PUEBLO RESERVOIR
1993 SEDIMENTATION SURVEY

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16. ABSTRACT

The Bureau of Reclamation surveyed Pueblo Reservoir in April 1993 to compile field data for computing a present storage-elevation relationship. The report describes the survey procedures and equipment used during the 1993 collection and provides data for future surveys. The report also provides results of the investigation to monitor changes caused by sediment accumulation in the reservoir since dam closure on January 9, 1974.

As of May 1993, at reservoir spillway crest elevation (feet) 4898.7, the surface area was 5,671 acres, and the total capacity was 349,940 acre-feet. Since the reservoir's initial filling in January 1974, 8,181 acre-feet of sediment have been trapped in Pueblo Reservoir, resulting in a 2.28-percent loss in reservoir capacity. The average annual rate of sediment accumulation since 1974 is 423.9 acre-feet.

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PUEBLO RESERVOIR

1993 SEDIMENTATION SURVEY

by

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May 1994

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The Bureau of Reclamation's Sedimentation Section prepared and published this report. The hydrographic survey was supervised by Ronald Ferrari, Hydraulic Engineer. The hydrographic survey was assisted by personnel from the Eastern Colorado Projects Office and the Pueblo Reservoir Operations Office, who also conducted the field work of locating and flagging the existing sediment range end markers and surveying all the above water ranges. Ronald Ferrari completed the data processing, sediment computations, area-capacity tables, and the report. Joseph Lyons, Hydraulic Engineer, was consulted in the sediment computations and report preparation.

U.S. Department of the Interior
Mission Statement

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally-owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

CONTENTS

TABLES

Table

FIGURES

Figure

CONTENTS — CONTINUED

FIGURES — CONTINUED

INTRODUCTION

Pueblo Dam and Reservoir, located on the Arkansas River in Pueblo County, are 6 miles west of the city of Pueblo in south-central Colorado. Pueblo Reservoir, formed by Pueblo Dam, is one of the major storage features of the Fryingpan-Arkansas Project. The Fryingpan-Arkansas Project is a multipurpose, transmountain development which diverts water from the Fryingpan River and tributaries on the western slope of the Rocky Mountains to the Arkansas River on the eastern slope. Additional reservoirs that form the project include Ruedi Reservoir on the western slope and Turquoise Lake, Mt. Elbert Forebay Reservoir, and Twin Lakes Reservoir on the eastern slope. Pueblo Reservoir is the largest and the terminal storage feature of the Fryingpan-Arkansas project (fig. 1).

Construction of the Fryingpan-Arkansas Project was authorized by Public Law 87-590 (76 Stat. 389) and signed by the President on August 16, 1962. Construction of Pueblo Dam began in 1970 and was completed in August 1975. The left embankment was modified in 1980 by the addition of a downstream stability berm to provide protection against potentially weak foundation soils. Initial water storage began on January 9, 1974. Maximum elevation was attained in water year 1986 at reservoir elevation 4887.1 feet.

Pueblo Dam is a composite concrete and earthfill structure, about 10,200 feet long at crest elevation 4925.0. The concrete section has a structural height of 250 feet and a hydraulic* height of 191 feet. The earthfill portions consist of the left and right abutment embankments, totaling 8,450 feet in length. The concrete dam consists of 23 massive-head buttresses which total 1,750 feet in length, and has a 550-foot overflow spillway section and a 1,200-foot nonoverflow section (fig. 2).

The uncontrolled overflow spillway has a crest elevation of 4898.7 feet and is located in the overflow section of the buttresses. The spillway consists of a concrete ogee crest, training walls, flip bucket, stilling basin, and an outlet channel. The spillway design flow is 191,500 ft^3/s (cubic feet per second) at reservoir elevation 4919.0.

Five separate outlets operate at Pueblo Dam. The Bessemer Ditch, located in the right embankment, is controlled by four high-pressure gates with a maximum discharge of 393 ft^3/s. The river outlet, located in the buttress over the streambed, is controlled by two gates with a maximum discharge of 1,120 ft^3/s. The spillway outlets, located under the spillway, consist of three gated conduits with a maximum discharge of 8,190 ft^3/s. The fish hatchery outlet, located in the buttress, is controlled by multilevel gated intakes for controlling water quality to the downstream fish hatchery. The maximum discharge rate is 30 ft^3/s. The south outlet, located in a buttress, has gated intakes and supplies a maximum discharge of 345 ft^3/s of municipal and industrial water (fig. 3).

Pueblo Reservoir has an approximate length of 11.4 miles and an average width of 0.8 miles at reservoir pool elevation 4900.0. The average width is determined by dividing the surface area by the reservoir length at elevation 4900.0. The total Arkansas River drainage area above the dam is 4,669 square miles, of which an estimated 4,170 square miles contributes

* The definition of terms such as "structural height," "hydraulic height," etc., may be found in manuals such as Reclamation's *Design of Small Dams* and *Guide for Preparation of Standing Operating Procedures for Dams and Reservoirs*, or ASCE's *Nomenclature for Hydraulics*.

sediment inflow. The estimated sediment contributing area is the total drainage area minus the contributing drainage areas above the dams located in the drainage area above Pueblo Reservoir.

At the beginning of reservoir storage in January 1974, Pueblo Reservoir had a calculated surface area of 5,671 acres and a capacity of 357,821 acre-feet at spillway crest elevation 4898.7.

SUMMARY AND CONCLUSIONS

This report presents the results of an investigation to monitor changes caused by sediment accumulations in Pueblo Reservoir after 19.3 years of reservoir operations. The report also describes the surveying procedures and equipment used in the 1993 investigation and provides data for future survey use. The primary purpose of the 1993 survey was the collection of data to compute the area-capacity relationships for operation of Pueblo Reservoir.

Table 1 contains a summary of reservoir sediment data for the 1993 survey. The 1993 survey determined that the reservoir has a storage capacity of 349,940 acre-feet and a surface area of 5,671 acres at spillway crest elevation 4,898.7. Since closure in January 1974, the reservoir has accumulated a volume of 8,181 acre-feet of sediment below elevation 4,898.7. This volume represents a 2.28-percent loss in total capacity and an average annual loss of 423.9 acre-feet for the operating period of January 1974 through May 1993.

DESCRIPTION OF BASIN

The Arkansas River originates in central Colorado and flows in a southerly direction to above Salida, Colorado, and then eastward to Pueblo Reservoir. The mean annual runoff of the drainage basin above Pueblo Reservoir prior to its construction was 511,800 acre-feet. The runoff was calculated using the 80-year average flow at the USGS (U.S. Geological Survey) gauge Arkansas River near Pueblo, Colorado, which was located about 5 miles downstream from the dam location. The total drainage area above Pueblo Dam is 4,669 square miles, and the net sediment contributing area is estimated to be 4,170 square miles. The net contributing area includes removal of areas above the upstream developed reservoirs that are assumed to trap all sediment inflow. The upper Arkansas River is a steep mountain stream, and the basin has about 25 mountain peaks above 14,000 feet. The river emerges from the mountainous area through the Royal Gorge, where the valley gradually gets wider through the foothills to the plains around Pueblo.

The vegetative cover in the basin above Pueblo is widely diversified because of the wide range of annual precipitation. The highest mountain peaks are above timberline and are devoid of cover. In the timber areas, conifers, aspens, brush, and grasses are found. In the woodland zone, pinon, juniper, scrub oak, sagebrush, and scattered growths of bunch grass predominate. In the plains region, vegetation consists mainly of grasses, shrubs, and occasional cactuses. The only trees in the plains region are cottonwood, willow, tamarisk, and associated deciduous trees that fringe the water courses and irrigation ditches.

Wide variations of climate occur in the Arkansas Basin. In the mountainous regions, the precipitation varies widely over relatively short distances. Much of the total precipitation occurs in the form of snow. In the plains, most of the precipitation is from rainfall, which at times occurs in the form of violent cloudbursts, producing small volumes but causing short-

duration flash floods of damaging intensities. The recorded annual normal precipitations within the watershed vary from 9 to 19 inches. Because of the variation in altitude, the mean annual temperatures range from 37 to 54 °F, and the extremes range from -54 to 105 °F.

RESERVOIR OPERATIONS

The reservoir is a multiuse facility having (following values are from May 1993 area-capacity tables):

- 131,504 acre-feet of surcharge storage between elevations 4898.70 and 4919.00
- 27,044 acre-feet of flood control storage between elevations 4893.79 and 4898.70
- 65,716 acre-feet of joint use storage between elevations 4880.54 and 4893.79
- 229,059 acre-feet of conservation storage between elevations 4796.70 and 4880.54
- 25,792 acre-feet of inactive storage between elevations 4764.00 and 4796.7
- 2,329 acre-feet of dead storage between elevations 4752.80 and 4764.00

Records for Pueblo Reservoir show a calculated average unregulated inflow of 595,355 acre-feet per year. The estimated mean annual runoff from the basin is 2.06 inches. Since normal operations have begun, Pueblo Reservoir operation has ranged from a minimum end-of-month elevation of 4873.4 in water year 1987 to a maximum elevation of 4887.1 in water year 1986. The inflow and end-of-month stage records in table 1 show the extreme annual fluctuation of the reservoir.

SURVEYS

Original Survey

The original sediment ranges were surveyed by the Bureau of Reclamation prior to inundation of water behind Pueblo Reservoir dam and are referred to as the original, or 1974, data. For future reference, Table 3 lists the local and state plane coordinates for the range line end points. Several of the ranges had portions of them resurveyed prior to inundation to account for construction borrow pit areas. The finalized original range line data used the resurvey data. Figure 4 illustrates the range line network for Pueblo Reservoir.

The original surface areas for Pueblo Reservoir were determined by planimetering topographic maps of the reservoir area developed prior to inundation—Map Numbers 382-706-2270 to 382-706-2290. The topographic maps have a scale of 1 inch equals 400 feet and a 5-foot contour interval. This study used these maps for digitizing the affected segmented areas as described in the reservoir area and capacity section.

1993 Resurvey

Fieldwork for the 1993 survey began in the spring of 1993. The hydrographic survey was completed in late April near reservoir elevation 4859.0. The preliminary field work, performed by personnel from the Eastern Colorado Projects Office and the Pueblo Reservoir Operations Office, consisted of locating and flagging the existing sediment range end markers, relocating the destroyed ones, and surveying the range lines not accessible by boat. The hydrographic survey was performed using Reclamation's small boat bathymetric survey system. The small boat system consisted of a sonic depth recorder and a reflector prism mounted on the boat. The distances from a known point, usually one of the range end markers, to the small boat were determined as the boat proceeded along the range line by an EDM (electronic distance measuring) instrument set up on shore and aimed at the mounted reflector target. Range distances were communicated by radio from the shore to the boat at preselected intervals and marked on the sonar charts as the boat proceeded across the reservoir. The boat was held on course as closely as possible by radio communication from the EDM operator to the survey boat. This system was used to collect the underwater data for range lines 1 through 10A, 20, 21, 30, 40, 41, 42, 50, and 60. The data for range lines 11 through 16, 43, 51, 61, and 62 were collected by conventional land survey methods. Data were not collected for range lines 17, 18, and 70 because their location was not affected by previous reservoir operations.

RESERVOIR AREA AND CAPACITY

Development of 1993 Contour Areas

For the purposes of the sedimentation analysis and to better represent storage changes, the reservoir was subdivided into segments, using the range lines to delineate the limit of each segmental boundary. The 1993 reservoir surface areas were computed by the width adjustment method described by Blanton (1982) and illustrated on figure 5. The method entails computing the new segmented contour area, A_1, between ranges by applying an adjustment factor to the original segmental contour area, A_0. The computed adjustment factor for each segment was the ratio of the new average width to the original average width for the ranges, outlining the segment at the specified contour elevation. The input data included the original and 1993 range line data along with the segmented areas for the affected contour elevations. A comparison of simultaneous plots of original and 1993 range profiles indicated the lateral distribution of sediment at the different measured contour elevations. Where these plots indicate changes have occurred on the side slopes of the reservoir, a decision was made to determine whether the change was caused by actual deposition, erosion, or survey inaccuracies. No area adjustment was made if the measured change was judged to be caused by survey inaccuracy. The 1993 total reservoir surface area at a given contour is the original total area minus the summation of all segmental areas silted in at that elevation. The 1993 total area computation results are listed in column (2) of table 2.

1993 Revised Storage Capacity

The storage-elevation relationships based on the 1993 underwater survey data were developed using Reclamation's area-capacity computer program ACAP85 (Reclamation, 1985). The 1993 surface areas resulting from the width adjustment computations at 5-foot contour intervals were used as the control parameters for computing reservoir capacity. The program

computes an area at 0.01- to 1.0-foot area increments by linear interpolation between the given contour intervals. The program begins by testing the initial capacity equation over successive intervals to ensure that the equation fits within an allowable error limit, which was set at 0.000001 for Pueblo Reservoir. This capacity equation is then used over the full range of intervals fitting within this allowable error limit. For the first interval at which the initial allowable error limit is exceeded, a new capacity equation (integrated from the basic area curve over that interval) begins testing the fit until it also exceeds the error limit. Thus, the capacity curve is defined by a series of curves, each fitting a certain region of data. Final area equations are derived by differentiating the capacity equations, which are of second order polynomial form:

$$y = a + a_2x + a_3x^2$$

where: y = capacity,
x = elevation above a reference base,
a = intercept, and
a_2 and a_3 = coefficients

Results of the 1993 Pueblo Reservoir area and capacity computations are listed in tables 1 and 2 and plotted on figure 6. A separate set of 1993 area and capacity tables will be published for the 0.01-, 0.1-, and 1-foot elevation increments (Reclamation, 1993). The 1993 area and capacity computations results are listed in columns (4) and (5) of table 2. Column (2) in the table gives the original measured contour areas used in the original area and capacity computation, and column (3) gives the original capacity computed by ACAP. Both the original and 1993 area and capacity curves are plotted on figure 6 for a visual comparison of changes. The 1993 survey determined that the reservoir has a storage capacity of 349,940 acre-feet and a surface area of 5,671 acres at spillway crest elevation 4898.7.

SEDIMENT ANALYSES

Sediments have accumulated in Pueblo Reservoir to a total volume of 8,181 acre-feet below elevation 4898.7, spillway crest, since storage began in January 1974. This volume represents a 2.28-percent loss in total capacity and an average annual accumulation rate of 423.9 acre-feet for the 19.3-year period of operation. The net sediment accumulation rate from the contributing basin was 0.102 acre-feet per square mile per year for the same period. The measured annual inflow rate is about 41 percent of the original annual estimate of 1,031 acre-feet.

Before projecting future sediment accumulation, the original estimate needs to be reanalyzed using the John Martin and Pueblo Reservoir sedimentation survey information. John Martin Reservoir is located downstream from Pueblo Reservoir and had a net contributing drainage area of 18,102 square miles prior to Pueblo Reservoir closure in 1974. Ten sediment surveys were conducted on John Martin Reservoir from April 1942 through March 1972. The calculated average annual sediment accumulation between the surveys varied from -0.0398 to 0.443 acre-feet per square mile. For the 29.9-year period, the annual sediment accumulation rate was 0.148 acre-feet per square mile for the contributing drainage area. A sedimentation survey conducted in June 1980 calculated an annual sediment accumulation rate, from March 1972, of 0.077 acre-feet per square mile for the reduced net contributing drainage area. The John Martin Reservoir values illustrate the extreme variation of the calculated annual sediment accumulation values between surveys.

It is recommended that an annual rate of 0.130 acre-feet per square mile of contributing drainage area be used for projecting sediment accumulation in Pueblo Reservoir. This value was determined using the 29.9-year annual rate for John Martin Reservoir and the 19.3-year annual rate for Pueblo Reservoir. This value will be better defined in the future after each survey of Pueblo Reservoir.

The results of the sediment data and volume computations for the 1993 survey are shown in tables 1 and 2. The data include a tabulation of incremental sediment inflow volume and sediment accumulation computed for the period between initial conditions and the 1993 resurvey. Table 1 includes information on the drainage basin, records of estimated inflow, reservoir operations, and reservoir storage.

RESERVOIR SEDIMENT DISTRIBUTION

Longitudinal Distribution

The distribution of sediment throughout the length of the reservoir is illustrated by plots of the thalweg profile representing the original and 1993 resurveyed profiles for the Arkansas River as shown on figure 7. Thalweg elevations representing original and resurveyed reservoir conditions were taken from the original and 1993 survey notes. Except for the possibility of some missed low points, the plotted profile should closely resemble actual channel bottom conditions during the original range survey completed prior to inundation of the reservoir. Except for some minor inaccuracies in sounding and being slightly off line, the bottom of the 1974 and 1993 profiles should closely represent channel bottom conditions at the time of those resurveys. The channel distance used for range line location is the original river channel distance from the dam to each range line in an upstream direction on the Arkansas River.

Lateral Distribution

Ground profiles for the 31 original sediment ranges are shown on figures 8 through 38. The survey data were obtained from copies of the original survey data books. Several of the lines had portions resurveyed prior to reservoir inundation to account for borrow pit areas. The original data used for the sedimentation analysis accounted for the borrow pit areas. The 1993 range profile data are superimposed on these plots to indicate the changes which have occurred and to represent in general the lateral distribution of sediment within the reservoir. A 1993 survey was not accomplished for range lines 17, 18, and 70 because they were located upstream from elevation 4900.0, and no reservoir deposition was judged to have occurred above that elevation. For sediment computation purposes, a complete section was needed for all ranges; for this reason, the original data were inserted into the 1993 data file to complete the areas not surveyed in 1993.

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Bureau of Reclamation, Denver Office, "*Pueblo Reservoir Area and Capacity Tables, Fryingpan - Arkansas Project,*" Great Plains Region, Denver, CO, May 1993.

RESERVOIR SEDIMENT
DATA SUMMARY

Pueblo Reservoir
NAME OF RESERVOIR

1
DATA SHEET NO.

DAM	1. OWNER Bureau of Reclamation		2. STREAM Arkansas River		3. STATE Colorado	
	4. SEC. 36 TWP. 20S RANGE 66W		5. NEAREST P.O. Pueblo		6. COUNTY Pueblo	
	7. LAT 38° 16' 15" LONG 104° 43' 30"		8. TOP OF DAM ELEVATION 4925		9. SPILLWAY CREST EL. 4898.7	
RESERVOIR	10. STORAGE ALLOCATION	11. ELEVATION TOP OF POOL	12. ORIGINAL SURFACE AREA, Ac	13. ORIGINAL CAPACITY, AF	14. GROSS STORAGE ACRE- FEET	15. DATE STORAGE BEGAN
	a. SURCHARGE	4,919.00	7,377[1]	131,504	489,325[1]	
	b. FLOOD CONTROL	4,898.70	5,671	27,046	357,821	1/9/74
	c. POWER					
	d. JOINT USE	4,893.79	5,352	65,980	330,775	16. DATE NORMAL OPERATION BEGAN
	e. CONSERVATION	4,880.54	4,642	234,376	264,795	
	f. INACTIVE	4,796.70	1,282	26,661	30,419	8/75
	g. DEAD	4,764.00	421	3,758	3,732	
	17. LENGTH OF RESERVOIR 11.4 MILES			AVG. WIDTH OF RESERVOIR 0.8 MILES		
BASIN	18. TOTAL DRAINAGE AREA 4,669 SQUARE MILES			22. MEAN ANNUAL PRECIPITATION 9" to 19" INCHES		
	19. NET SEDIMENT CONTRIBUTING AREA 4,170[2] SQUARE MILES			23. MEAN ANNUAL RUNOFF 2.06 INCHES		
	20. LENGTH MILES	AV. WIDTH MILES		24. MEAN ANNUAL RUNOFF 595,355[3] ACRE-FEET		
	21. MAX. ELEVATION	MIN. ELEVATION		25. ANNUAL TEMP. MEAN37-54°F RANGE 105°F to(-)54°F		

SURVEY DATA	26. DATE OF SURVEY	27. PER. YRS.	28. ACCL. YRS.	29. TYPE OF SURVEY	30. NO. OF RANGES OR INTERVAL	31. SURFACE AREA, AC.	32. CAPACITY ACRE-FEET	33. C/I RATIO AF/AF
	1/74			Contour (D)	5-ft	5,671[4]	358,121[4]	0.60
	5/93	19.3	19.3	Range (D)	31	5,671[5]	349,940[5]	0.59

26. DATE OF SURVEY	34. PERIOD ANNUAL PRECIP.	35. PERIOD WATER INFLOW, ACRE FEET			WATER INFLOW TO DATE, AF	
		a. MEAN ANN.	b. MAX. ANN.	c. TOTAL	a. MEAN ANN.	b. TOTAL
5/93	9" to 19"	595,355[3]	1,007,400[3]	11,907,100[3]	595,355[3]	11,907,100[3]

26. DATE OF SURVEY	37. PERIOD CAPACITY LOSS, ACRE-FEET			38. TOTAL SEDIMENT DEPOSITS TO DATE, AF		
	a. TOTAL	b. AV. ANN.	c. /MI.^{2}-YR.	a. TOTAL	b. AV. ANNUAL	c. /MI.^{2}-YR.
5/93	8,181	423.9	0.102	8,181	423.9	0.102

26. DATE OF SURVEY	39. AV. DRY WT. (#/FT^3)	40. SED. DEP. TONS/MI.^{2}-YR.		41. STORAGE LOSS, PCT.		42. SEDIMENT INFLOW, PPM	
		a. PERIOD	b. TOTAL TO DATE	a. AV. ANNUAL	b. TOTAL TO DATE	a. PER.	b. TOT.
5/93				0.12	2.28		

26. DATE OF SURVEY	43. DEPTH DESIGNATION RANGE IN FEET BELOW SPILLWAY CREST ELEVATION 4898.7										
5/93		173.7-153.7	153.7-133.7	133.7-113.7	113.7-93.7	93.7-73.7	73.7-53.7	53.7-33.7	33.7-13.7	13.7-crest	
	PERCENT OF TOTAL SEDIMENT LOCATED WITHIN DEPTH DESIGNATION										
		0.8	16.7	2.4	22.0	14.0	12.8	12.6	17.0	1.7	

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	100-105	105-110	110-115	115-120	120-125
	PERCENT OF TOTAL SEDIMENT LOCATED WITHIN REACH DESIGNATION														
	N/A														

Table 1. - Reservoir sediment data summary (page 1 of 2).

45. RANGE IN RESERVOIR OPERATION[6]

YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AF	YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AF
1974	4792.6	4775.6	448,200	1975	4798.8	4790.1	567,900
1976	4821.8	4800.1	414,900	1977	4830.2	4799.6	234,000
1978	4800.8	4797.11	401,500	1979	4820.1	4797.2	581,400
1980	4832.0	4799.8	779,300	1981	4831.4	4797.4	327,400
1982	4837.3	4799.0	618,600	1983	4879.6	4820.0	944,100
1984	4884.3	4868.0	1,007,400	1985	4886.4	4875.3	978,000
1986	4887.1	4876.4	767,400	1987	4881.8	4873.4	792,400
1988	4880.8	4851.2	454,200	1989	4866.1	4838.6	467,600
1990	4851.5	4828.6	427,200	1991	4854.5	4800.0	506,400
1992	4856.4	4823.6	522,300	1993	4863.7	4834.5	666,900

46. ELEVATION - AREA - CAPACITY DATA FOR **1993 CAPACITY**

ELEV.	AREA	CAP.	ELEV.	AREA	CAP.	ELEV.	AREA	CAP.
4752.8	0	0	4755	16	18	4760	318	853
4765	445.7	2,762	4770	471.8	5,056	4775	691.4	7,964
4780	794	11,677	4785	904.3	15,923	4790	1,007	20,701
4795	1,159	26,116	4800	1,280	32,214	4805	1,431	38,991
4810	1,643	46,676	4815	1,813	55,316	4820	2,005	64,861
4825	2,167	75,291	4830	2,368	86,629	4835	2,579	98,996
4840	2,737	112,286	4845	2,910	126,404	4850	3,089	141,401
4855	3,298	157,369	4860	3,530	174,439	4865	3,763	192,671
4870	3,992	212,059	4875	4,238	232,634	4880	4,587	254,696
4885	4,823	278,221	4890	5,115	303,066	4895	5,424	329,414
4898.7	5,671	349,940	4900	5,758	357,369	4905	6,154	387,149
4910	6,532	418,864	4915	6,998	452,689	4920	7,475	488,871
4925	8,027	527,626						

47. REMARKS AND REFERENCES

[1] In May 1984, Reclamation recomputed the area and capacity of Pueblo Reservoir using the cubic spline option of the Bureau of Reclamation program ACAP. The original surface areas were used as input data.

[2] Estimated noncontributing area into reservoir. Sediment inflow is affected by several upstream reservoirs such as Turquoise Lake, Twin Lakes, Clear Creek Reservoir, De Weese Reservoir, and several other small reservoirs and diversion structures.

[3] Calculated inflow to Pueblo Reservoir for water years 1974 through 1993. Runoff contributed by 4,669-square-mile drainage area plus diverted water from the western slope.

[4] Surface area and capacity at spillway crest elevation 4898.7. For sediment computation purposes, the original capacity was recomputed using the segmented least squares fit option of the Bureau of Reclamation program ACAP. This option is the current method used by Reclamation. The original surface areas were used as input data.

[5] 1993 surface area and capacity at spillway crest elevation 4898.7. The 1993 area and capacity tables were computed using the segmented least squares fit option of the Bureau of Reclamation program ACAP. This option is the current method used by Reclamation.

[6] Maximum and minimum end-of-month reservoir elevations for indicated water years. Calculated inflows to Pueblo Reservoir for indicated water years.

48. AGENCY MAKING SURVEY Bureau of Reclamation

49. AGENCY SUPPLYING DATA Bureau of Reclamation | DATE March 1994

Table 1. - Reservoir sediment data summary (page 2 of 2).

(1) Elevation (feet)	(2) Original Area (acres)	(3) Original Total Capacity (acre-feet)	(4) 1993 Area (acres)	(5) 1993 Capacity (acre-feet)	(6) Measured Sediment Volume (acre-feet)	(7) Percent Measured Sediment	(8) Percent Reservoir Depth
4925	8,027	535,807	8,027	527,626	8,181	100.0	-
4915	6,998	460,870	6,998	452,689	8,181	100.0	-
4905	6,154	395,330	6,154	387,149	8,181	100.0	-
4898.7	5,671	358,121	5,671	349,940	8,181	100.0	100.0
4895	5,424	337,595	5,424	329,414	8,181	100.0	97.9
4885	4,853	286,267	4,823	278,221	8,046	98.3	92.1
4875	4,358	240,160	4,238	232,634	7,526	92.0	86.4
4865	3,836	199,325	3,763	192,671	6,654	81.3	80.6
4855	3,361	163,392	3,298	157,369	6,023	73.6	74.8
4845	2,925	132,022	2,910	126,404	5,618	68.7	69.1
4835	2,636	104,260	2,579	98,996	5,264	64.3	63.6
4825	2,239	79,862	2,167	75,291	4,571	55.9	57.6
4815	1,882	59,400	1,813	55,316	4,084	49.9	51.8
4805	1,532	42,420	1,431	38,991	3,429	41.9	46.0
4795	1,288	28,435	1,159	26,116	2,319	28.3	40.3
4785	934	17,555	904.3	15,923	1,632	19.9	34.5
4775	695	9,417	691.4	7,964	1,453	17.8	28.8
4765	447	4,192	445.7	2,762	1,430	17.5	23.0
4755	199	987	16	18	969	11.8	17.3
4752.8	146	608	0	0	608	7.4	16.0
4745	15	62	0	0	62	0.8	11.5
4735	2	10	0	0	10	0.1	5.8
4725	0	0	0	0	0	0	0

(1) Elevation of reservoir water surface.
(2) Original reservoir surface area values.
(3) Original reservoir capacity recomputed using ACAP85 from original measured surface areas.
(4) Reservoir surface area from 1993 survey.
(5) 1993 calculated reservoir capacity from 1993 survey data using ACAP85.
(6) Measured sediment volume = column (3) - column (5).
(7) Measured sediment expressed in percentage of total sediment, 8,181 acre-feet at spillway crest elevation 4898.7.
(8) Depth of reservoir expressed in percentage of total depth of 173.7 feet, from spillway crest and river channel at elevation 4725.0.

Table 2. - Summary of 1993 survey results.

Range	State Plane North	Coordinated East	Range Station	Elevation
R-1L	587,507	2,219,856	10+00	4929.45
R-1R	579,101	2,220,427	94+28	4919.69
R-2L	587,267	2,212,999	10+00	4938.91
R-2R	581,211	2,214,826	73+26	4961.83
R-3L	586,875	2,209,859	10+00	4928.76
R-3R	580,458	2,210,691	74+73	4938.32
R-4L	585,609	2,207,795	10+00	4926.26
R-4R	580,959	2,207,861	56+52	4923.68
R-5L	585,609	2,207,795	10+00	4926.26
R-5R	581,822	2,204,335	61+30	4938.19
R-6L	587,009	2,204,440	10+00	4937.85
R-6R	584,375	2,201,957	46+21	4926.27
R-AL	588,231	2,203,507	10+00	4937.20
R-6AR	586,617	2,199,501	53+21	4964.26
R-7L	590,607	2,201,603	10+00	4950.27
R-7R	587,644	2,197,358	61+78	4994.39
R-8L	593,797	2,197,652	10+00	4980.54
R-8R	590,275	2,197,834	45+27	4934.29
R-9L	593,143	2,193,634	10+00	4917.62
R-9R	590,987	2,193,587	31+57	4971.81
R-9AL	593,918	2,192,468	10+00	4925.00
R-9AR	592,354	2,191,076	30+95	4919.42
R-10L	595,922	2,189,382	10+00	4953.49
R-10R	593,444	2,189,130	34+91	4935.21
R-10AL	597,153	2,187,293	10+00	5026.48
R-10AR	593,383	2,187,623	47+85	4997.72
R-11L	596,567	2,185,286	10+00	4941.71
R-11R	594,223	2,186,209	35+20	5016.18

Table 3. - Range end coordinates (page 1 of 3).

Range	State Plane Coordinates North	East	Range Station	Elevation
R-12L	596,787	2,183,661	10+00	4958.50
R-12R	593,338	2,181,392	51+30	4951.77
R-13L	598,041	2,180,579	10+00	5096.39
R-13R	596,384	2,179,565	29+43	4952.85
R-14L	599,139	2,178,125	10+00	5126.88
R-14R	597,780	2,177,388	25+46	4958.83
R-15L	600,190	2,177,160	10+00	5130.88
R-15R	599,580	2,175,601	26+75	4973.79
R-16L	602,340	2,174,976	10+00	5112.17
R-16R	600,945	2,173,985	27+11	4979.47
R-17L	604,115	2,170,788	10+00	4939.50
R-17R	602,928	2,169,824	25+30	4949.46
R-18L	606,968	2,168,478	10+00	4994.91
R-18R	605,201	2,167,850	28+75	5006.77
R-20L	579,326	2,216,463	10+00	4983.01
R-21R	575,943	2,218,757	33+18	4921.68
R-30L	587,267	2,212,999	10+00	4938.91
R-30R	586,875	2,209,859	41+65	4928.76
R-40L	580,458	2,210,691	10+00	4938.32
R-40R	581,211	2,214,826	52+04	4961.83
R-41L	578,340	2,210,256	10+00	4930.07
R-41R	577,707	2,212,202	30+47	4959.98
R-42L	574,679	2,210,598	10+00	4943.09
R-42R	574,714	2,211,410	18+12	4965.54
R-43L	572,053	2,209,129	10+00	4948.79
R-43R	571,389	2,209,557	17+90	5002.19
R-50L	581,822	2,204,335	10+00	4938.19
R-50R	580,959	2,207,861	46+31	4923.68

Table 3. - Range end coordinates (page 2 of 3).

Range	State Plane North	Coordinated East	Range Station	Elevation
R-51L	580,671	2,202,892	10+00	4927.46
R-51R	579,872	2,203,306	19+00	4922.49
R-60L	593,900	2,194,423	10+00	4947.93
R-60R	593,918	2,192,468	29+56	4925.00
R-61L	595,481	2,192,879	10+00	4928.07
R-61R	595,486	2,191,910	19+70	4960.04
R-62L	596,983	2,194,953	10+00	4966.23
R-62R	596,932	2,192,876	30+78	4928.63
R-70L	593,931	2,180,234	10+00	4970.61
R-70R	593,338	2,181,392	23+02	4951.77

Table 3. - Range end coordinates (page 3 of 3).

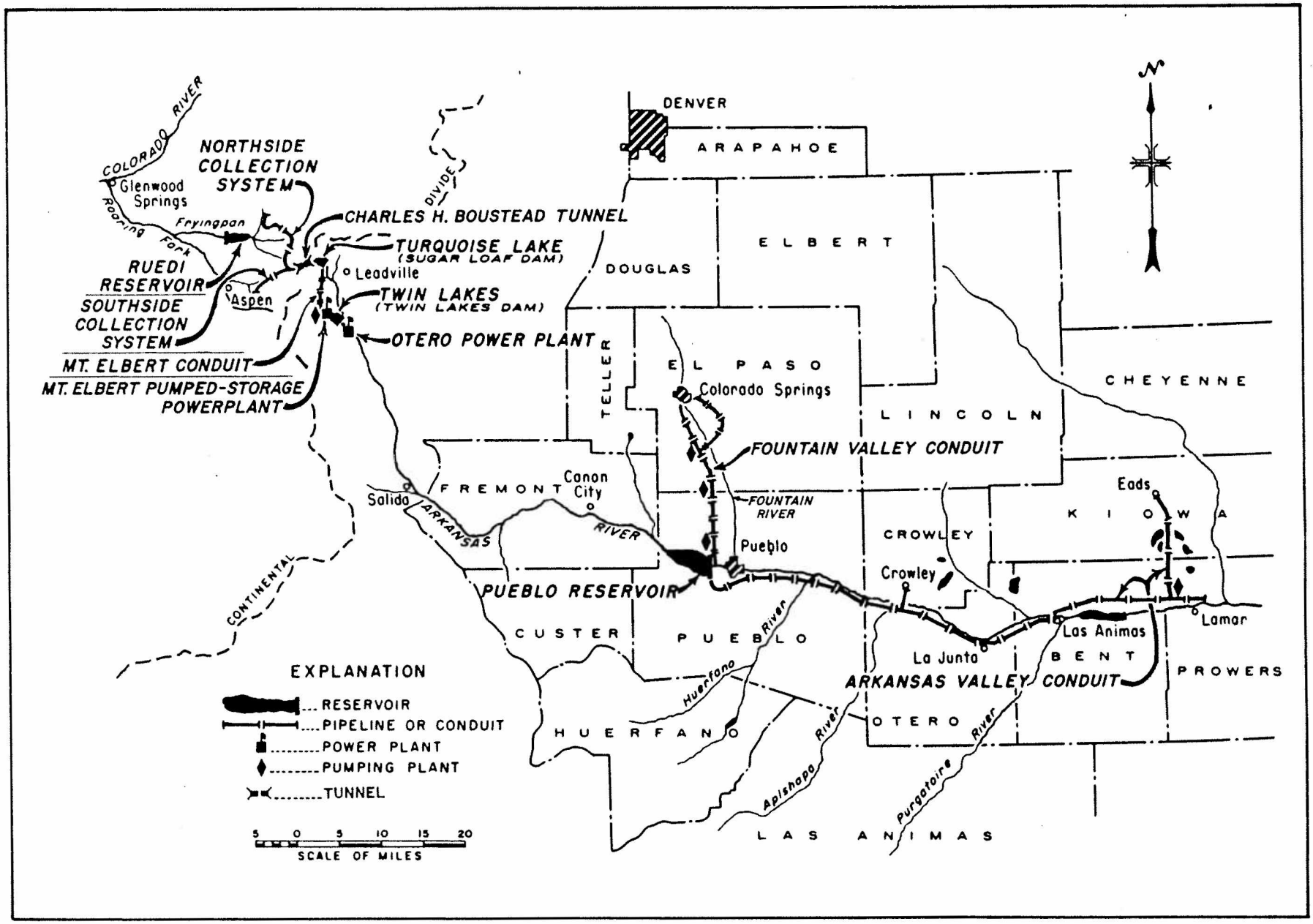

Figure 1. - Pueblo Reservoir location map.

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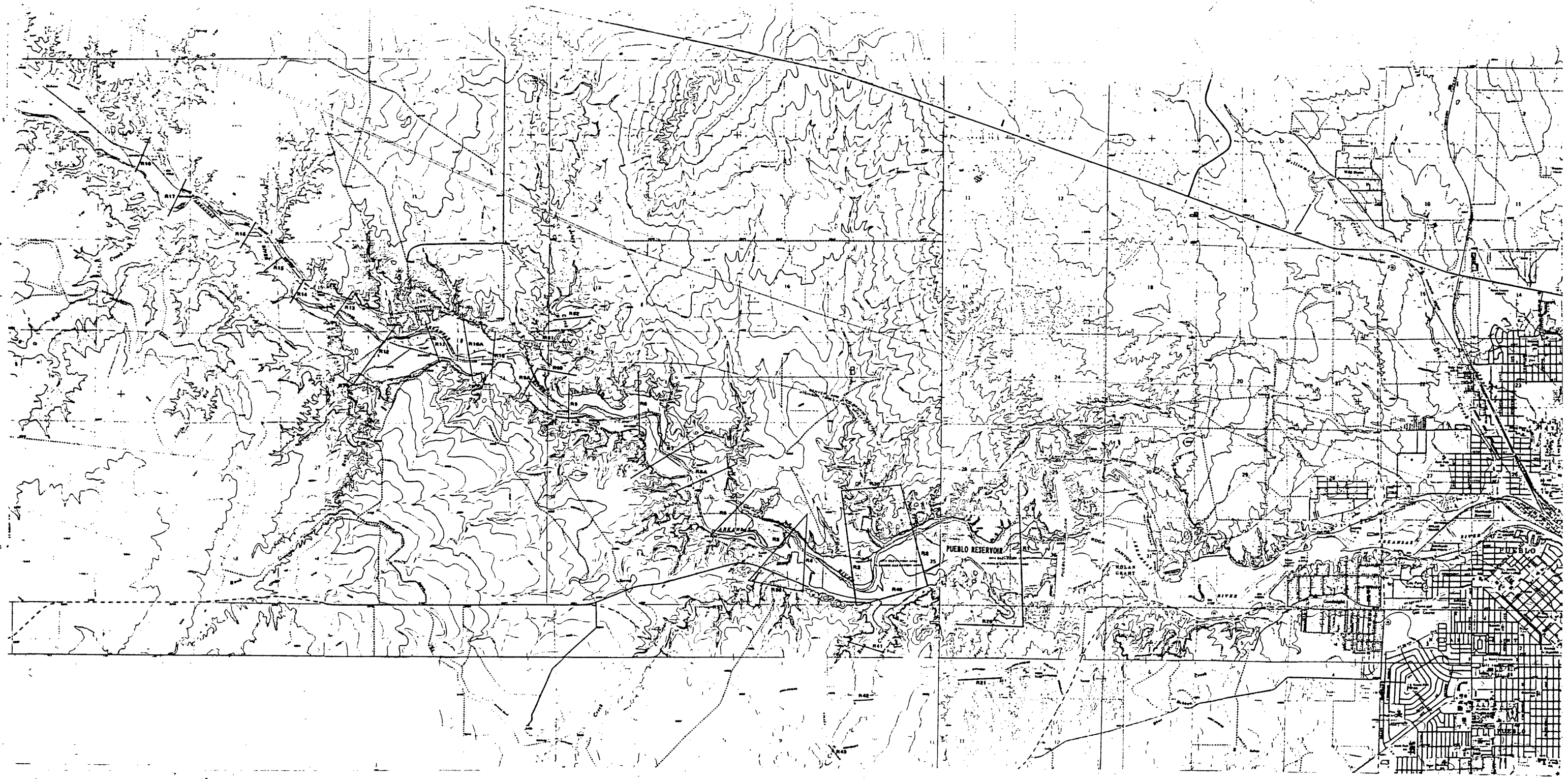
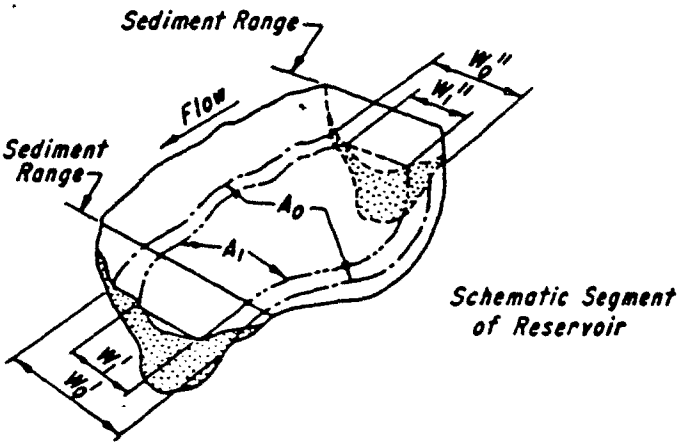


Figure 4. - Pueblo Reservoir range location map.

WIDTH ADJUSTMENT METHOD FOR REVISING CONTOUR AREAS IN COMPUTATION OF RESERVOIR SEDIMENTATION



Initial Survey	New Survey
A_0 = Contour Area	A_1 = Contour Area (Computed)
W_0' = Downstream Width	W_1' = Downstream Width
W_0'' = Upstream Width	W_1'' = Upstream Width

$$A_1 = A_0 \left(\frac{\frac{W_1' + W_1''}{2}}{\frac{W_0' + W_0''}{2}} \right)$$

Figure 5. - Width adjustment method for revising contour area.

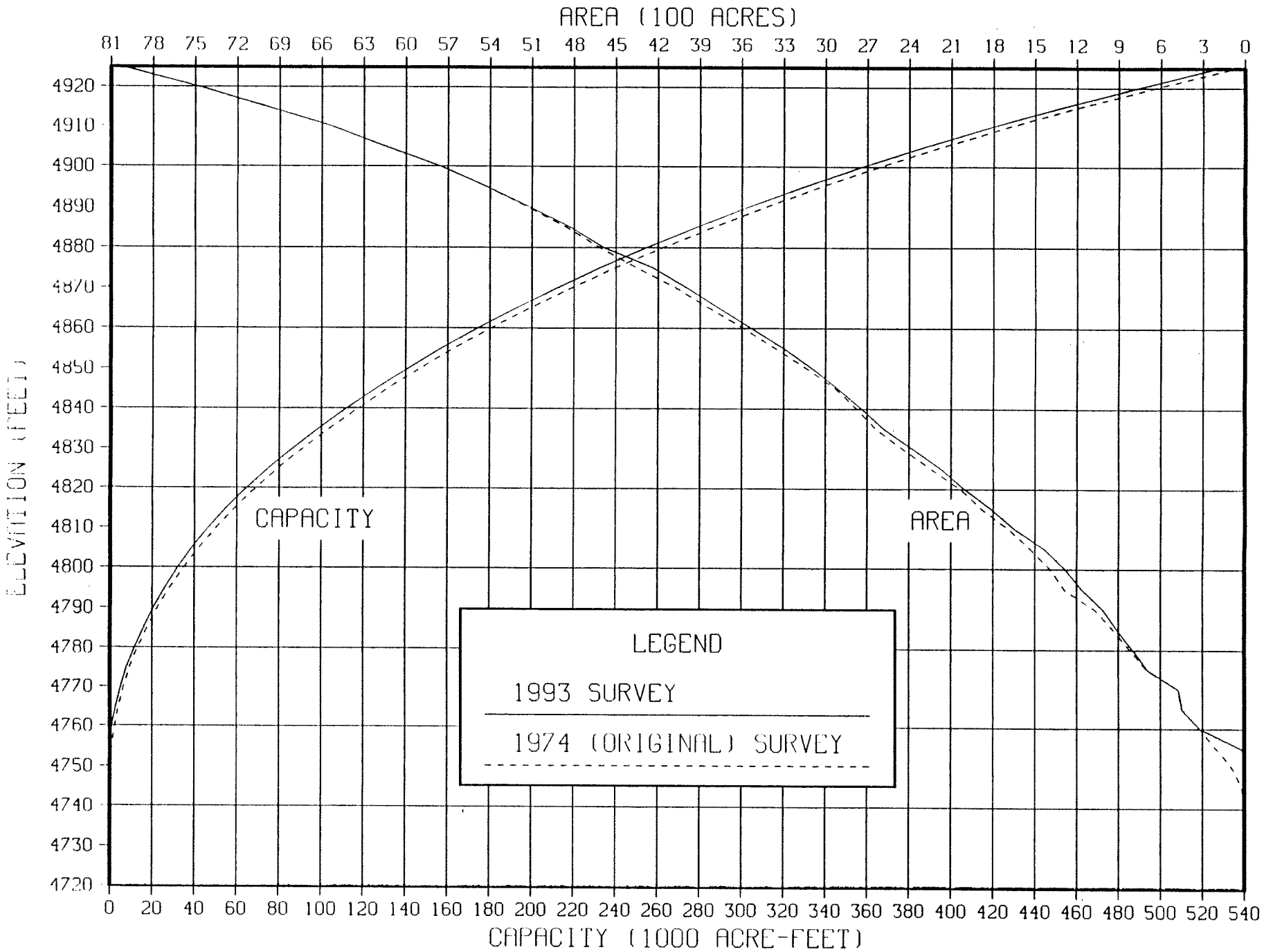


Figure 6. - Area and capacity curves — Pueblo Reservoir.

PUEBLO RESERVOIR SEDIMENTATION SURVEY

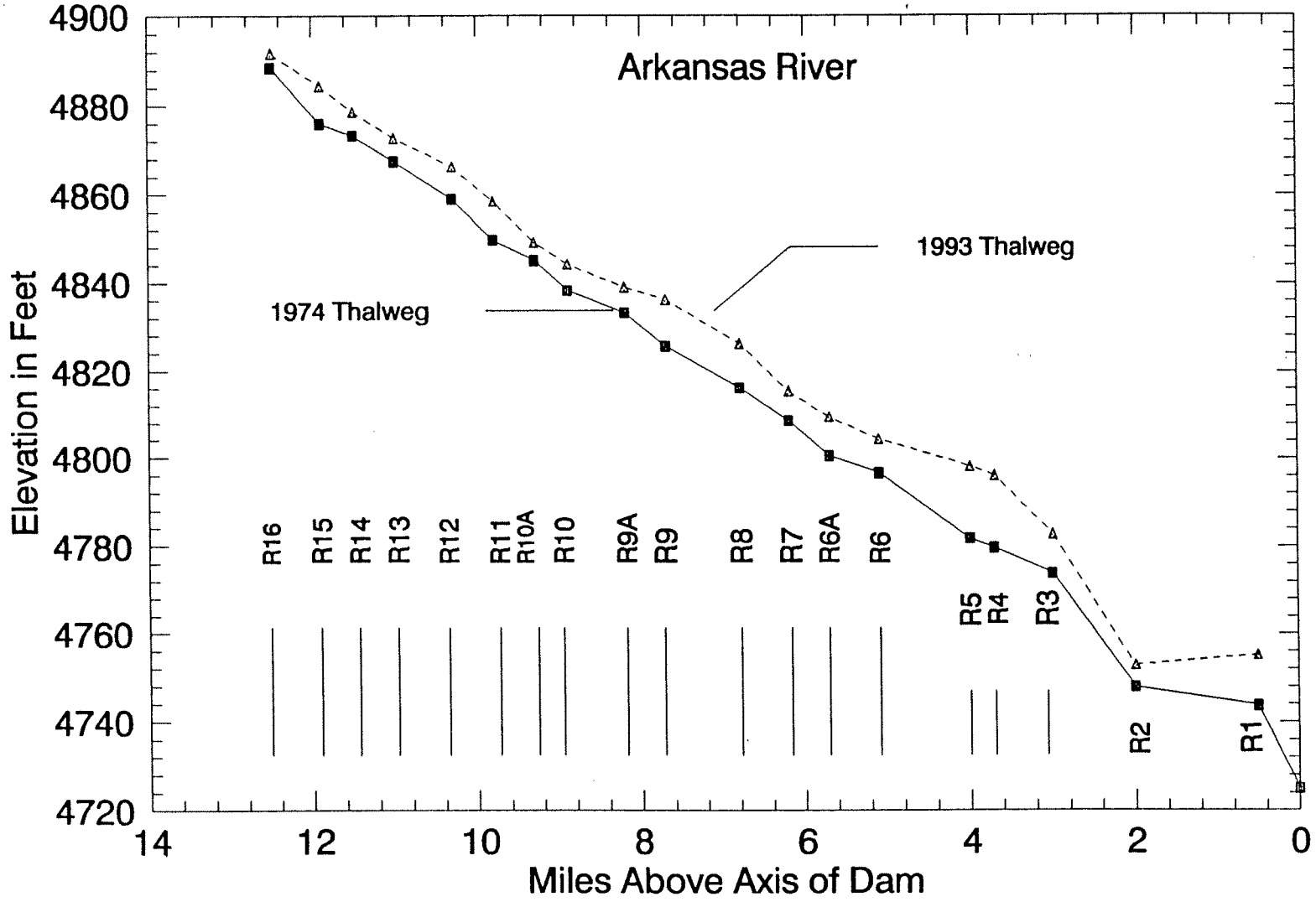


Figure 7. - Longitudinal profile — Arkansas River.

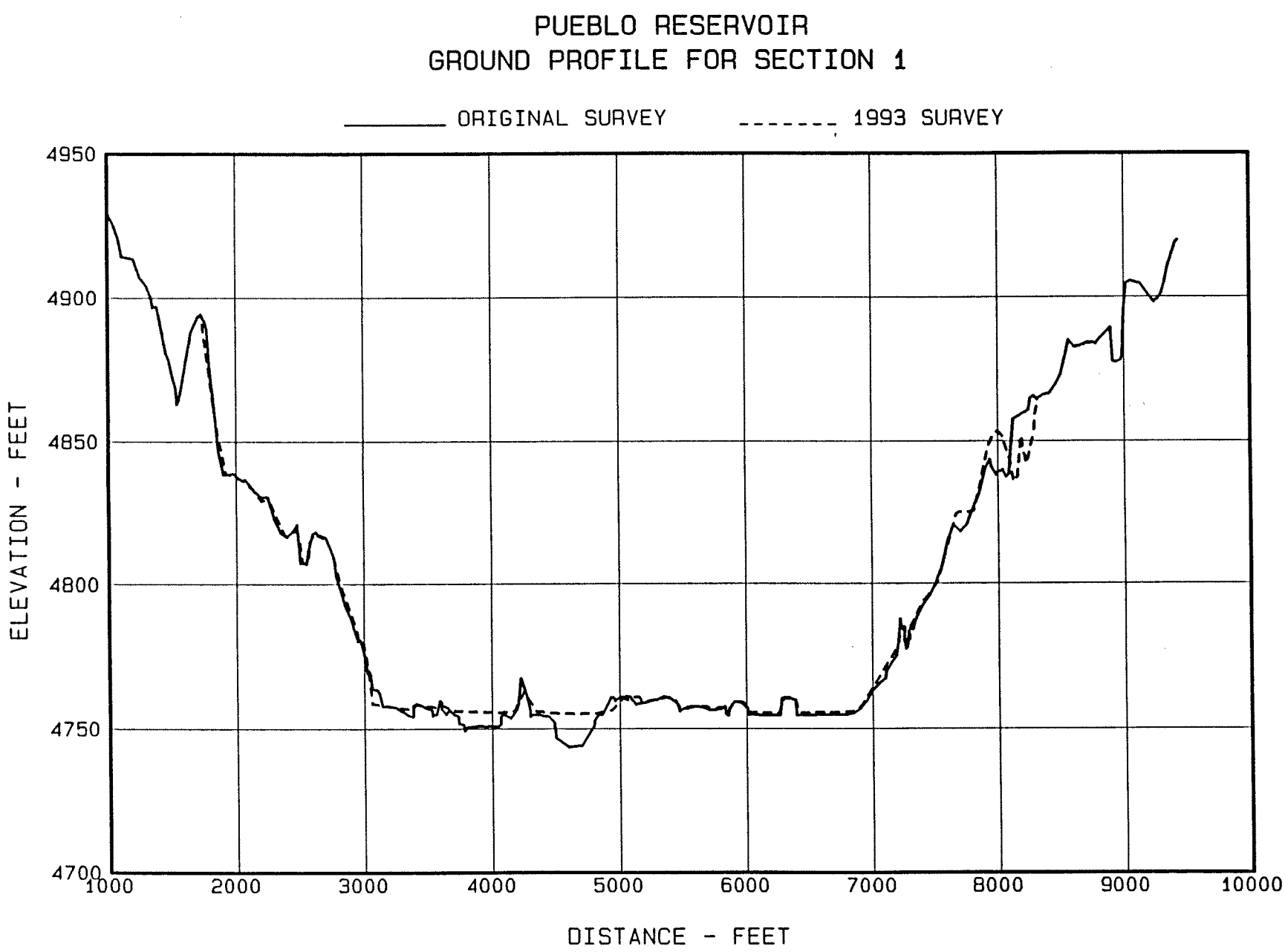


Figure 8. - Sediment Range 1 - Arkansas River.

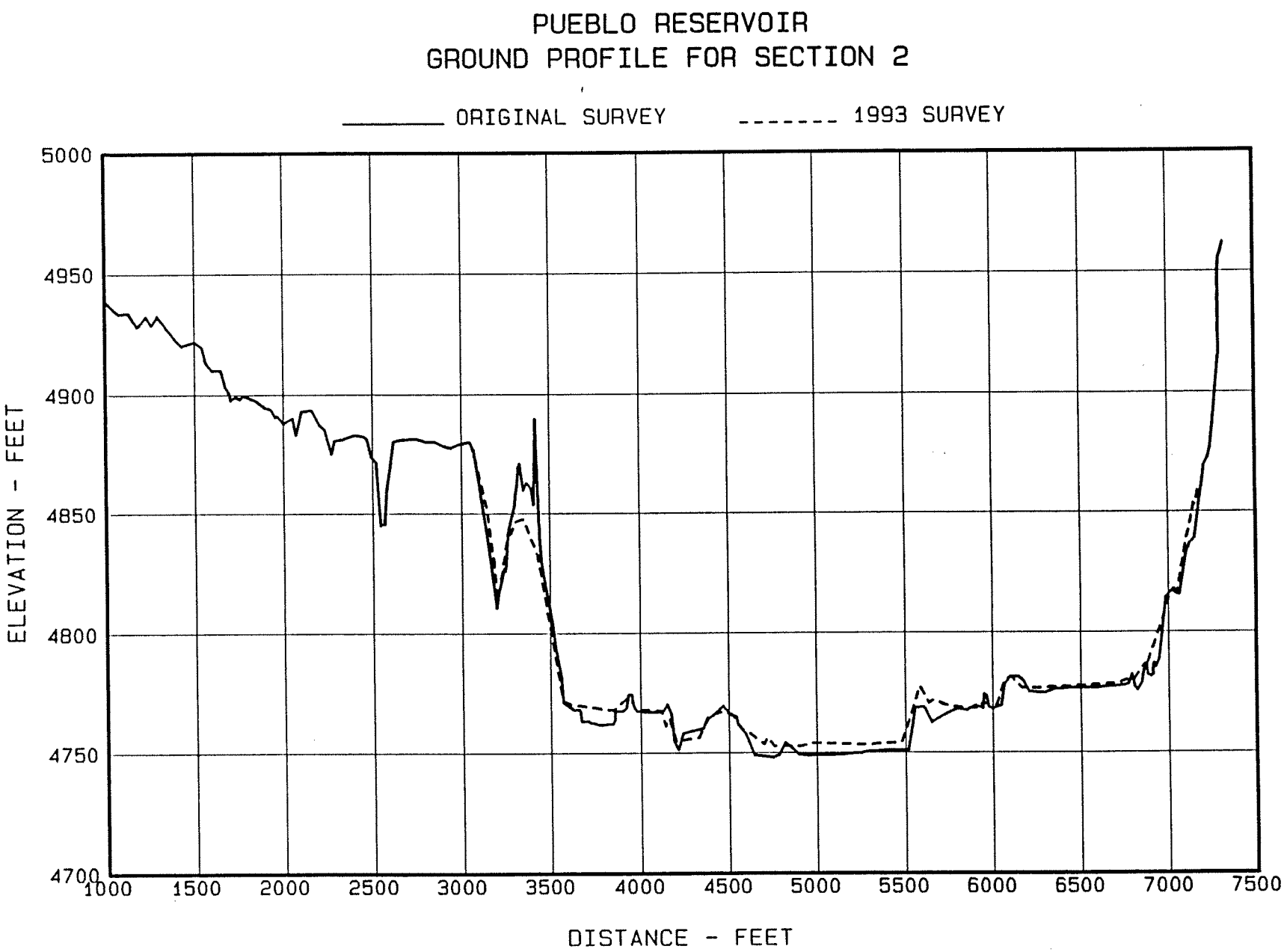


Figure 9. - Sediment Range 2 - Arkansas River.

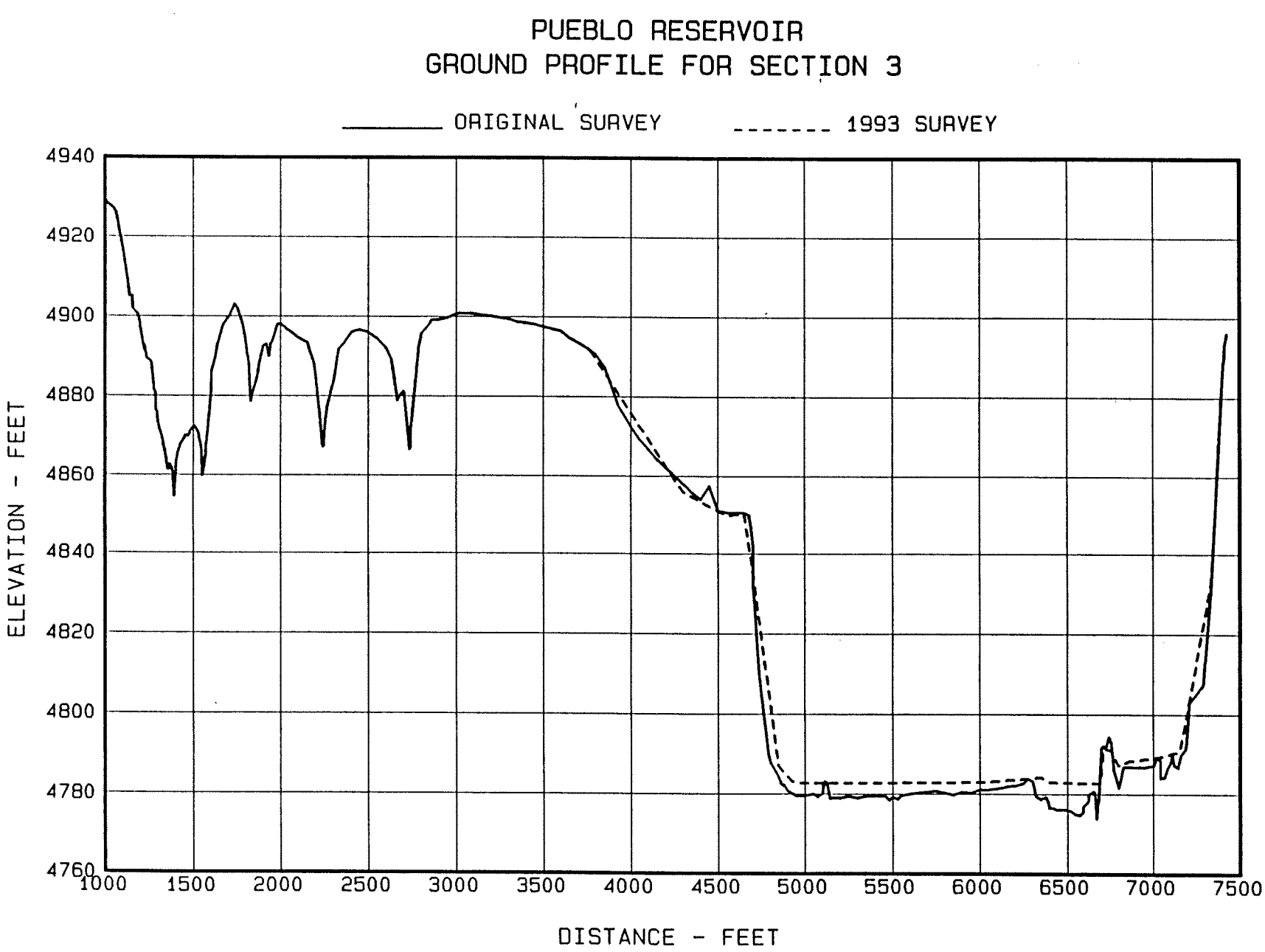


Figure 10. - Sediment Range 3 - Arkansas River.

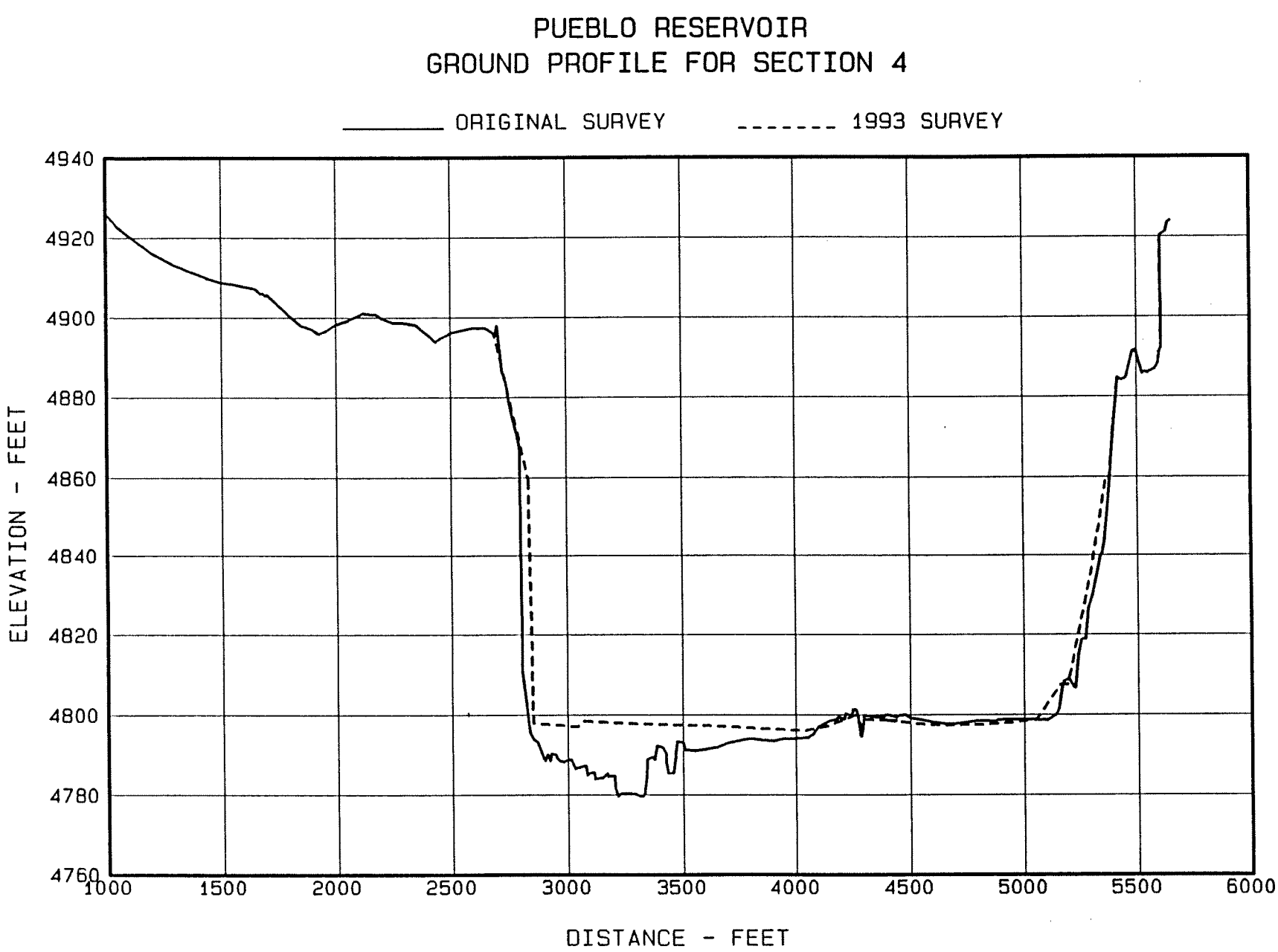


Figure 11. - Sediment Range 4 - Arkansas River.

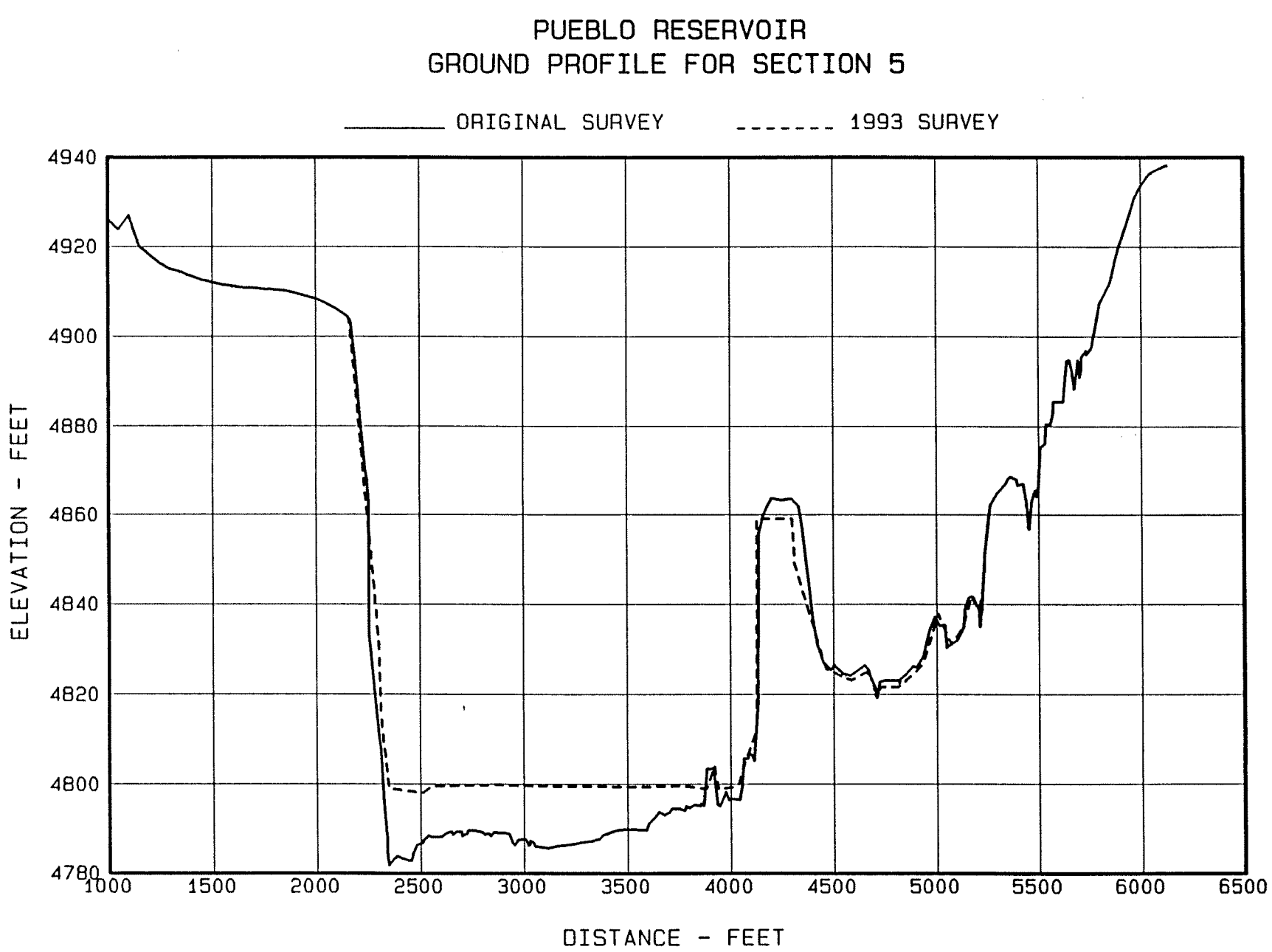


Figure 12. - Sediment Range 5 - Arkansas River.

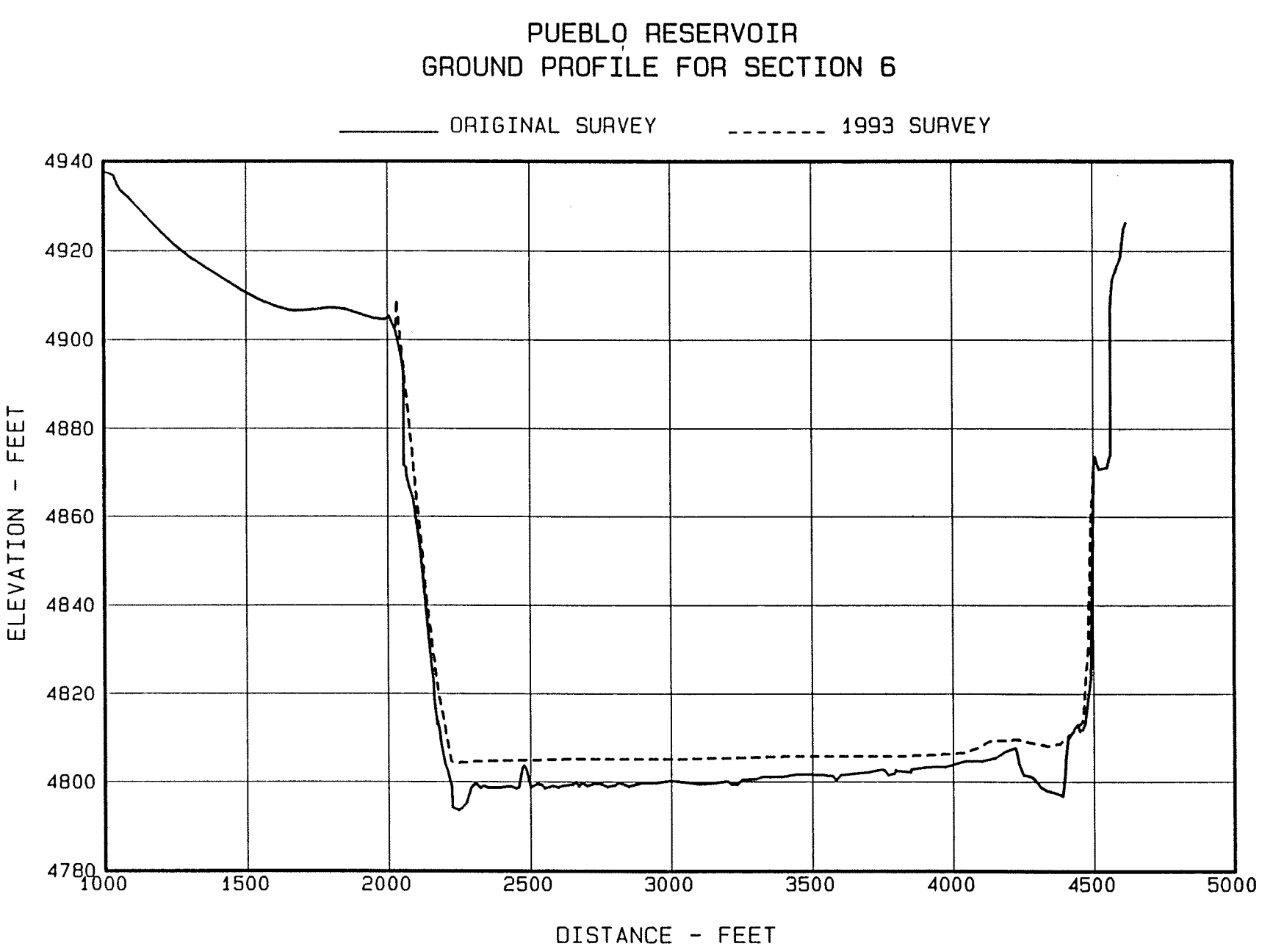


Figure 13. - Sediment Range 6 - Arkansas River.

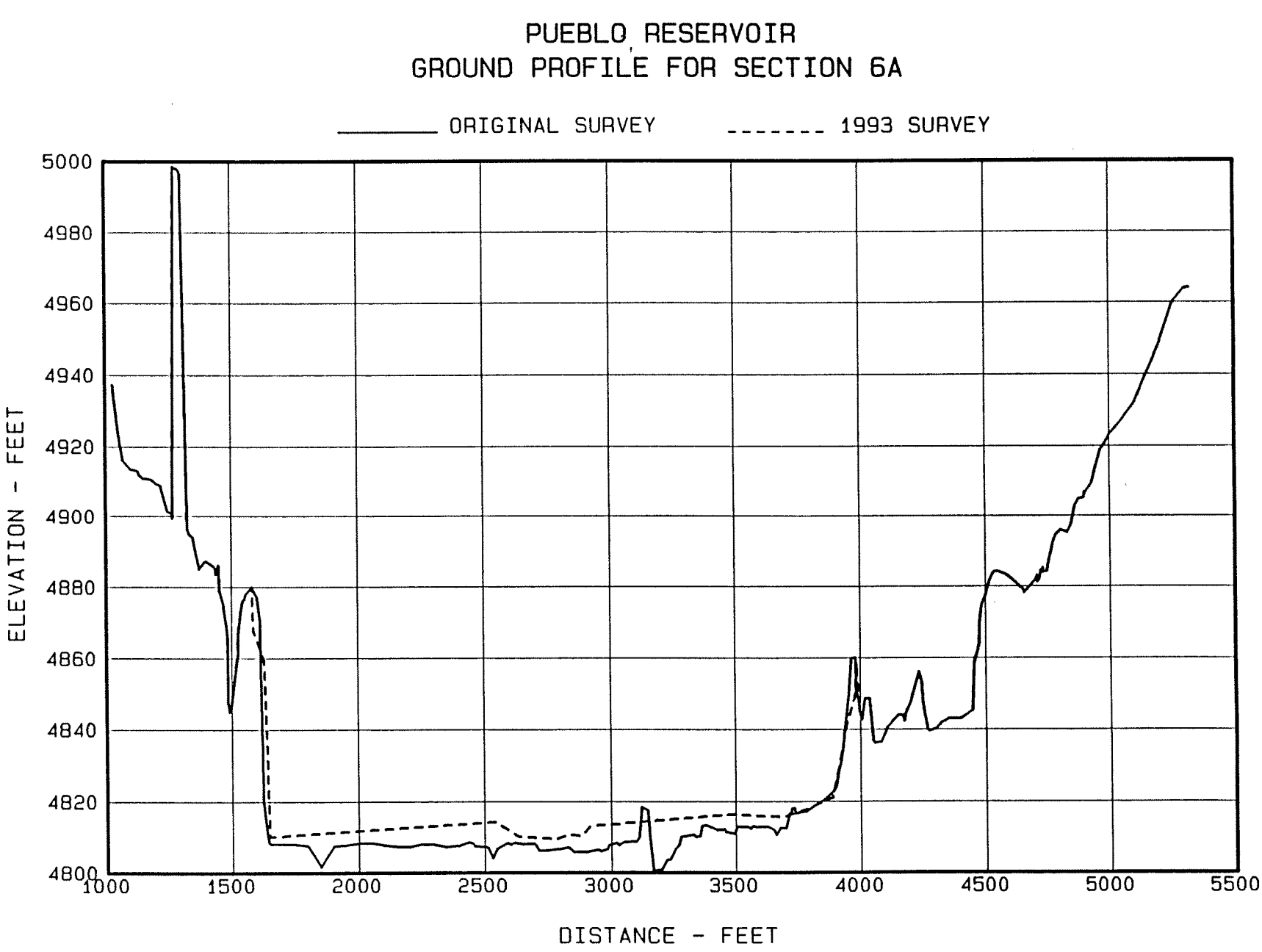


Figure 14. - Sediment Range 6A - Arkansas River.

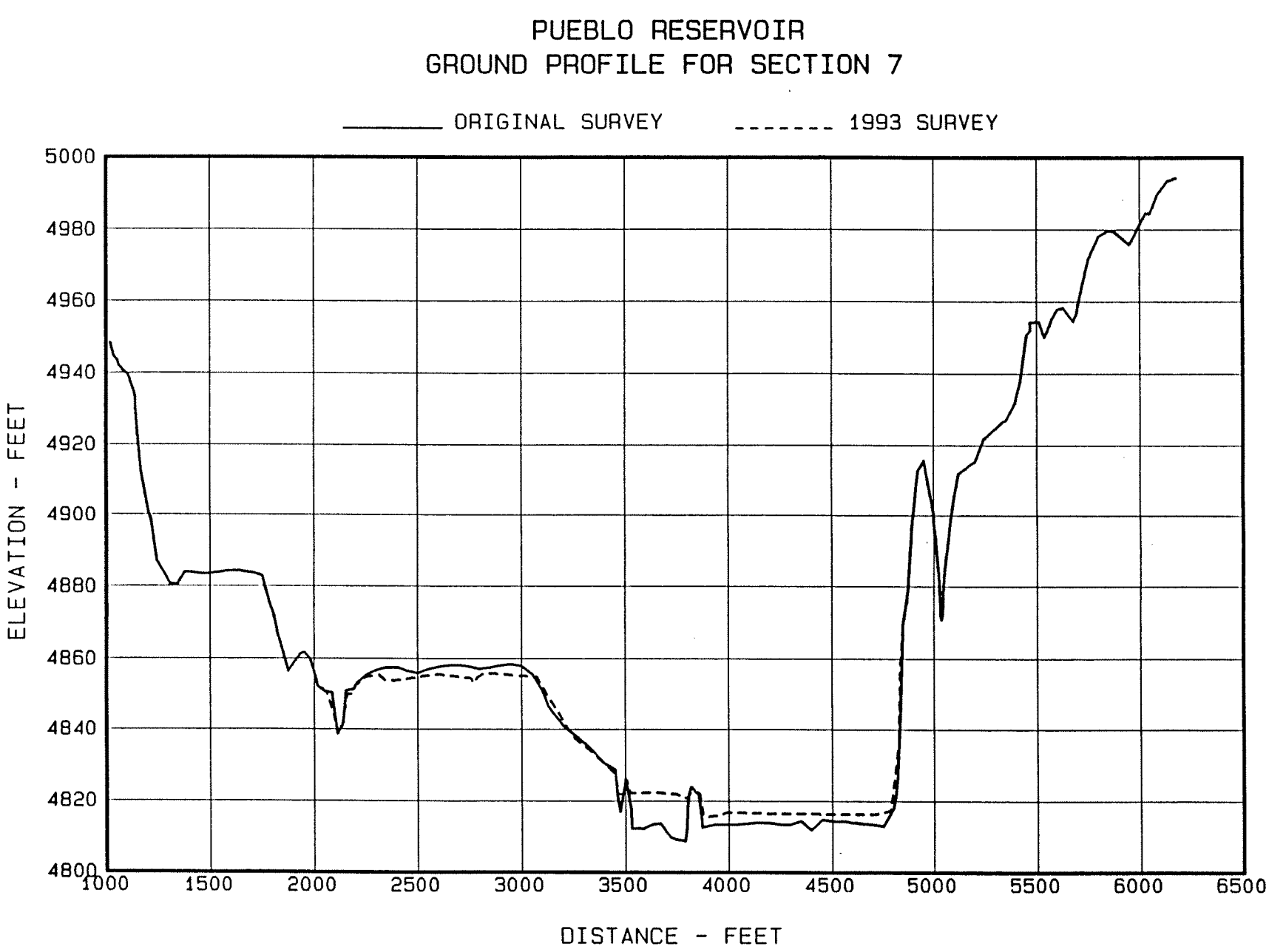


Figure 15. - Sediment Range 7 - Arkansas River.

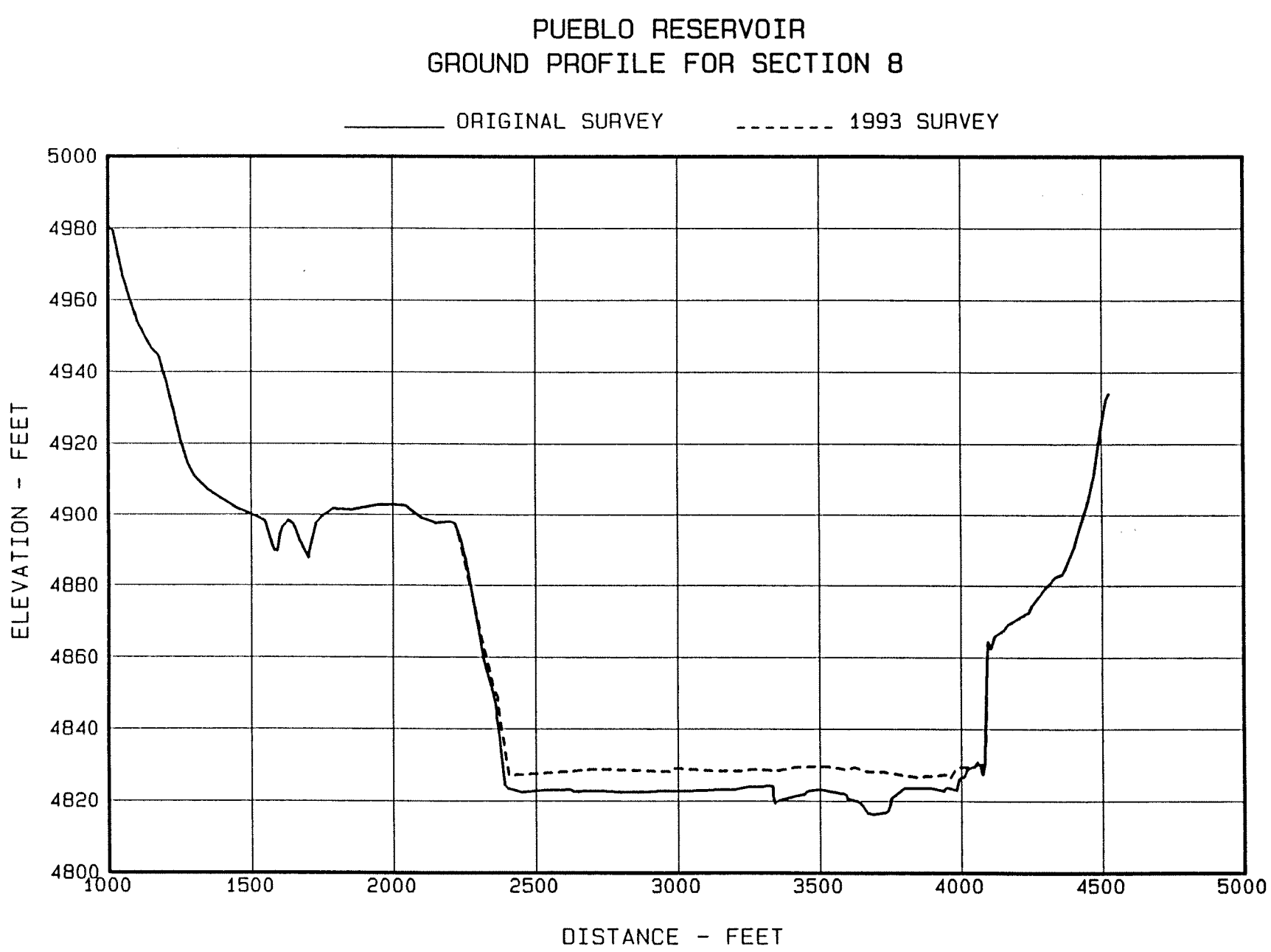


Figure 16. - Sediment Range 8 - Arkansas River.

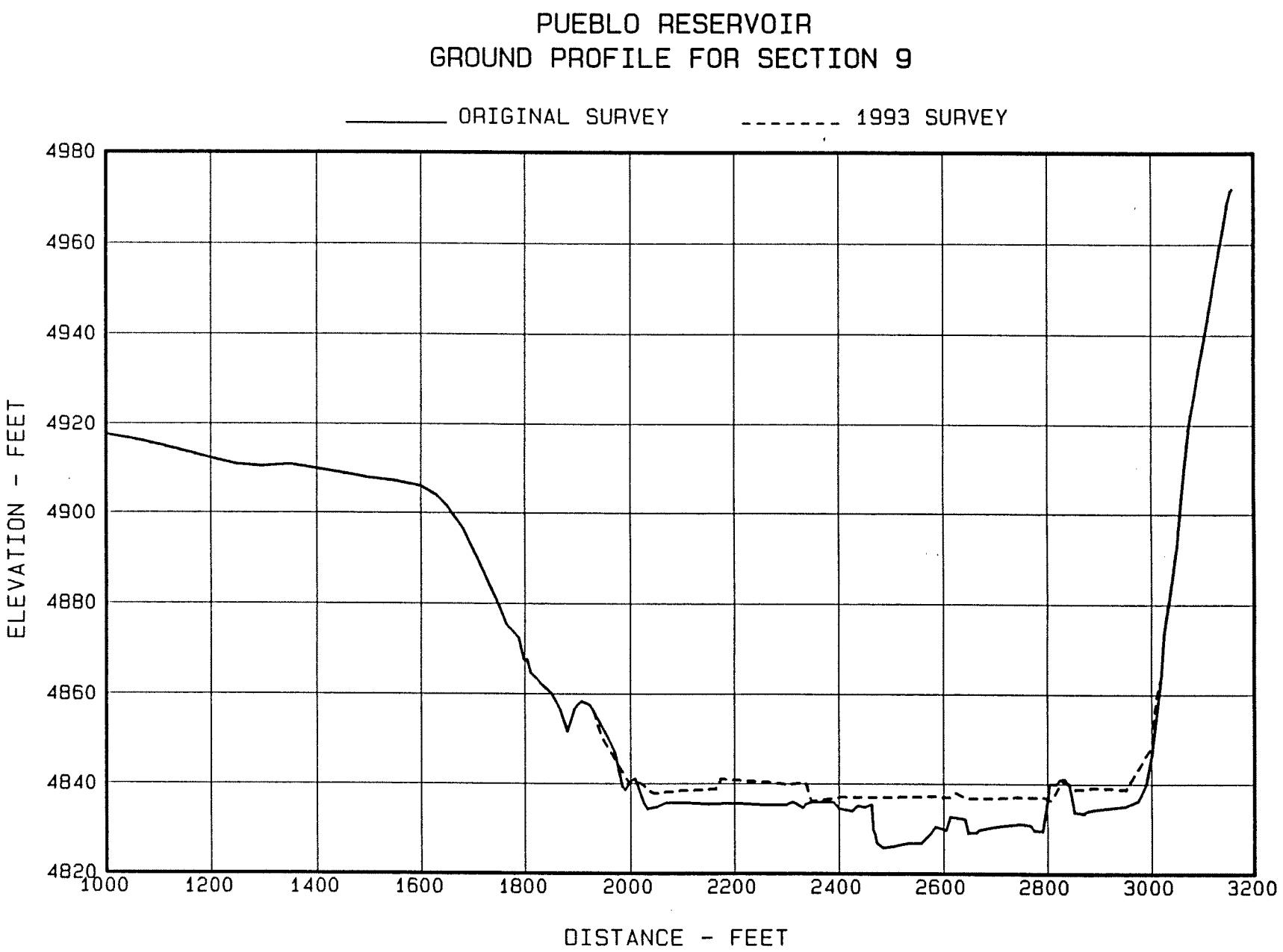


Figure 17. - Sediment Range 9 - Arkansas River.

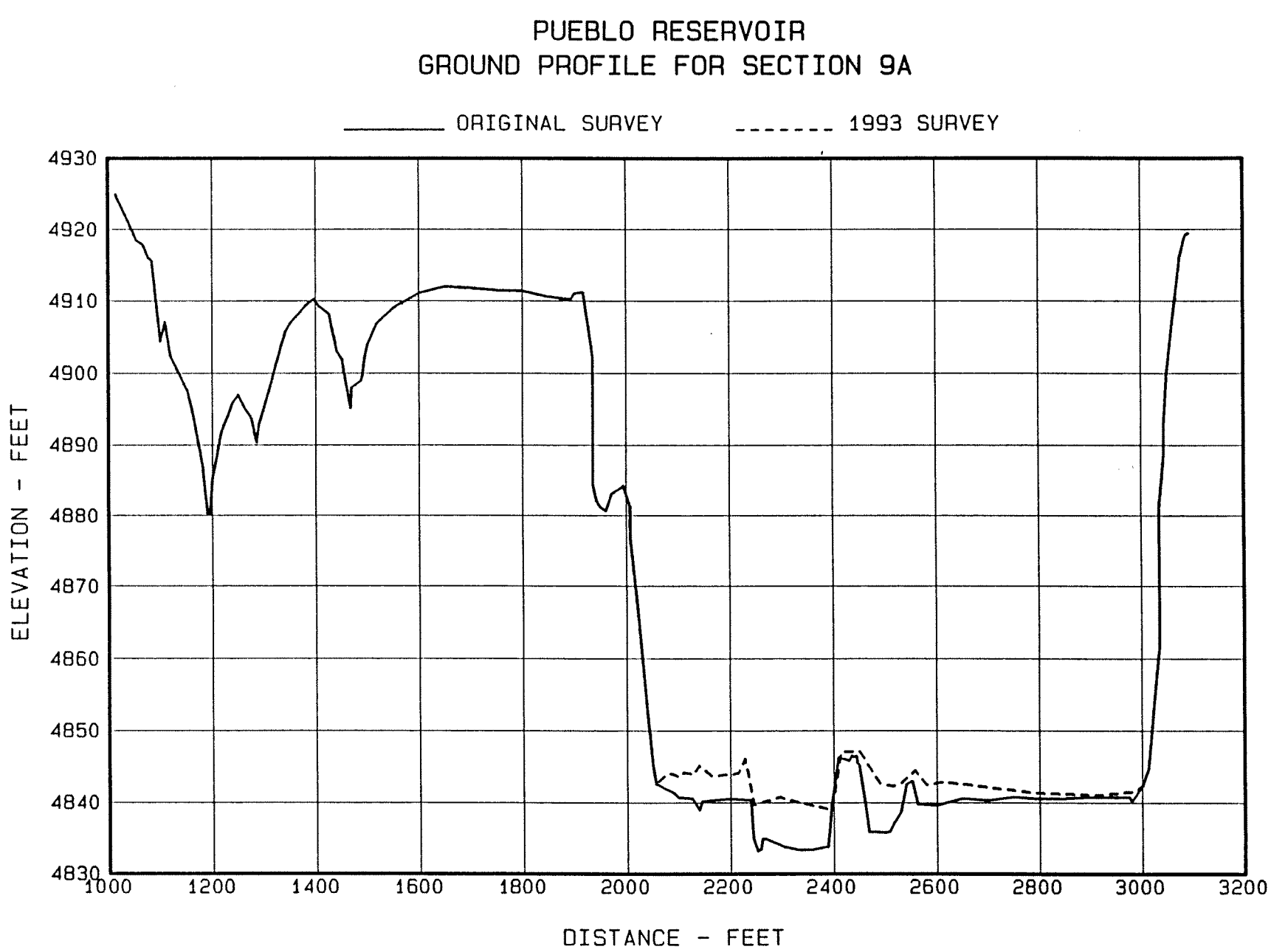


Figure 18. - Sediment Range 9A - Arkansas River.

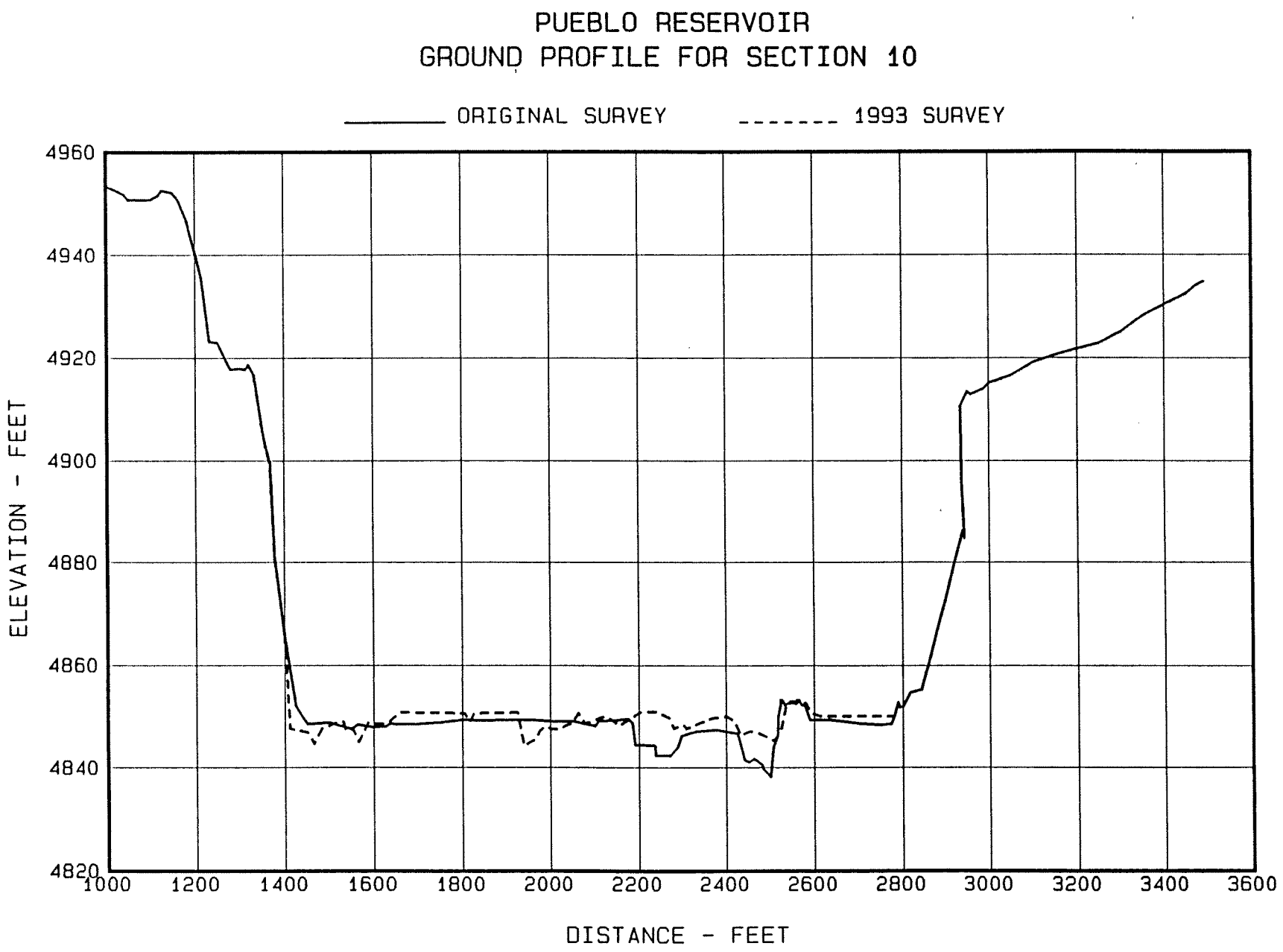


Figure 19. - Sediment Range 10 - Arkansas River.

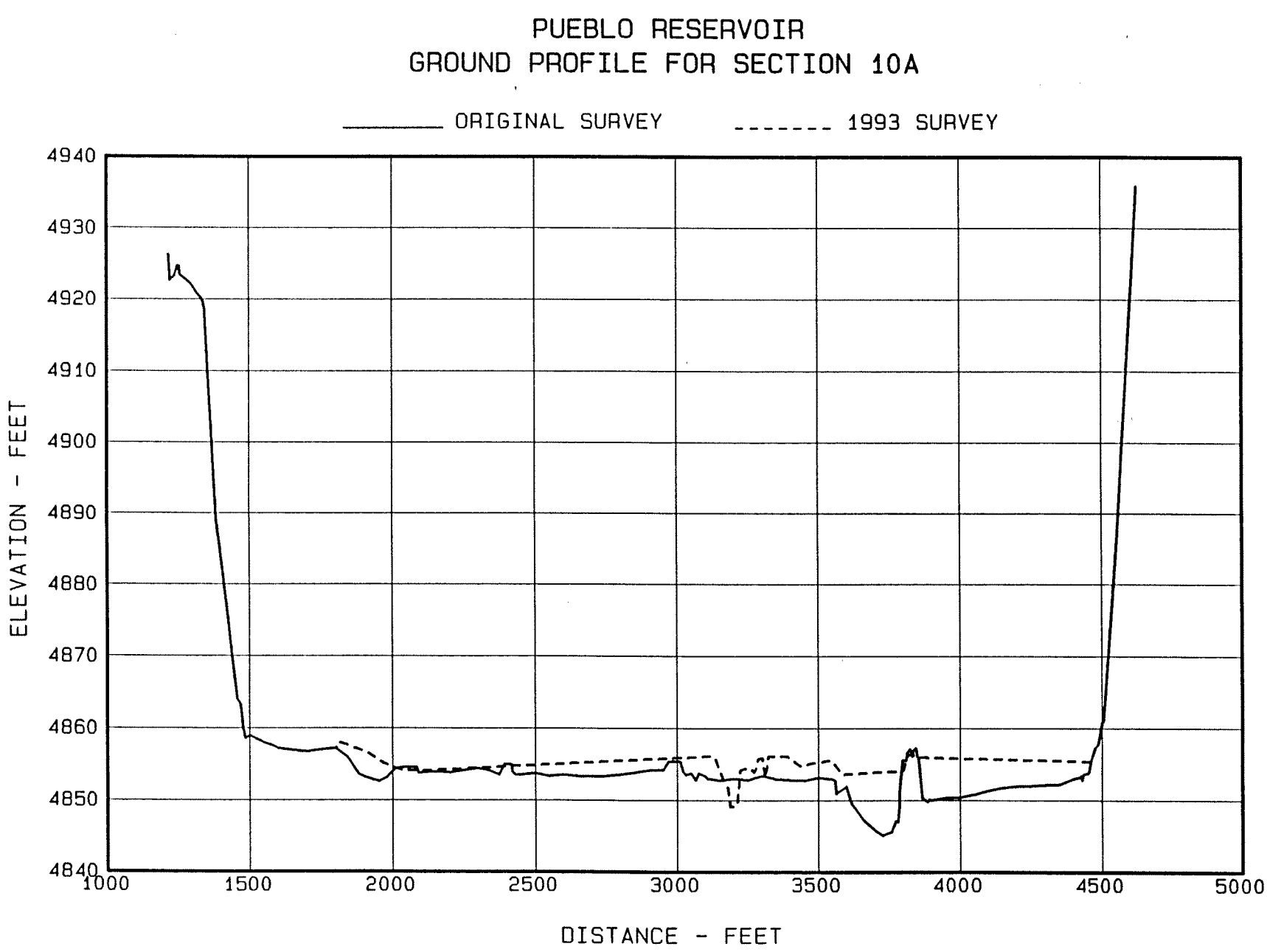


Figure 20. - Sediment Range 10A - Arkansas River.

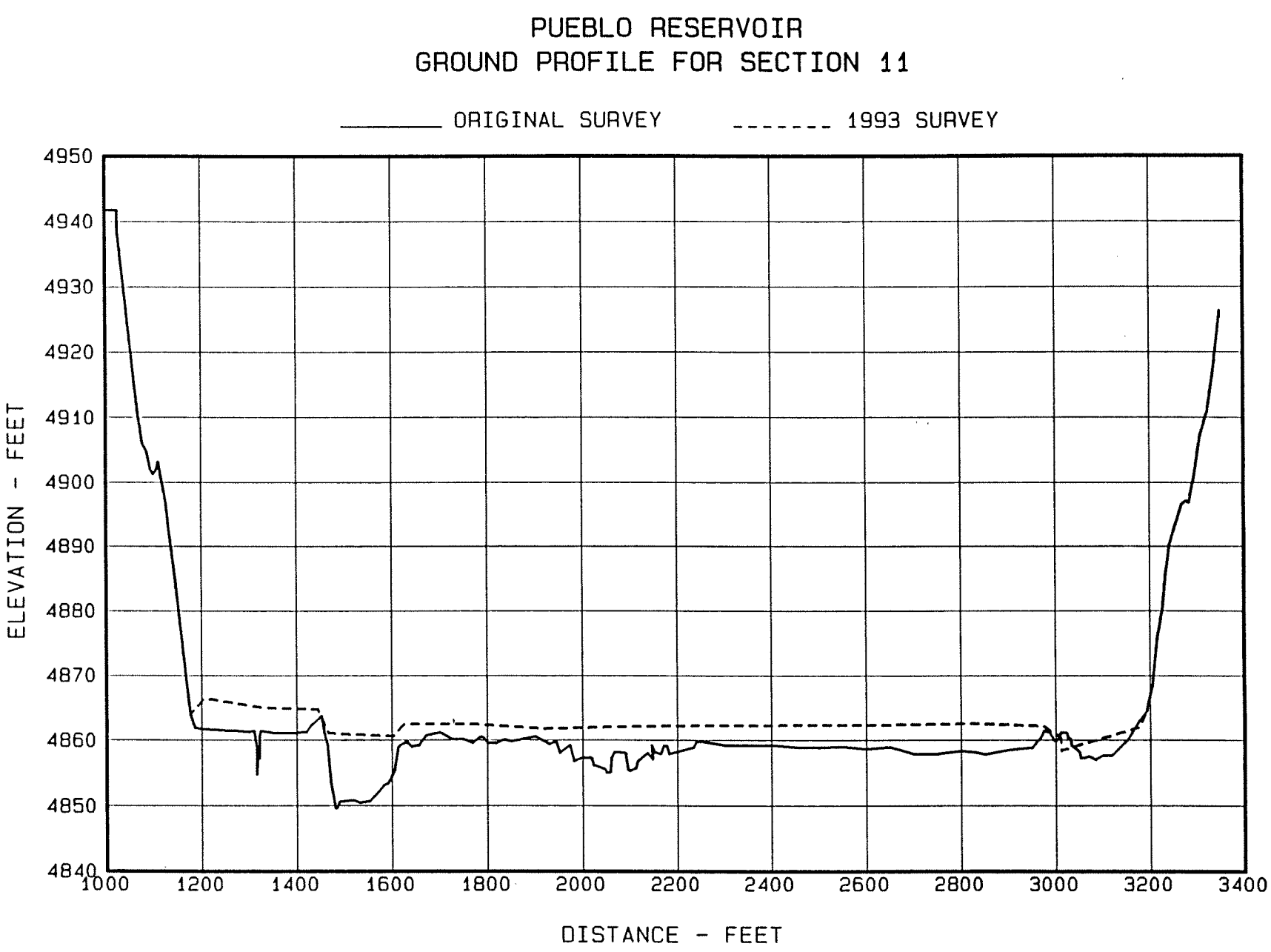


Figure 21. - Sediment Range 11 - Arkansas River.

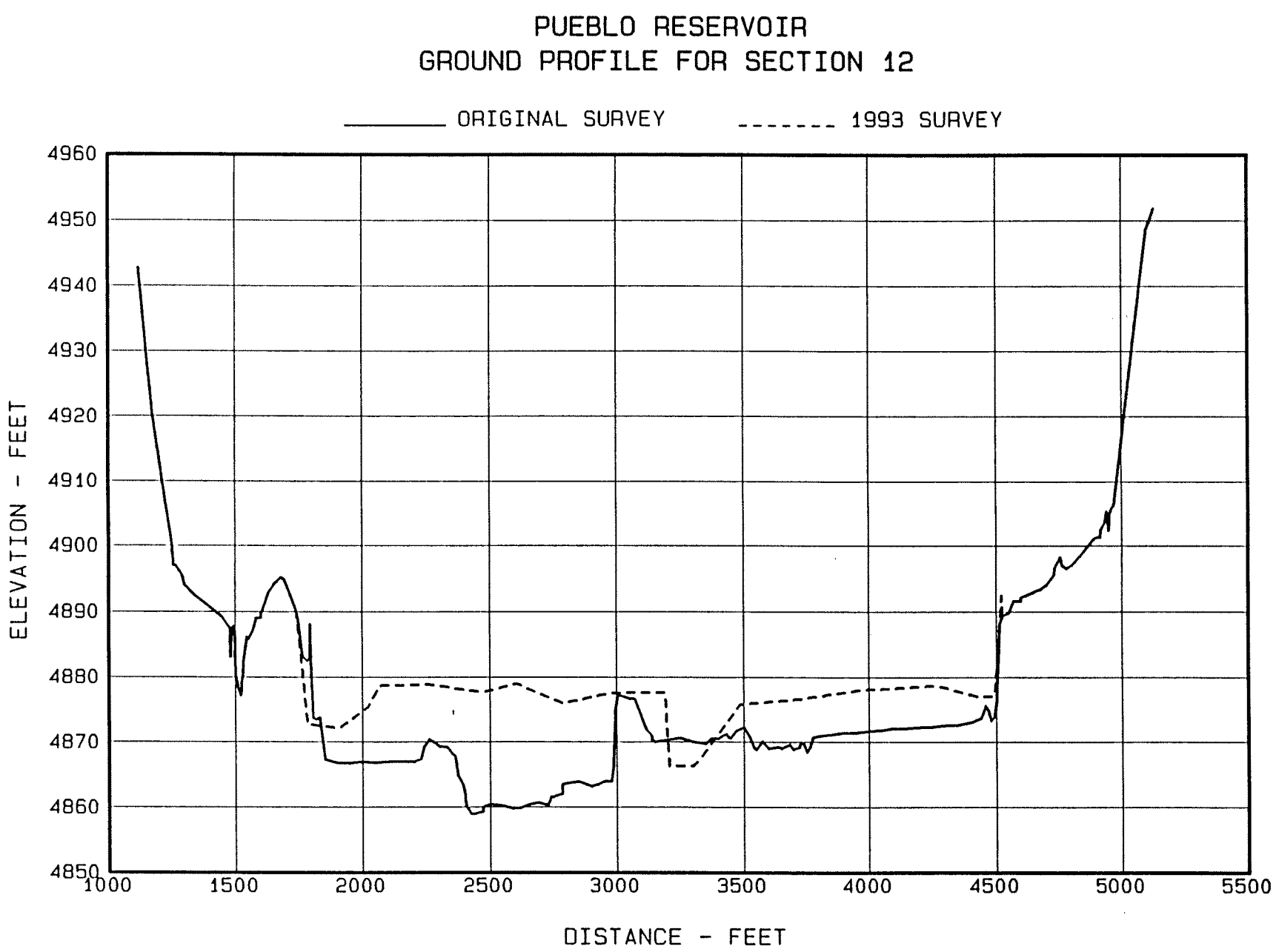


Figure 22. - Sediment Range 12 - Arkansas River.

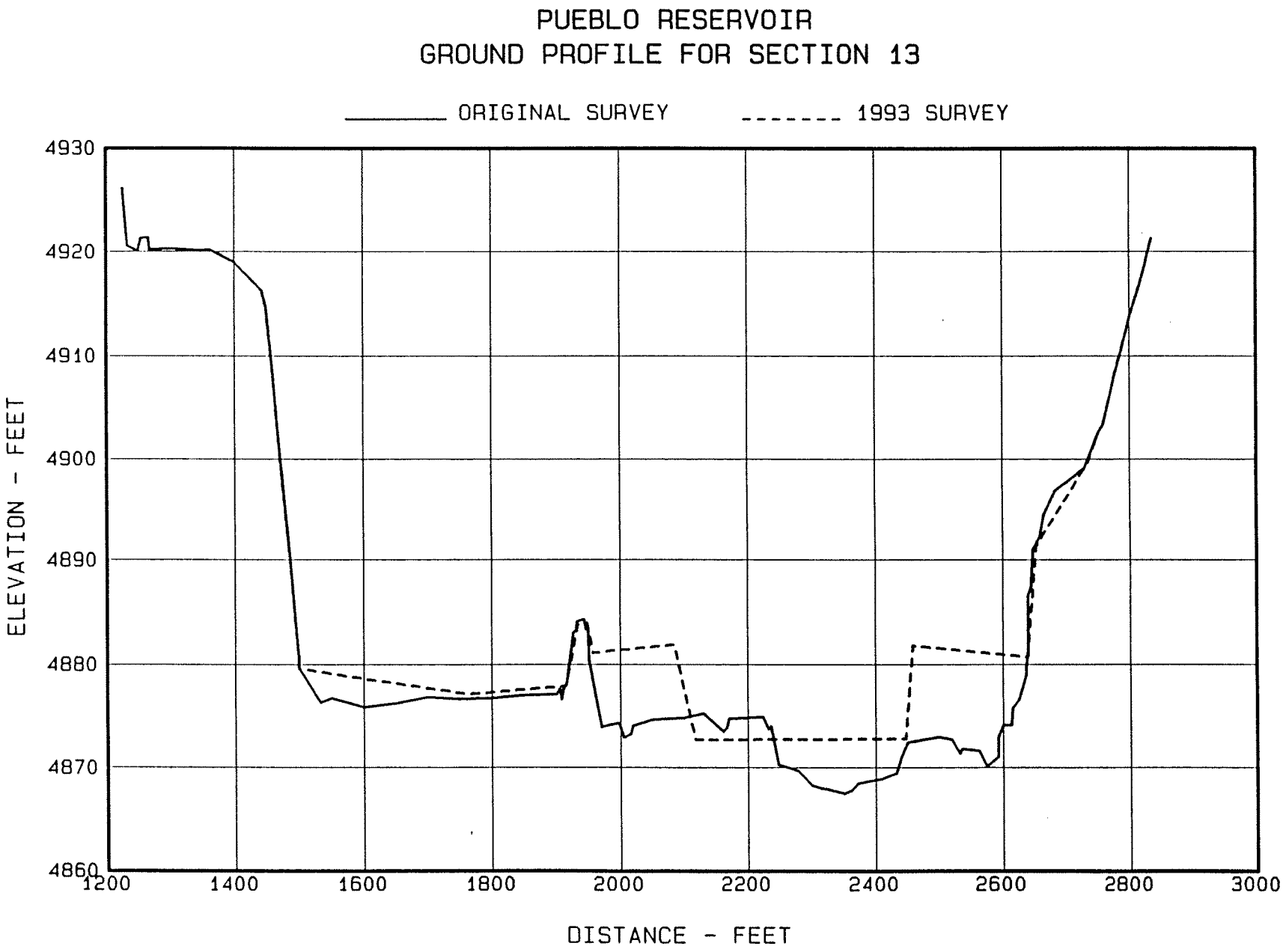


Figure 23. - Sediment Range 13 - Arkansas River.

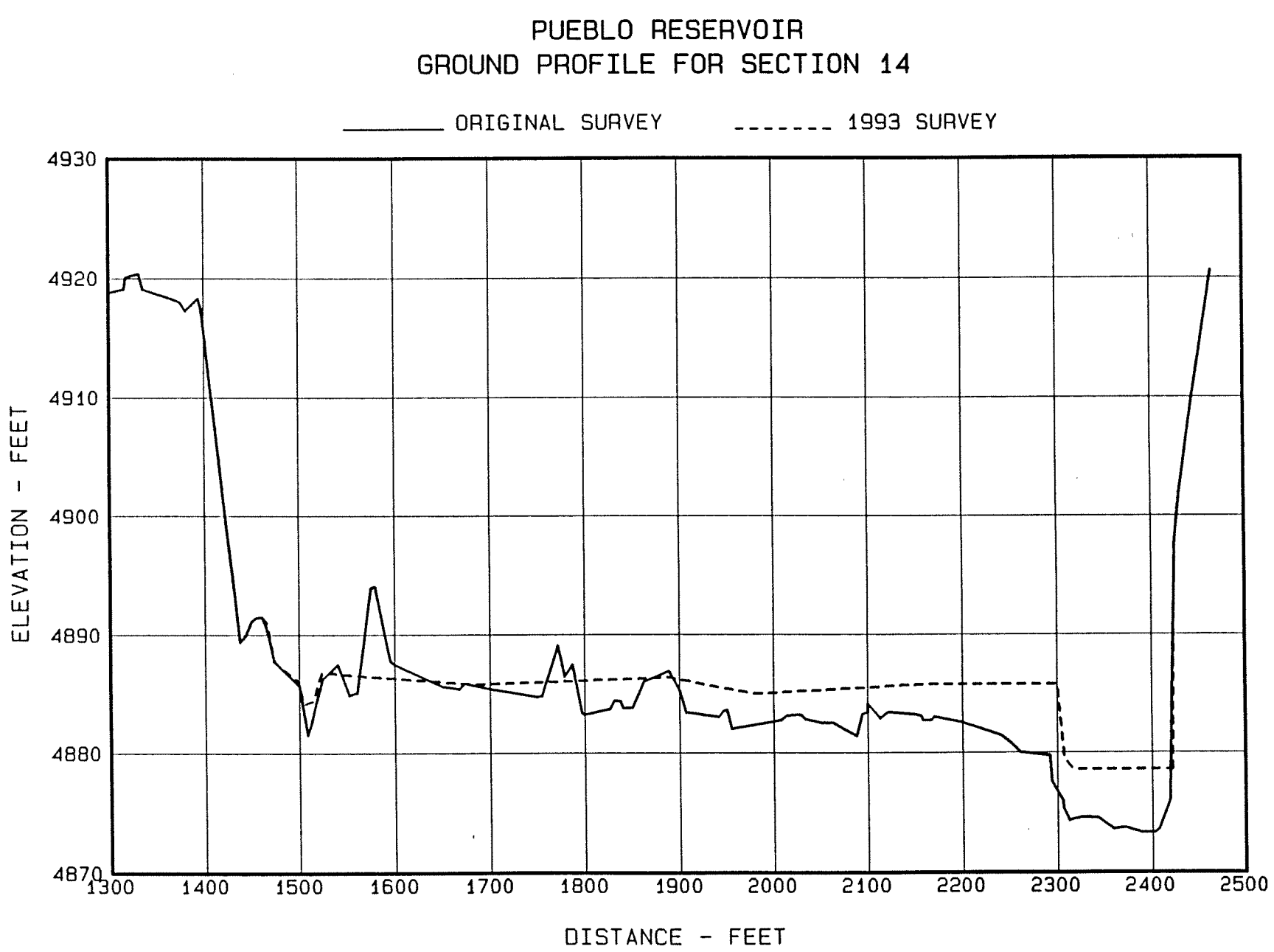


Figure 24. - Sediment Range 14 - Arkansas River.

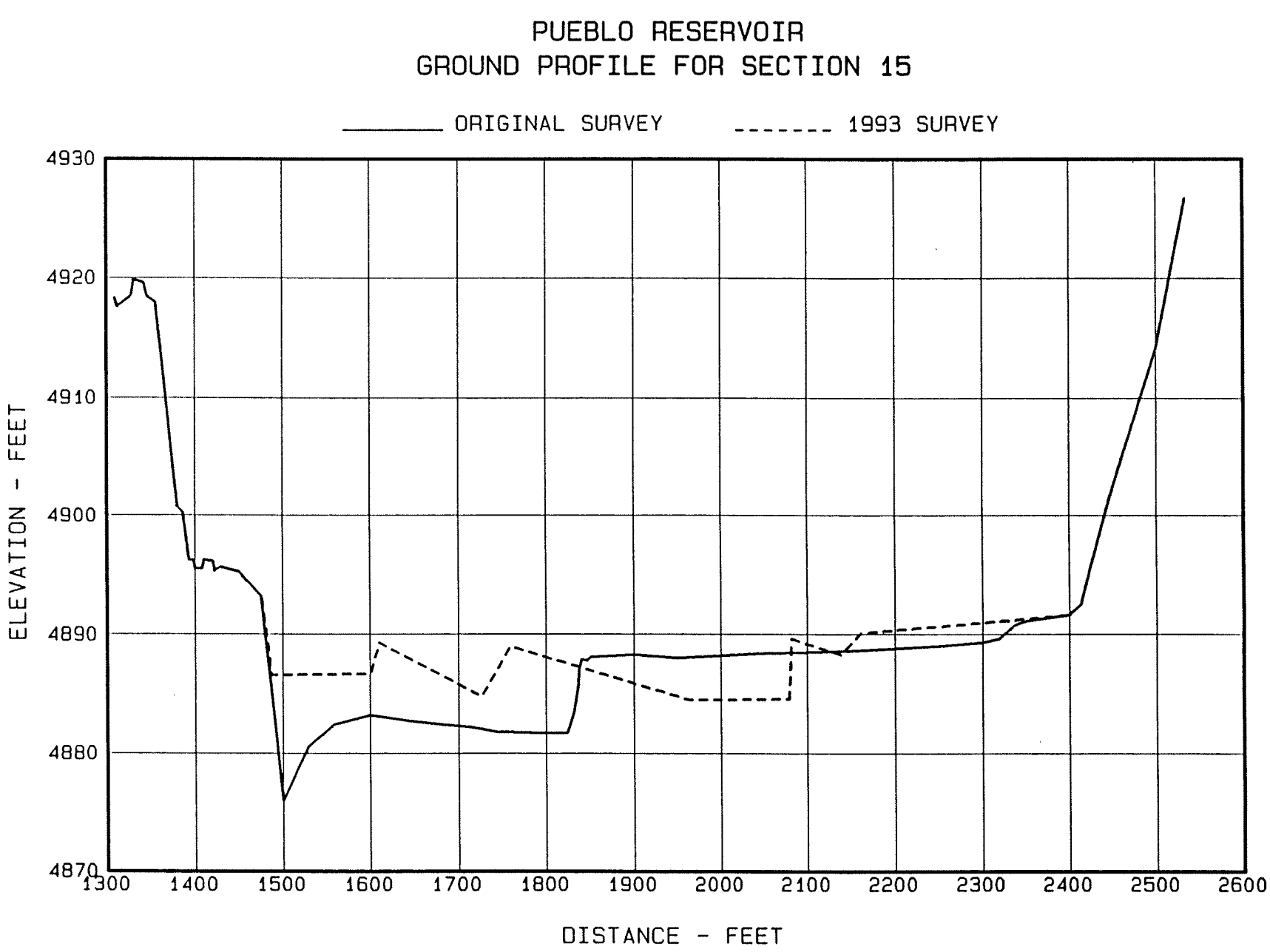


Figure 25. - Sediment Range 15 - Arkansas River.

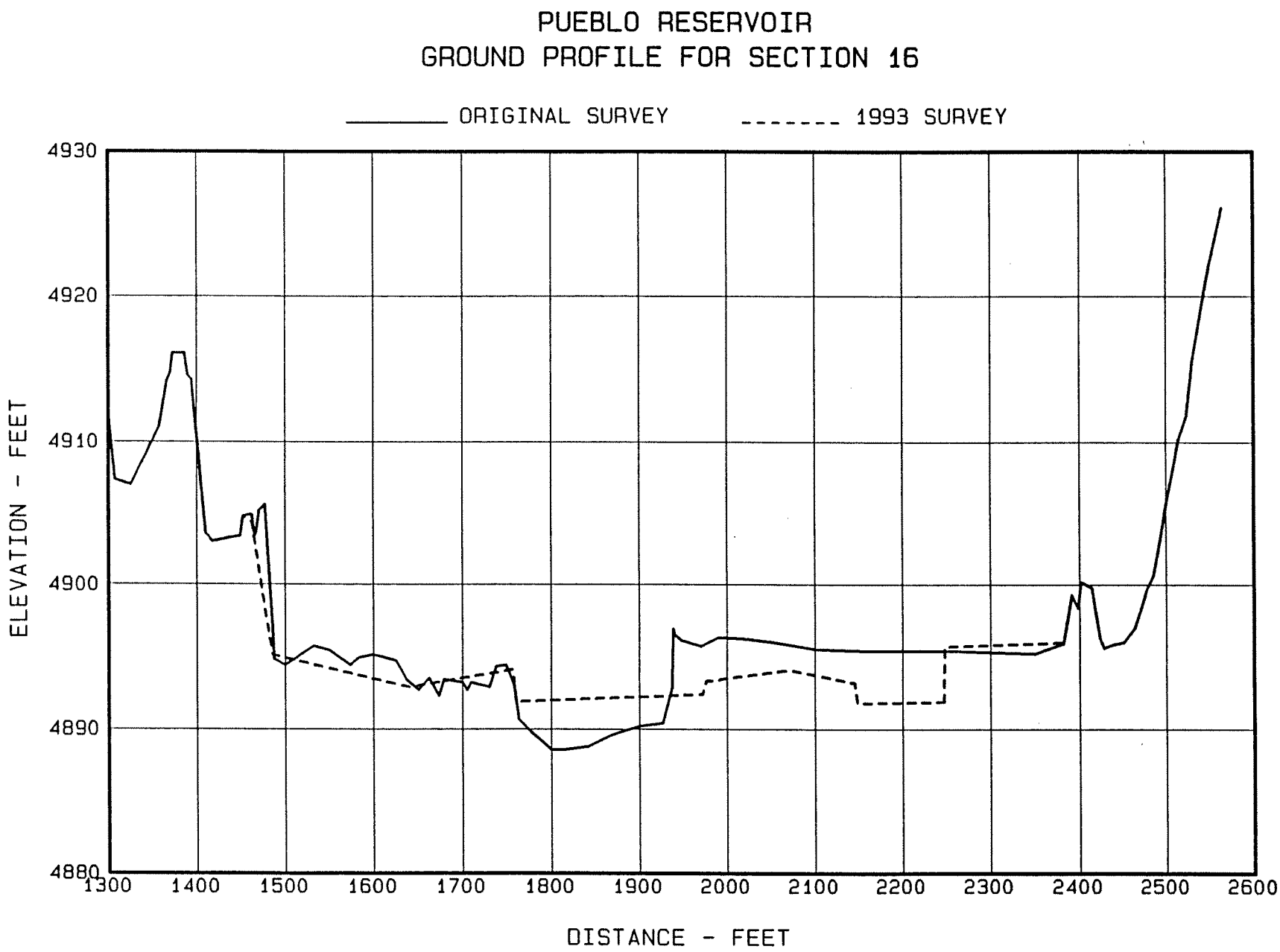


Figure 26. - Sediment Range 16 - Arkansas River.

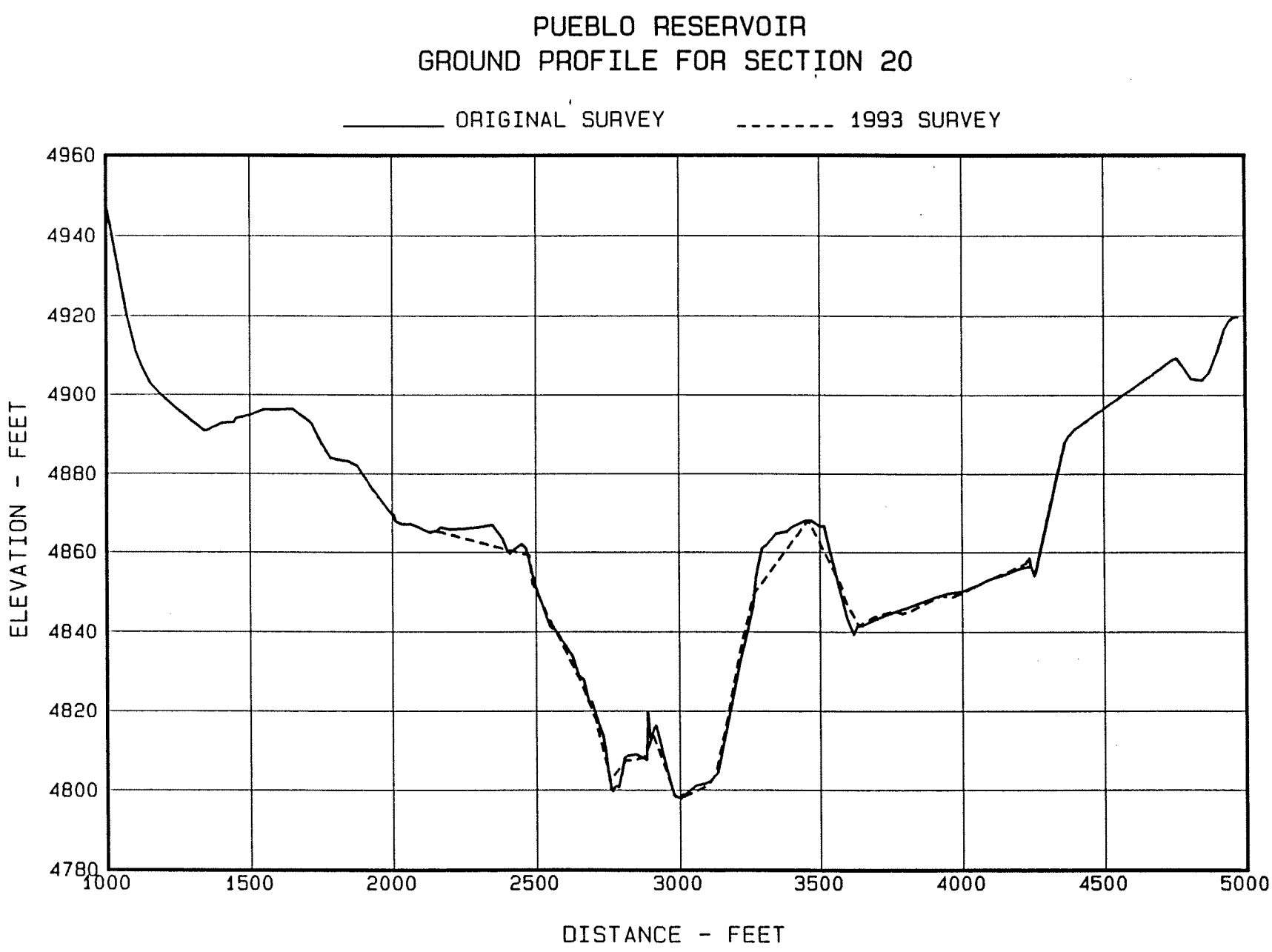


Figure 27. - Sediment Range 20 - Boggs Creek.

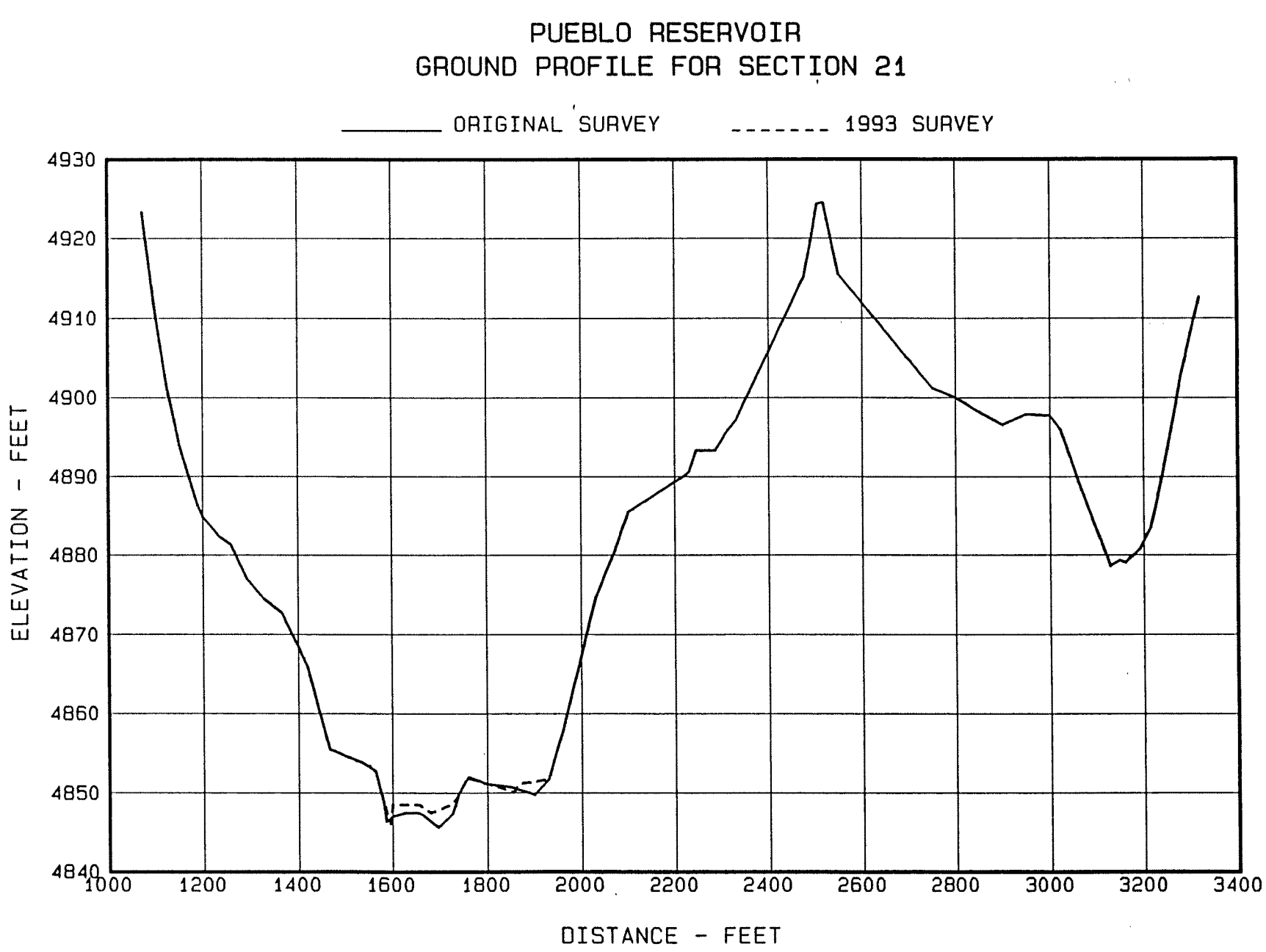


Figure 28. - Sediment Range 21 - Boggs Creek.

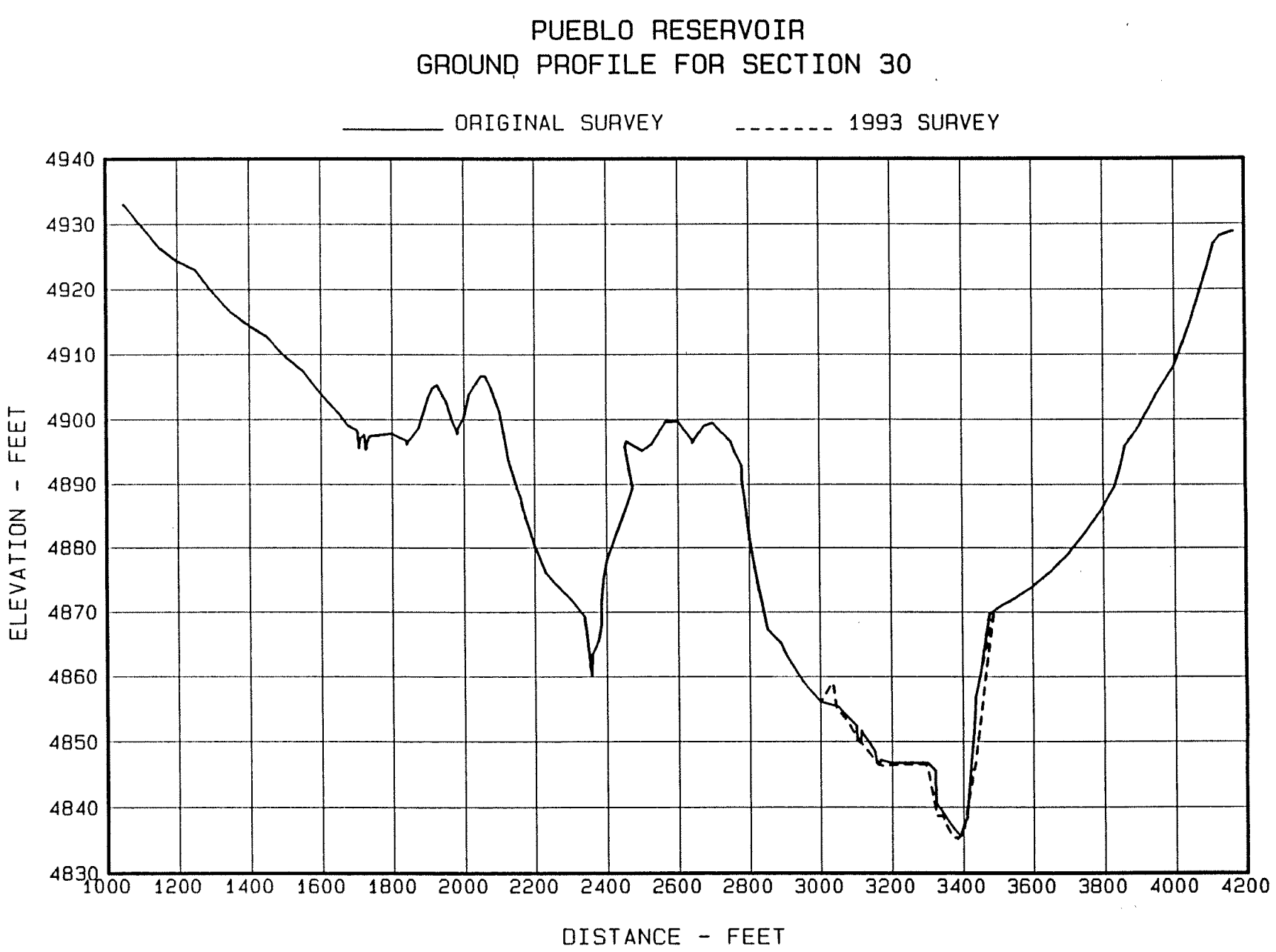


Figure 29. - Sediment Range 30 - Above Marina.

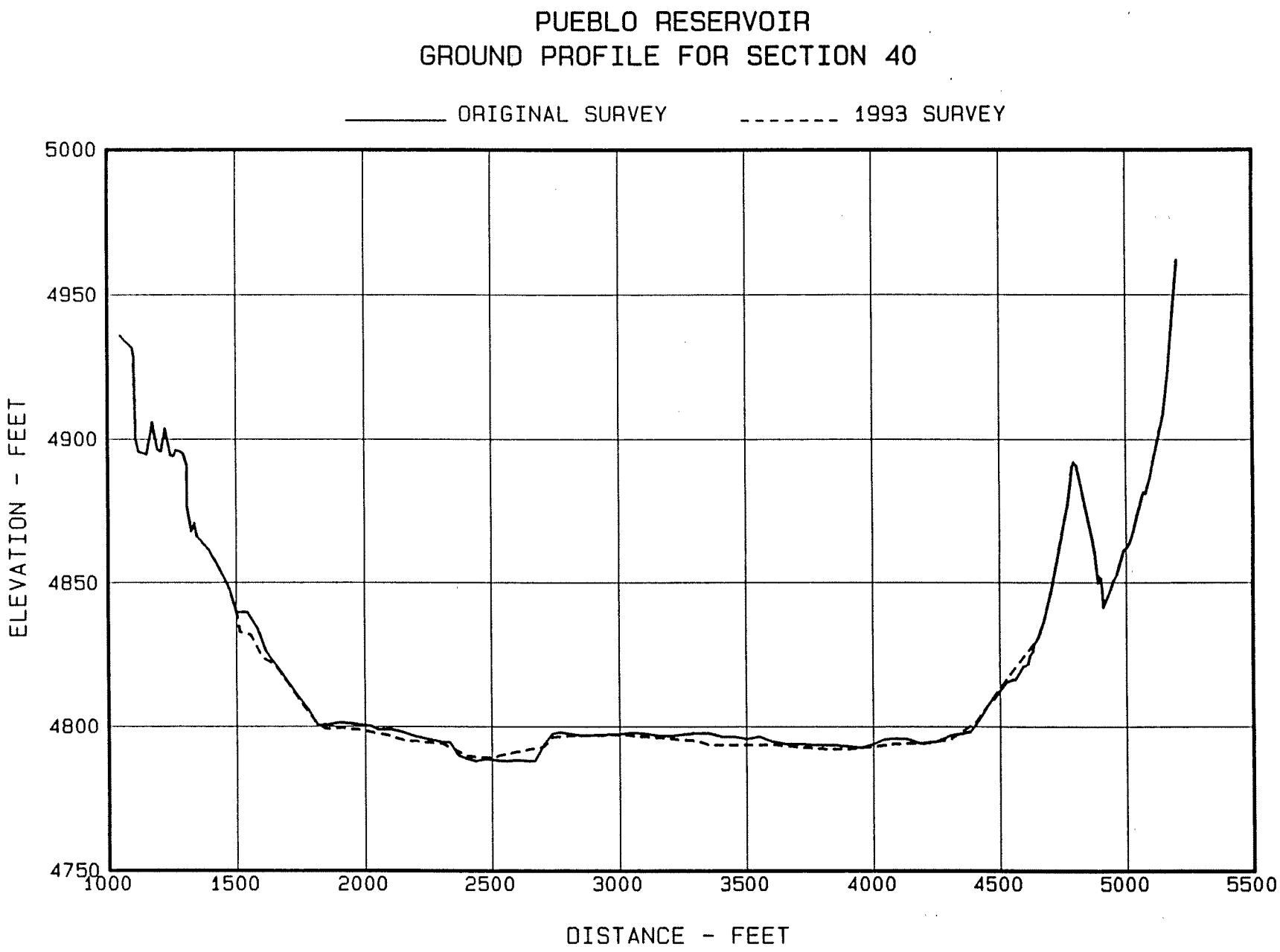


Figure 30. - Sediment Range 40 - Rock Creek.

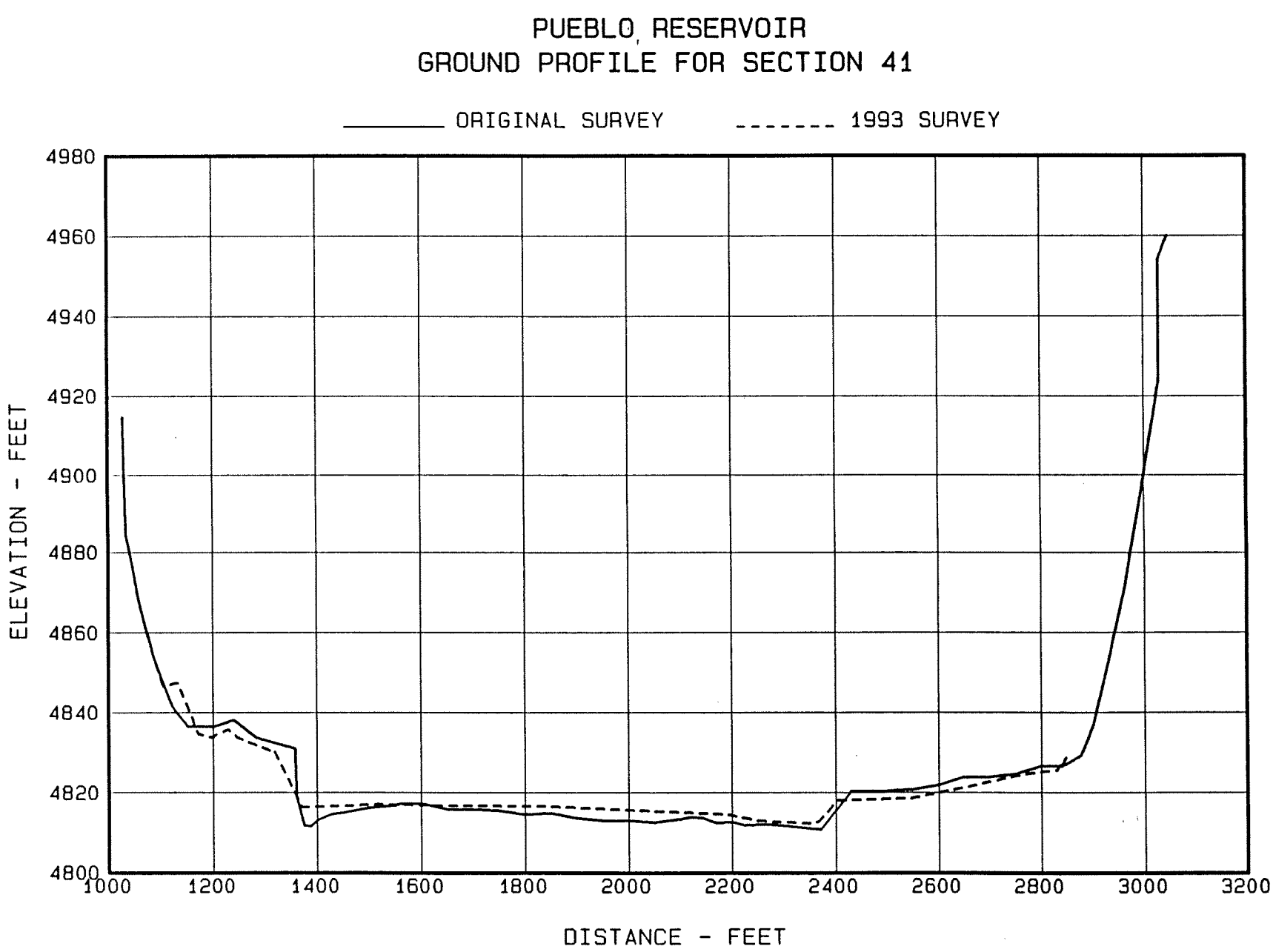


Figure 31. - Sediment Range 41 - Rock Creek.

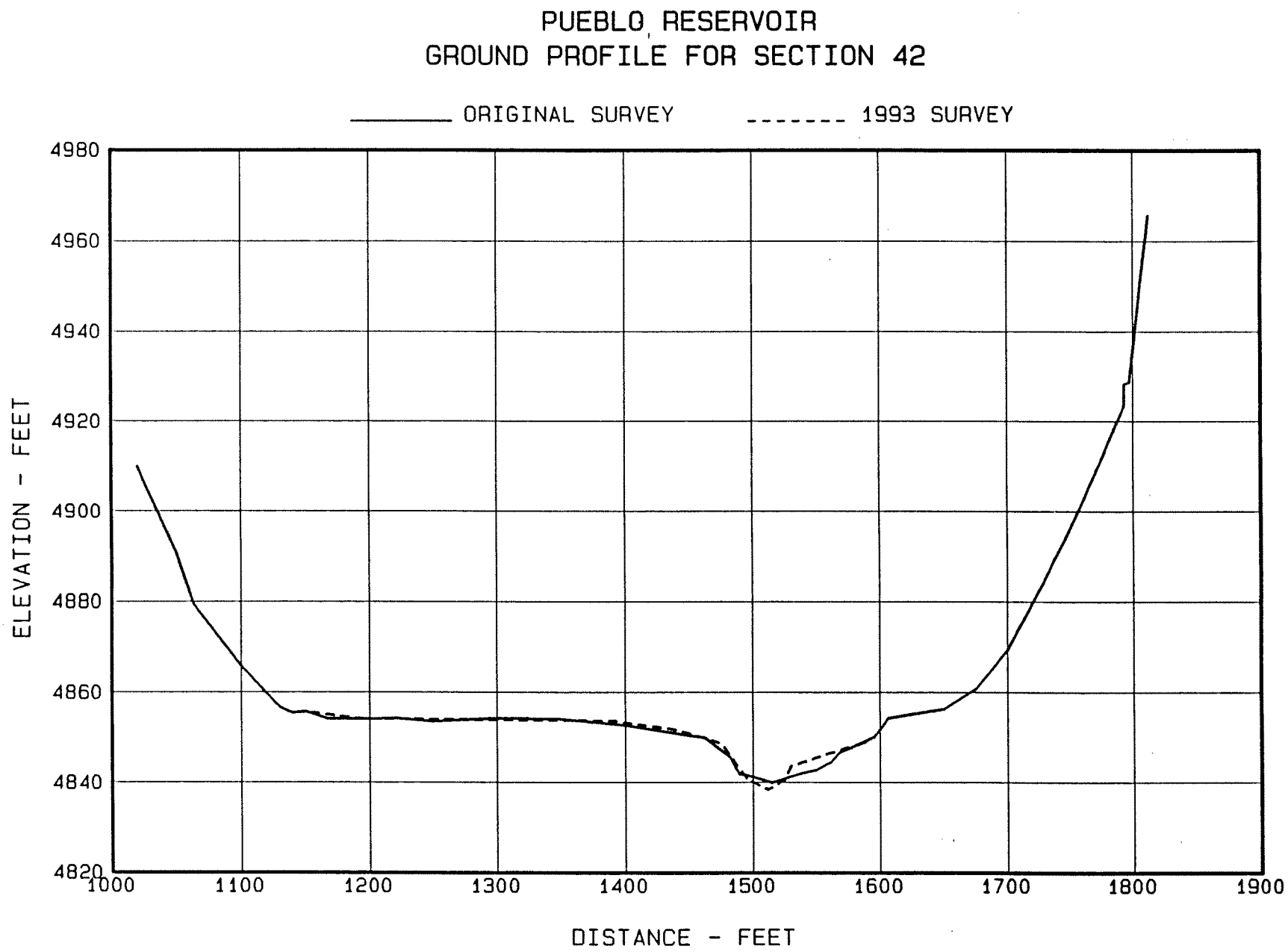


Figure 32. - Sediment Range 42 - Rock Creek.

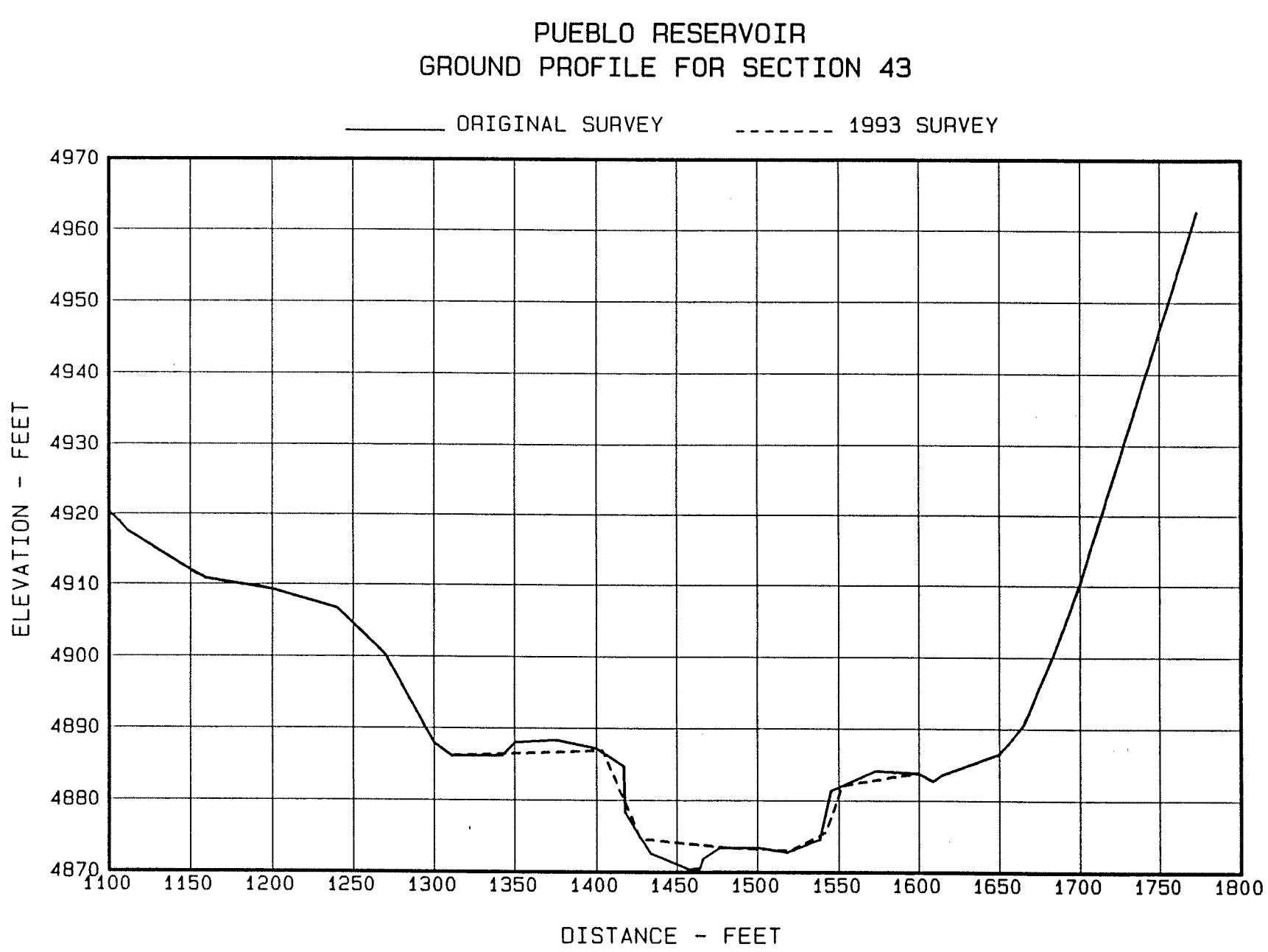


Figure 33. - Sediment Range 43 - Rock Creek.

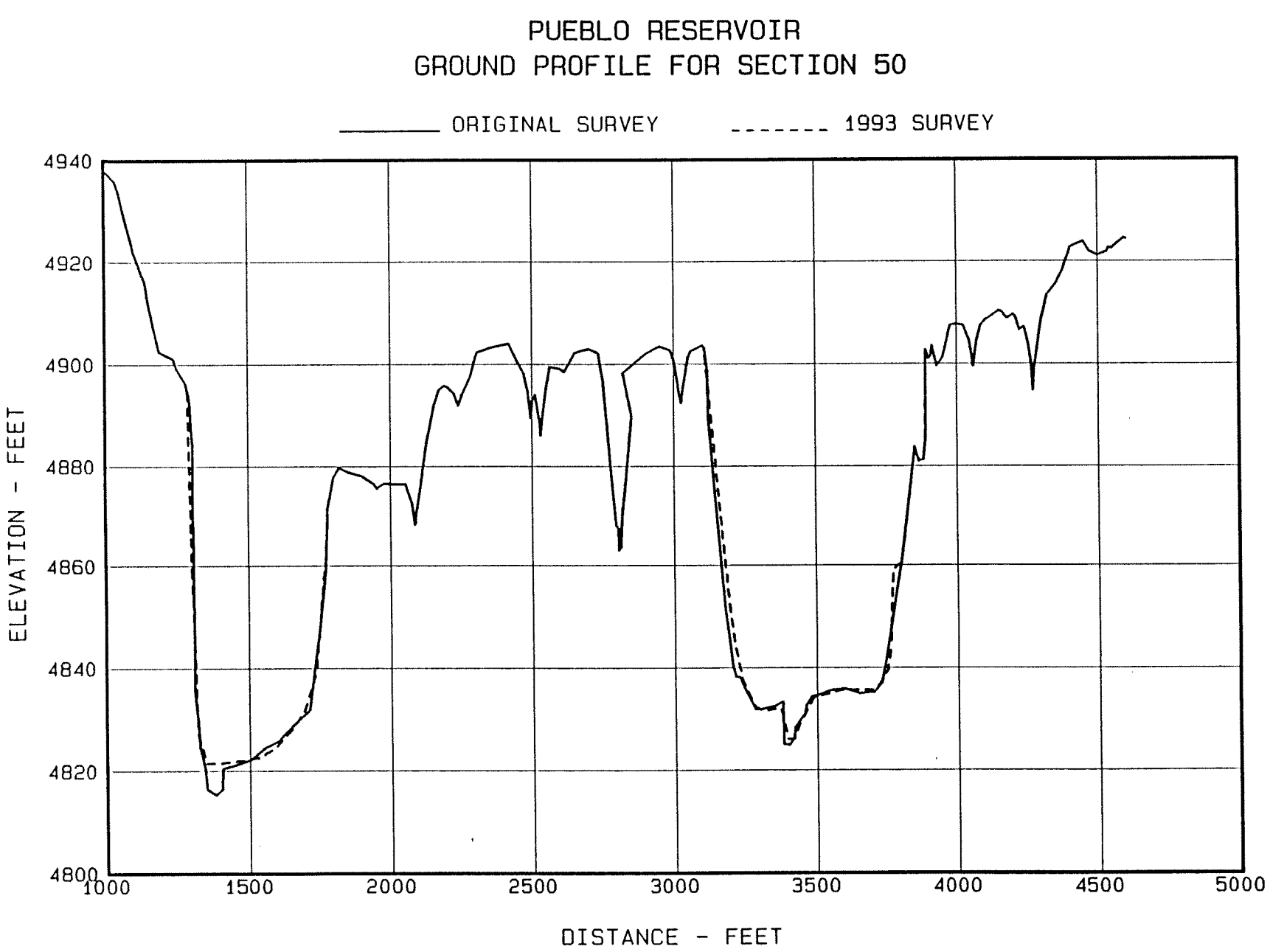


Figure 34. - Sediment Range 50 - Peck Creek.

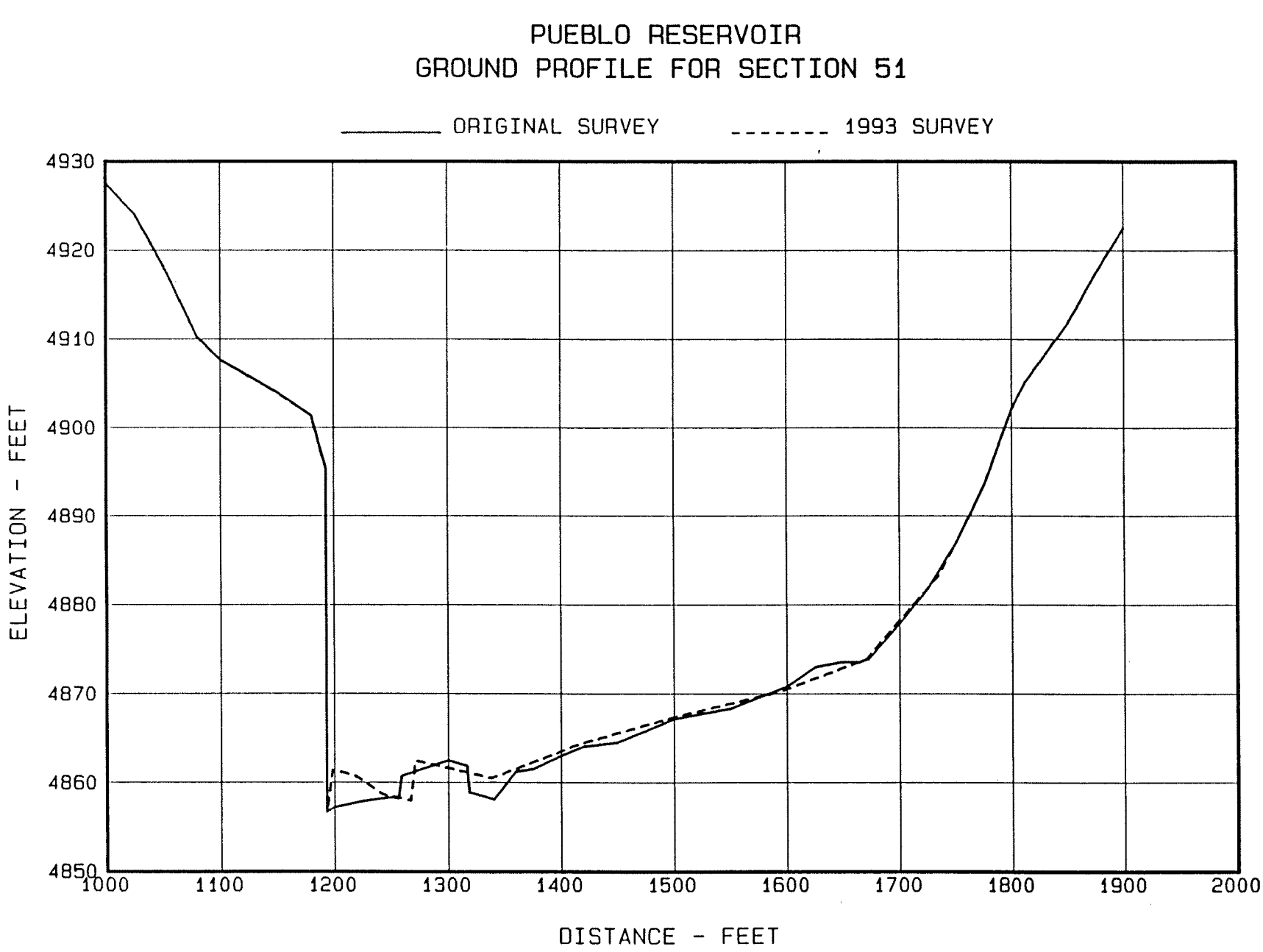


Figure 35. - Sediment Range 51 - Peck Creek.

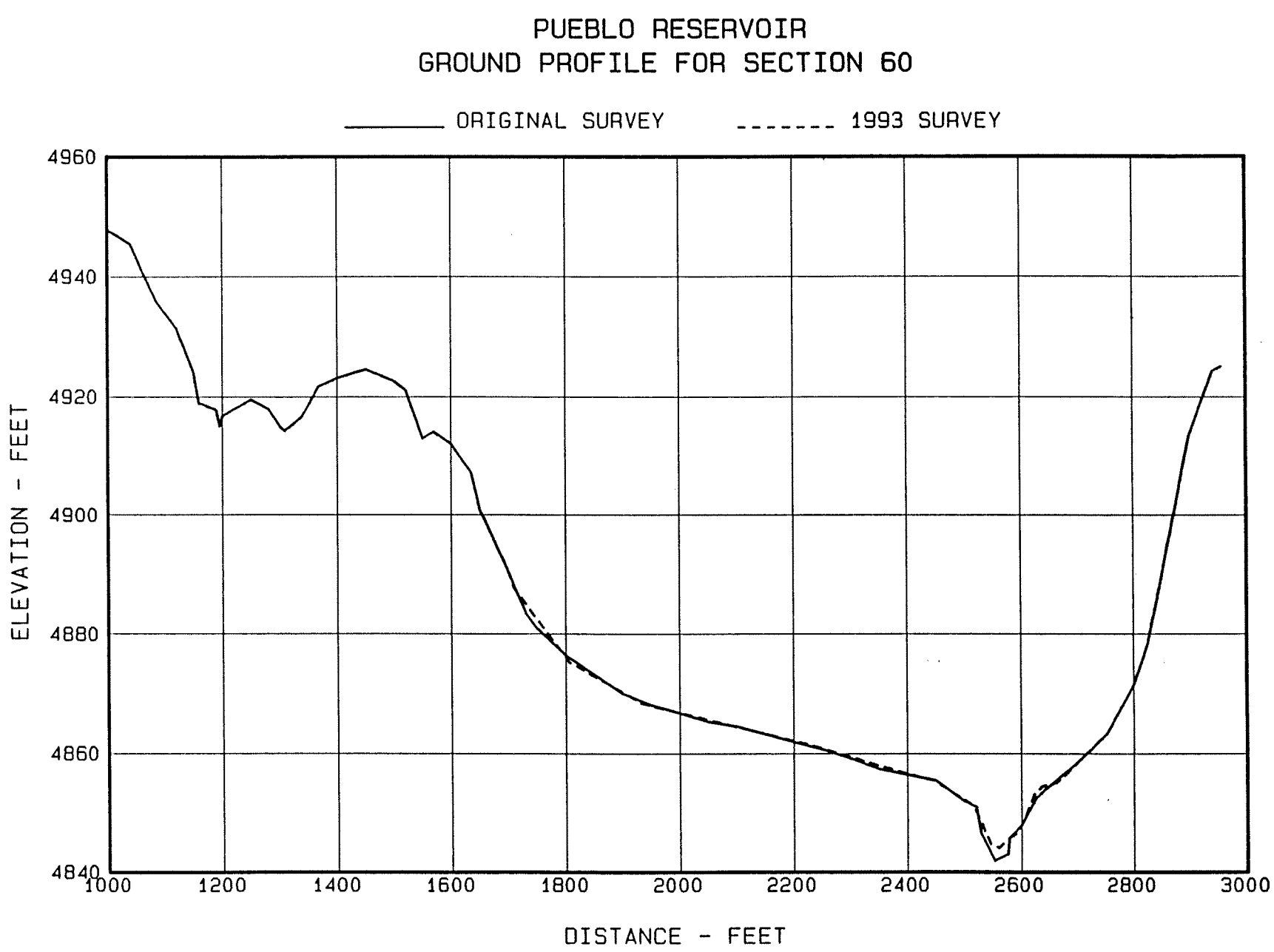
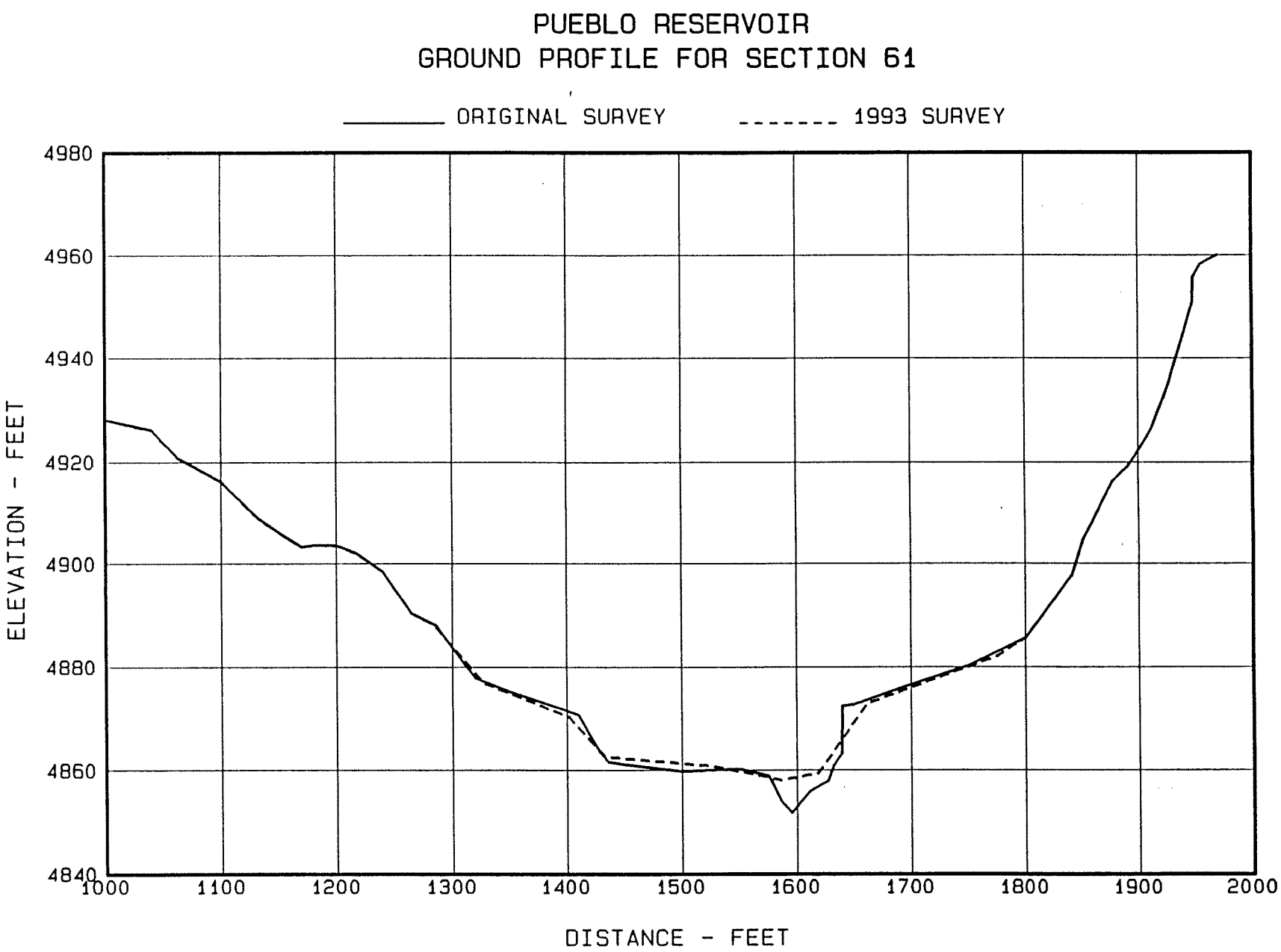


Figure 36. - Sediment Range 60 - Turkey Creek.



61

Figure 37. - Sediment Range 61 - Turkey Creek.

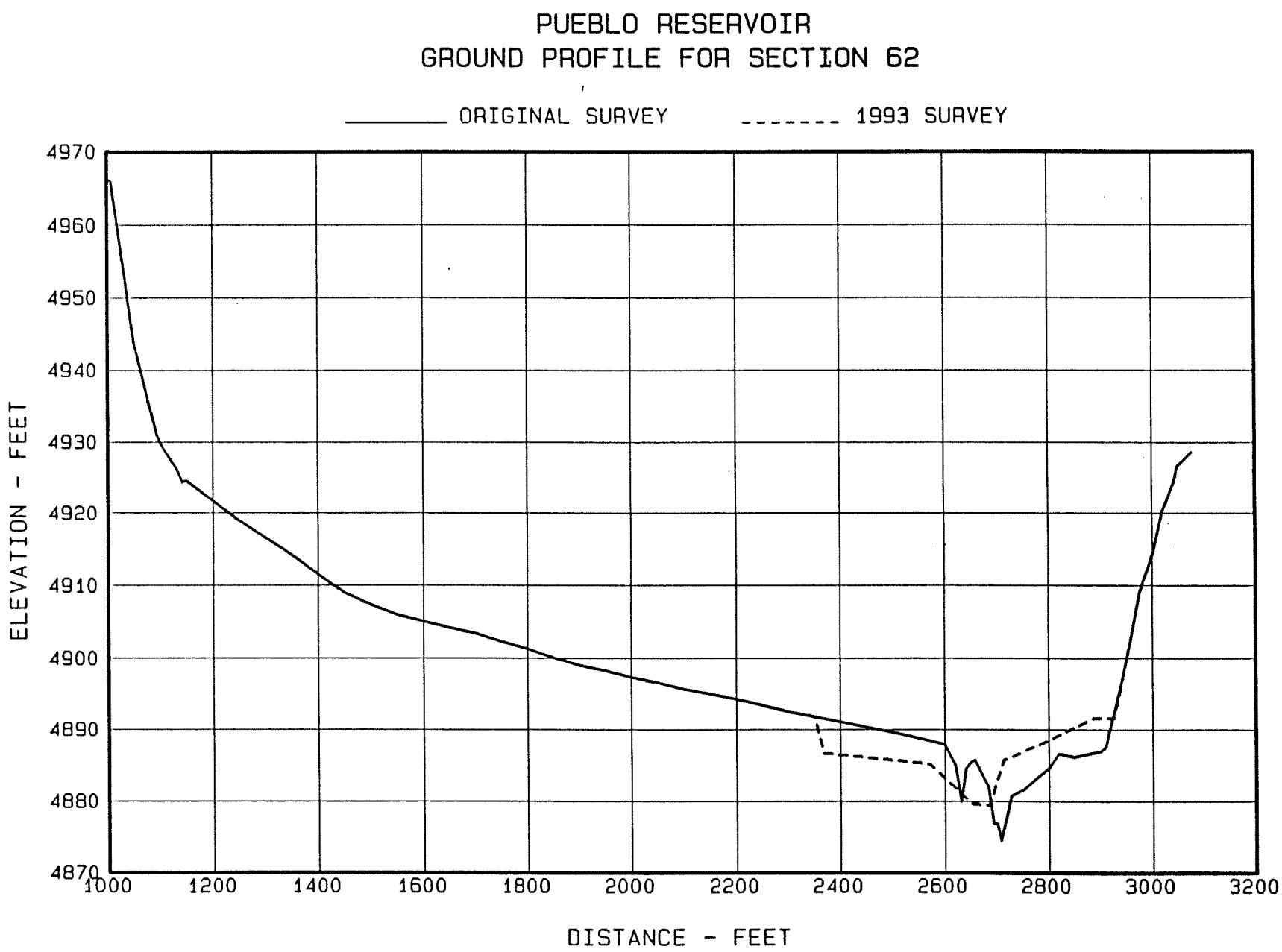


Figure 38. - Sediment Range 62 - Turkey Creek.

Mission

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American Public.