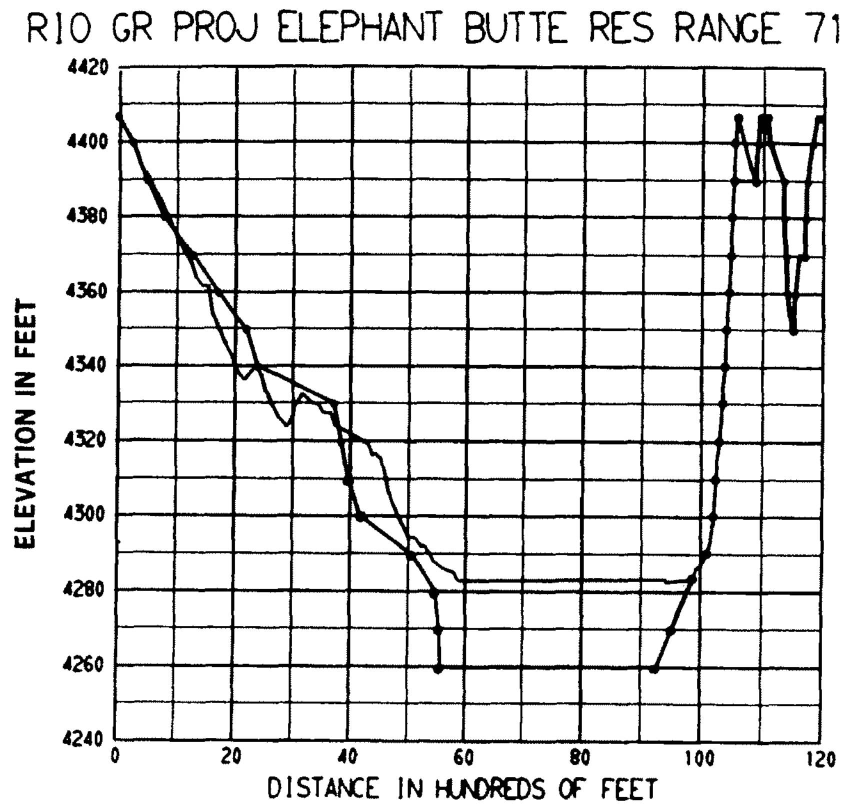


Figure 39. 1915 and 1969 sedimentation range profiles—Range 71.

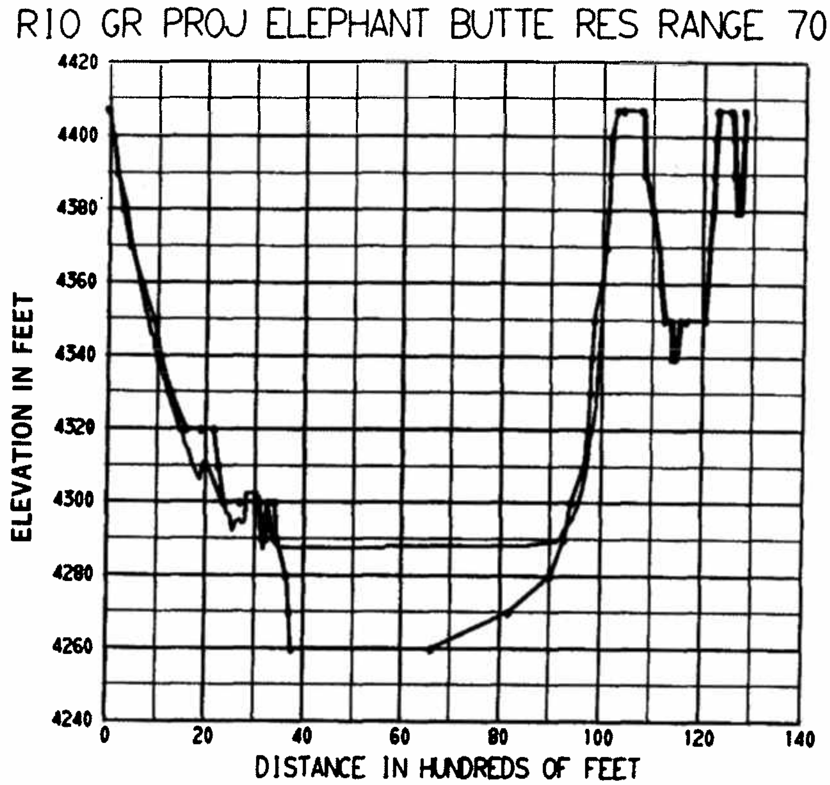


Figure 40. 1915 and 1969 sedimentation range profiles—Range 70.

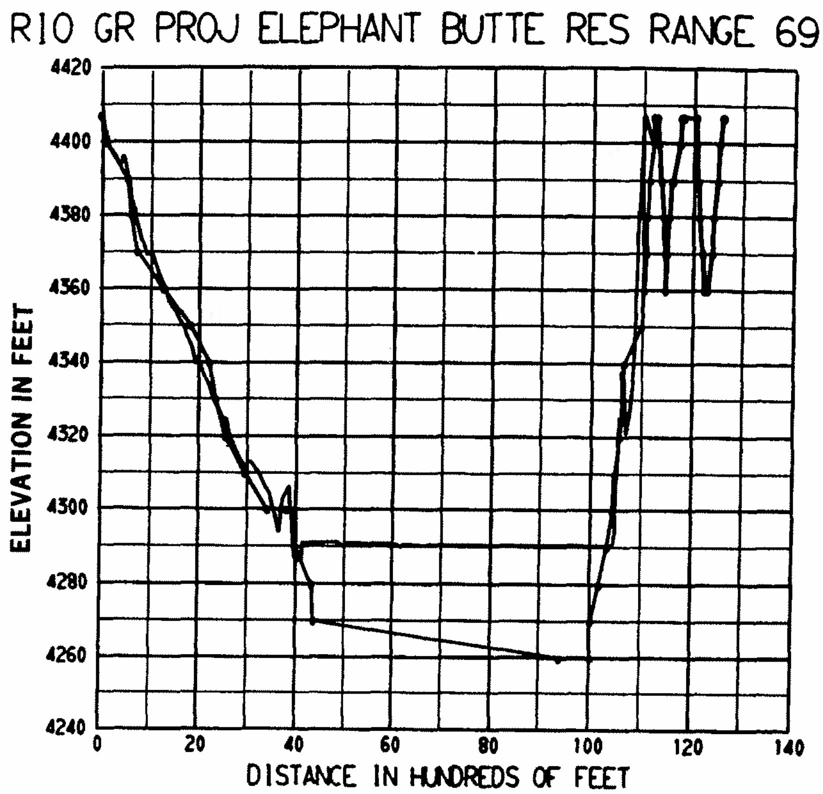


Figure 41. 1915 and 1969 sedimentation range profiles—Range 69.

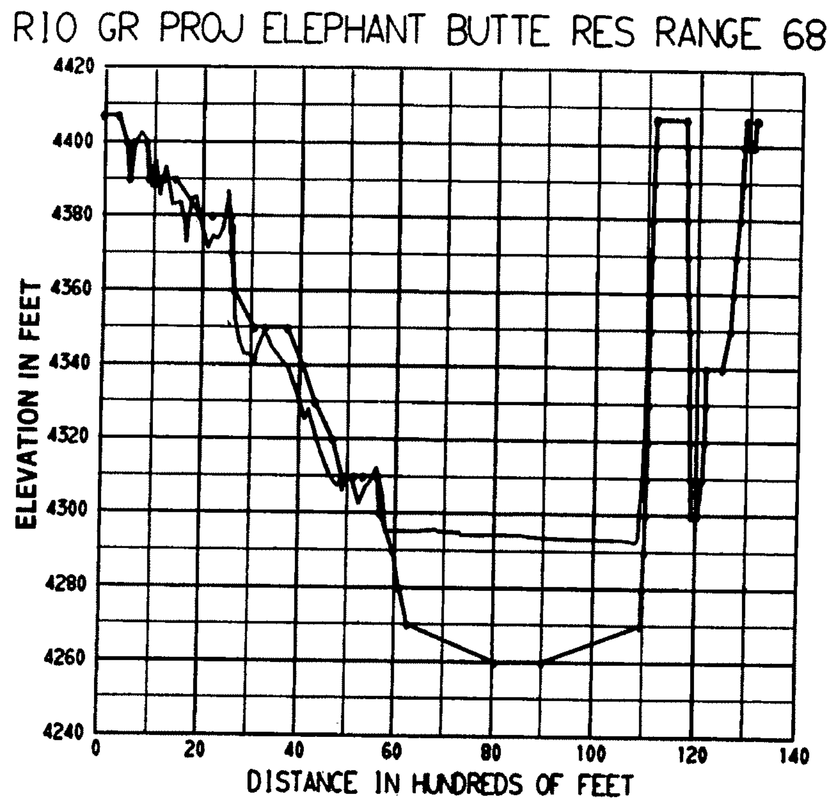


Figure 42. 1915 and 1969 sedimentation range profiles—Range 68.

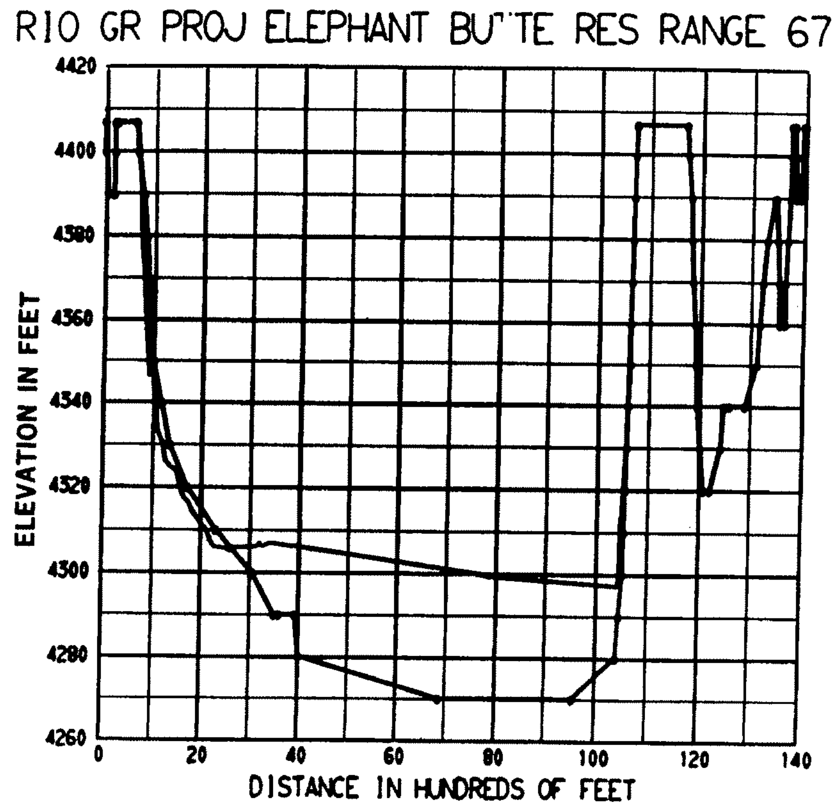


Figure 43. 1915 and 1969 sedimentation range profiles—Range 67.

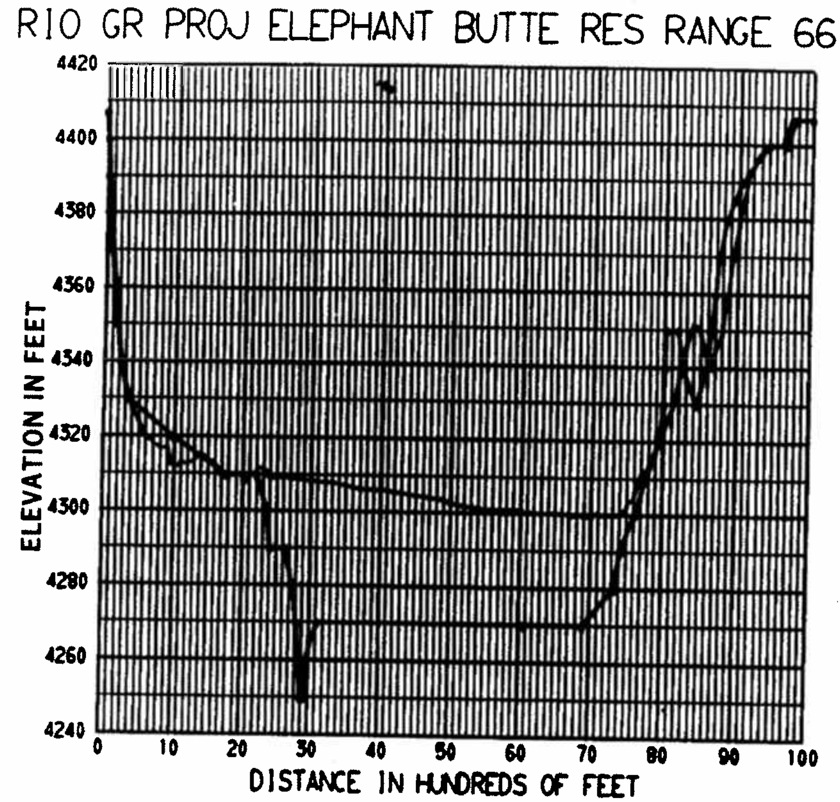


Figure 44. 1915 and 1969 sedimentation range profiles--Range 66.

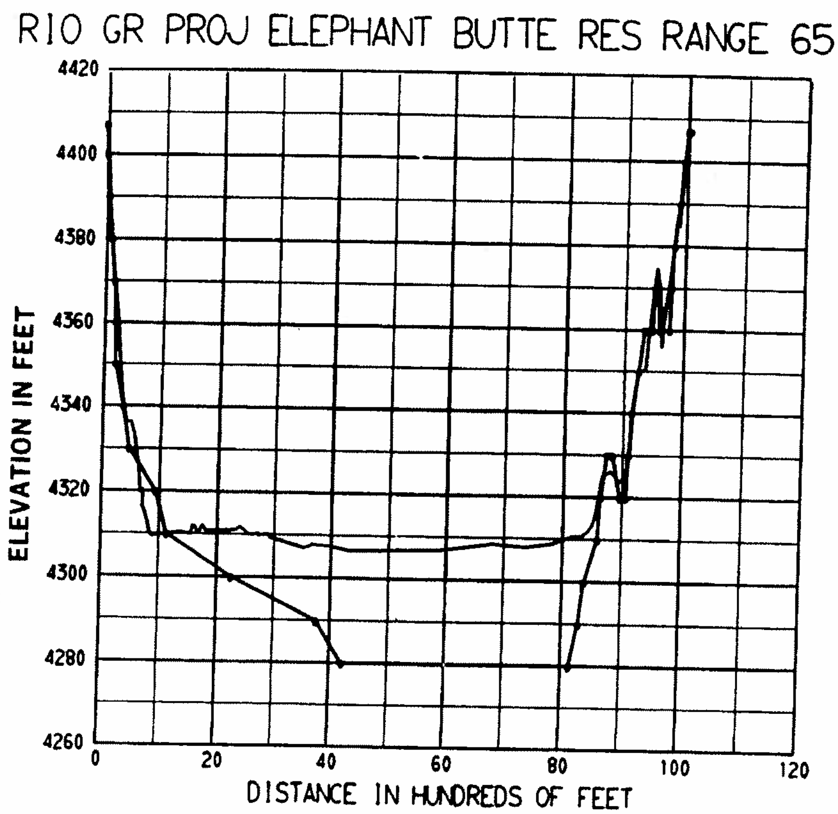


Figure 45. 1915 and 1969 sedimentation range profiles--Range 65.

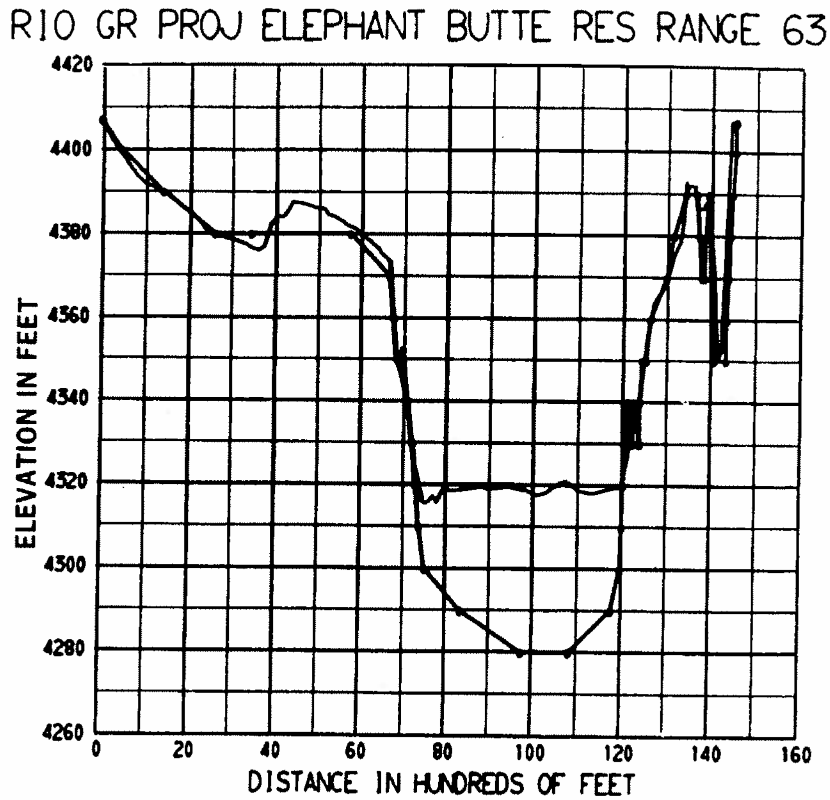


Figure 46. 1915 and 1969 sedimentation range profiles—Range 63.

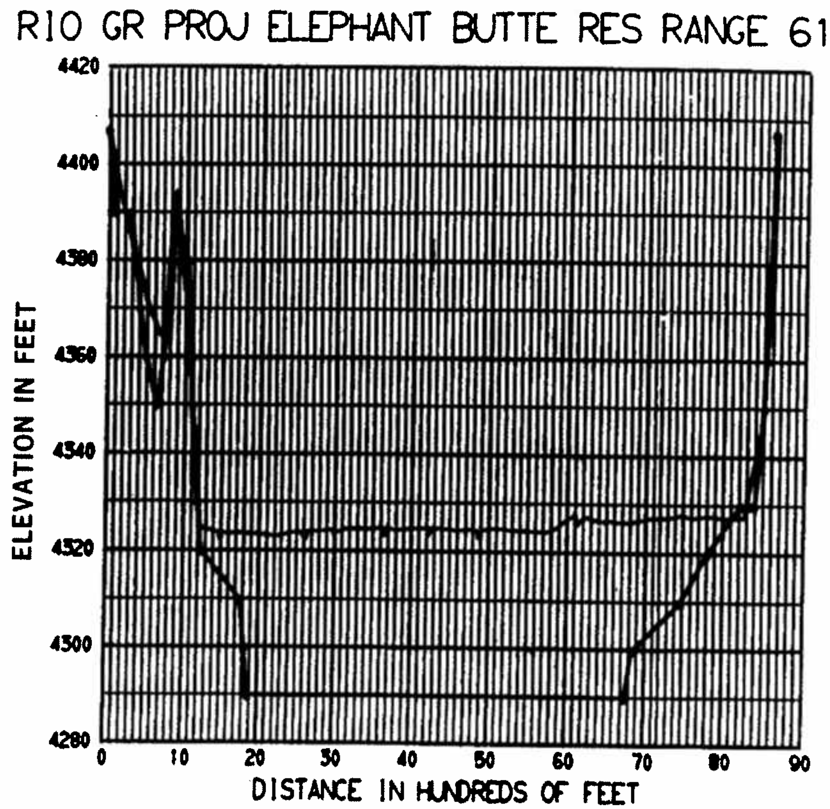


Figure 47. 1915 and 1969 sedimentation range profiles—Range 61.

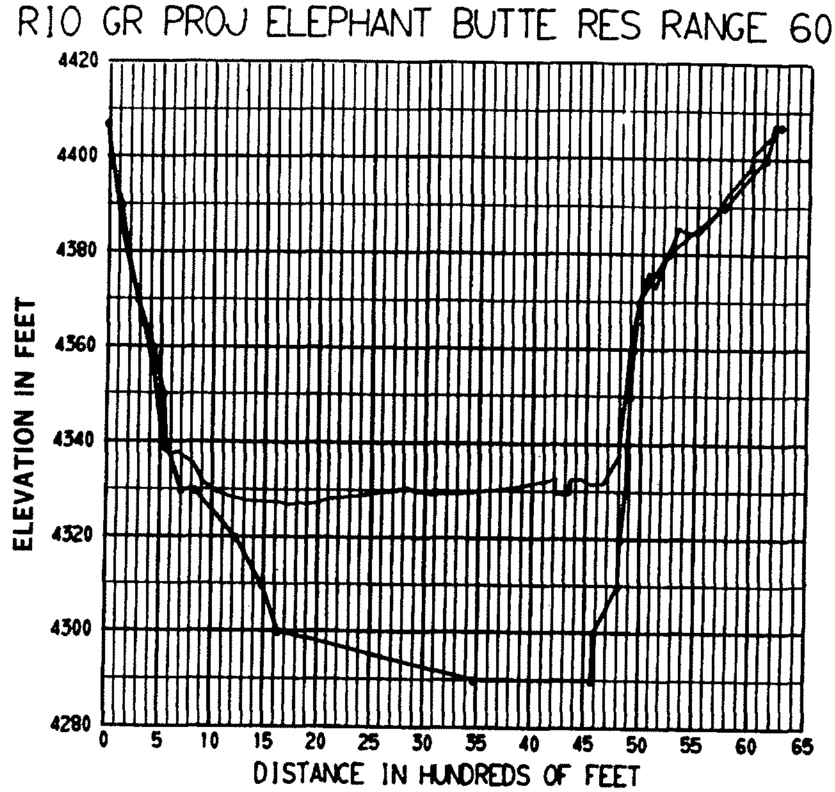


Figure 48. 1915 and 1969 sedimentation range profiles—Range 60.

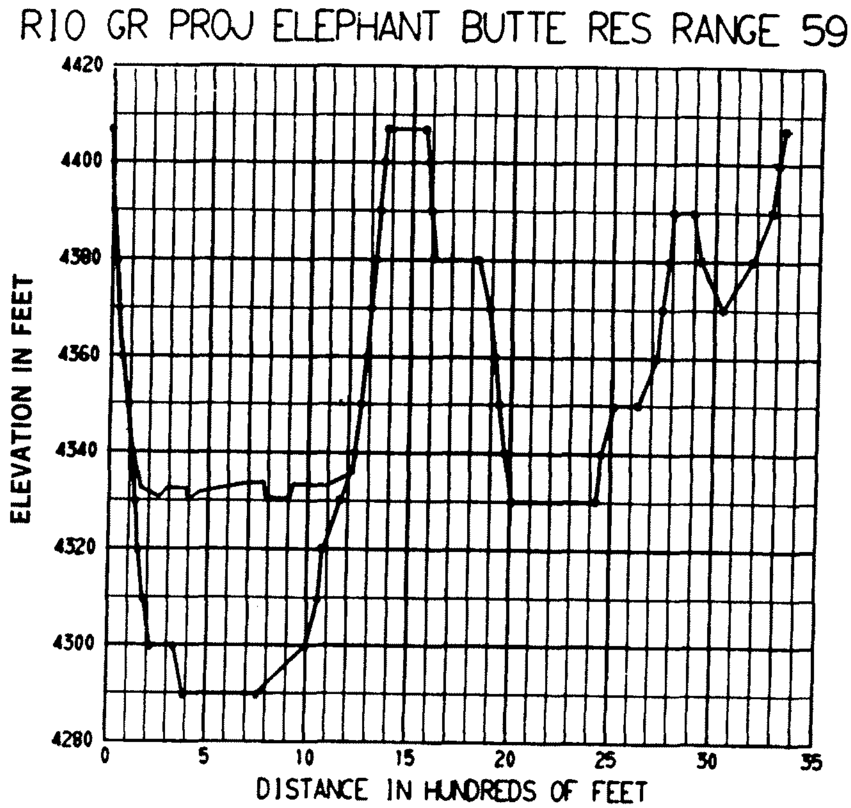


Figure 49. 1915 and 1969 sedimentation range profiles—Range 59.

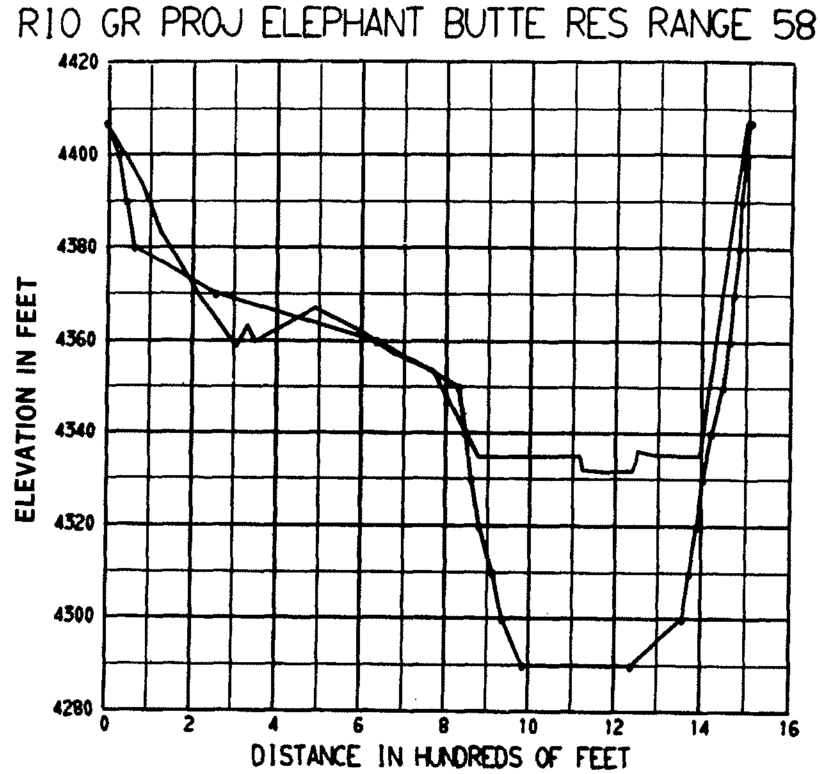


Figure 50. 1915 and 1969 sedimentation range profiles—Range 58.

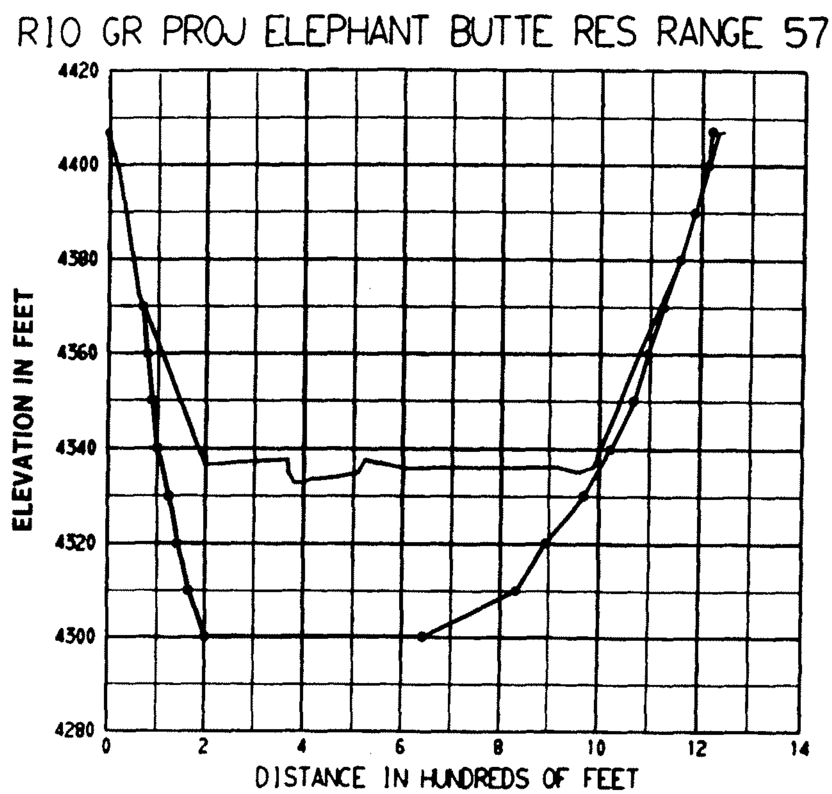


Figure 51. 1915 and 1969 sedimentation range profiles—Range 57.

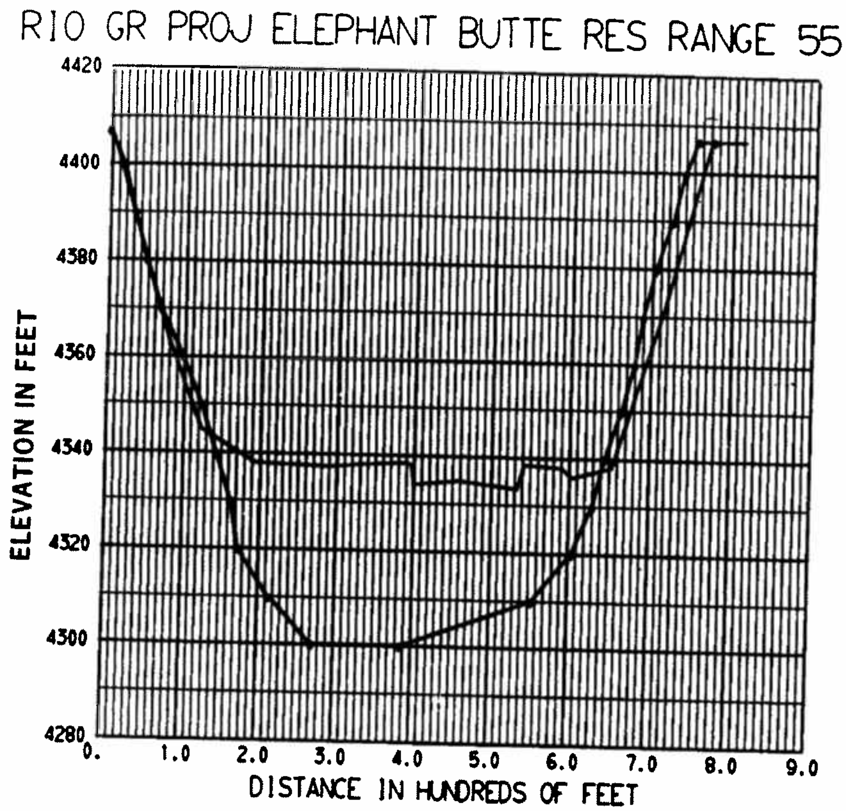


Figure 52. 1915 and 1969 sedimentation range profiles—Range 55.

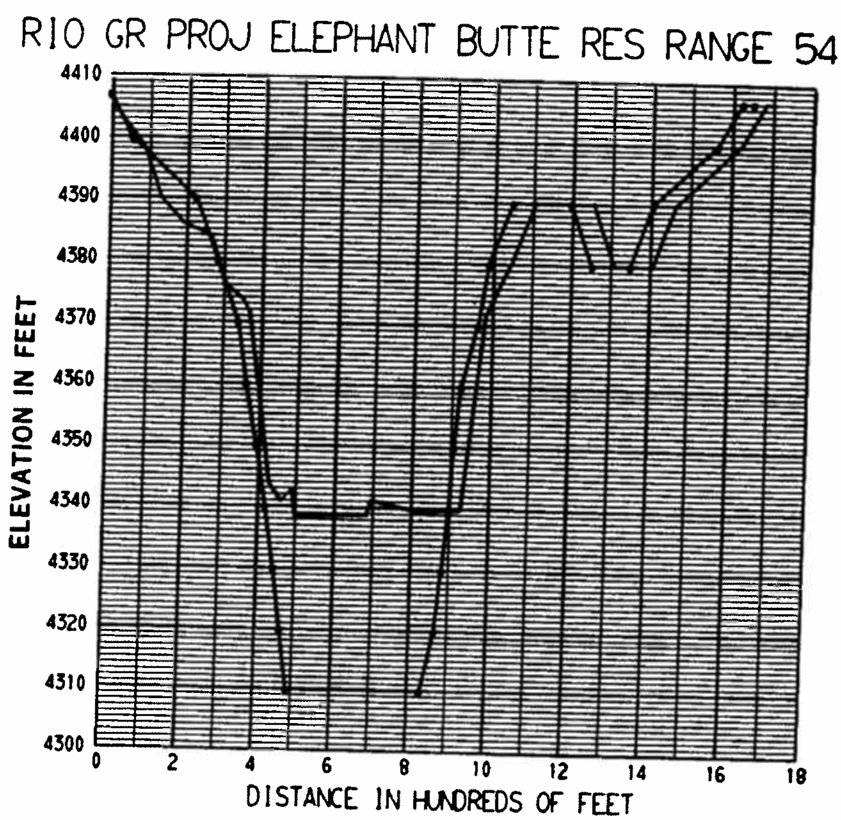


Figure 53. 1915 and 1969 sedimentation range profiles—Range 54.

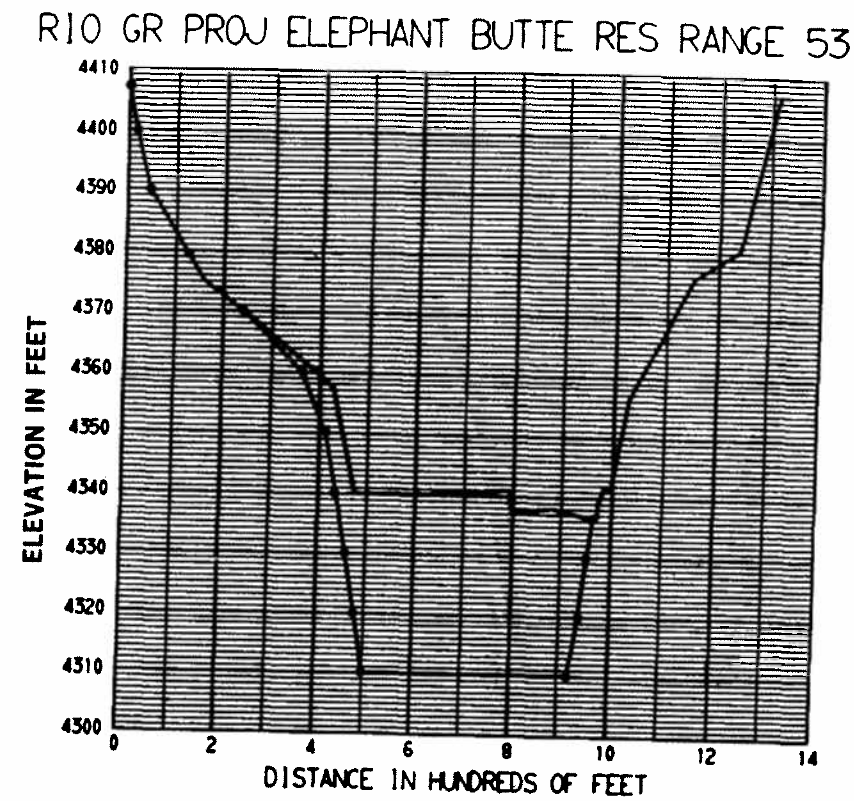


Figure 54. 1915 and 1969 sedimentation range profiles—Range 53.

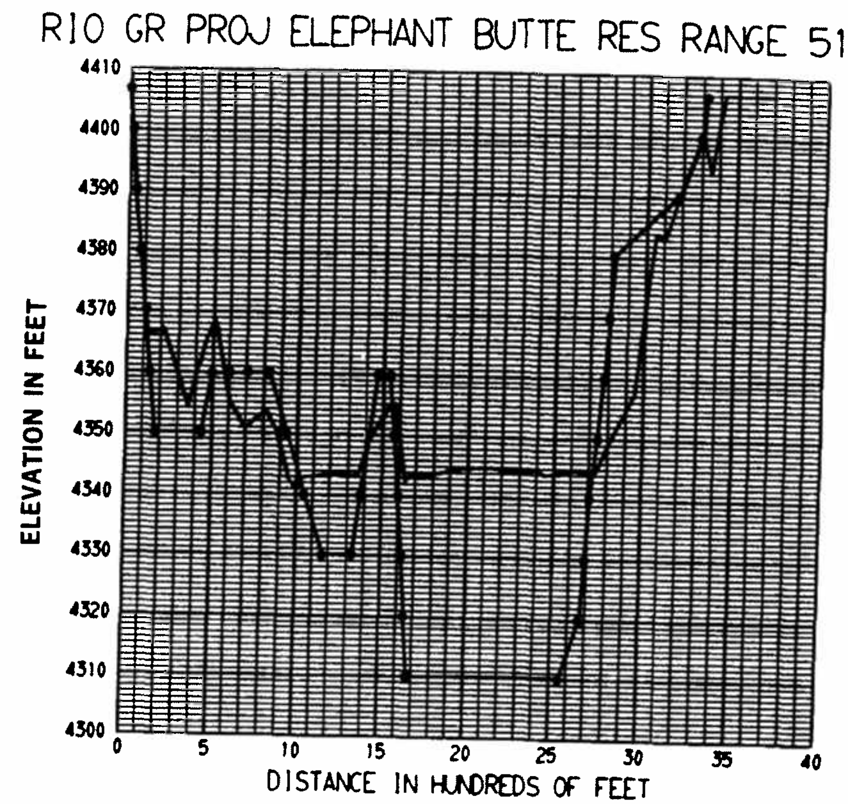


Figure 55. 1915 and 1969 sedimentation range profiles—Range 51.

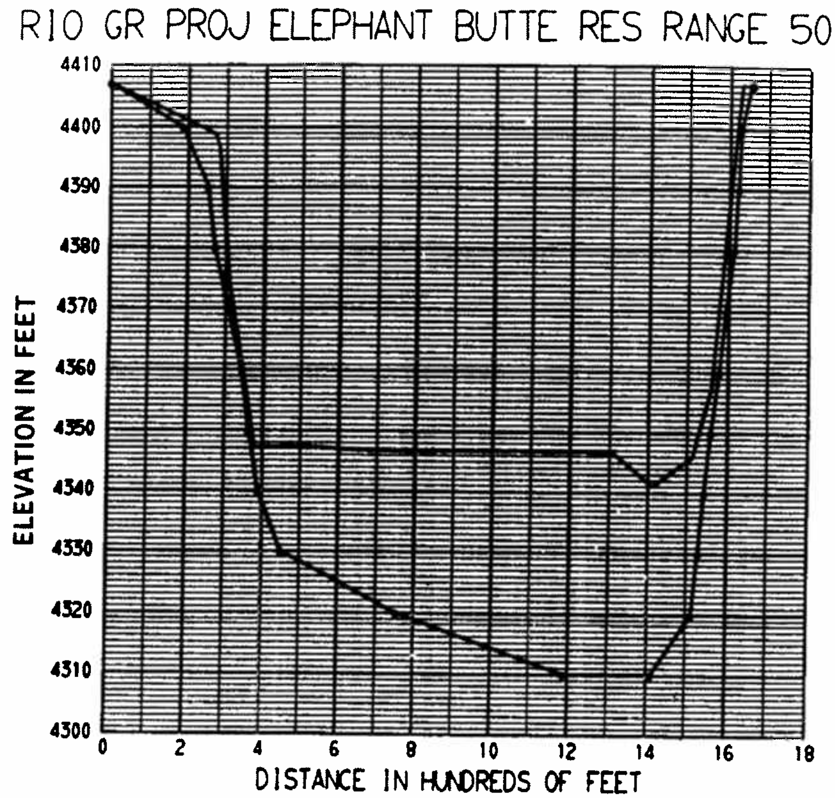


Figure 56. 1915 and 1969 sedimentation range profiles—Range 50.

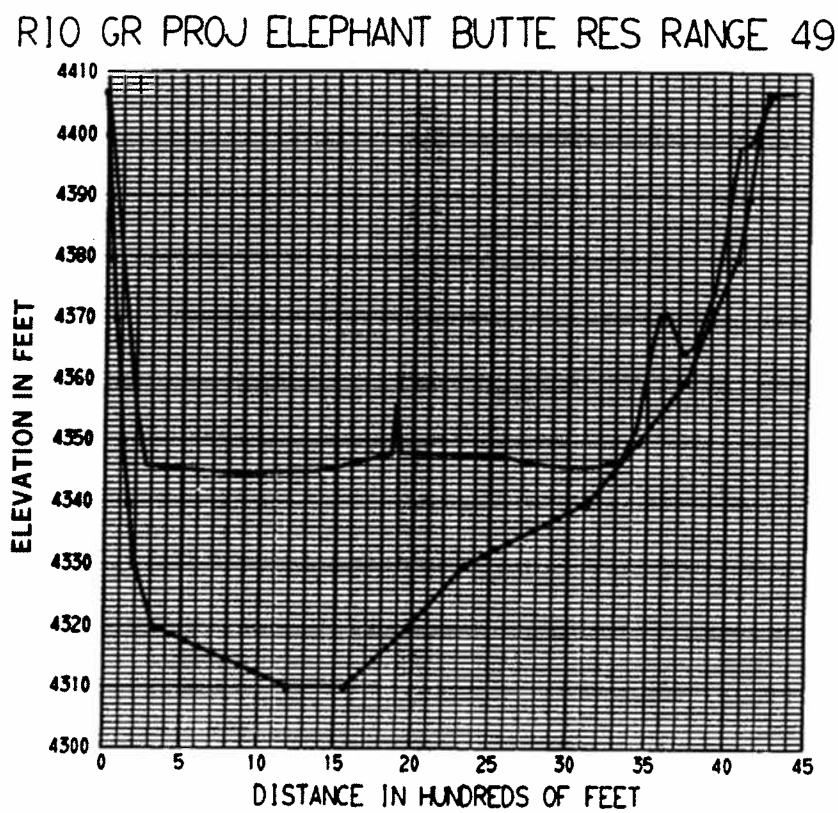


Figure 57. 1915 and 1969 sedimentation range profiles--Range 49.

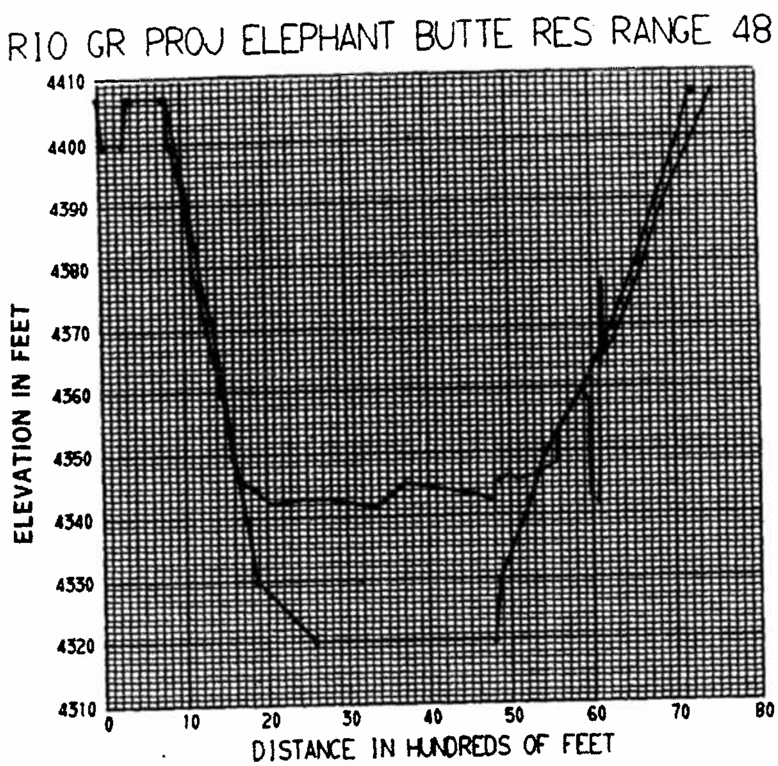


Figure 58. 1915 and 1969 sedimentation range profiles--Range 48.

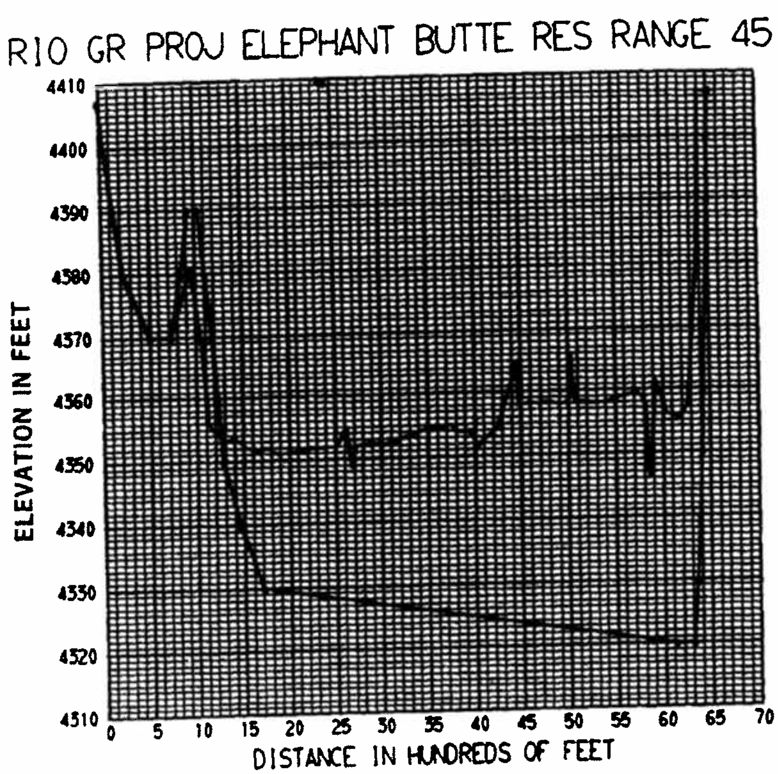


Figure 59. 1915 and 1969 sedimentation range profiles—Range 45.

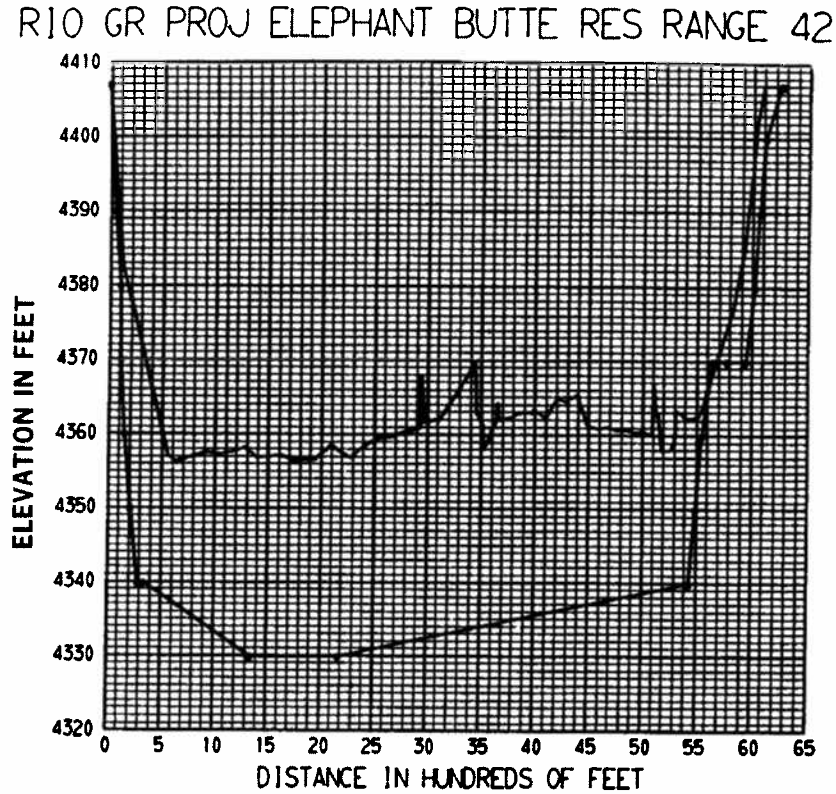


Figure 60. 1915 and 1969 sedimentation range profiles—Range 42.

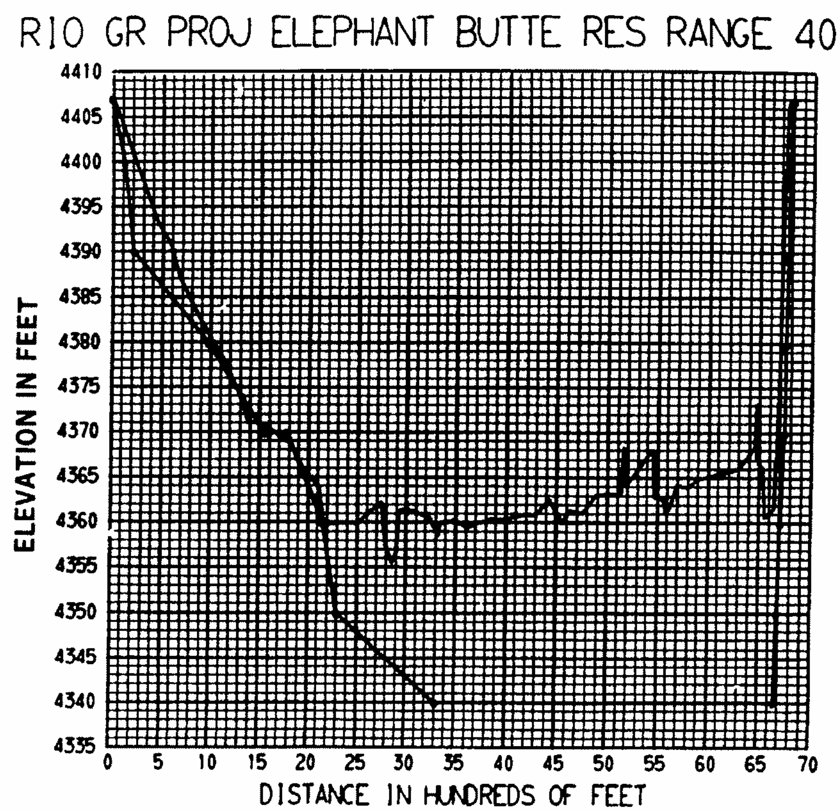


Figure 61. 1915 and 1969 sedimentation range profiles—Range 40.

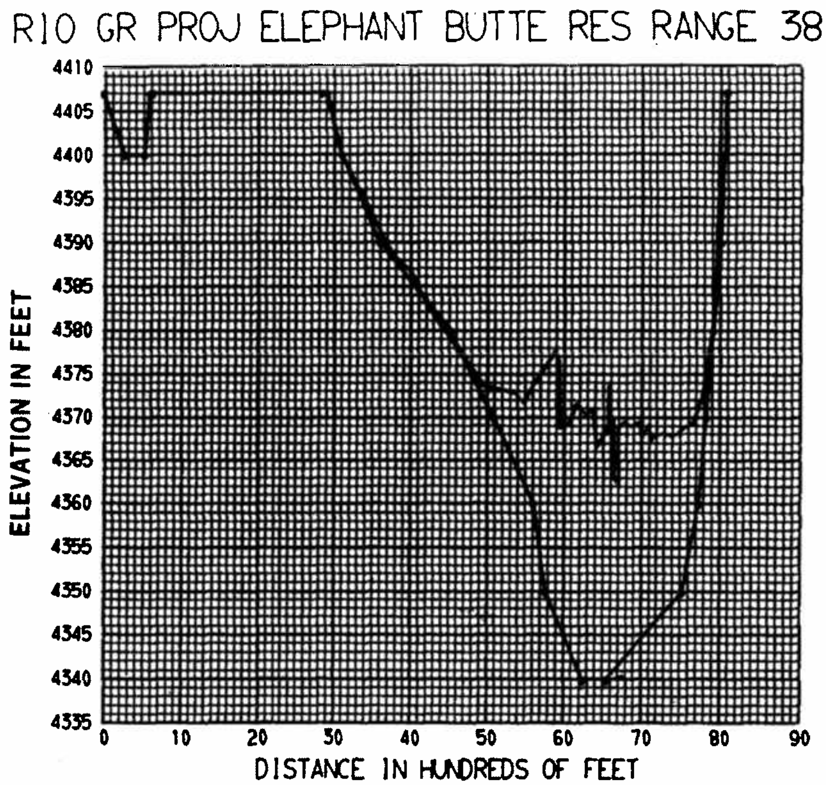


Figure 62. 1915 and 1969 sedimentation range profiles—Range 38.

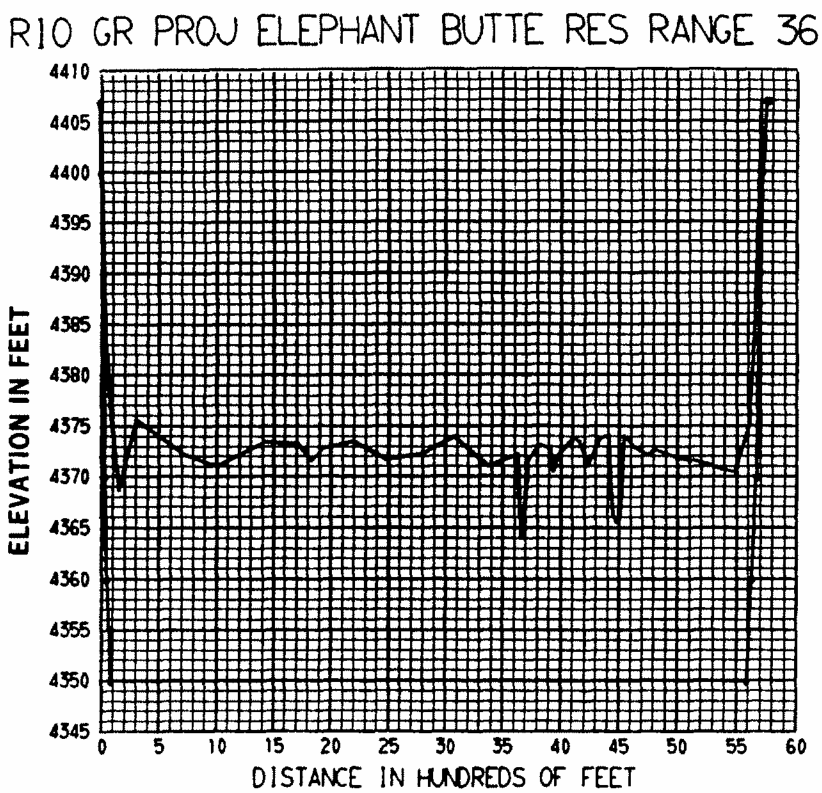


Figure 63. 1915 and 1969 sedimentation range profiles—Range 36.

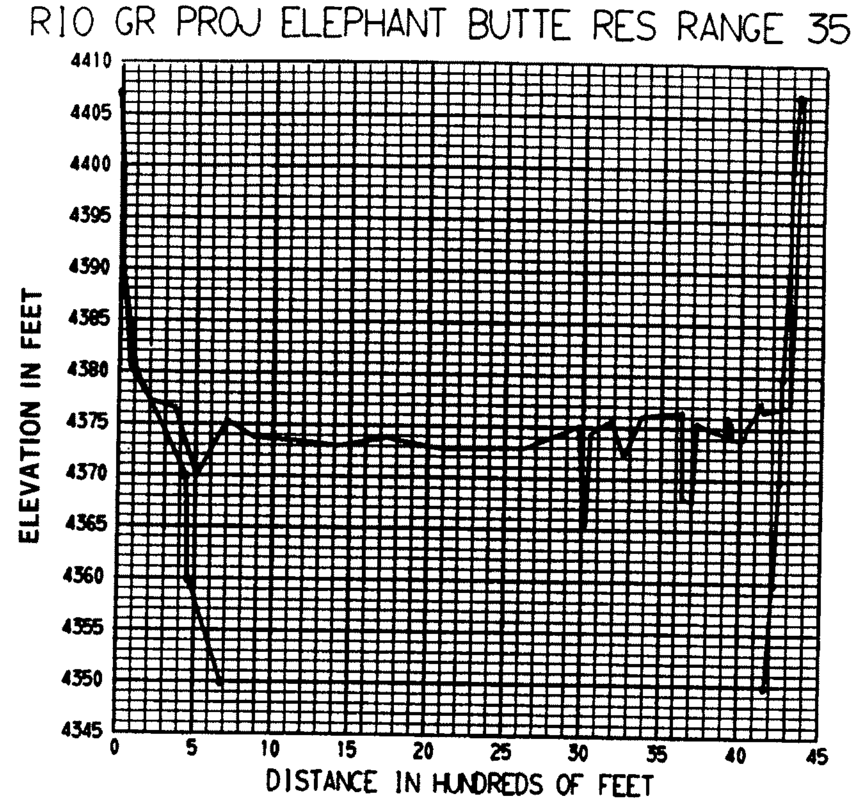


Figure 64. 1915 and 1969 sedimentation range profiles—Range 35.

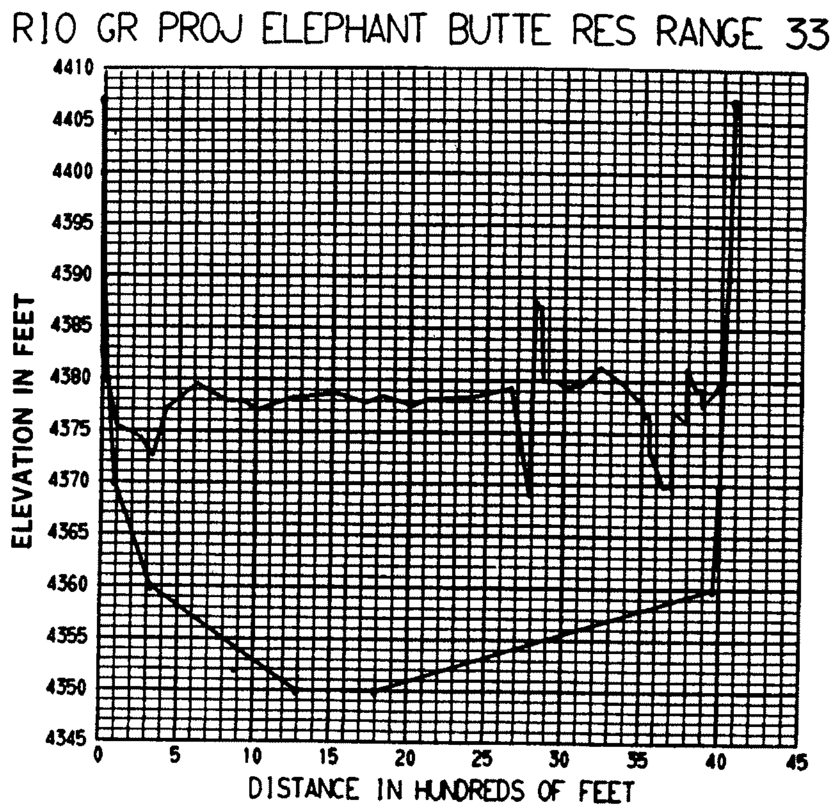


Figure 65. 1915 and 1969 sedimentation range profiles—Range 33.

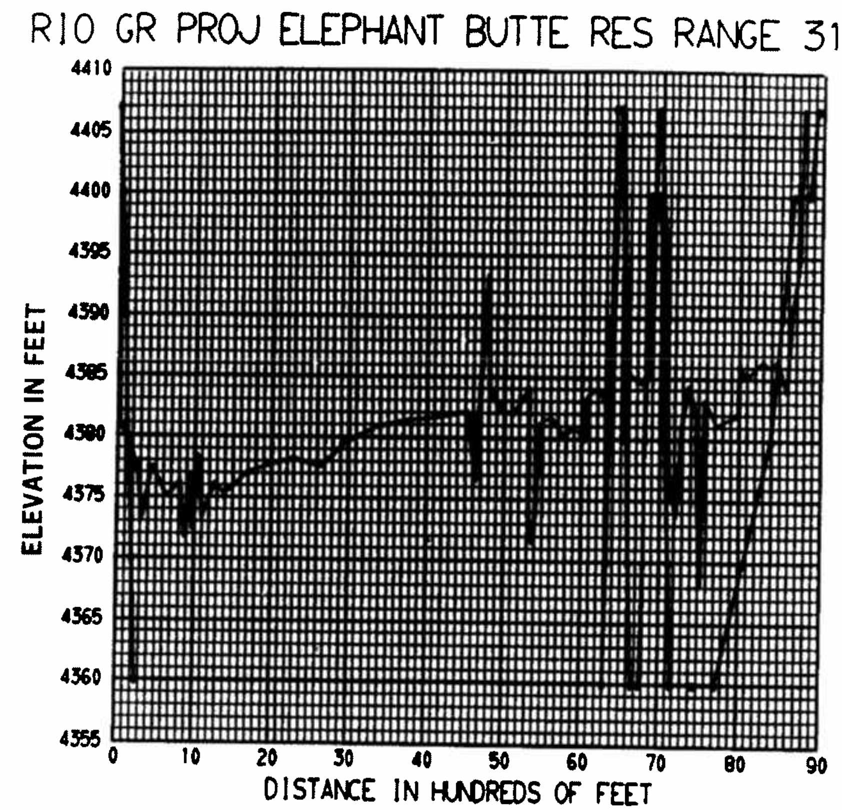


Figure 66. 1915 and 1969 sedimentation range profiles--Range 31.

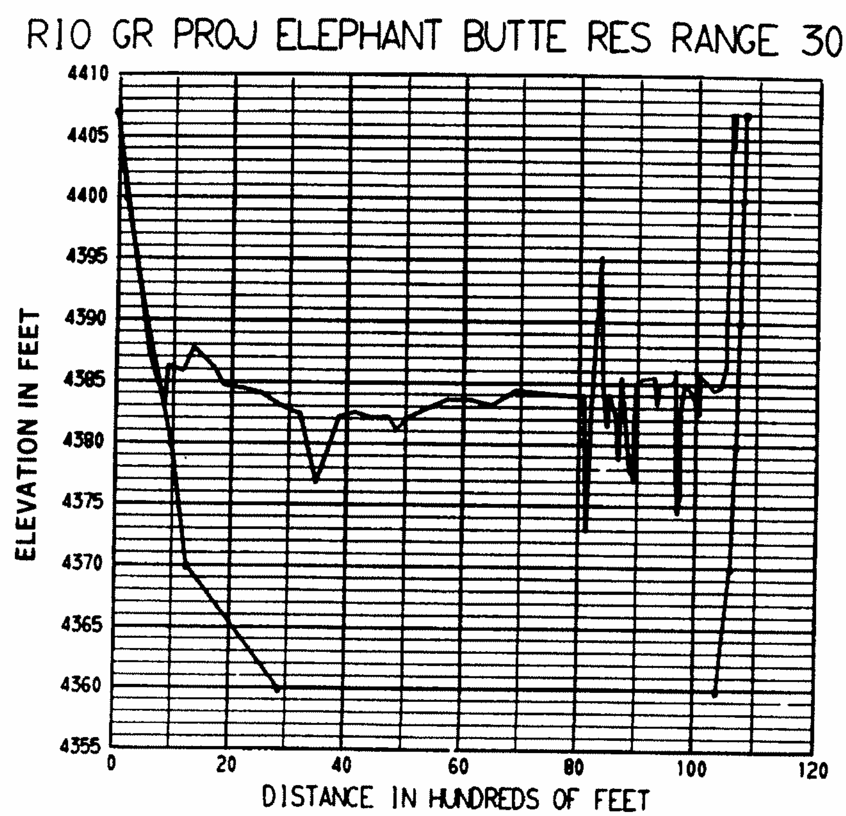


Figure 67. 1915 and 1969 sedimentation range profiles--Range 30.

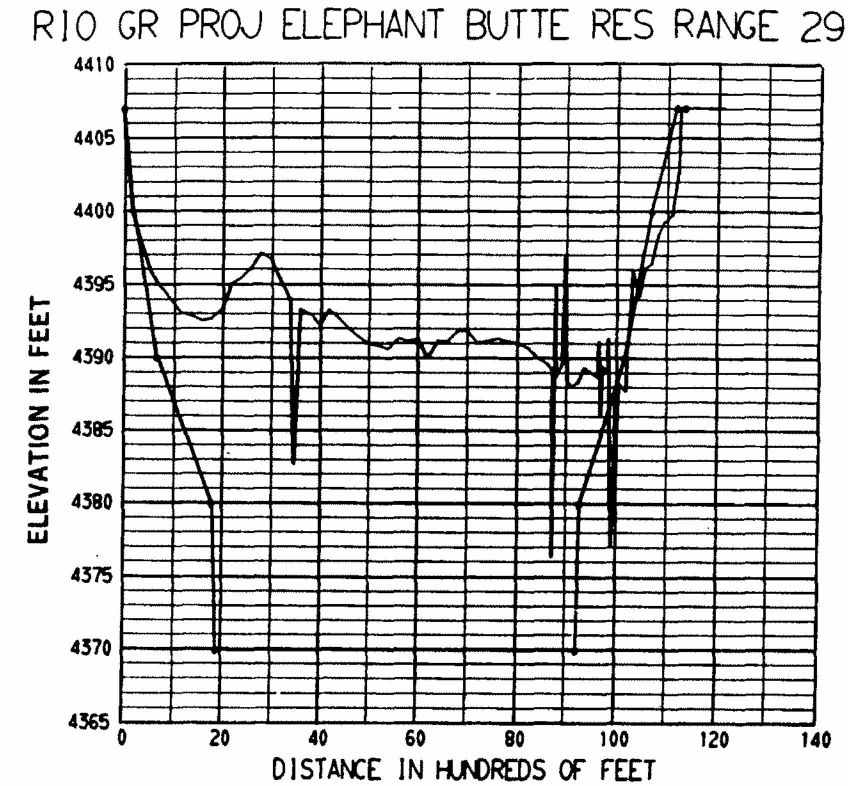


Figure 68. 1915 and 1969 sedimentation range profiles--Range 29.

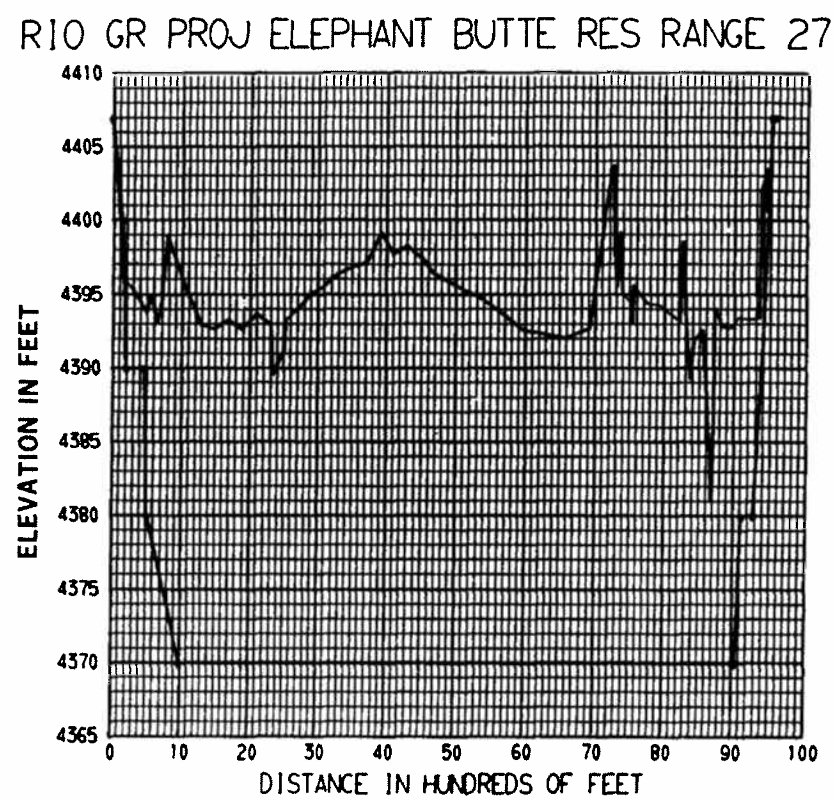


Figure 69. 1915 and 1969 sedimentation range profiles -Range 27.

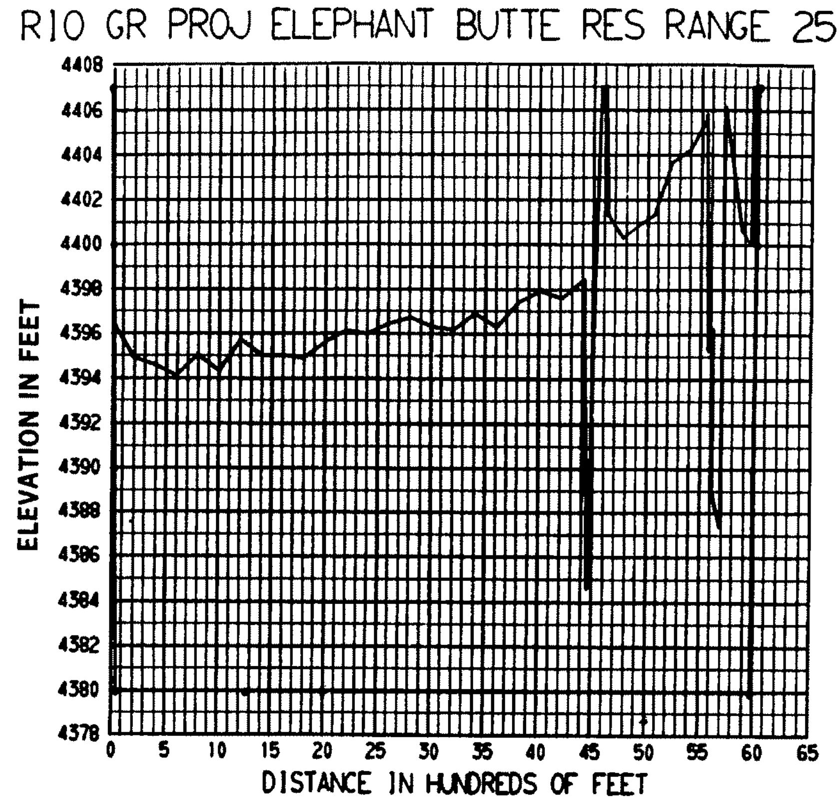


Figure 70. 1915 and 1969 sedimentation range profiles—Range 25.

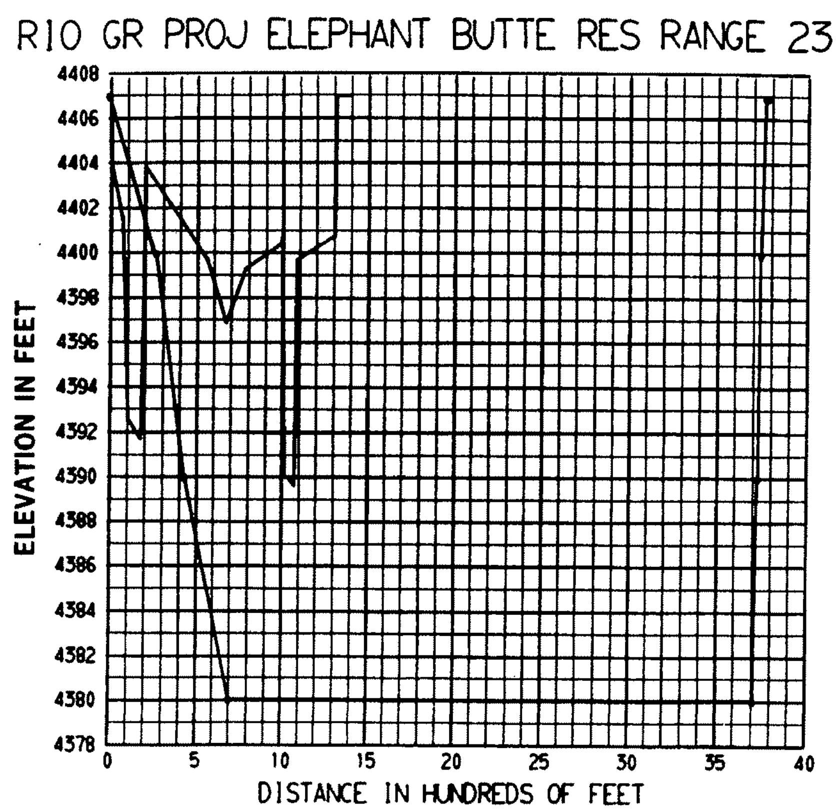


Figure 71. 1915 and 1969 sedimentation range profiles—Range 23.

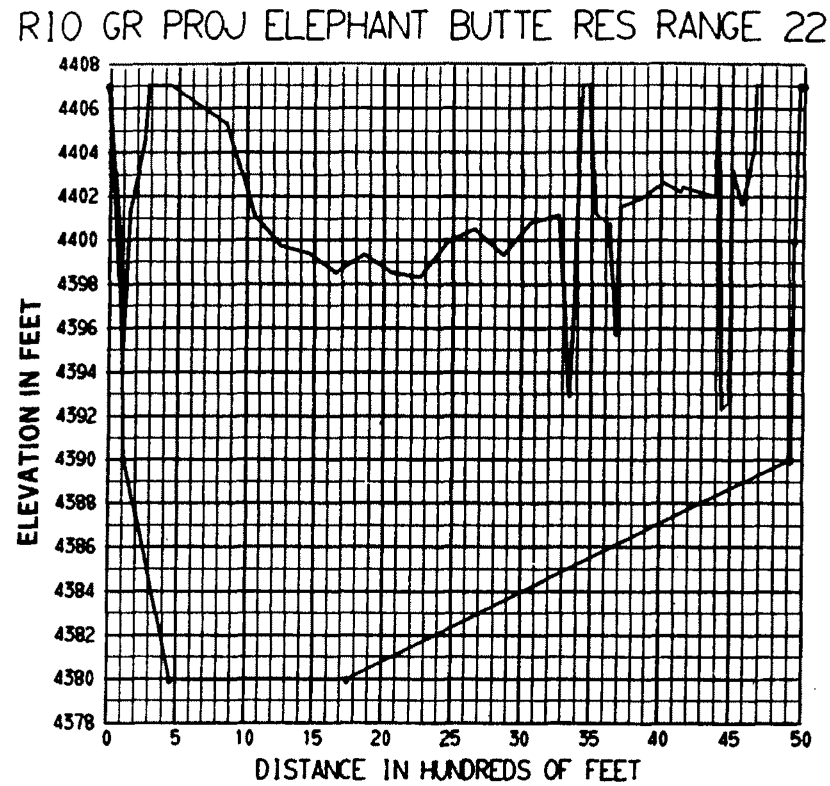


Figure 72. 1915 and 1969 sedimentation range profiles—Range 22.

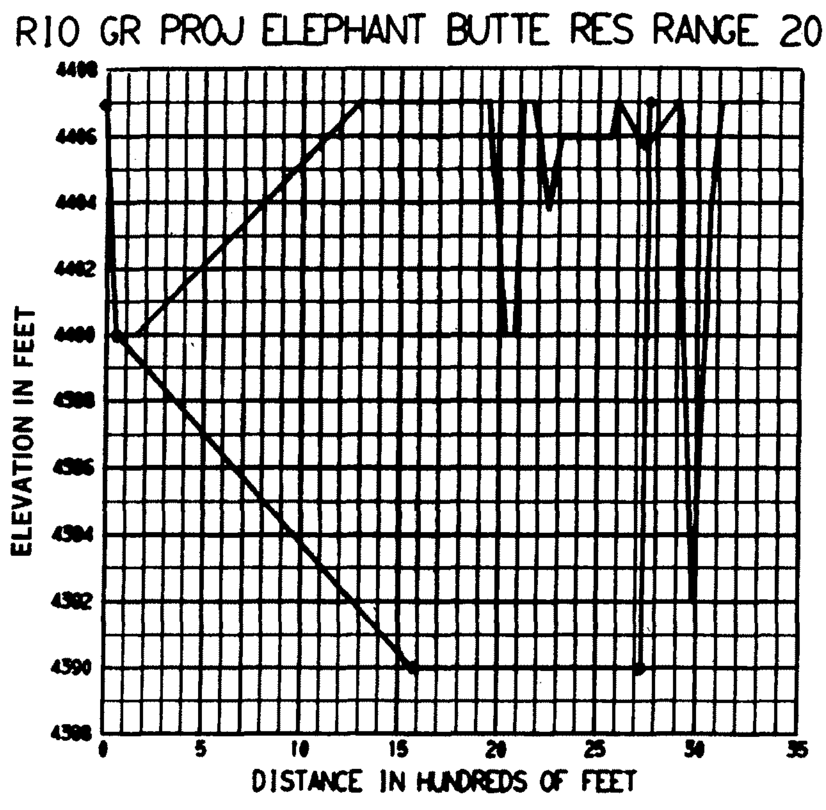


Figure 73. 1915 and 1969 sedimentation range profiles—Range 20.

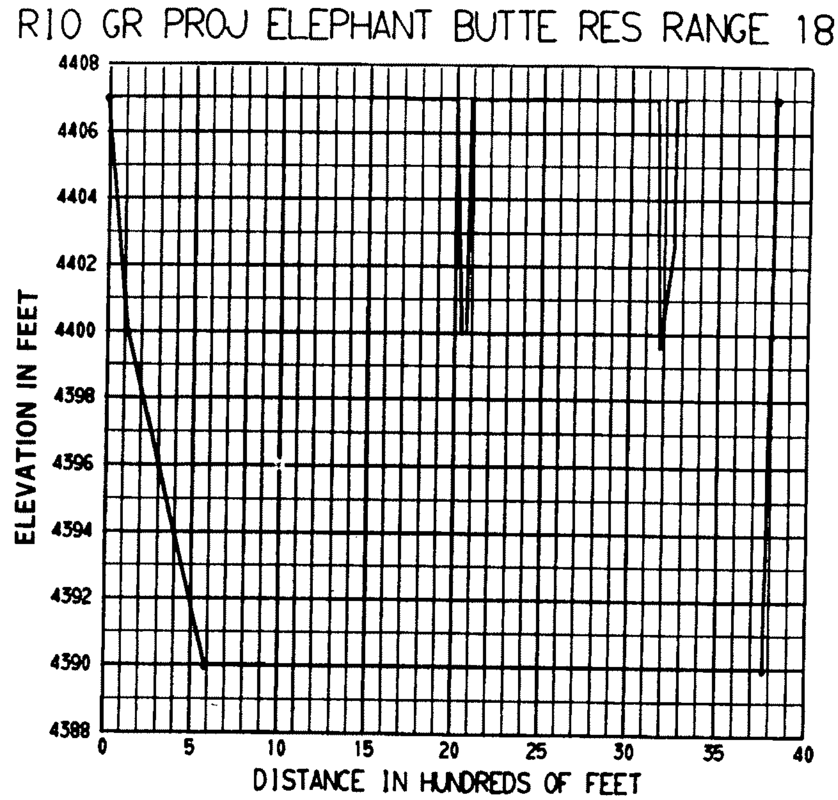


Figure 74. 1915 and 1969 sedimentation range profiles—Range 18.

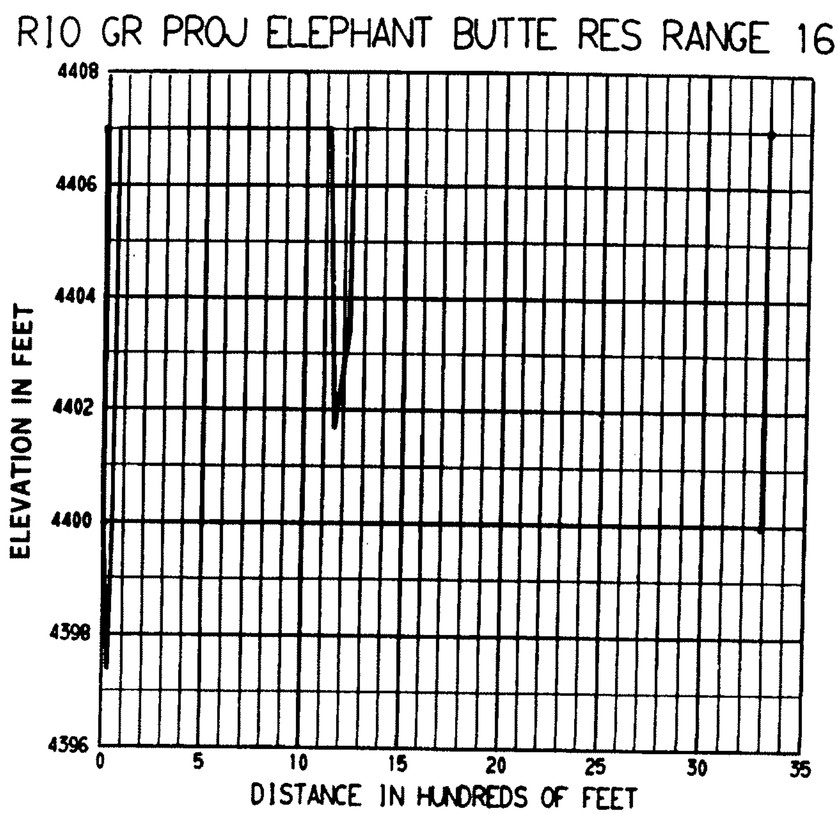


Figure 75. 1915 and 1969 sedimentation range profiles—Range 16.

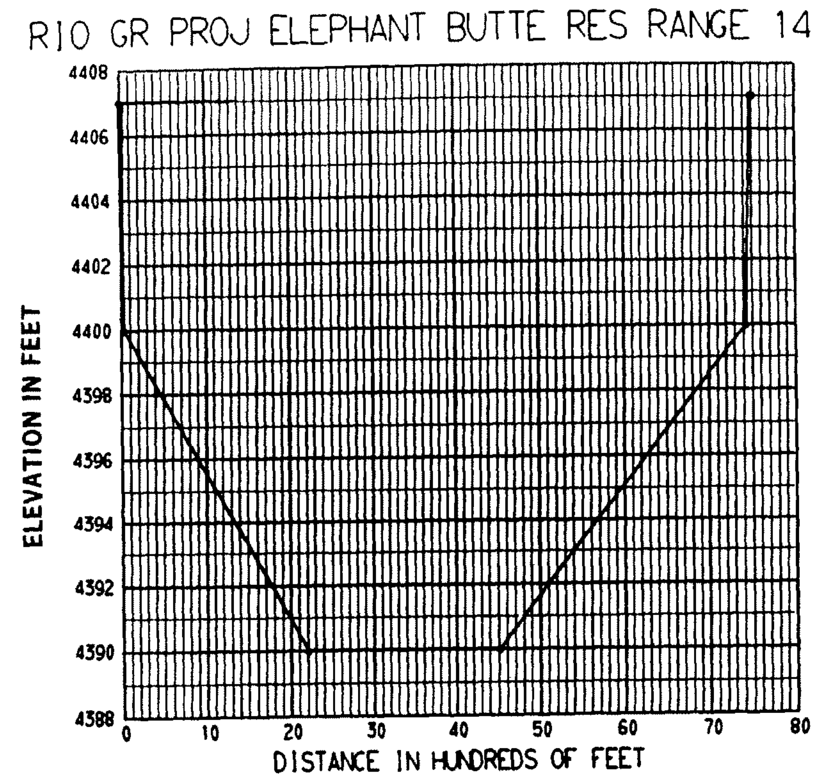


Figure 76. 1915 and 1969 sedimentation range profiles—Range 14.

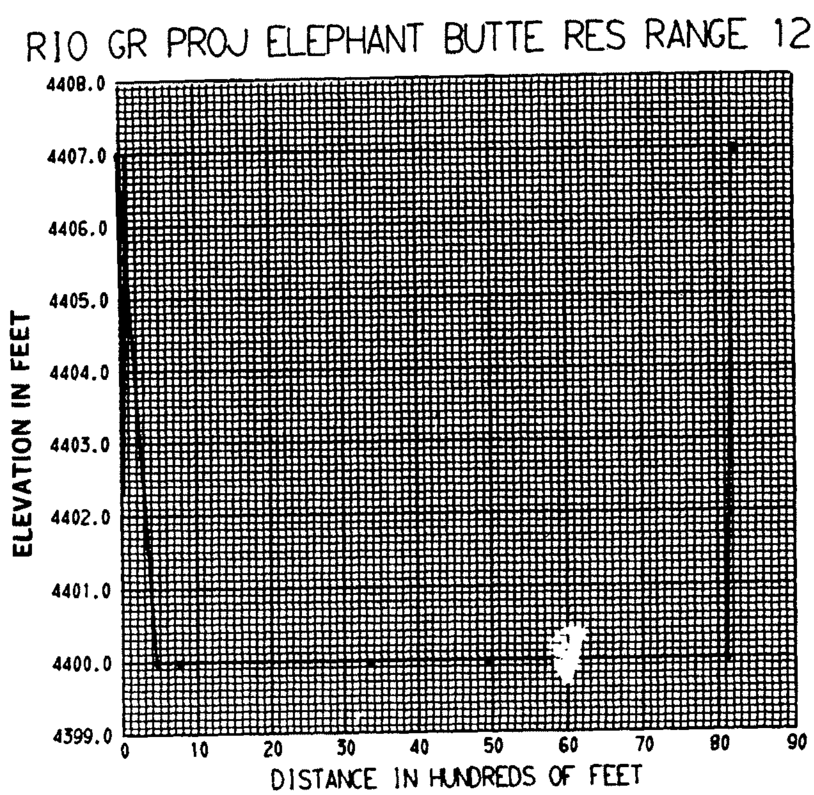


Figure 77. 1915 and 1969 sedimentation range profiles—Range 12.

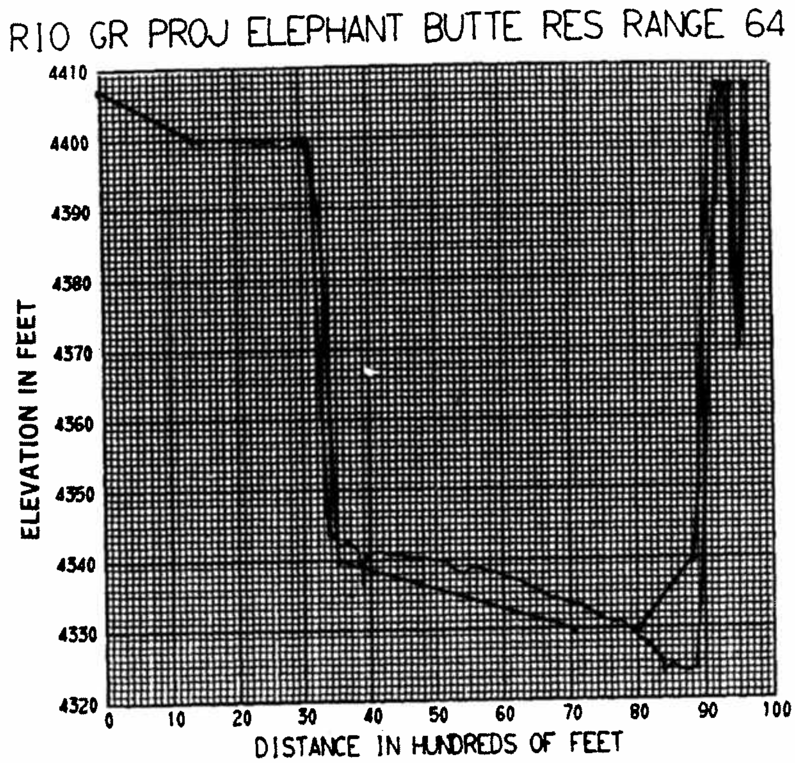


Figure 78. 1915 and 1969 sedimentation range profiles—Range 64 (located across mouth of Monticello Canyon).

# 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 | $1.12985 \times 10^6$ | Centimeter-dynes |
| Foot-pounds | 0.138255 | Meter-kilograms |
| Foot-pounds | $1.35582 \times 10^7$ | 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 | *$0.965873 \times 10^{-6}$ | 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 | *$4.4482 \times 10^5$ | 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 843-205

## ABSTRACT

The Elephant Butte Reservoir was surveyed in 1969 to gather data needed in computing the present reservoir capacity. The data were also used to compute the volume of sediments that accumulated in the reservoir since the dam was closed in 1915. Reservoir capacity is 2,137,200 acre-feet and the surface area 36,600 acres at spillway crest elevation 4407 feet. Sediments accumulated at an annual rate of 9,164 acre-feet between 1915 and 1969. Seventeen sediment samples of reservoir deposits were collected from sites of the reservoir ranges immediately above the dam during the 1969 survey. An average unit weight of 62 lb/cu ft was determined from analyses of samples collected during 1952, 1957, and 1969. Particle size analyses of these samples indicated an average breakdown of 60 percent clay, 31 percent silt, and 9 percent sand. Sonic depth recording apparatus 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 8 to 42 feet throughout the reservoir length. Depths ranged from 10 to 44 feet for the laterally deposited sediments.



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