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Erosion of the Cliffs of Outer Cape Cod: Tables and Graphs

by

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The following tables and graphs place in convenient storage the results of several years of careful surveying and at the same time provide rudimentary interpretation of results by comparing erosion rates. The reader will find listed in the bibliography pertinant published papers which analyze these coastal erosion data in great detail.

The Marindin Surveys

Mr. Henry Marindin, an assistant to the Superintendent of the U. S. Coast and Geodetic Survey, conducted a most interesting and worthwhile series of measurements which allowed him to determine the rates of erosion on the cliffs and beaches of Outer Cape Cod (Marindin, 1889, 1891). These were made from August 1887 through 1889. Lines in Provincetown Harbor were surveyed in 1890. In brief, Marindin established a series of points, 229 in all, approximately 300 meters apart along almost the entire eastern coast of Cape Cod and on around the Provincelands hook (Figures 1-6F). From these points, which he marked in the field by oaken stakes, he published measured distances and elevations over the ground more or less at right angles to the coast. The elevations were established on a mean sea level datum that he derived from tidal observations made at Chatham, in 1887. Marindin located his origins in terms of latitude and longitude but, because of a change in the geodetic grid, it is necessary to correct his origins by subtracting 0.6 second from each of his latitudes in order to plot the points on contemporary charts. This survey, which was carried out under the usual adversities of scrubby vegetation and variable weather, technically was an excellent job. After repeating some of his measurements we fully appreciate Marindin's difficulties and accomplishments.

Marindin simply compared the new position of the cliff base, or cliff top, or high water line with its position on earlier charts that had been surveyed in 1848, 1856 or 1868. He gives the average rate of erosion along the coast as 3.2 feet per year. Marindin published all of the data concerning the location of the points of origin, the azimuths of the lines and the distances along the lines to cliff tops, cliff bases and water lines. He specifically stated that he hoped that someday someone would repeat his measurements.

Giese and Tasha, using both plane table and transit surveying methods reoccupied 74 of Marindin's points of origin located between Nauset at the south end of the cliffs, and Pilgrim Lake in the Provincelands. They marked each of the relocated points of origin with a concrete post which held a circular brass plate. They found none of Marindin's original oak stakes but in a few places our relocated points matched the descriptions of landmarks as given by Marindin. The average rate of change for the coast was obtained by drawing a line of best fit through all the points which were resurveyed (Figure 8).

Before resurveying Marindin's points we tried determining erosion rates by comparing the position of the coast, based on Marindin's data, with the position of the coast as given on the appropriate maps of the T-series, prepared from aerial photographs in 1940 by the U. S. Coast Geodetic Survey. We found that the rates of coastal changes measured this way were so erratic that the method was useless (Figure 8).

We compared the profiles measured in 1958 and 1959 with the profiles measured in 1879. Where the profiles crossed cliffs we compared the rate of change of the cliff lip and cliff base and used the average of the two. Where the profiles crossed dunes we chose the base of the foredune on the sea side as a point for comparison, supporting this choice where

possible by using mean sea level. Mean sea level itself is a bit complicated to use because these beaches change severely from day to day (Zeigler and Tuttle, 1961), and also because the local mean sea level differs from the Geodetic Sea level of 1929.

The major sources of error in determining rates of coastal change by this manner are failure to re-occupy the exact point of origin of the original survey, short term differential erosion of the cliffs and short term changes in the position of high water or beach level. The coast of Cape Cod has a smooth outline;therefore one might reason that the rate of erosion or accretion does not vary appreciably from place to place over long periods of time and the variation observed from profile to profile consequently is due to one of the above mentioned causes of error.

We assumed that the true rate of coastal change is the average of the values measured by us, and were careful to allow for the fact that coastal change is different from the Province-lands where the coast is accreting, the cliffs where the coast is cutting and the spit where the rate of erosion is much faster. This is illustrated by Figure 8.

We fully recognize the inherent danger of measuring a natural change over a limited period of years and dividing by the number of years to obtain an average. While such a number is probably nearly correct for the inclusive years it may become considerably less accurate if extrapolated for ten times the length of the observed period and even less when extended 100 times. On the other hand the coast of Cape Cod has maintained a smooth outline facing the sea for as long as people have been around to make maps. Until something indicates that the coast has been subjected to more severe sea states or more severe erosion we shall assume that the rates of coastal change presented herein are valid and therefore useful to be used in computations.

Changes along Outer Cape Cod are summarized in Figure 9. The main cliff section facing the sea is being eroded at a rate of approximately 2.5 feet per year. This erosion becomes less to the north and finally a point is reached near Pilgrim Lake where the coast is neither building nor cutting. On to the north of this point the great Provincetown hook of loose sands is developed and its coast is growing into the sea. Erosion rates show that Nauset Spit on the south end of our survey was being driven into the marshes at approximately 5 feet per year but we do not think this is a valid figure. At about the time the surveying was being done Nauset Spit was cut by a series of breakthroughs and coastal adjustments were rapid. We have observed no serious bending of this spit in the years following our survey and therefore we assume Nauset Spit must be retreating at the same rate as the cliffs.

Rate of cliff retreat can also be stated in terms of volume because the topography is known, relief having been measured during the surveying. Inasmuch as this report is concerned only with that part of the Cape north of Nauset Inlet, the volume figures are computed only for this section.

Table 1 presents the erosion rates in terms of cubic yards of sediment delivered to the sea per year for a 25,700 yard long strip of coast undergoing erosion as shown on Figure 9. Inasmuch as the cliffs have retreated about 60 yards in seventy years and the sea has removed a wedge below mean high water, in this case extreme high water is almost exactly at the base of the cliffs, this yearly increment is added also. How much material is made available offshore from the beach is unknown, clearly the volume available is greater than the values given in Table 1.

TABLE 1

Average yearly volume of sediment eroded from Outer Cape Cod between Nauset Coast Guard and Pilgrim Lake.

	Length yds.	Av. Cliff Ht. yds.	Erosion Rate/year	Volume per year cu. feet
Cliff Section between Nauset and Highland to the point where Erosion decreases Marindin Stations 54 to 141.	25,700	24.12	0.85	526,850
Rate of Erosion in the Region from Highland to point where accretion begins Marindin Stations 141-152	3,700	21.64	0.64	55,022
Material eroded from below sea level since Marindin Survey of 1887-89 between present mean high water and extreme high water 70 years ago.	Total Volume Eroded (Width) (59.50	(Length) (29,400	(Thickness) (6)	1,749,320
		Average yearly volume		24,990
Total yearly volume of sediment available to maintain beaches and bars				606,862

This work has been supported by the Geography Branch of the Office of Naval Research, Contract Number Nonr 1254 (00), (NR-388-018), and by Nonr 2196 (00).

The writers wish to acknowledge the cooperative spirit of members of the National Park Service at the Cape Cod National Seashore. Their enthusiasm for the work we have been doing is most rewarding. Also, we wish to thank the people in the towns of Provincetown, Truro, Wellfleet, Eastham, Orleans and Chatham for understanding and assistance to our field parties. The nature of this work is such that we must cross property boundaries and drive on beaches and in many other ways depend on local permission in order to complete our tasks. We hope that the results presented here will provide a useful basis for future development of their coastline and in some measure repay them for their tolerance.

Explanation of Tables

Profile Number- is that used by Marindin in his report of 1889. Readers will perhaps note that Marindin re-numbered his profiles for his final report so that the profiles were ordered from South to North. Locations of these profiles are correctly plotted on the accompanying charts.

Latitude- Latitudes have been adjusted by subtracting 0.6" from latitudes given by Marindin in accordance with new geodetic grids for all present day charts.

Longitude- Same as that of Marindin.

Azimuth- Geodetic azimuth measure from south through west to sourth, the same as for Marindin

Elevations- Based on Woods Hole levelling from various benchmarks some of which were the same ones used by Marindin

Profile Dates- Dates given for both surveys, and last date of recovery, i.e. whether the measurements could be re-located or not.

Note: Much detail is not stored in this report, such as the surveyors descriptions of each origin, photographs of the origin and profile and details of field surveying. This information is stored in the original field notes in Woods Hole.

Miller, R. L. and Zeigler, J. M. - A study of the relation between dynamics and sediment patterns in the region of shoaling waves. Fifth International Sedimentol. Congress, Geneva. Ecologae Helveticae 51 (3): 542-551. 1958.

Miller, R. L. and Zeigler, J. M.- A model relating dynamics and sediment pattern in equilibrium in the region of shoaling waves, breaker zone, and foreshore. Jour. Geol. 66 (4): 417-441. 1958.

Zeigler, J. M., Hayes, C. R. and Tuttle, S. D.- Beach changes during storms on Outer Cape Cod, Mass., Jour. Geol. 67 (3): 318-336. 1959.

Miller, R. L. and Zeigler, J. M. - Comparison of theoretical near-bottom mass transport velocities with observed sediment size and sorting patterns. Internat. Oceanogr. Congress. 1959, 635-36. 1959.

Zeigler, J. M. and Tuttle, S. D. - Beach changes based on daily measurements of four Cape Cod beaches. Jour. Geol. 68 (5): 583-599. 1961.

Zeigler, J. M. and Miller, R. L. - A study of sediment distribution in the zone of shoaling waves over complicated bottom topography. Shepard Commemorative Volume. In press.

Zeigler, J. M., Tuttle, S. D., Giese, Graham, and Tasha, Herman - Residence Time of Sand on Beaches and Bars of Outer Cape Cod.

The Following Information is on File in Drawer 13, Room 101, Old Main, Woods Hole Oceanographic Institution:

1. Manila Folder with contents indexed on outside, namely:

   A. Folder containing computations and pertinent data, plus, indexes of photographs of origin points.

   B. Complete xerox copies of Marindin's Original Report.

   C. Deck of information cards made by G. Giese which give survey dates, and reference to Field Note Books, Profile data for 187 and 188 are on pages 129-135 of the beach profile notebook for 1962.

2. Four field notebooks with original levelling information and station descriptions labelled I, II, III, IV.

3. Sheets from which blue cover tables were made.

4. Envelope containing aerial photographs on which all Marindin origin points were located.

5. Original plane table sheets in rolls.

6. Large scale plots of the profiles.

7. Multilith master sheets of this report.

8. All bench mark information, of which there is considerable.

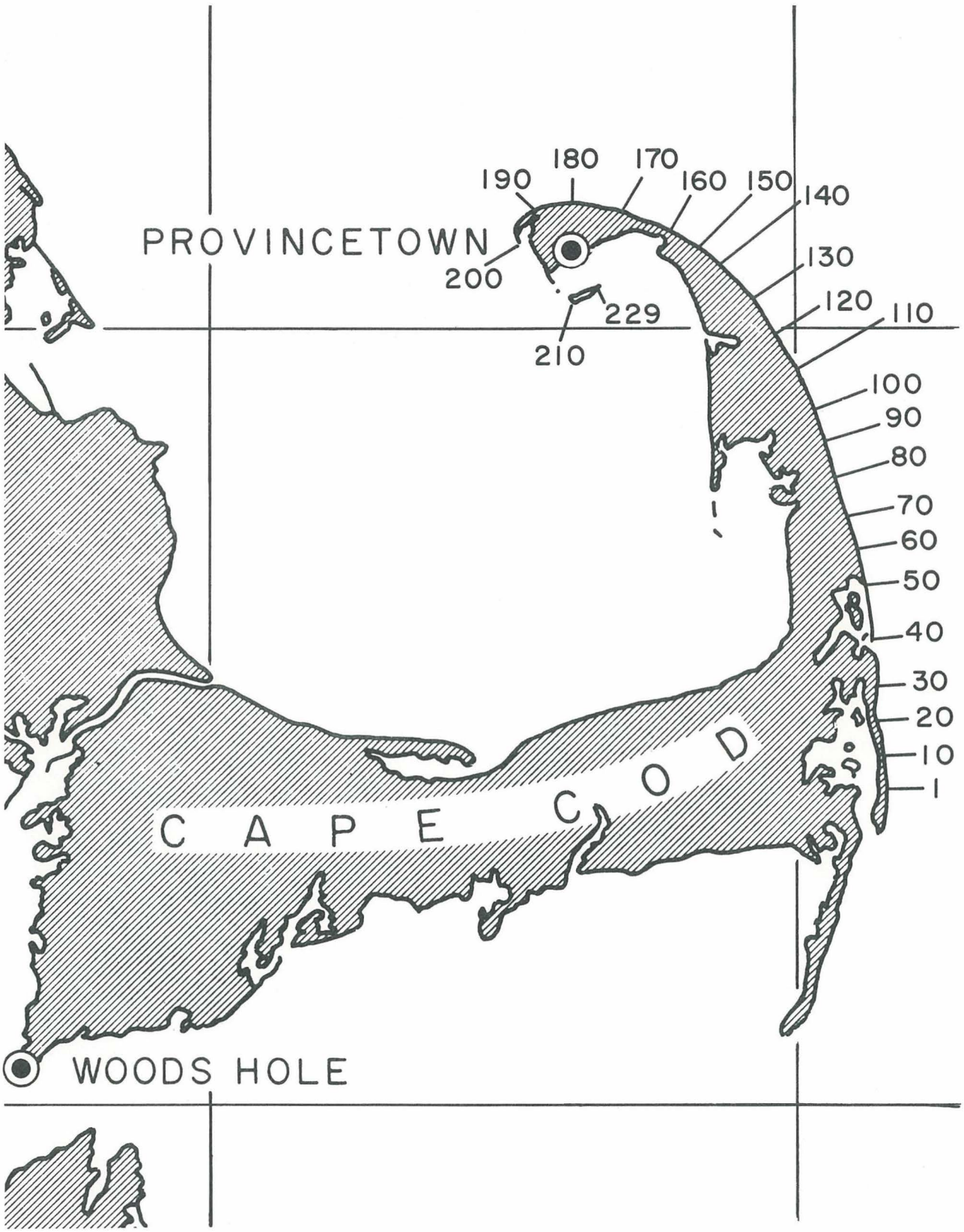


Figure 1. Index chart of Cape Cod showing approximate positions of profiles.

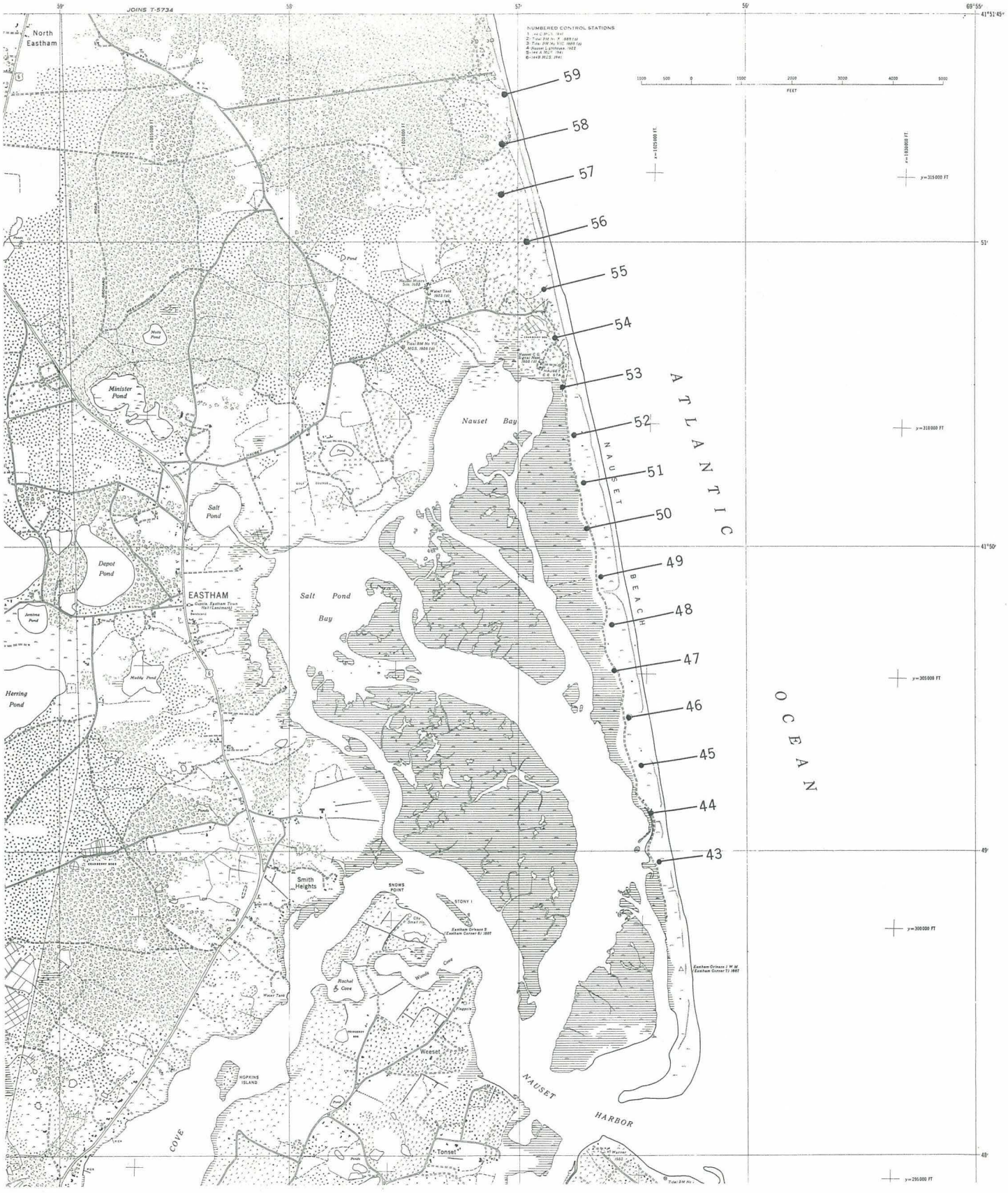


Figure 2. Exact positions of profiles 43 through 59.

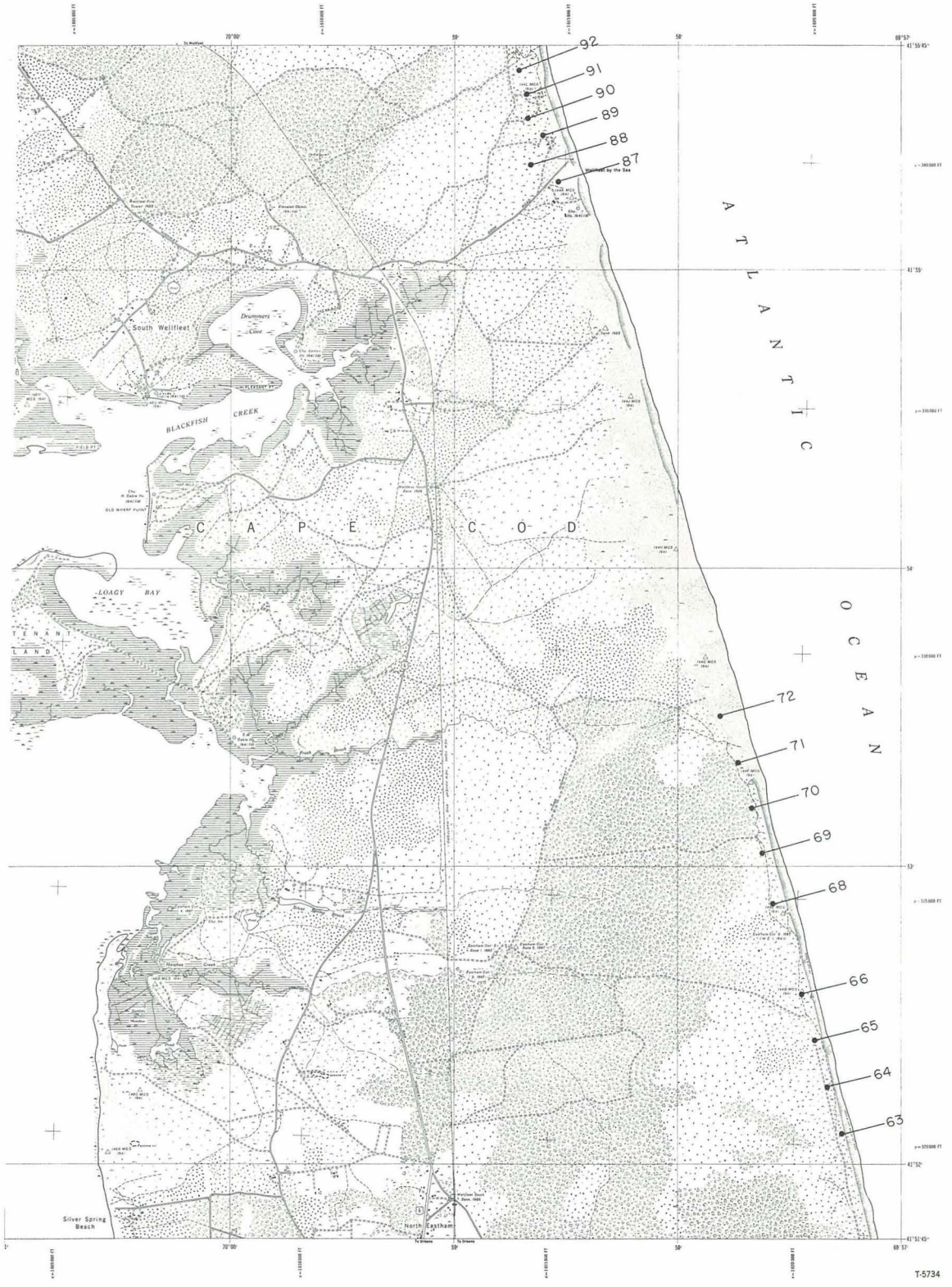


Figure 3. Exact positions of profiles 63 through 72 and 87 through 92.

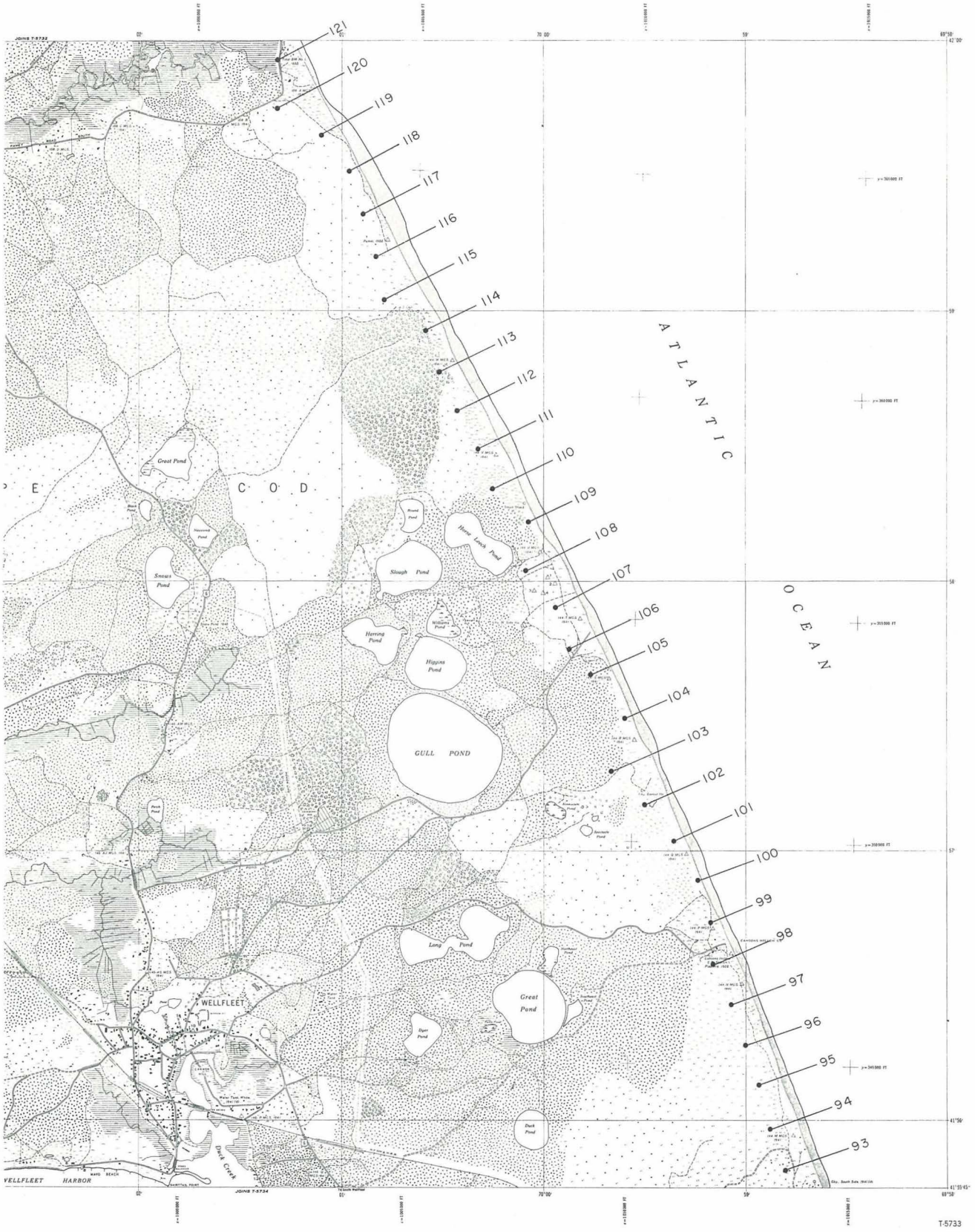


Figure 4. Exact positions of profiles 93 through 121

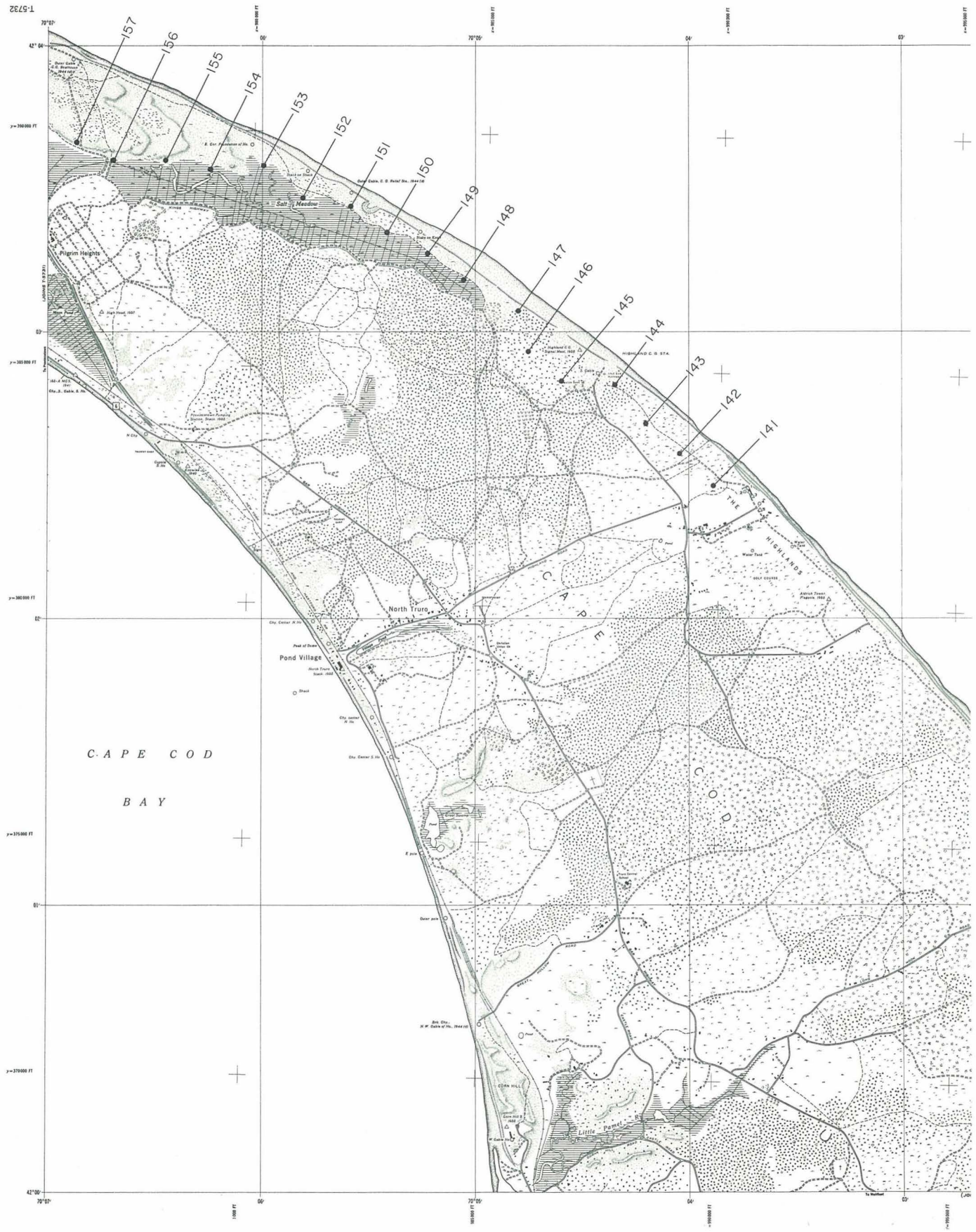


Figure 5. Exact positions of profiles 141 through 157.

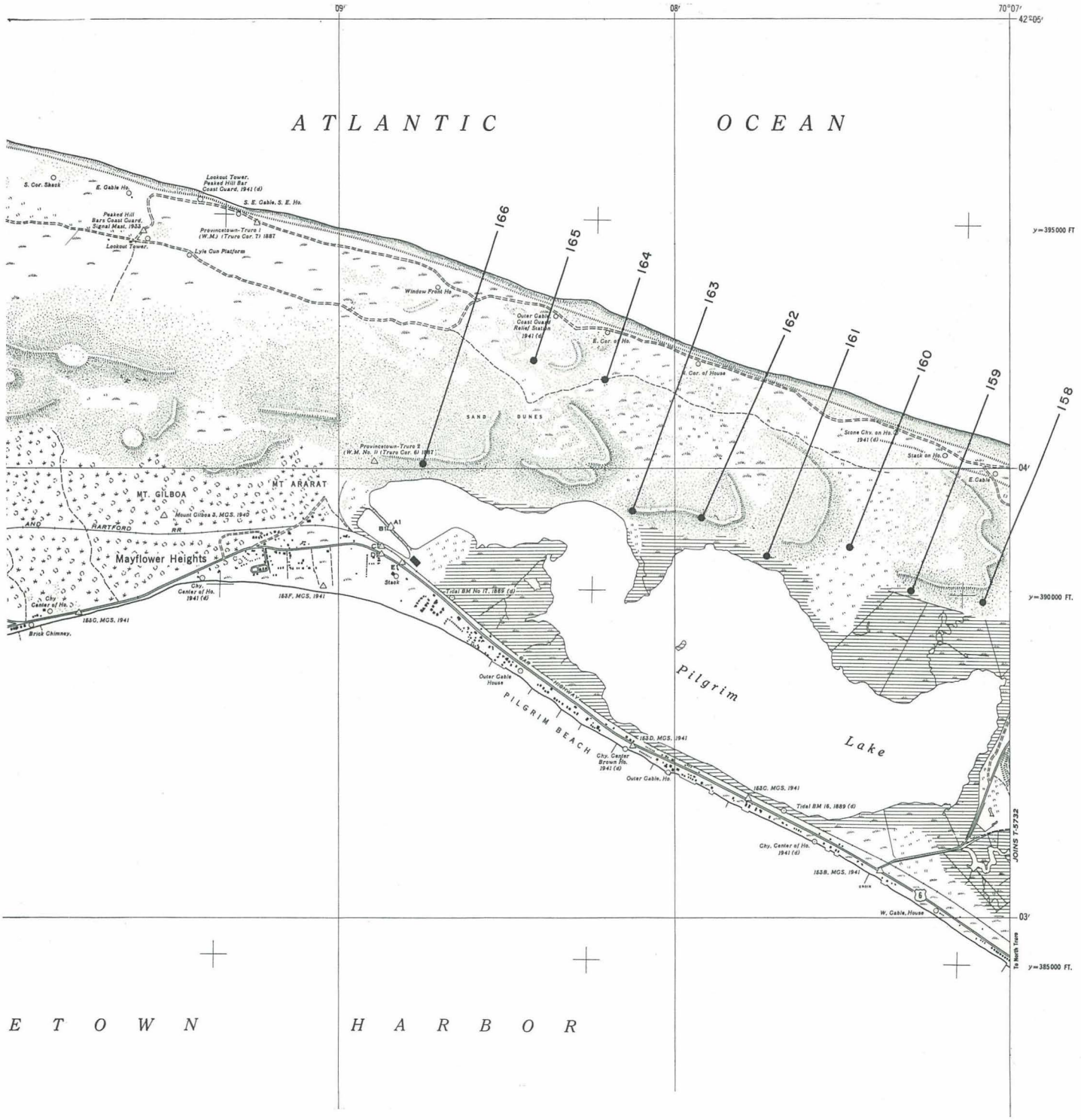


Figure 6. Exact positions of profiles 158 through 166.

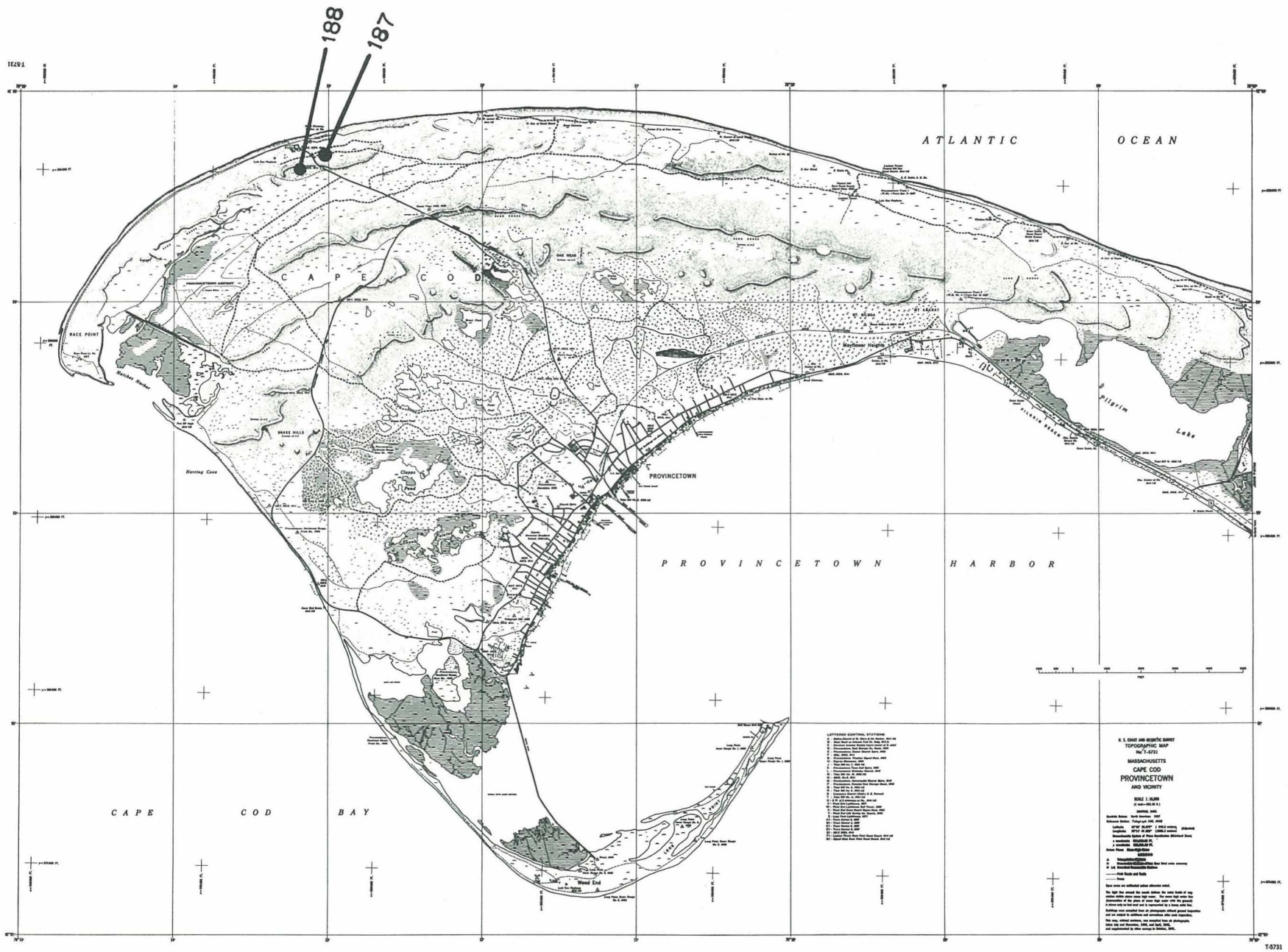


Figure 7. Exact positions of profiles 187 and 188.

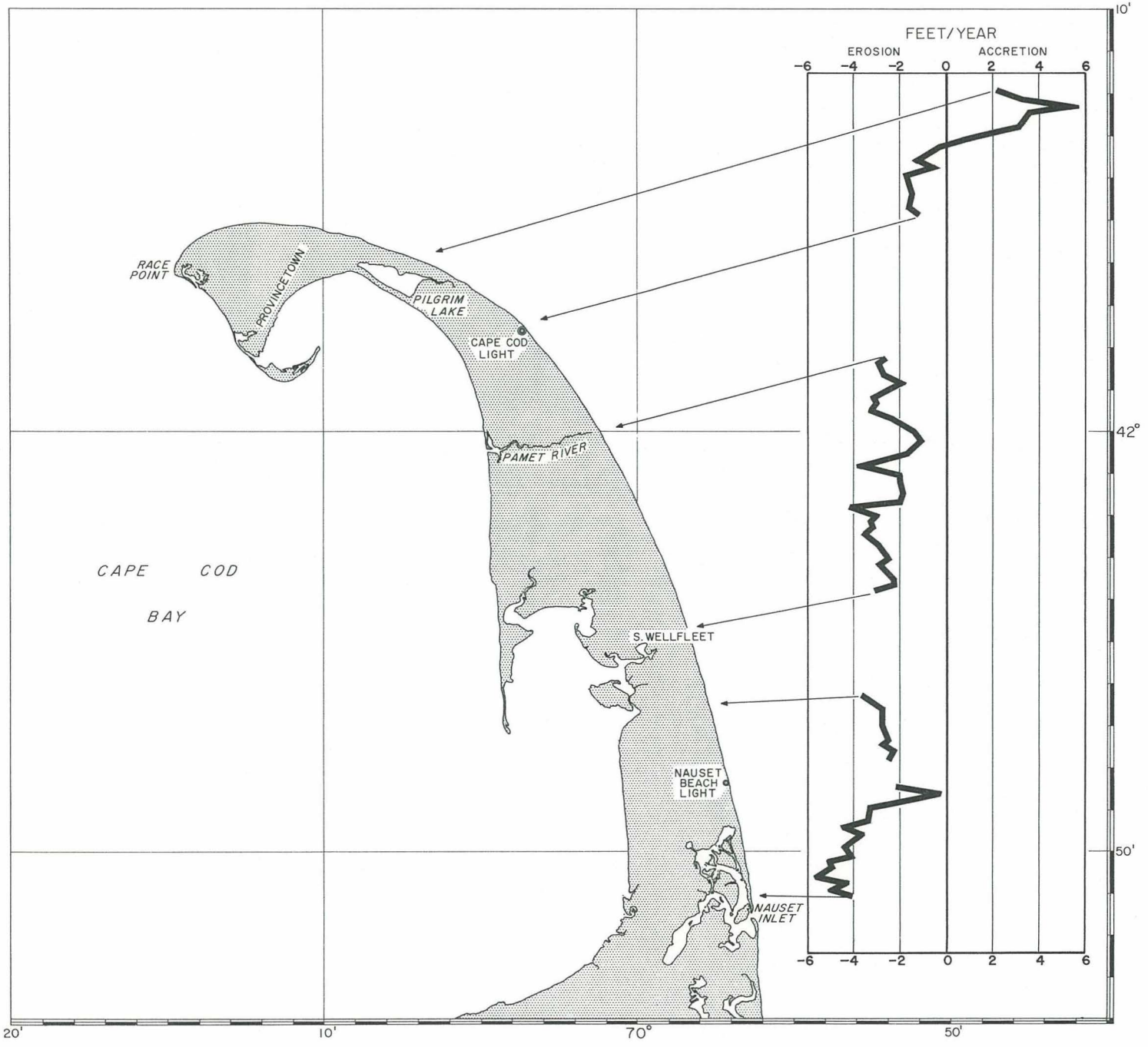


Figure 8. Erosion rates, east side of Cape Cod based on re-survey of profiles established in 1889.

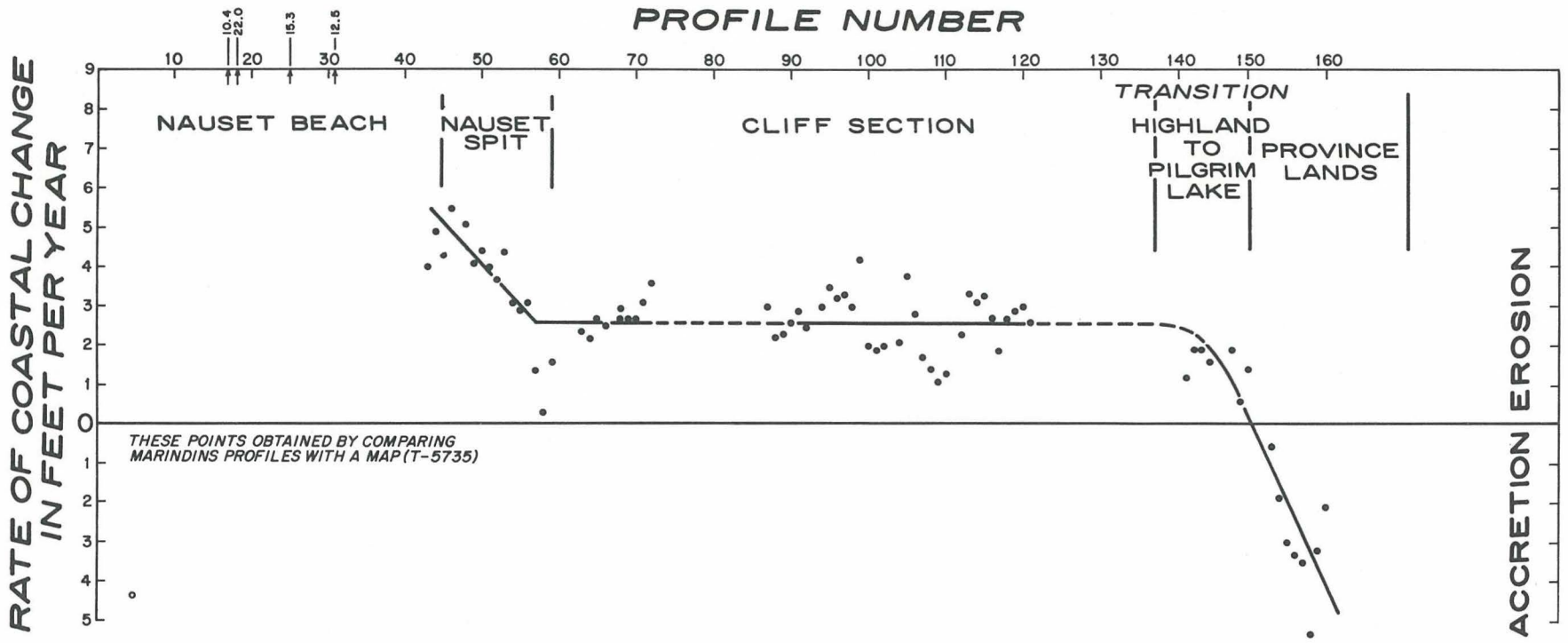


Figure 9. Rates of erosion and derivation of average rate.

43

Lat. 41° 48' 57.7"
Long. 69° 56' 23.3"
Az. 258° 52'

Dist.	Elev.	Remarks
0	7.78	Top of Mon.
0	7.14	
57	7.89	
130	10.98	Top of berm
146	8.69	High tide mark
200	0.32	

Profile date: 10/9/56

Monument lost: 9/17/57

Average loss/yr: 4.0' (11' contour)

44

Lat. 41° 49' 07.3"
Long. 69° 56' 25.7"
Az. 258° 52'

Dist.	Elev.	Remarks
0	8.87	Top of Mon.
0	8.03	
105	11.86	Top of berm
125	8.80	High tide mark
170	2.10	

Profile date: 10/9/56

Monument lost: 9/17/57

Average loss/yr: 4.9'
(11' contour)

45

Lat. 41° 49' 16.7"
Long. 69° 56' 28.1"
Az. 258° 52'

Dist.	Elev.	Remarks
0	13.89	Top of Mon.
0	13.10	
38	14.72	
59	19.72	
122	23.04	Top of dune
146	12.75	Foot of dune
191	12.39	Top of berm
245	3.50	

Profile date: 10/9/56

Average loss/yr: 4.3' Dune foot

46

Lat. 41° 49' 26.2"
Long. 69° 56' 30.8"
Az. 258° 52'

Dist.	Elev.	Remarks
0	13.59	Top of Mon.
0	11.96	
20	15.20	
144	25.41	
165	25.13	Bluff Station
197	11.90	Foot of Bluff
259	11.86	Top of berm
268	9.70	High tide mark
302	5.66	

Profile date: 10/9/56

Average loss/yr: 5.5' Dune foot

47

Lat. 41° 49' 35.5"
Long. 69° 56' 35.1"
Az. 258° 52'

Dist.	Elev.	Remarks
0	5.99	Top of Mon.
0	5.35	
140	11.51	
194	10.33	
223	13.65	
243	17.08	
306	25.32	
336	29.19	Bluff Station
360	14.69	Foot of Bluff
393	10.79	
404	9.96	High tide mark

Profile date: 10/9/56

Average loss/yr: 5.0' Berm

48

Lat. 41° 49' 44.5"
Long. 69° 56' 35.7"
Az. 258° 52'

Dist.	Elev.	Remarks
0	10.08	Top of Mon.
0	9.49	
47	7.90	
115	16.99	
200	24.98	Bluff Station
233	12.43	Foot of Bluff
281	12.14	High tide mark

Profile date: 10/9/56

Monument lost: 9/17/57

Average loss/yr: 5.1' Dune foot

49

Lat. 41° 49' 54.1"
Long. 69° 56' 38.1"
Az. 258° 52'

Dist.	Elev.	Remarks
0	9.74	Top of Mon.
0	8.00	
84	13.53	
138	13.71	
236	26.51	Top of dune
243	20.50	Foot of dune
265	12.42	High tide mark

Profile date: 10/9/56

Average loss/yr: 4.1' (15' contour)

50

Lat. 41° 50' 03.6"
Long. 69° 56' 41.4"
Az. 258° 52'

Dist.	Elev.	Remarks
0	7.38	Top of Mon.
0	6.63	
93	24.07	
139	27.44	
158	28.43	
227	20.53	
299	20.26	Top of dune
347	10.83	Foot of dune
397	11.08	
442	11.06	Top of berm
455	7.03	
482	7.42	High tide mark
547	-1.30	

Profile date: 10/11/56

Average loss/yr: 4.4' Dune foot

51

Lat. 41° 50' 12.4"
Long. 69° 56' 43.0"
Az. 258° 52'

Dist.	Elev.	Remarks
0	17.96	Top of Mon.
0	16.97	
67	26.79	
80	24.15	
117	24.50	
153	20.60	
187	21.44	
231	19.65	Top of dune
242	14.62	Foot of dune
320	10.11	Top of berm
345	6.22	
356	6.22	High tide mark
406	0.59	

Profile date: 10/11/56

Average loss/yr: 4.0' Dune foot

52

Lat. 41° 50' 22.1"
Long. 69° 56' 45.1"
Az. 258° 52'

Dist.	Elev.	Remarks
0	14.68	Top of Mon.
0	14.00	
88	16.38	
144	19.07	
163	22.29	
205	27.12	Bluff Station
232	13.09	Foot of Bluff
262	10.52	
297	10.25	
309	8.19	High tide mark
375	1.95	

(Monument lost 9/17/57)

(Profile date 10/11/56)

Average loss/yr: 3.7' Dune foot

53

Lat. 41° 50' 31.7"
Long. 69° 56' 48.5"
Az. 258° 52'

Dist.	Elev.	Remarks
0	5.51	Top of Mon.
0	4.85	
36	6.36	
159	14.20	
185	19.00	
214	26.89	
232	26.66	Bluff Station
285	11.22	Foot of bluff
328	7.73	
351	7.49	High tide mark
374	3.71	

Profile Date: 10/11/56

Average loss/yr: 4.4' Dune foot

54

Lat. 41° 50' 41.2"
Long. 69° 56' 50.4"
Az. 258° 52'

Dist.	Elev.	Remarks
0	21.40	Top of Mon.
0	20.95	
96	29.22	
123	26.77	
204	36.14	Bluff Station
222	17.45	Foot of Bluff

Profile Date: 10/11/56

Average loss/yr: 3.4' Bluff Foo

55

Lat. 41° 50' 50.8"
Long. 69° 56' 53.4"
Az. 258° 52'

Dist.	Elev.	Remarks
0	32.31	Top of Mon.
0	31.86	
32	27.19	
109	27.52	
169	37.08	
204	32.92	
211	30.24	Bluff Station
225	13.63	Foot of Bluff

Profile date: 10/11/56

Average loss/yr: 3.3 Bluff Foot

56

Lat. 41° 51' 00.2"
Long. 69° 56' 58.0"
Az. 258° 52'

Dist.	Elev.	Remarks
0	54.24	Top of Mon.
0	53.55	
9	52.47	
50	54.48	
214	52.07	
235	49.15	
253	48.64	
257	47.45	
298	42.93	
322	42.17	Bluff Station
361	12.22	Foot of Bluff

Profile date: 10/15/56

Average loss/yr: 3.3 Bluff Foot

57

Lat. 41° 51' 09.4"
Long. *69° 57' 04.2"
Az. 258° 52'

Dist.	Elev.	Remarks
0	54.06	Top of Mon.
0	53.28	
257	62.81	
347	65.93	
391	67.73	
415	68.58	
516	56.38	
567	57.83	
631	52.29	Bluff Station
682	11.29	Foot of Bluff

Profile date: 10/15/56

Average loss/yr: 1.5 Bluff Foot

* Marindin's report
Gives the longitude as:
69° 56' 04.2"
This is assumed an error
because this point falls
approx. 2/3 mile offshore.

58

Lat. 41° 51' 19.3"
Long. 69° 57' 04.2"
Az. 258° 52'

Dist.	Elev.	Remarks
0	59.72	Top of Mon.
0	59.07	
87	59.62	
121	62.42	
198	61.38	
225	59.12	
250	62.78	
300	58.25	
311	57.91	
338	56.18	
375	56.38	Bluff Station
431	13.00	Foot of Bluff

Profile date: 10/15/56

Average loss/yr: 0.4 Bluff Foot

59

Lat. 41° 51' 29.4"
Long. 69° 57' 03.4"
Az. 258° 52'

Dist.	Elev.	Remarks
0	42.35	Top of Mon.
0	41.75	
11	40.95	Bluff Station
68	14.81	Foot of Bluff

Profile date: 10/15/56

Station lost (over edge of bluff) 9/17/57

Average loss/yr: 2.1 Bluff Foot

63

Lat. 41° 52' 06.2"
Long. 69° 57' 16.7"
Az. 256° 13'

Dist.	Elev.	Remarks
0	77.35	Top of Mon.
0	76.69	
61	77.49	Bluff Station
137	14.43	Foot of Bluff

Profile date: 8/17/56

Average loss/yr: 1.9 Bluff

Average loss/yr: 2.9 Foot

2.4 Average

64

Lat. 41° 52' 15.4"
Long. 69° 57' 19.8"
Az. 256° 06'

Dist.	Elev.	Remarks
0	75.76	Top of Mon.
0	73.86	
28	74.31	
57	74.96	Bluff Station
132	11.52	Foot of Bluff

Profile date: 8/17/56

Average loss/yr: 2.0 Bluff

Average loss/yr: 2.4 Foot

2.2 Average

65

Lat. 41° 52' 24.9"
Long. 69° 57' 23.7"
Az. 256° 10'

Dist.	Elev.	Remarks
0	75.60	Top of Mon.
0	74.84	
29	73.56	
49	72.88	W. side of road cut
64	73.10	E. side of road cut
99	73.39	Bluff Station
164	13.76	Foot of Bluff

Profile date: 8/17/56

Average loss/yr: 2.3 Bluff

Average loss/yr: 3.1 Foot

2.7 Average

66

Lat. 41° 52' 34.2"
Long. 69° 57' 26.8"
Az. 256° 07'

Dist.	Elev.	Remarks
0	73.73	Top of Mon.
0	73.00	
17	72.64	W. side of road cut
36	72.31	E. side of road cut
79	73.14	Bluff Station
154	14.82	Foot of Bluff

Profile date: 8/17/56

Average loss/yr: 1.6 Bluff

Average loss/yr: 3.4 Foot

2.5 Average

68

Lat. 41° 52' 52.6"
Long. 69° 57' 34.6"
Az. 256° 14'

Dist.	Elev.	Remarks
0	71.56	Top of Mon.
0	69.87	
73	73.21	
116	72.79	W. side of road
145	73.93	
229	69.04	Bluff Station
308	11.32	Foot of Bluff

Profile date: 8/17/56

Average loss/yr: 2.4 Bluff

Average loss/yr: 3.0 Foot

2.7 Average

69

Lat. 41° 53' 02.5"
Long. 69° 57' 37.5"
Az. 256° 10'

Dist.	Elev.	Remarks
0	68.49	Top of Mon.
0	67.16	
42	66.39	
54	67.34	
132	67.01	
172	71.34	
217	72.54	Bluff Station
304	13.34	Foot of Bluff

Profile date: 8/17/56

Average loss/yr: 2.6 Bluff

Average loss/yr: 2.8 Foot

2.7 Average

70

Lat. 41° 53' 11.9"
Long. 69° 57' 40.0"
Az. 256° 07'

Dist.	Elev.	Remarks
0	76.61	Top of Mon.
0	75.11	
46	78.37	
75	77.87	W. side of road
118	76.09	
143	78.32	Bluff station
173	65.24	
237	17.64	Foot of Bluff

Profile date: 8/17/56

Average loss/yr: 2.6 Bluff

Average loss/yr: 2.8 Foot

2.7 Average

71

Lat. 41° 53' 30.3"
Long. 69° 57' 49.0"
Az. 256° 03'

Dist.	Elev.	Remarks
0	51.82	Top of Mon.
0	50.64	
287	52.97	Bluff Station
352	13.82	Foot of Bluff

Profile date: 8/17/56

Average loss/yr: 3.4 Bluff

Average loss/yr: 3.7 Foot

3.6 Average

71

Lat. 41° 53' 21.2"
Long. 69° 57' 44.5"
Az. 256° 00'

Dist.	Elev.	Remarks
0	61.34	Top of Mon.
0	61.07	
164	54.36	
194	56.00	Bluff Station
263	13.50	Foot of Bluff

Profile date: 8/17/56

Monument lost: 3/17/59

Average loss/yr: 2.9 Bluff

Average loss/yr: 3.4 Foot

3.1 Average

87

Lat. 41° 55' 17.9"
Long. 69° 58' 32.5"
Az. 253° 27'

Dist.	Elev.	Remarks
0	43.07	Top of Mon.
0	42.66	
39	46.08	
129	51.70	
178	52.87	
194	51.48	
311	53.52	Bluff Station
382	19.44	Foot of Bluff

Profile date: 8/1/57

Average loss/yr: 3.1 Bluff

Average loss/yr: 3.0 Foot

3.0 Average

88

Lat. 41° 55' 21.2"
Long. 69° 58' 39.5"
Az. 253° 31'

Dist.	Elev.	Remarks
0	66.23	Top of Mon.
0	65.72	
188	63.57	
325	63.38	
478	55.68	
506	55.35	
541	51.20	
634	48.74	
724	41.32	
760	37.86	Bluff Station
814	19.51	Foot of Bluff

Profile date: 8/2/57

Average loss/yr: 2.3 Bluff

Average loss/yr: 2.2 Foot

2.2 Average

89

Lat. 41° 55' 26.9"
Long. 69° 58' 36.5"
Az. 253° 20'

Dist.	Elev.	Remarks
0	73.89	Top of Mon.
0	73.46	
46	70.90	
99	65.50	
188	59.66	
262	63.17	
357	60.85	
367	61.26	
373	61.22	Bluff Station
456	16.44	Foot of Bluff

Profile date: 8/15/57

Average loss/yr: 2.2 Bluff

Average loss/yr: 2.4 Foot

2.3 Average

90

Lat. 41° 55' 31.1"
Long. 69° 58' 40.4"
Az. 253° 25'

Dist.	Elev.	Remarks
0	88.86	Top of Mon.
0	88.44	
54	84.98	
111	86.50	
175	81.48	
233	82.50	
288	81.44	
356	76.84	
451	74.54	
469	71.29	
479	66.04	Bluff Station
595	20.29	Head of Terrace
627	19.90	Terrace Station
628	17.43	Foot of Terrace

Profile date: 8/5/57

Average loss/yr: 2.3 Bluff

Average loss/yr: 3.0 Foot

2.6 Average

91

Lat. 41° 55' 35.5"
Long. 69° 58' 41.0"
Az. 253° 25'

Dist.	Elev.	Remarks
0	87.04	Top of Mon.
0	86.94	
47	86.41	
72	88.26	
132	87.64	
293	78.53	
370	81.11	
397	78.44	
401	78.34	Bluff Station
502	20.34	Head of Terrace
516	20.29	Terrace Station
518	16.13	Foot of Terrace

Profile date: 8/7/57

Monument lost: 3/16/59

Average loss/yr: 2.7 Bluff

Average loss/yr: 3.0 Foot

2.9 Average

92

Lat. 41° 55' 40.2"
Long. 69° 58' 43.0"
Az. 253° 20'

Dist.	Elev.	Remarks
0	74.45	Top of Mon.
0	73.97	
100	51.60	
199	43.92	
328	43.59	
395	42.38	
410	37.38	
453	35.08	
464	33.86	
485	30.44	Bluff Station
521	21.49	Edge of blow-out
527	15.62	Foot of Bluff

Profile date: 8/7/57

Average loss/yr: 2.4 Bluff

Average loss/yr: 2.6 Foot

2.5 Average

96

Lat. 41° 56' 16.3"
Long. 69° 59' 00.2"
Az. 250° 02'

Dist.	Elev.	Remarks
0	84.84	Top of Mon.*
0	83.42	On road
32	87.02	E. top of road cut
53	85.03	
83	79.35	
140	73.30	
250	88.56	
302	87.97	
390	97.41	
407	95.43	
419	95.21	
423	92.08	
447	85.76	Bluff Station
560	15.80	Foot of Bluff

Profile date: 8/9/57

Average loss/yr: 3.0 Bluff

Average loss/yr: 3.4 Foot

3.2 Average

* Monument placed 12 feet west of true origin, which falls on asphalt road.

97

Lat. 41° 56' 25.3"
Long. 69° 59' 04.4"
Az. 248° 35'

Dist.	Elev.	Remarks
0	104.45	Top of Mon.
0	103.73	
100	97.68	W. edge of road fill
161	93.70	E. edge of road fill
281	91.89	
341	93.96	
405	96.14	
425	95.82	Bluff Station
543	12.01	Foot of Bluff

Profile date: 8/13/57

Average loss/yr: 3.3 Bluff

Average loss/yr: 3.4 Foot

3.3 Average

98

Lat. 41° 56' 34.7"
Long. 69° 59' 09.5"
Az. 247° 00'

Dist.	Elev.	Remarks
0	108.37	Top of Mon.
0	107.70	
60	102.36	
116	92.86	
228	83.49	
303	75.51	
387	75.66	
432	78.27	
440	78.59	Bluff Station
556	9.74	Foot of Bluff

Profile date: 8/13/57

Average loss/yr: 3.0 Bluff

Average loss/yr: 3.1 Foot

3.0 Average

99

Lat. 41° 56' 44.1"
Long. 69° 59' 10.2"
Az. 247° 00'

Dist.	Elev.	Remarks
0	106.97	Top of Mon.
0	106.57	
13	107.83	
77	104.03	
94	99.96	
142	99.05	
154	96.72	Bluff Station
271	10.88	Foot of Bluff

Profile date: 8/13/57

Average loss/yr: 4.4 Bluff

Average loss/yr: 4.0 Foot

4.2 Average

100

Lat. 41° 56' 53.6"
Long. 69° 59' 14.7"
Az. 249° 40'

Dist.	Elev.	Remarks
0	83.80	Top of Mon.
0	83.16	
9	86.37	
21	86.36	
31	86.20	
48	82.07	
75	82.12	
98	78.23	
124	77.75	
140	77.99	Bluff Station
246	11.49	Foot of Bluff

Profile date: 8/13/57

Average loss/yr: 1.7 Bluff

Average loss/yr: 2.2 Foot

2.0 Average

101

Lat. 41° 57' 02.3"
Long. 69° 59' 21.6"
Az. 246° 09'

Dist.	Elev.	Remarks
0	73.95	Top of Mon.
0	73.30	
26	78.93	
62	82.63	
100	83.44	
171	95.29	
189	94.31	
198	93.92	
207	89.47	
235	83.49	
271	76.78	Bluff Station
383	5.23	Foot of Bluff

Profile date: 8/13/57

Average loss/yr: 1.7 Bluff

Average loss/yr: 2.0 Foot

1.9 Average

102

Lat. 41° 57' 10.1"
Long. 69° 59' 30.1"
Az. 246° 09'

Dist.	Elev.	Remarks
0	14.93	Top of Mon.
76	4.60	
134	2.72	Edge of bog
296	2.80	Edge of bog
362	5.15	
398	10.19	
450	25.61	
492	38.85	
534	46.74	
543	48.20	
561	43.48	
574	42.93	
602	37.99	Bluff Station
638	16.69	Foot of Bluff

Profile date: 8/14/57

Average loss/yr: 1.7 Bluff

Average loss/yr: 2.3 Foot

2.0 Average

104

Lat. 41° 57' 29.6"
Long. 69° 59' 35.7"
Az. 246° 10'

Dist.	Elev.	Remarks
0	96.12	Top of Mon.
0	95.38	
38	89.81	
77	92.04	Bluff Station
203	14.64	Foot of Bluff

Profile date: 8/14/57

Average loss/yr: 1.7 Bluff

Average loss/yr: 2.5 Foot

2.1 Average

105

Lat. 41° 57' 39.2"
Long. 69° 59' 46.1"
Az. 246° 10'

Dist.	Elev.	Remarks
0	63.42	Top of Mon.
0	62.78	
63	64.55	
135	69.84	
227	66.64	
285	64.82	
328	66.86	
371	75.27	
390	74.36	
401	71.03	
431	69.58	Bluff Station
503	14.12	Foot of Bluff

Profile date: 8/14/57

Average loss/yr: 3.2 Bluff

Average loss/yr: 4.3 Foot

3.8 Average

106

Lat. 41° 57' 45.1"
Long. 69° 59' 52.4"
Az. 244° 38'

Dist.	Elev.	Remarks
0	32.78	Top of Mon.
30	32.96	
63	28.56	
328	26.36	S. side of road
395	34.03	
446	35.82	
543	49.08	Bluff Station
660	13.63	Foot of Bluff

Profile date: 8/14/57

Average loss/yr: 2.7 Bluff

Average loss/yr: 2.9 Foot

2.8 Average

107

Lat. 41° 57' 54.4"
Long. 69° 59' 56.4"
Az. 242° 30'

Dist.	Elev.	Remarks
0	28.85	Top of Mon.
0	28.42	
95	15.88	
291	6.50	
362	10.83	
448	23.17	
517	26.08	
529	27.00	Bluff Station
551	16.51	Foot of Bluff

Profile date: 8/16/57

Average loss/yr: 1.7 Bluff

Average loss/yr: 1.6 Foot

1.7 Average

108

Lat. 41° 58' 02.4"
Long. 70° 00' 05.1"
Az. 243° 54'

Dist.	Elev.	Remarks
0	20.52	Top of Mon.
0	19.97	
218	19.35	
319	20.16	
471	28.31	
508	35.73	
551	29.28	
670	39.34	
699	38.00	
723	35.02	
732	35.08	Bluff Station
769	15.79	Foot of Bluff

Profile date: 8/16/57

Average loss/yr: 0.8 Bluff

Average loss/yr: 2.0 Foot

1.4 Average

109

Lat. 41° 58' 13.1"
Long. 70° 00' 04.5"
Az. 243° 54'

Dist.	Elev.	Remarks
0	63.48	Top of Mon.
0	62.73	
47	66.45	
79	65.47	
107	66.87	
157	61.08	
177	58.28	
199	55.16	
213	49.40	Bluff Station
264	15.23	Foot of Bluff

Profile date: 8/16/57

Average loss/yr: 0.7 Bluff

Average loss/yr: 1.5 Foot

1.1 Average

110

Lat. 41° 58' 20.2"
Long. 70° 00' 15.6"
Az. 243° 54'

Dist.	Elev.	Remarks
0	72.86	Top of Mon.
0	72.30	
161	62.44	
313	64.78	
338	57.83	
377	60.35	
419	54.88	
489	56.90	
572	57.82	
587	54.85	
593	55.19	
601	52.41	
654	44.87	Bluff Station
699	15.74	Foot of Bluff

Profile date: 8/16/57

Average loss/yr: 1.0 Bluff

Average loss/yr: 1.6 Foot

1.3 Average

112

Lat. 41° 58' 37.8"
Long. 70° 00' 25.9"
Az. 243° 51'

Dist.	Elev.	Remarks
0	118.60	Top of Mon.
0	118.05	
106	132.78	
156	134.35	
207	127.07	
327	116.55	
418	124.03	
448	119.17	
487	106.99	
501	107.24	Bluff Station
643	14.49	Foot of Bluff

Profile date: 8/20/57

Average loss/yr: 2.2 Bluff

Average loss/yr: 2.3 Foot

2.3 Average

113

Lat. 41° 58' 46.4"
Long. 70° 00' 30.7"
Az. 243° 51'

Dist.	Elev.	Remarks
0	89.93	Top of Mon.
0	89.58	
176	115.14	
375	117.86	Bluff Station
533	16.39	Foot of Bluff

Profile date: 8/20/57

Average loss/yr: 3.1 Bluff

Average loss/yr: 3.5 Foot

3.3 Average

114

Lat. 41° 58' 55.8"
Long. 70° 00' 35.2"
Az. 243° 50'

Dist.	Elev.	Remarks
0	96.21	Top of Mon.
0	95.81	
153	66.28	
191	71.98	
242	73.36	
253	66.25	
321	62.05	Bluff Station
400	14.97	Foot of Bluff

Profile date: 8/20/57

Average loss/yr: 2.9 Bluff

Average loss/yr: 3.3 Foot

3.1 Average

115

Lat. 41° 59' 02.4"
Long. 70° 00' 47.6"
Az. 243° 00'

Dist.	Elev.	Remarks
0	134.23	Top of Mon.
0	133.78	
69	134.16	
145	128.26	
275	125.45	
360	136.92	
461	147.29	
472	143.39	
651	155.53	
664	147.62	
762	136.91	Bluff Station
951	17.27	Foot of Bluff

Profile date: 8/21/57

Average loss/yr: 3.2 Bluff

Average loss/yr: 3.4 Foot

3.3 Average

116

Lat. 41° 59' 12.3"
Long. 70° 00' 49.7"
Az. 241° 56'

Dist.	Elev.	Remarks
0	152.78	Top of Mon.
0	152.33	
207	158.77	
379	173.61	
450	171.61	Bluff Station
683	11.32	Foot of Bluff

Profile date: 8/21/57

Average loss/yr: 2.9 Bluff

Average loss/yr: 2.4 Foot

2.7 Average

117

Lat. 41° 59' 21.8"
Long. 70° 00' 53.7"
Az. 241° 56'

Dist.	Elev.	Remarks
0	144.99	Top of Mon.
0	144.44	
206	149.03	
261	145.71	
328	150.31	
333	150.58	Bluff Station
532	23.49	Foot of Bluff

Profile date: 8/22/57

Average loss/yr: 1.8 Bluff

Average loss/yr: 2.0 Foot

1.9 Average

118

Lat. 41° 59' 30.5"
Long. 70° 00' 57.4"
Az. 241° 55'

Dist.	Elev.	Remarks
0	114.03	Top of Mon.
0	113.38	
102	109.19	
148	110.75	
192	107.84	Bluff Station
321	16.50	Foot of Bluff

Profile date: 8/22/57

Average loss/yr: 2.9 Bluff

Average loss/yr: 2.5 Foot

2.7 Average

119

Lat. 41° 59' 38.5"
Long. 70° 01' 06.1"
Az. 241° 56'

Dist.	Elev.	Remarks
0	42.99	Top of Mon.
0	42.49	
66	21.60	
173	18.83	
321	27.51	
406	53.87	
420	46.40	Bluff Station
463	13.47	Foot of Bluff

Profile date: 8/22/57

Average loss/yr: 2.7 Bluff

Average loss/yr: 2.1 Foot

2.9 Average

120

Lat. 41° 59' 44.5"
Long. 70° 01' 18.8"
Az. 241° 56'

Dist.	Elev.	Remarks
0	57.01	Top of Mon.
0	56.52	
314	19.88	
409	11.11	
783	56.50	
860	69.42	
944	77.75	
949	78.68	Bluff Station
1037	22.16	Foot of Bluff

Profile date: 8/22/57

Average loss/yr: 2.8 Bluff

Average loss/yr: 3.2 Foot

3.0 Average

121

Lat. 41° 59' 55.2"
Long. 70° 01' 19.5"
Az. 239° 22'

Dist.	Elev.	Remarks
0	5.00	Top of Pipe (in marsh)
0	3.50	E. Side of drainage ditch
42	6.59	
107	13.25	
247	21.87	
380	41.09	
451	45.37	
474	43.79	
501	33.09	Bluff Station
547	15.49	Foot of Bluff

Profile date: 8/22/57

Average loss/yr: 2.2 Bluff

Average loss/yr: 3.0 Foot

2.6 Average

141

Lat. 42° 02' 27.7"
Long. 70° 03' 52.9"
Az. 222° 50'

Dist.	Elev.	Remarks
0	91.37	Top of Mon.
214	100.68	
270	108.41	
377	129.21	
461	131.21	
512	126.34	Bluff Station
669	15.36	Foot of Bluff
690	7.86	Foot of terrace

Profile date: Nov., 1958

Average loss/yr: 1.1 Bluff

Average loss/yr: 1.2 Foot

1.2 Average

142

Lat. 42° 02' 34.4"
Long. 70° 04' 02.6"
Az. 221° 05'

Dist.	Elev.	Remarks
0	72.78	Top of Mon.
253	66.45	
396	76.40	
547	79.66	
552	79.56	Bluff Station
639	6.89	Foot of Bluff

Profile date: Jan., 1959

Average loss/yr: 1.5 Bluff

Average loss/yr: 2.4 Foot

1.9 Average

143

Lat. 42° 02' 40.9"
Long. 70° 04' 12.1"
Az. 221° 05'

Dist.	Elev.	Remarks
0	59.36	Top of Mon.
0	58.96	
188	61.88	
359	48.19	
443	55.73	
476	63.66	
510	69.14	
531	76.26	Bluff Station
661	6.55	Foot of Bluff

Profile date: Jan., 1959

Average loss/yr: 1.8 Bluff

Average loss/yr: 2.1 Foot

1.9 Average

144

Lat. 42° 02' 48.9"
Long. 70° 04' 20.6"
Az. 217° 05'

Dist.	Elev.	Remarks
0	64.66	Top of Mon.
46	66.49	
116	62.22	
264	72.30	
268	72.47	Bluff Station
363	17.91	Foot of Bluff

Profile date: Nov. 1958

Average loss/yr: 0.9 Bluff

Average loss/yr: 2.3 Foot

1.6 Average

147

Lat. 42° 03' 04.6"
Long. 70° 04' 53.2"
Az. 212° 37'

Dist.	Elev.	Remarks
0	17.62	Top of Mon.
105	20.37	
390	28.42	
420	21.07	
543	21.62	Terrace Station
552	16.32	Foot of Terrace

Profile date: Nov. 1958

Average loss/yr.
at 16' contour: 1.9

148

Lat. 42° 03' 10.9"
Long. 70° 05' 03.5"
Az. 212° 38'

Dist.	Elev.	Remarks
0	5.78	Top of Mon.
81	5.65	
152	11.72	
188	15.40	
285	16.48	
319	23.64	
332	26.76	
341	30.72	
400	23.59	
450	23.52	Terrace Station
485	8.45	Foot of Terrace

Profile date: Jan. 1959

Average loss/yr.
at 16' contour: 0.6

149

Lat. 42° 04' 16.6"
Long. 70° 05' 13.5"
Az. 209° 45'

Dist.	Elev.	Remarks
0	5.79	Top of Mon.
0	5.24	
36	5.74	
59	7.23	
224	32.15	
295	36.38	
336	27.00	
377	22.14	
387	13.44	

Profile date: 1/28/59

Average loss/yr.
at 16' contour: 1.4

151

Lat. 42° 03' 26.4"
Long. 70° 05' 35.6"
Az. 206° 56'

Dist.	Elev.	Remarks
0	6.76	Top of Mon.
0	6.53	
34	8.94	
123	22.99	
173	20.46	
268	30.94	
308	29.46	
343	27.56	Bluff Station
363	9.70	Foot of Bluff

Profile date: 1/28/59

Average loss/yr.
at 16' contour: 0.4

152

Lat. 42° 03' 28.2"
Long. 70° 05' 48.7"
Az. 206° 25'

Dist.	Elev.	Remarks
0	5.15	Top of Mon.
185	6.84	
226	5.94	
294	11.28	
373	44.24	
439	47.69	
618	33.61	
671	27.59	
701	10.11	Foot of terrace

Profile date: 2/6/59

Average gain/yr.
at 16' contour: 0.6

153

Lat. 42° 03' 34.8"
Long. 70° 05' 59.5"
Az. 206° 25'

Dist.	Elev.	Remarks
0	5.13	Top of Mon.
134	12.52	
152	16.45	
210	24.24	
241	27.88	
293	36.32	
340	31.54	
480	33.90	Terrace Station
520	13.31	Foot of Terrace

Profile date: 2/6/59

Average gain/yr.
at 16' contour: 1.9

154

Lat. 42° 03' 34.0"
Long. 70° 06' 14.7"
Az. 206° 30'

Dist.	Elev.	Remarks
0	4.12	Top of Mon.
109	8.23	
164	20.28	
301	14.95	
517	11.16	
731	5.53	
851	36.81	
882	37.16	
994	27.13	
1063	36.89	Bluff Station
1105	21.24	Foot of Bluff

Profile date: 4/23/59

Average gain/yr.
at 21' contour: 3.0

155

Lat. 42° 03' 35.7"
Long. 70° 06' 27.0"
Az. 204° 25'

Dist.	Elev.	Remarks
0	24.53	Top of Mon.
59	32.31	
116	13.51	
471	10.49	
761	8.11	
835	30.16	
901	14.14	
1145	31.22	
1181	28.31	
1302	26.35	Bluff Station
1336	24.88	Foot of Bluff
1405	18.38	Foot of Terrace

Profile date: 6/1/59

Average gain/yr.
at 19' contour: 3.3

156

Lat. 42° 03' 35.8"
Long. 70° 06' 41.3"
Az. 204° 30'

Dist.	Elev.	Remarks
0	5.20	Top of Mon.
177	37.14	
182	37.27	
288	12.37	
344	27.54	
510	8.74	
788	6.80	
814	11.90	
860	11.95	
997	15.98	
1233	34.68	
1433	34.68	
1555	27.35	
1749	34.10	
1810	31.74	Terrace Station
1843	16.40	Foot of Terrace

Profile date: 7/10/59

Average gain/yr.
at 17' contour: 3.5

157

Lat. 42° 03' 38.8"
Long. 70° 06' 53.3"
Az. 205° 10'

Dist.	Elev.	Remarks
0	5.96	Top of Mon.
149	25.25	
289	6.82	
586	5.84	
793	5.83	
1019	6.07	
1259	8.83	
1482	21.25	
1877	35.55	
1884	35.53	Terrace Station
1947	16.29	Foot of Terrace

Profile date: 7/13/59

Average gain/yr.
at foot of terrace: 5.3

158

Lat. 42° 03' 42.2"
Long. 70° 07' 04.8"
Az. 201° 55'

Dist.	Elev.	Remarks
0	29.96	Surface
238	32.20	
504	32.97	
698	51.52	
1024	18.97	
1078	20.93	
1154	10.98	
1208	18.29	
1276	6.26	
1543	8.59	
1643	19.53	
1714	41.40	
1738	35.22	
1902	32.26	
1905	32.26	Edge old Terrace
1927	21.15	
1977	17.85	Edge new Terrace
1983	12.35	Foot new Terrace

Profile date: 12/3/59

Average gain/yr.
at foot of terrace: 3.2

159

Lat.	42°	03' 43.6"
Long.	70°	07' 17.8"
Az.	201°	55'

Dist.	Elev.	Remarks
0	8.11	Top of Mon.
172	30.71	
201	18.72	
280	6.78	
407	4.49	
508	13.00	
858	5.03	
1145	5.19	
1506	3.16	Edge of Bog
1527	6.42	
1586	4.36	
1670	33.58	
1749	17.29	
1888	31.23	
1985	34.71	
2025	28.13	
2116	33.56	Edge of Terrace
2144	21.92	Foot of Terrace

Profile date: 12/2/59

Average gain/yr.
at foot of terrace: 2.1

Lat.	42°	04'	41.2"
Long.	70°	13'	00.5"
Az.	352°	10'	True

Dist.	Elev.	Remarks
0	10.67	El. Top Monument
0+oo	8.97	
138	11.54	
270	12.25	
327	27.65	
498	49.07	
603	34.33	
665	32.26	
711	28.17	Bluff
735	20.80	
754	18.78	
827	12.18	Crest
996	0.00	Water edge at 1500 hours 4/17/62 assumed to be 0.00 feet

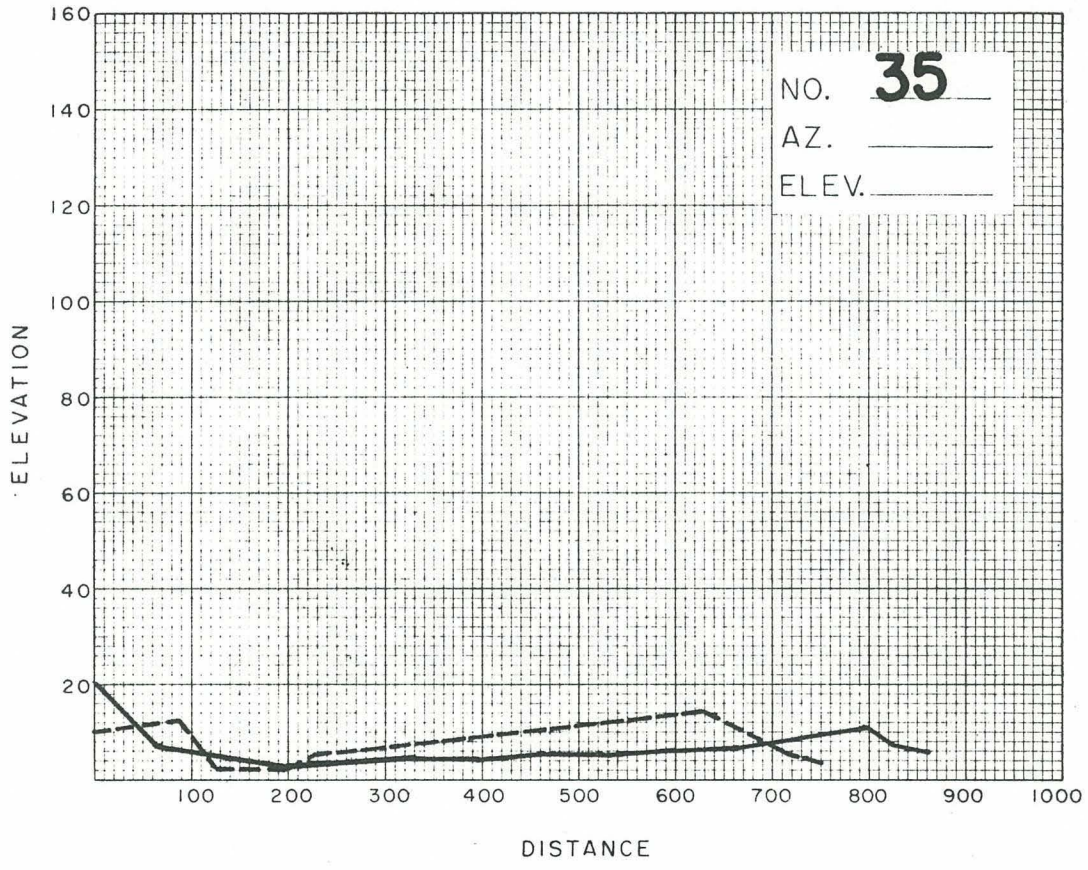
Profile Date 4/17/62

1962 Bluff 711
1888 Bluff 623
Gain 88 feet

Lat.	42°	04'	39.8"
Long.	70°	13'	10.5"
Az.			337.00

Dist.	Elev.	Remarks
0	23.14	Top of Monument
0	21.34	
72	14.36	
186	9.66	
288	14.11	Foot of dune
368	47.73	Top of dune
614	41.31	Top of bluff
668	23.62	Foot of bluff
730	16.67	Backshore
789	15.08	Foreshore
831	10.00	*El. at waters edge 1020 hours 4/17/62 taken to be 10 feet

1962 Crest 827
1888 Crest 843
Loss 16 feet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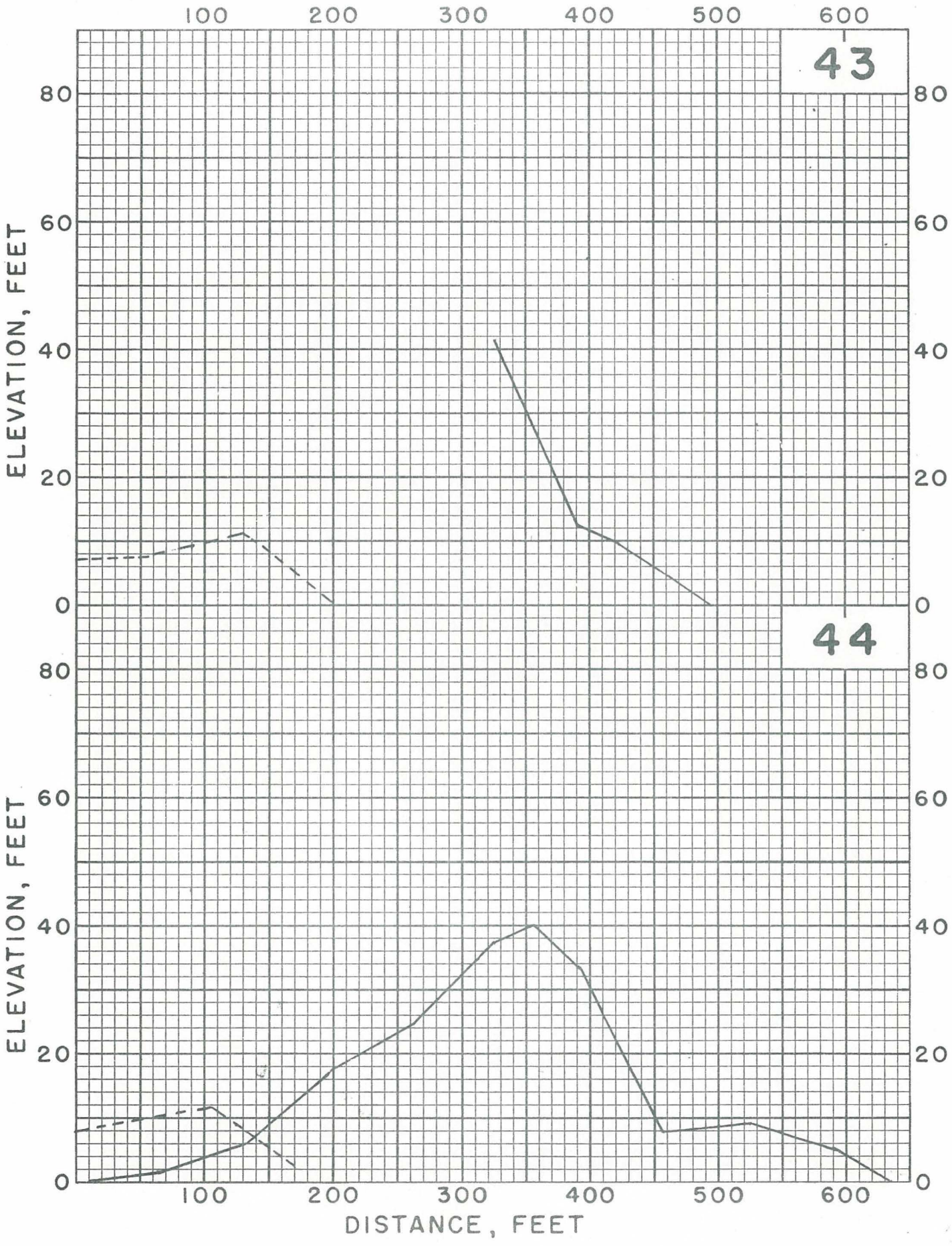
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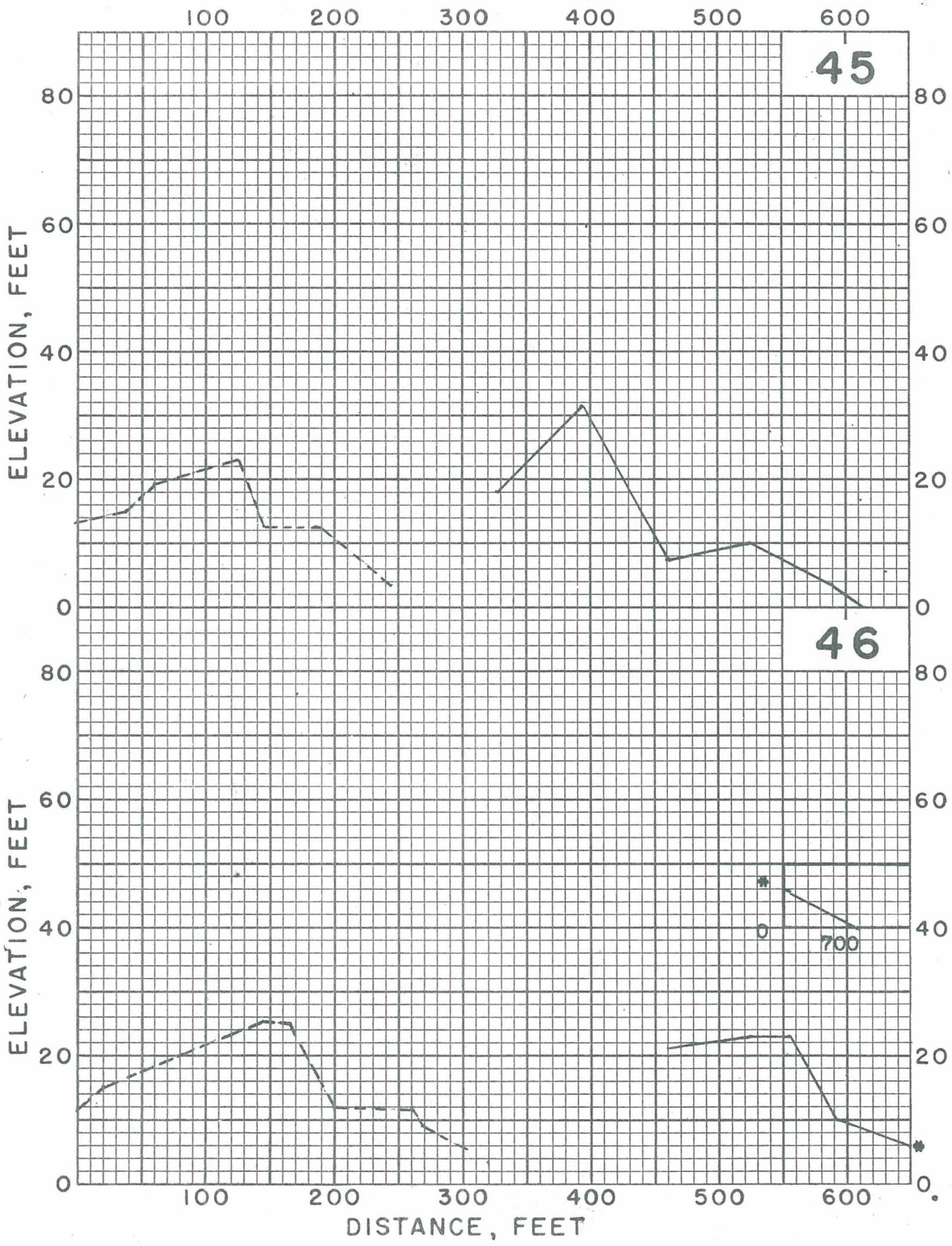
DISTANCE, FEET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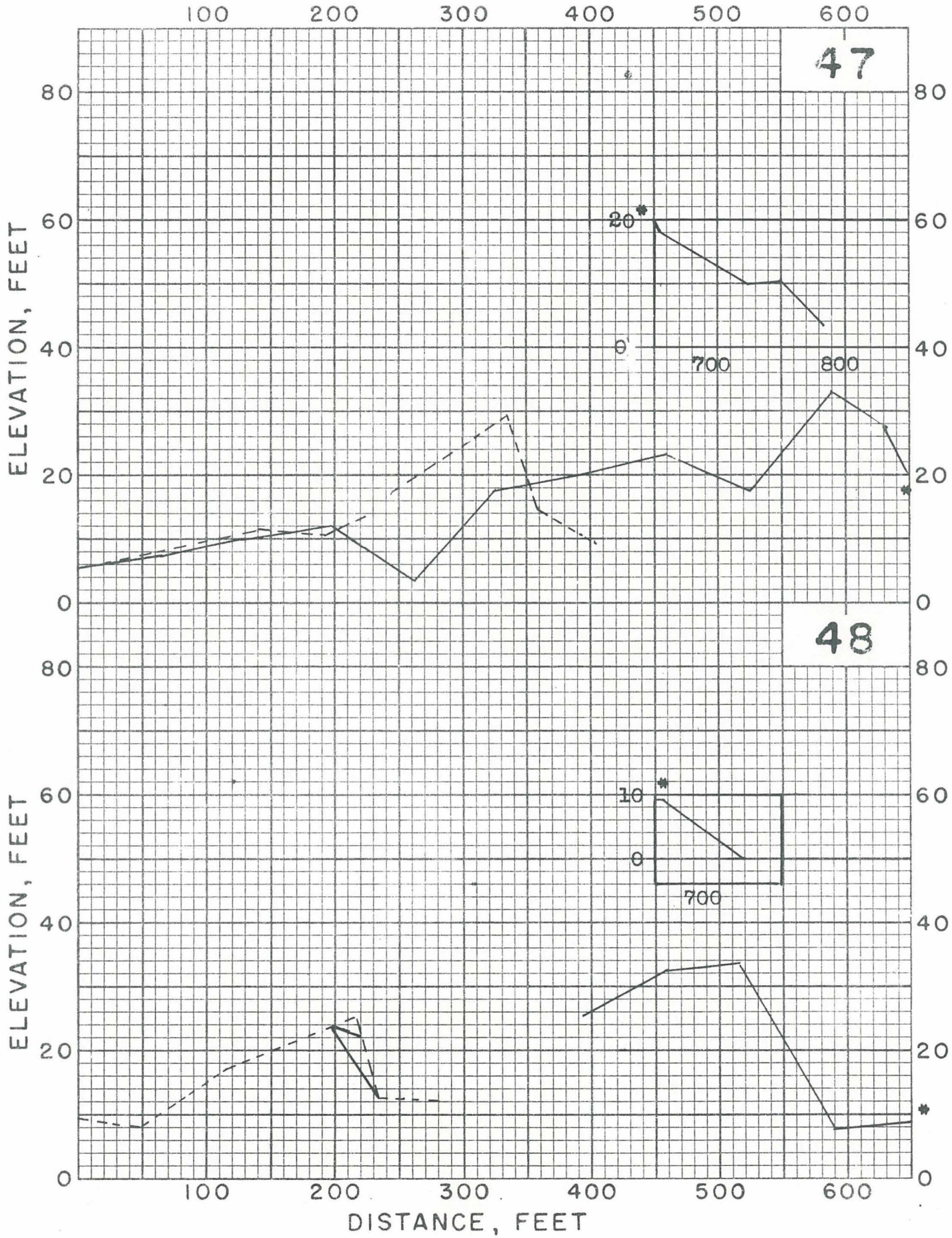
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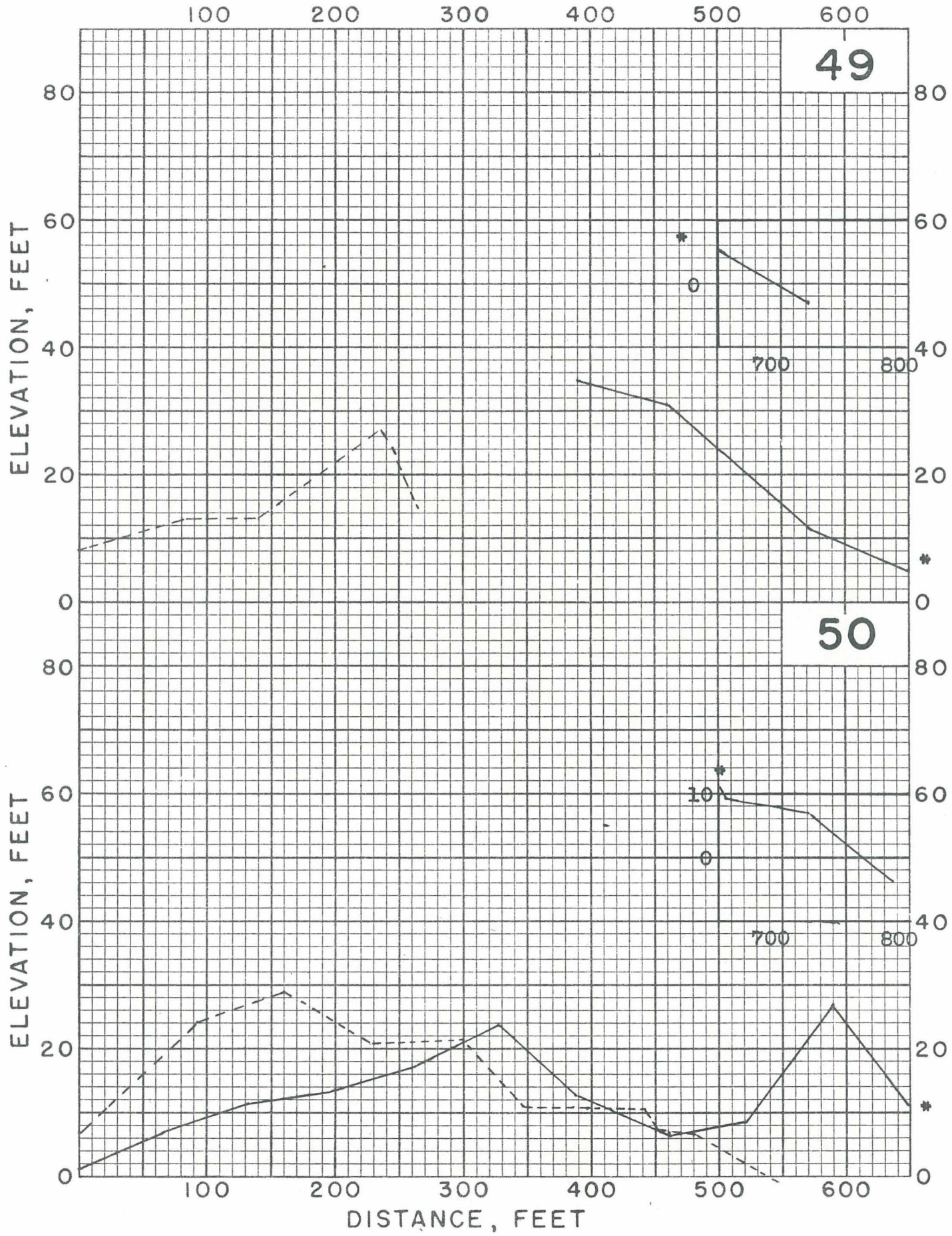
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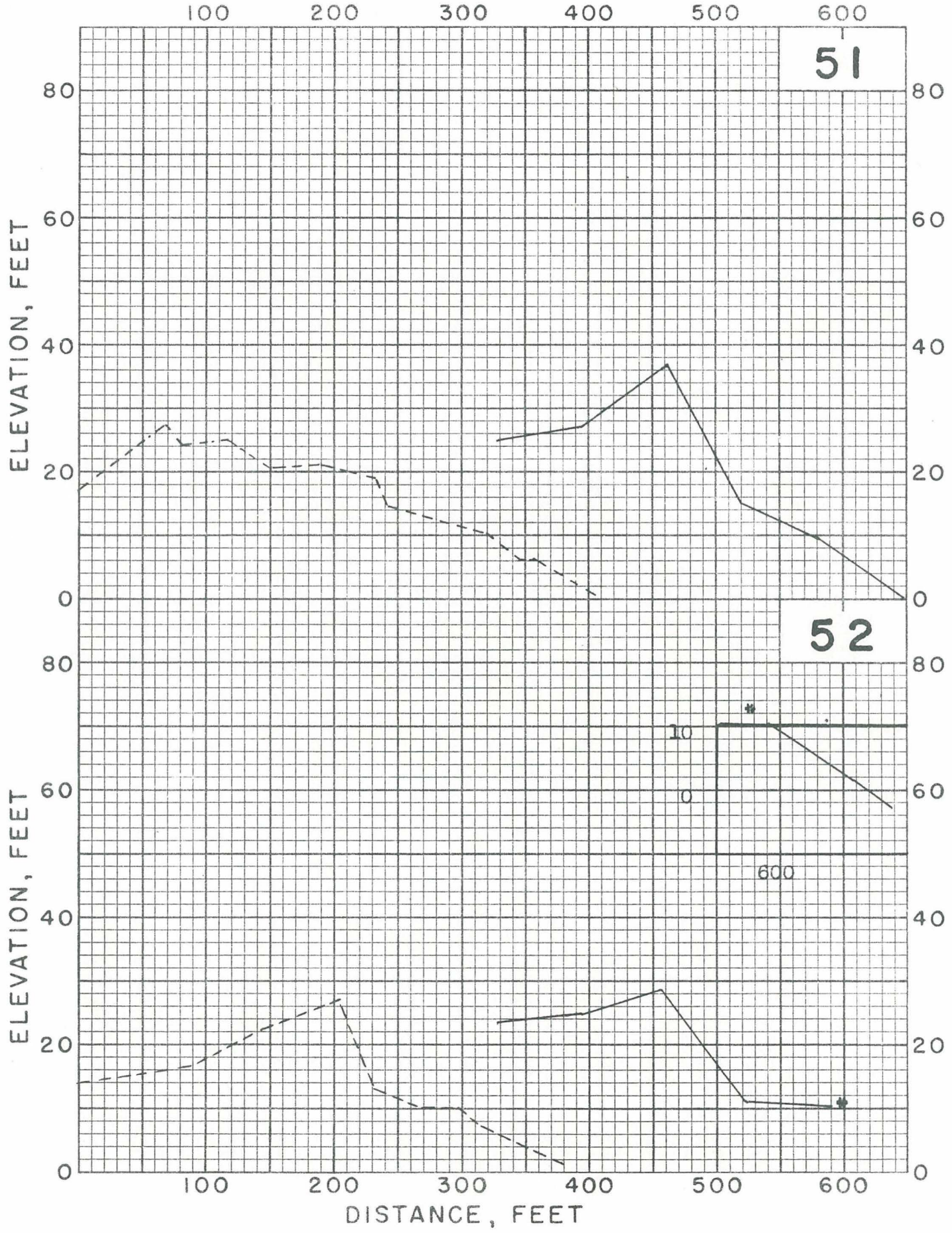
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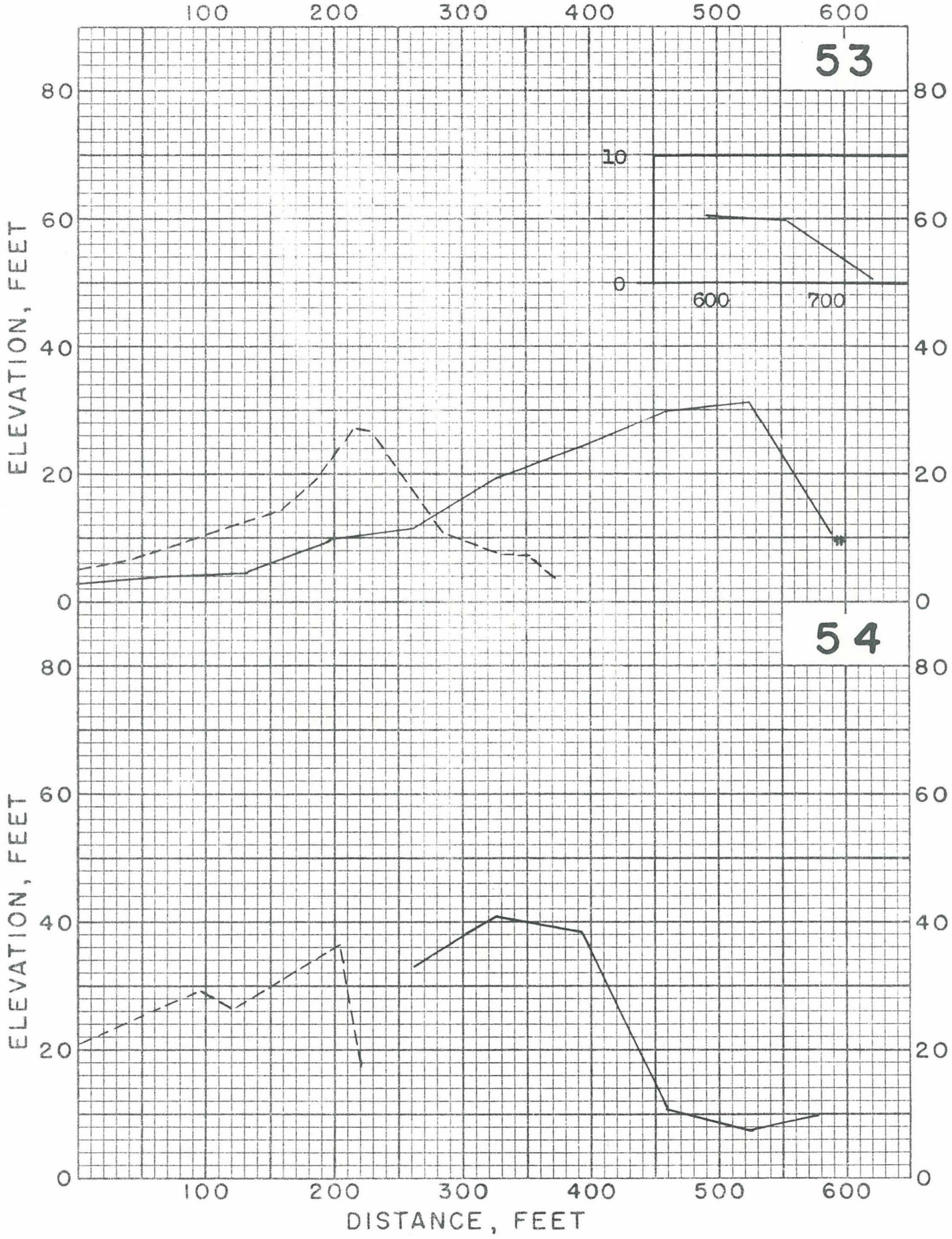
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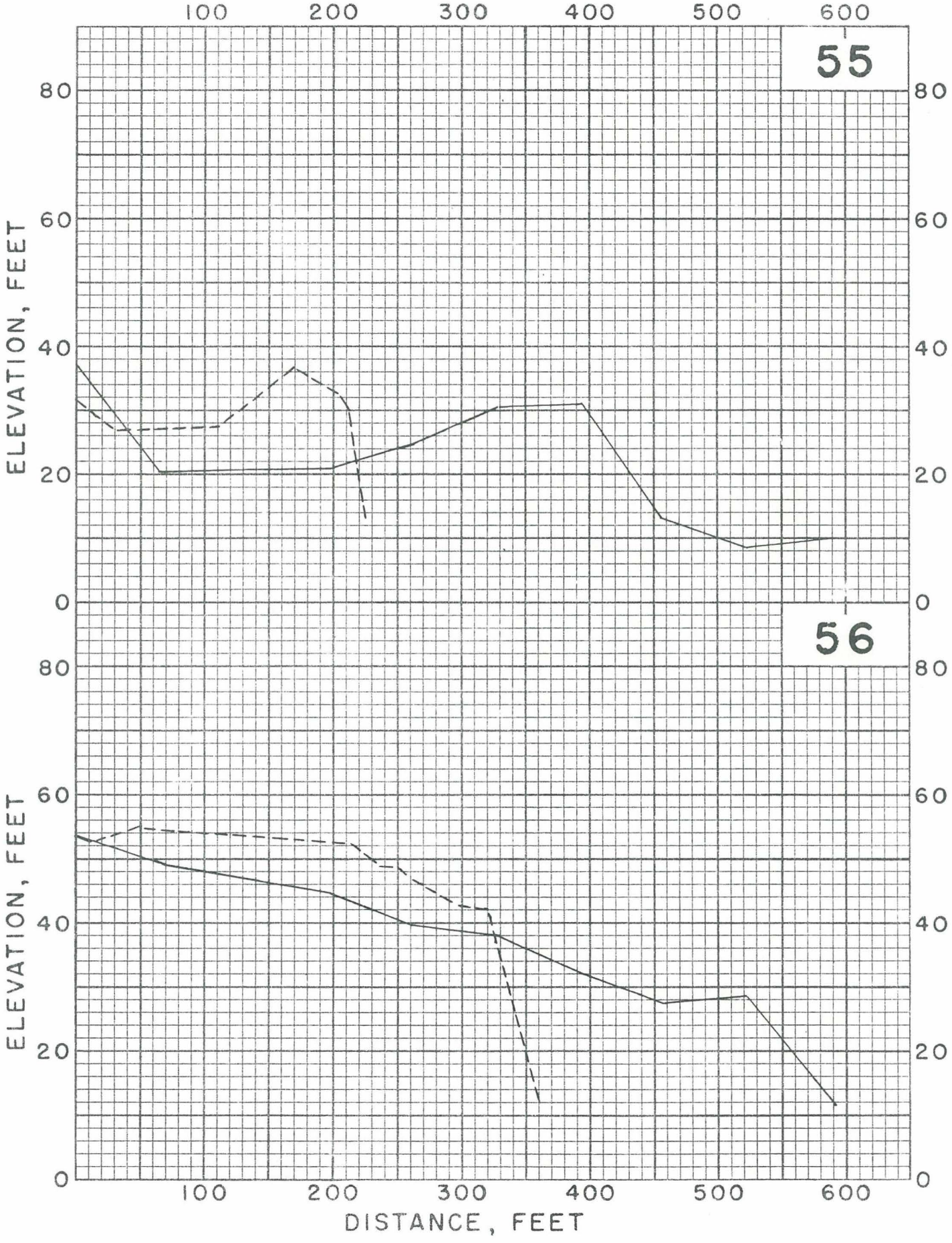
DISTANCE, FEET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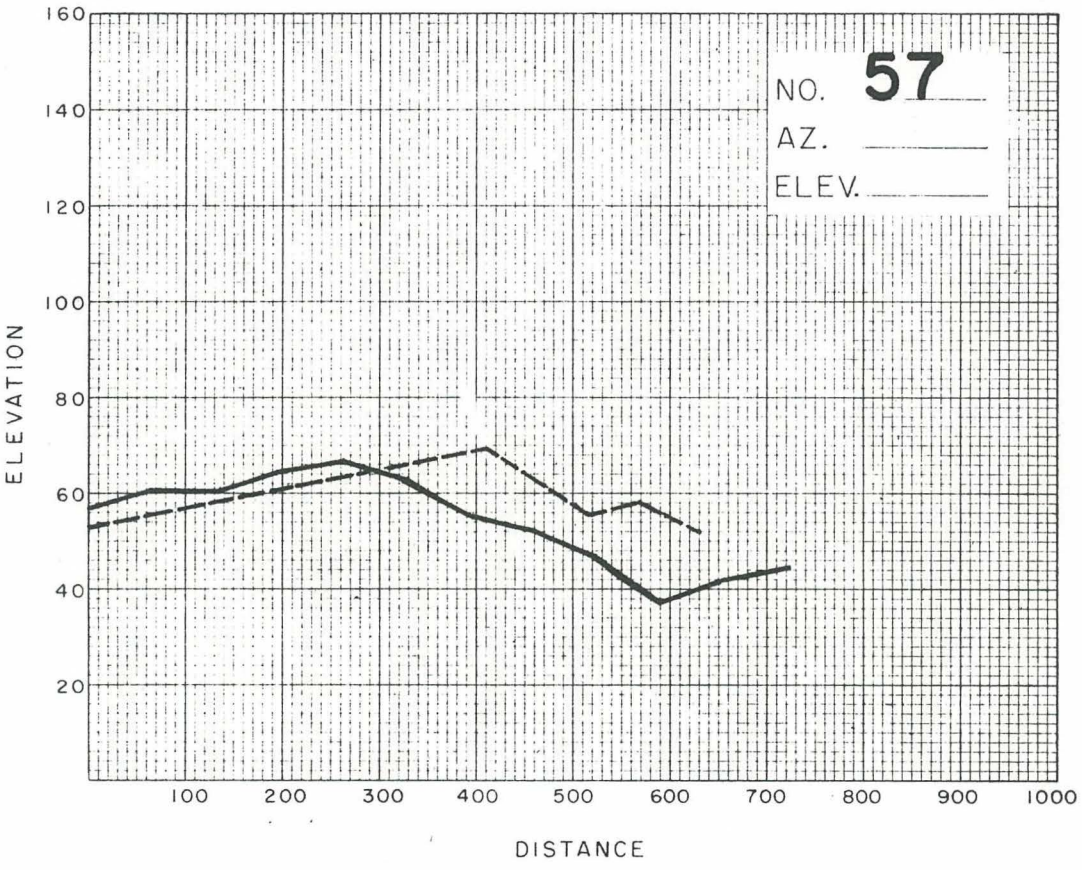
DISTANCE, FEET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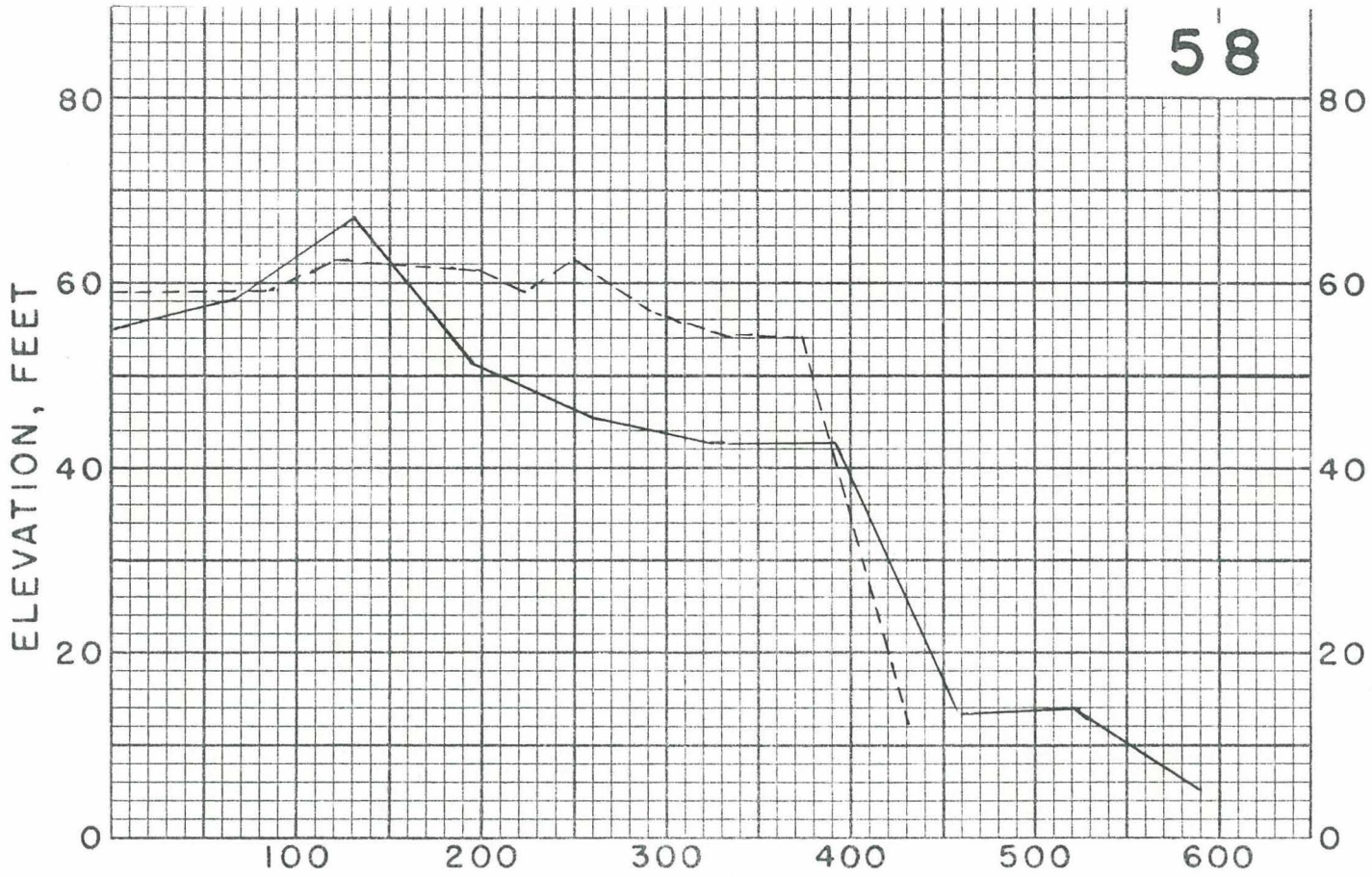
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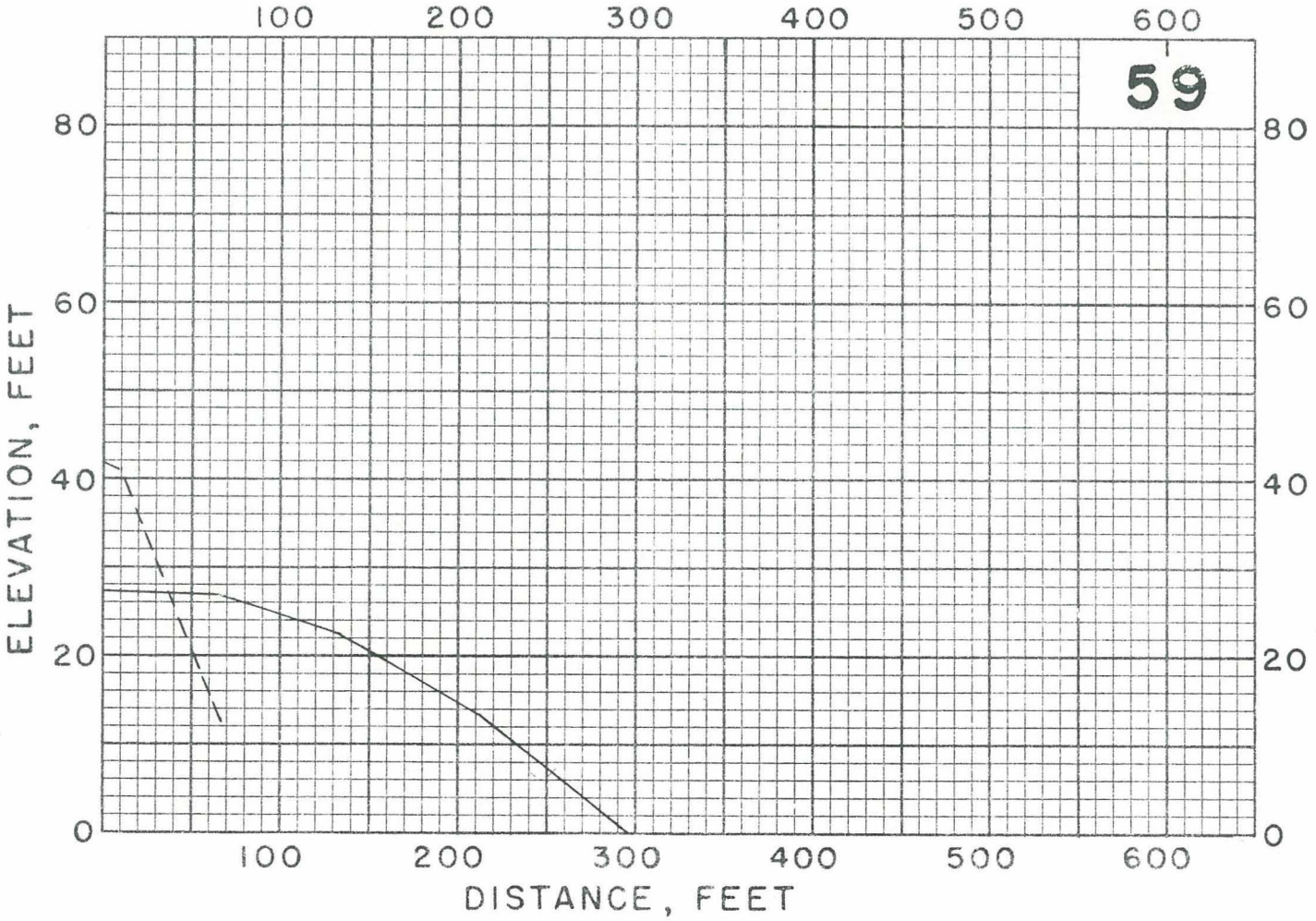
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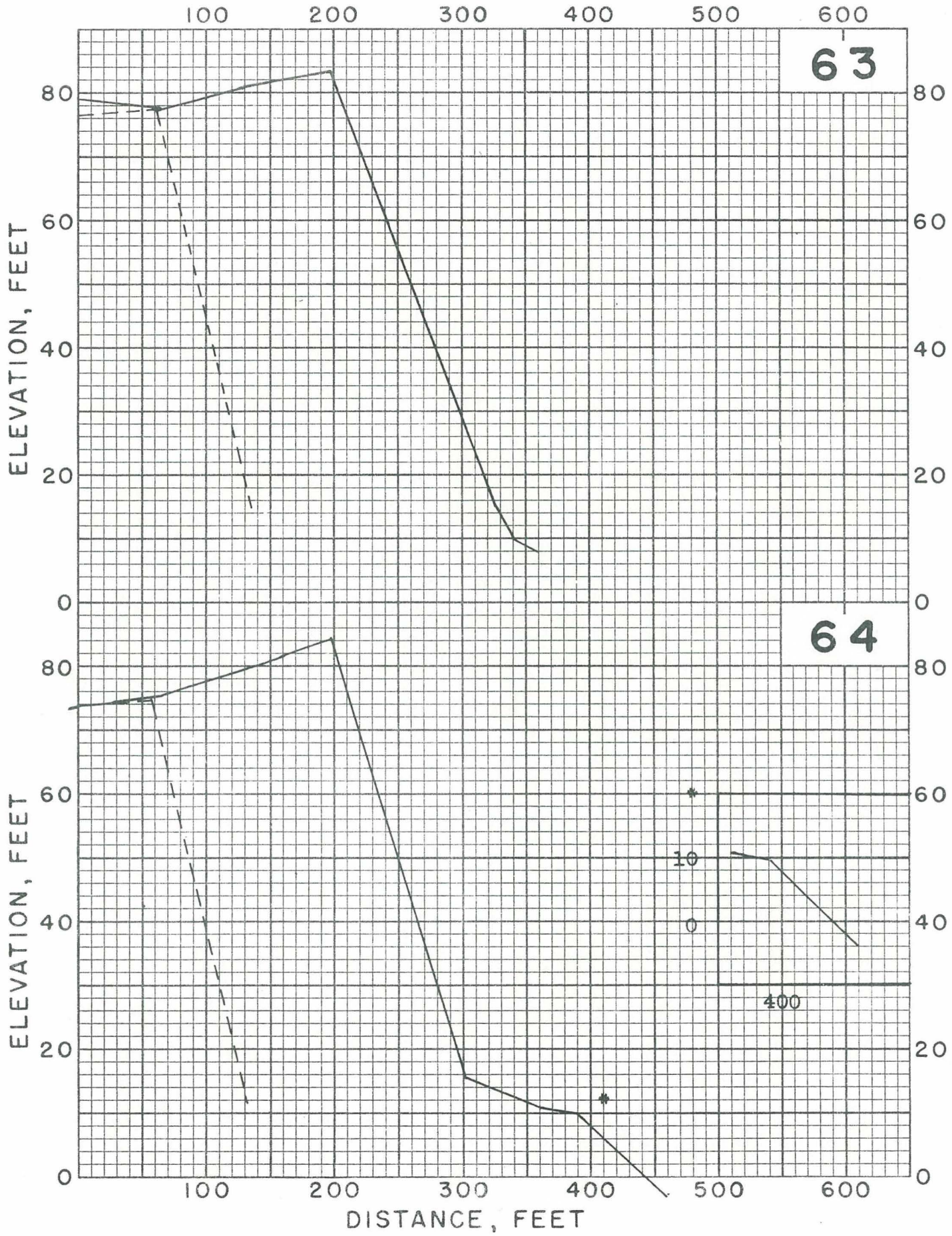
DISTANCE, FEET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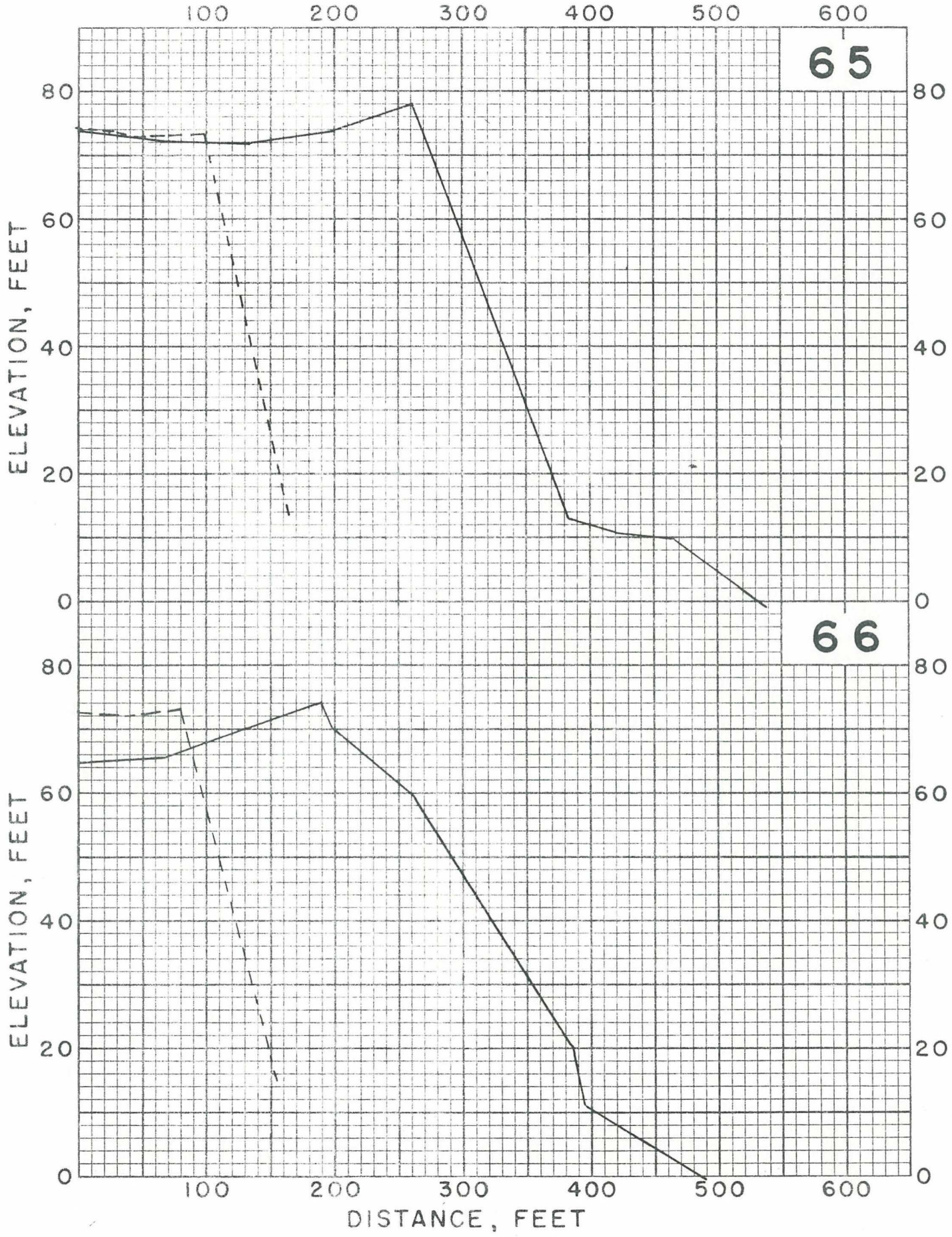
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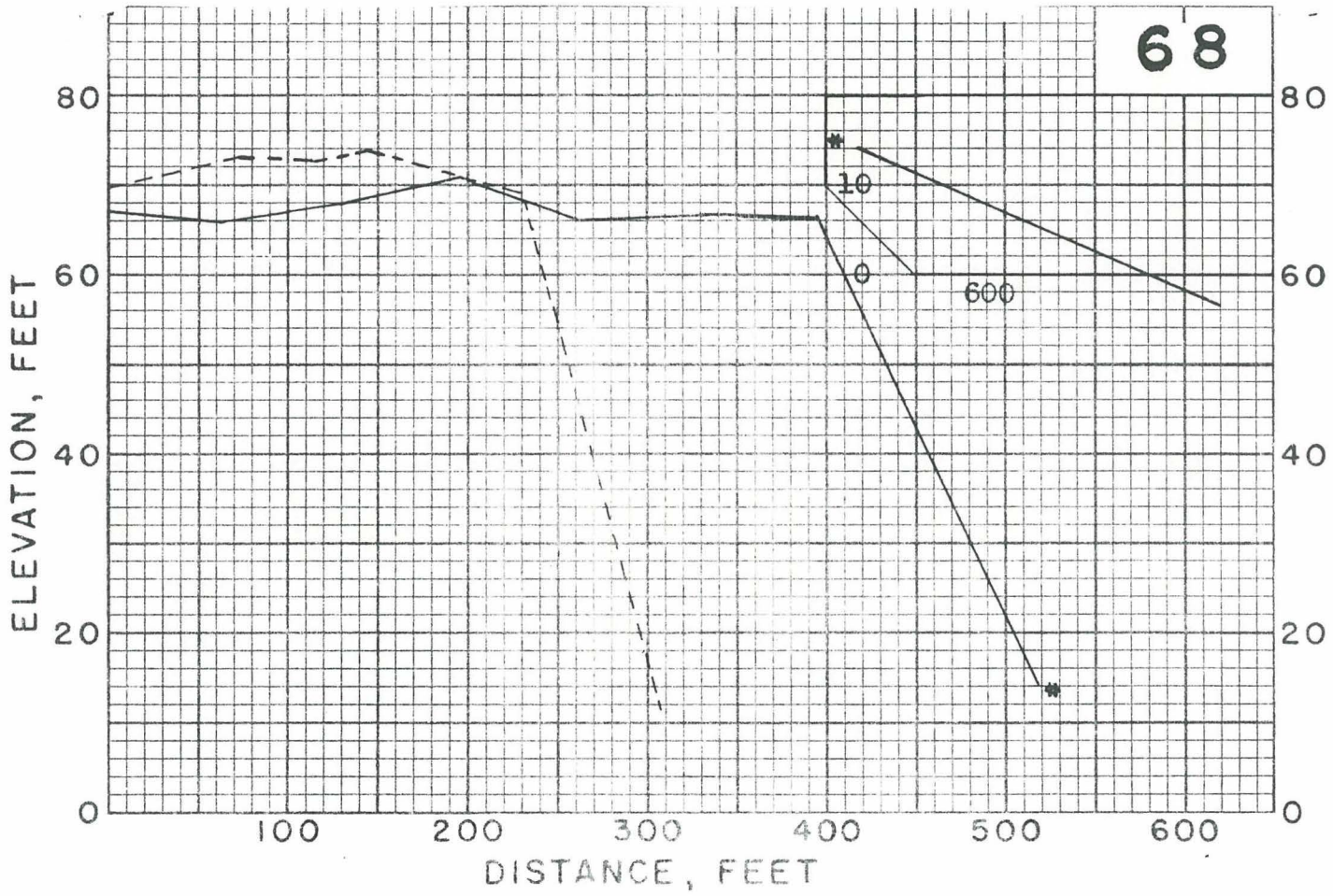
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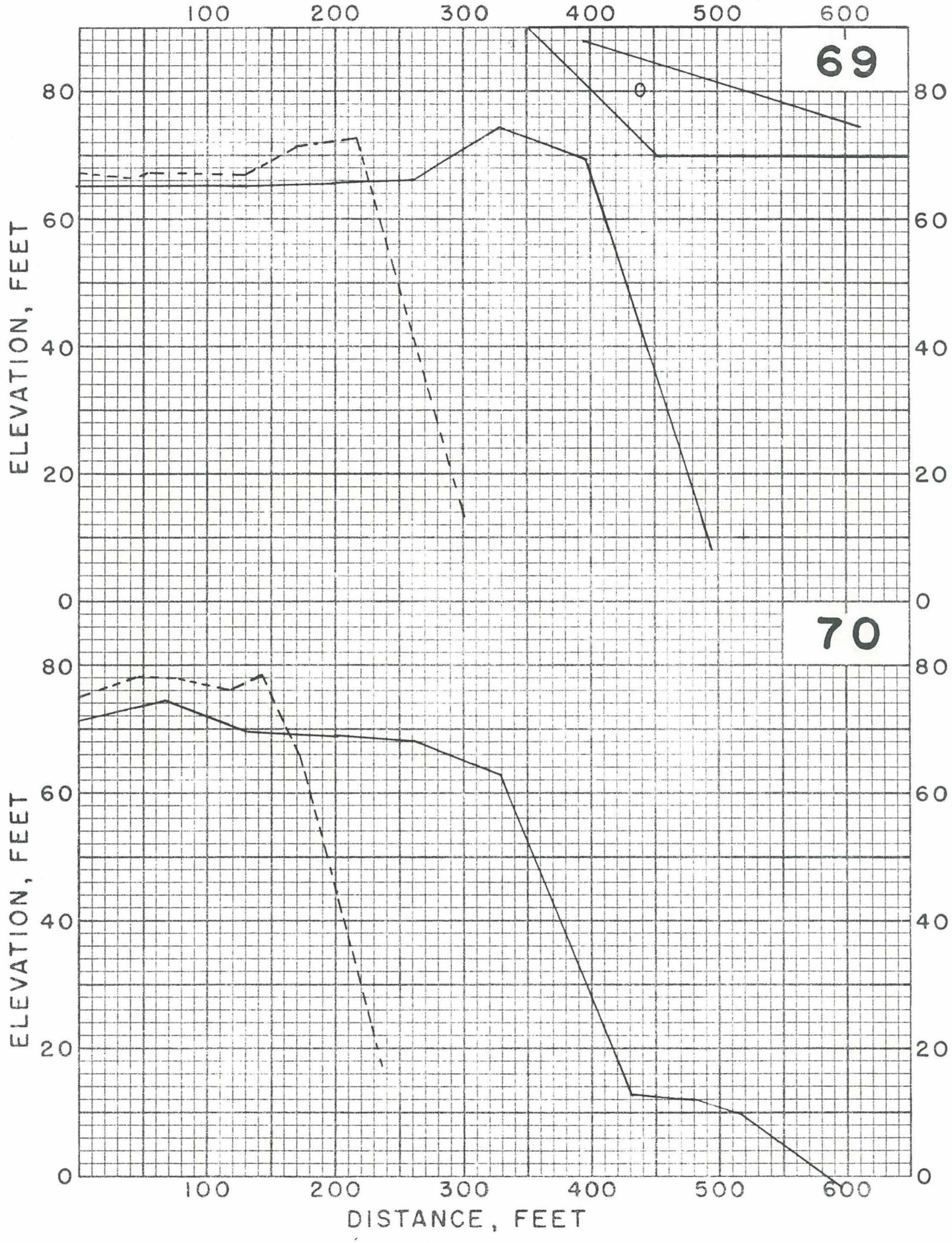
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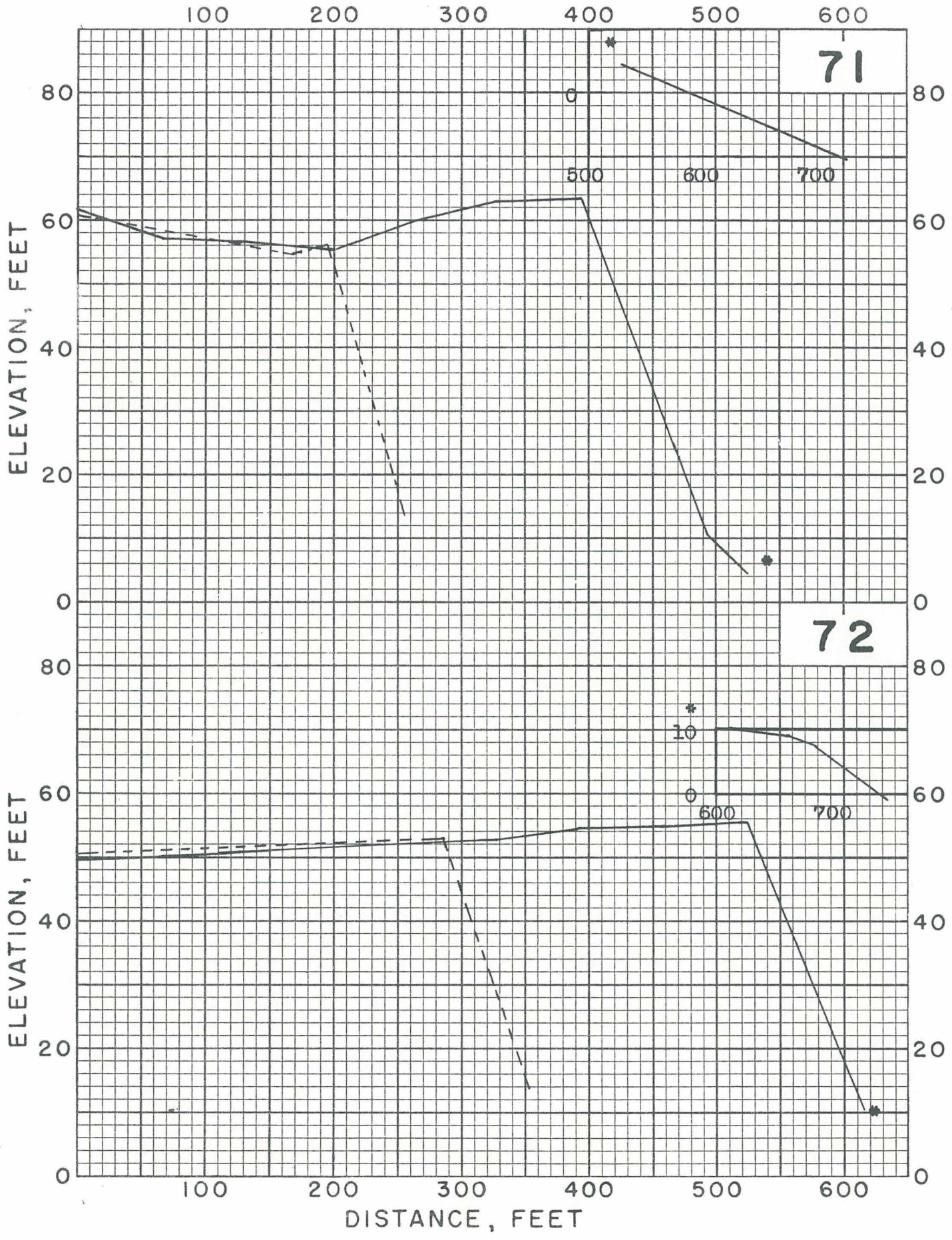
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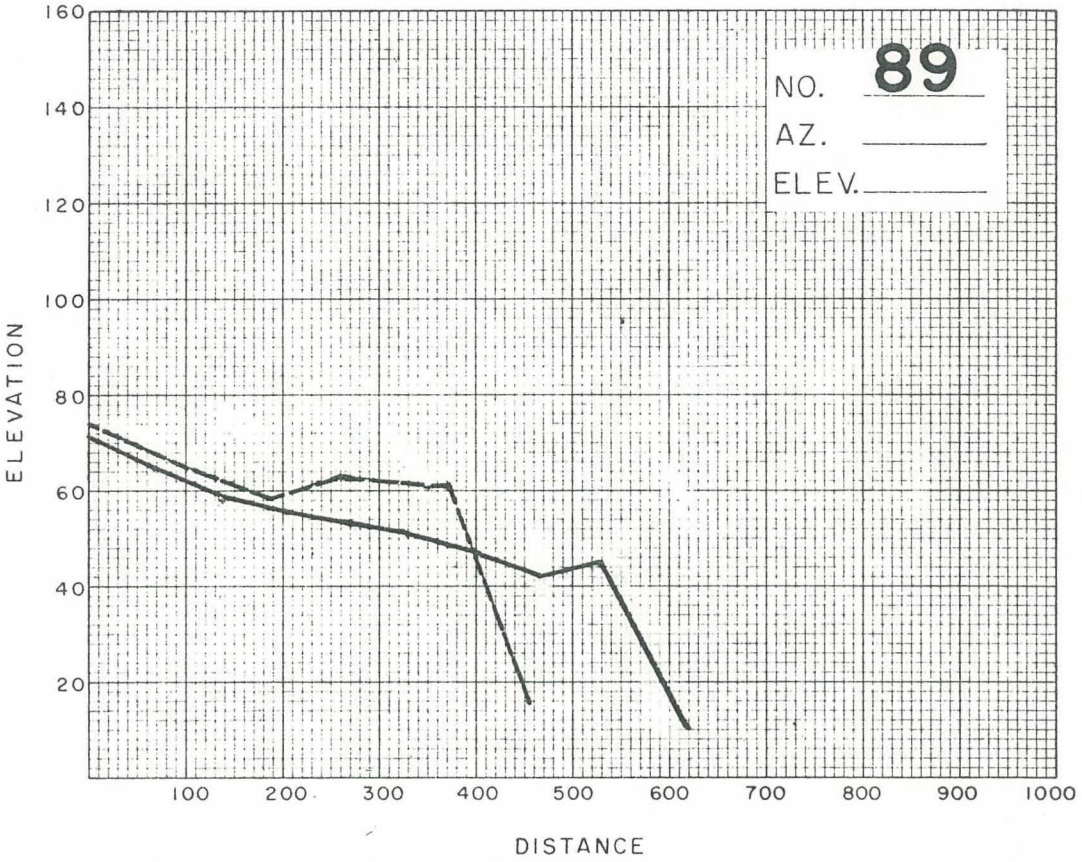
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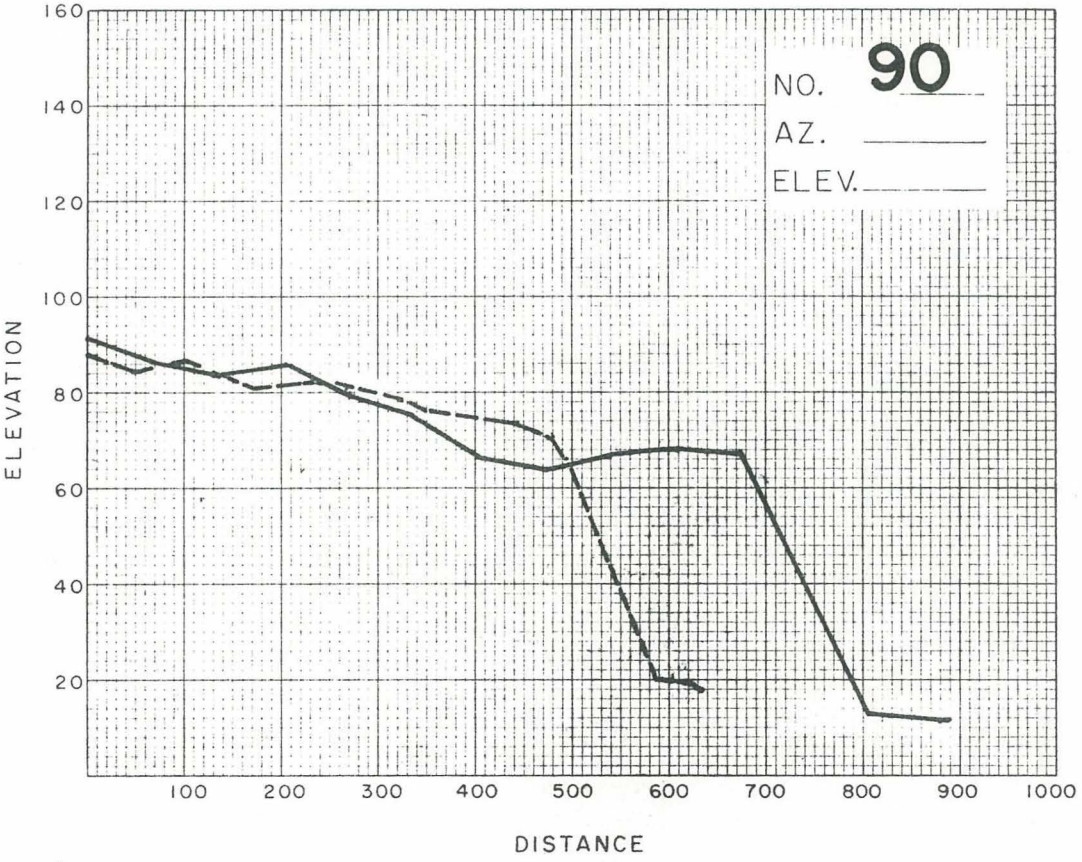
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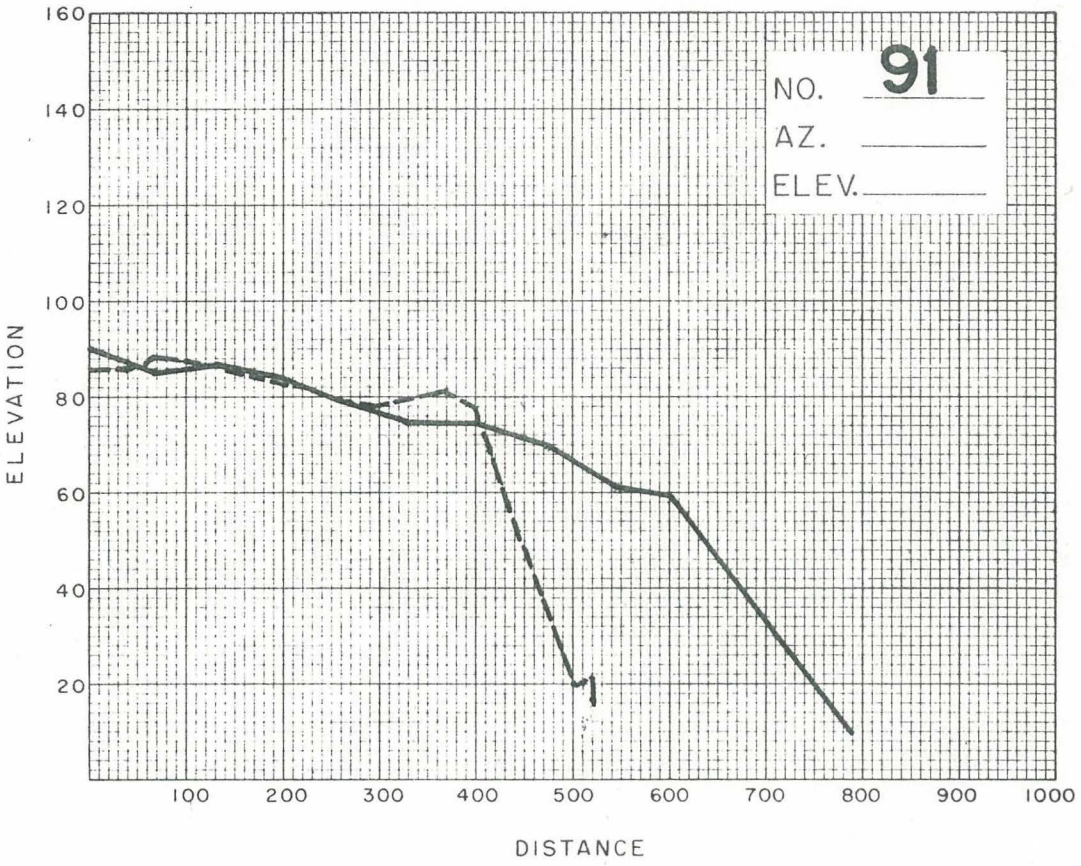
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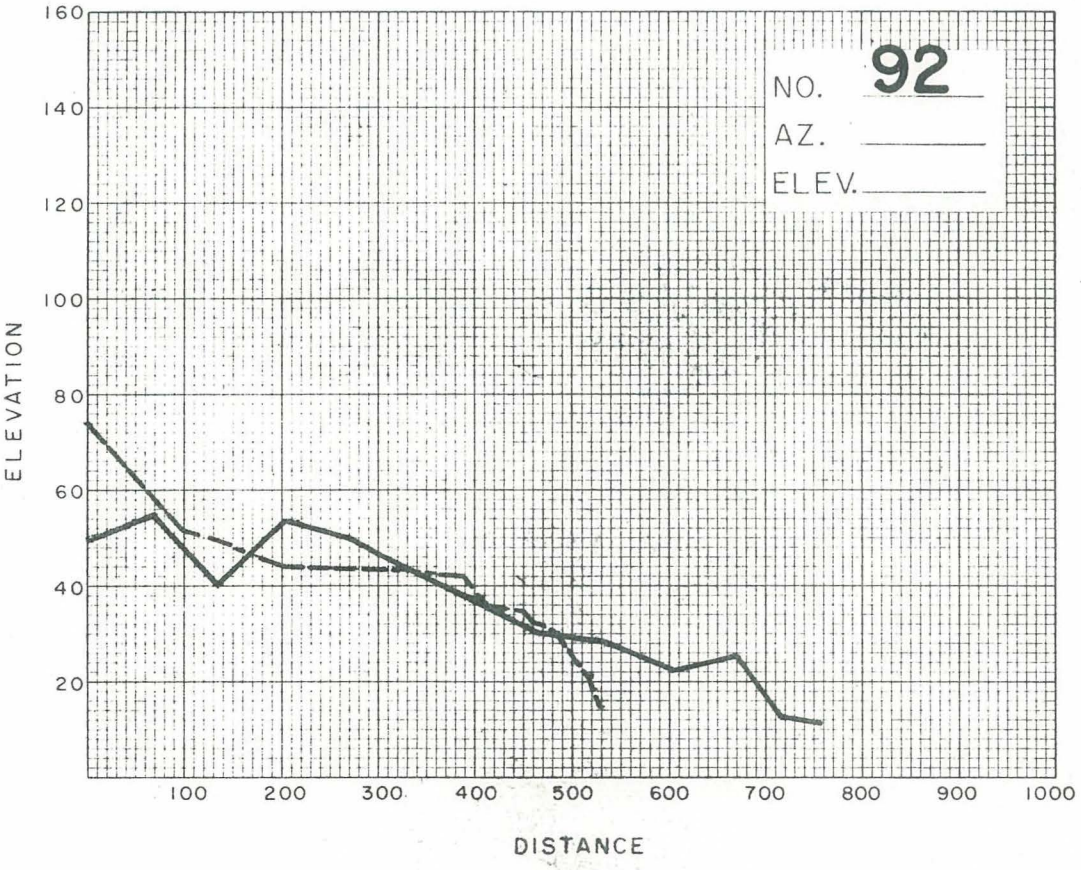
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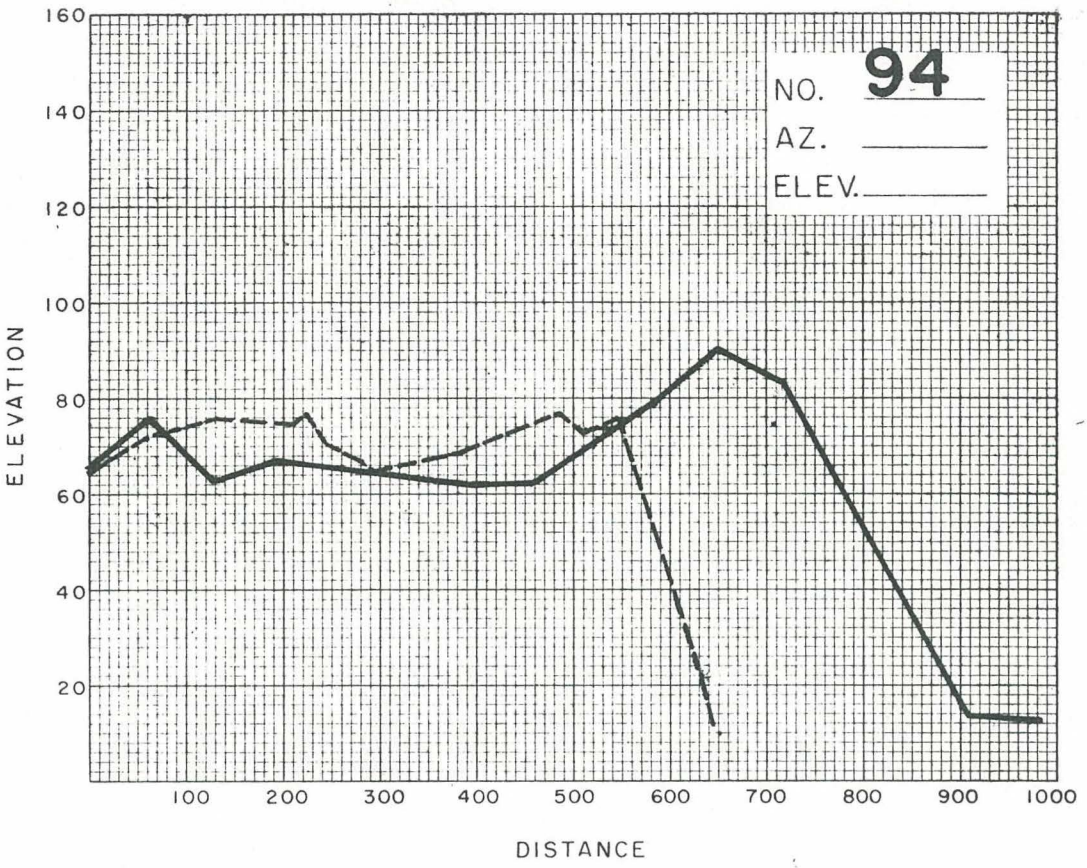
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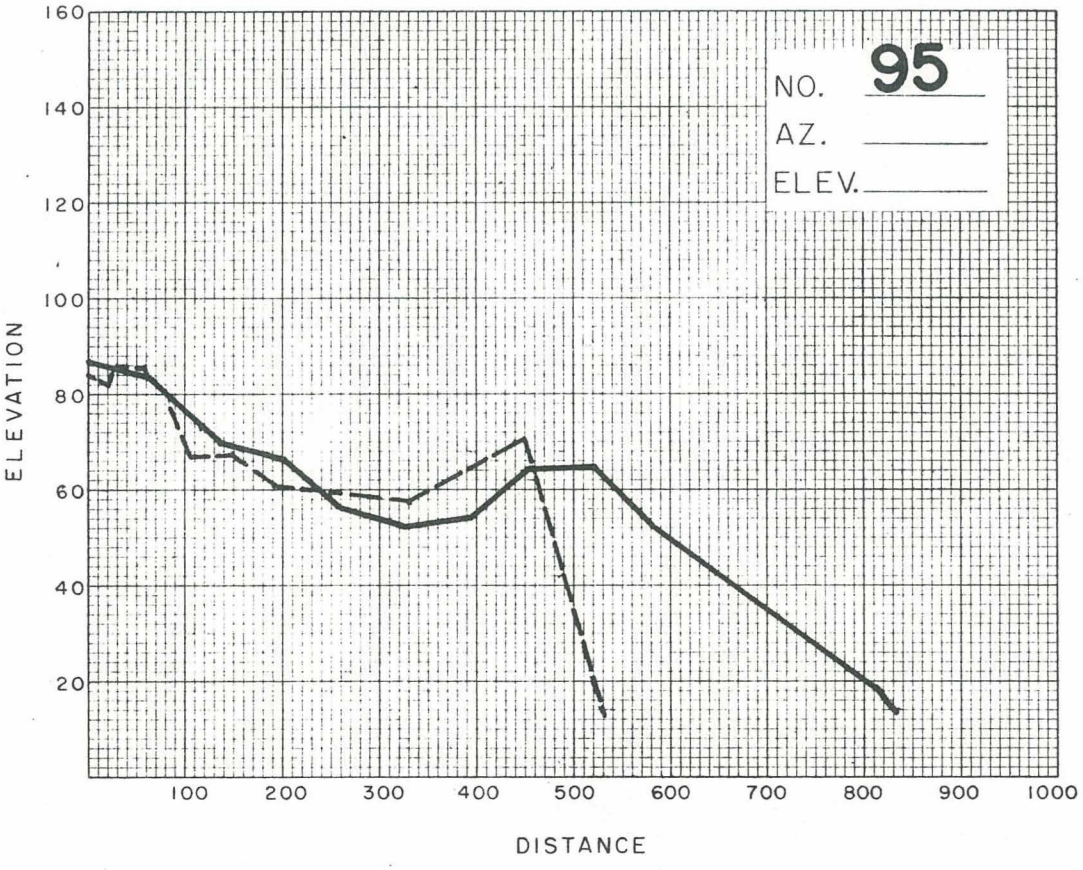
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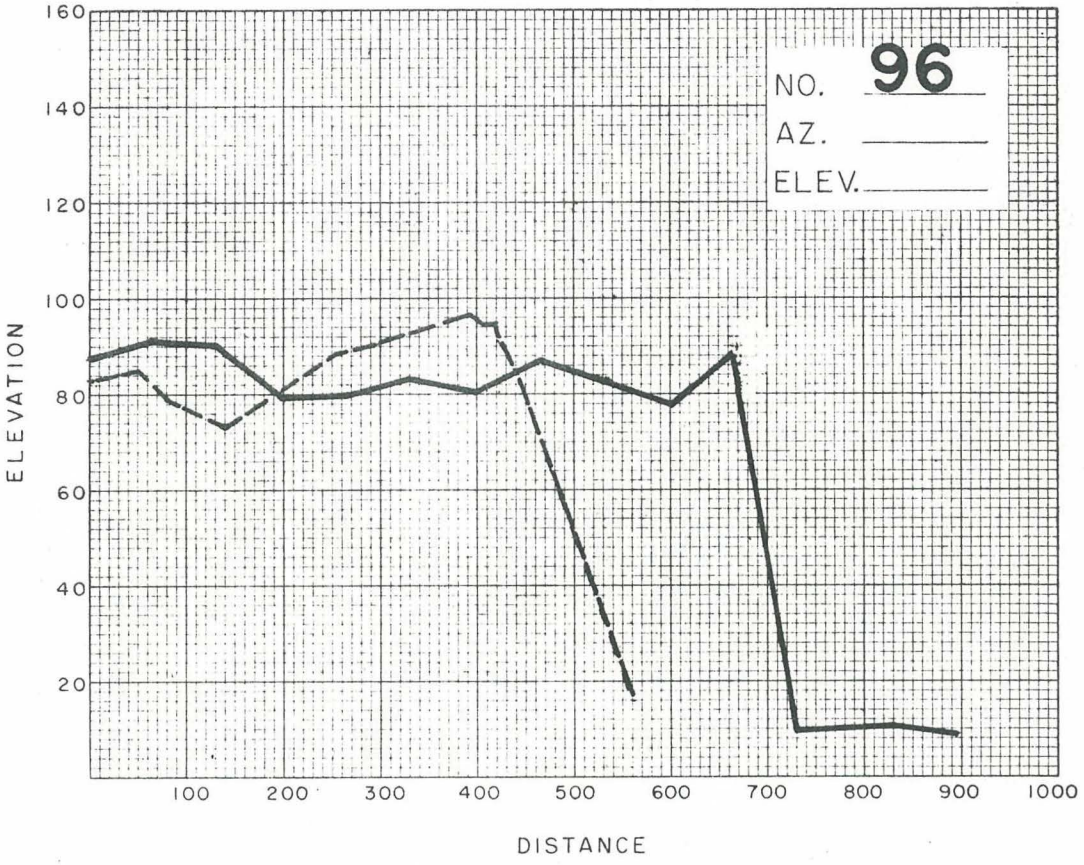
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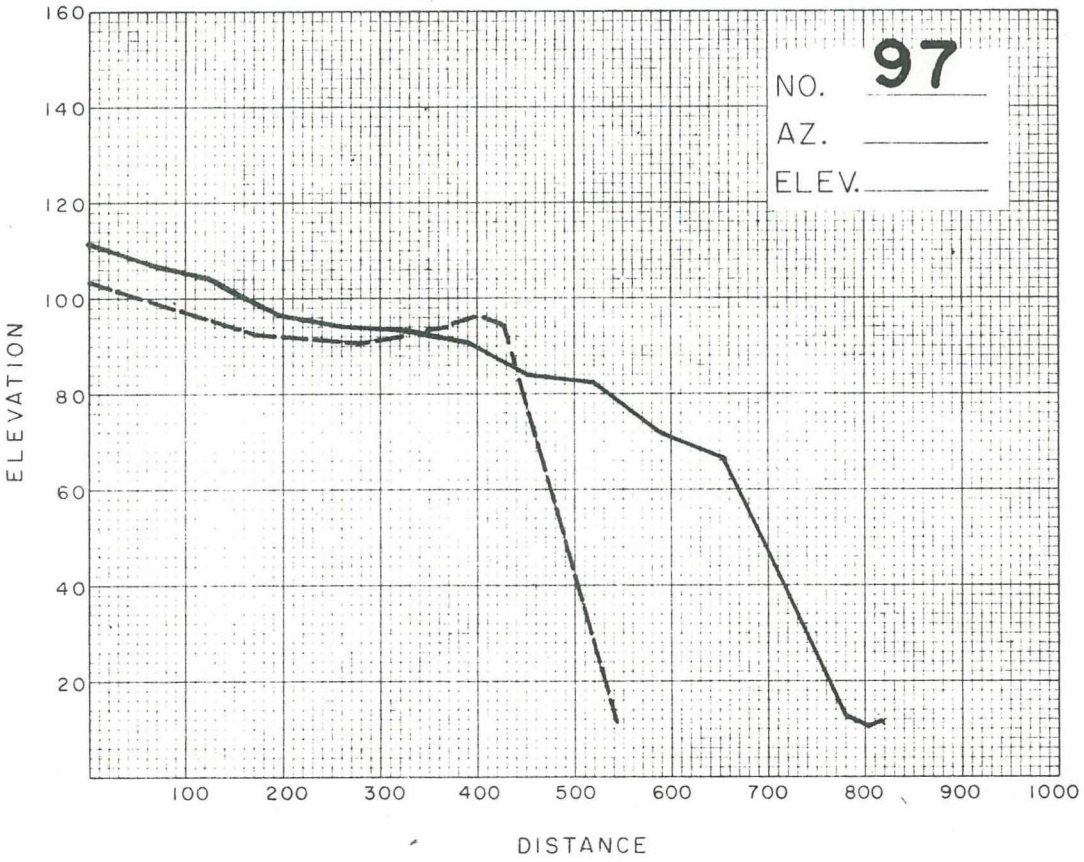
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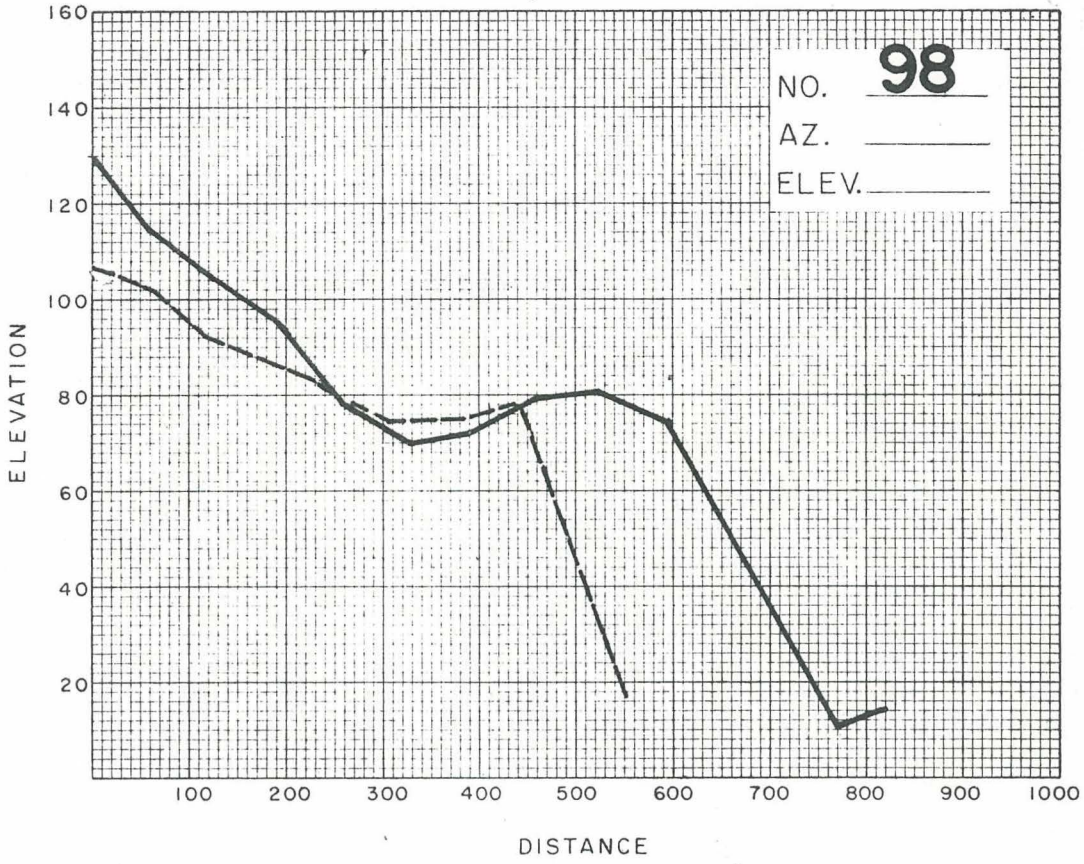
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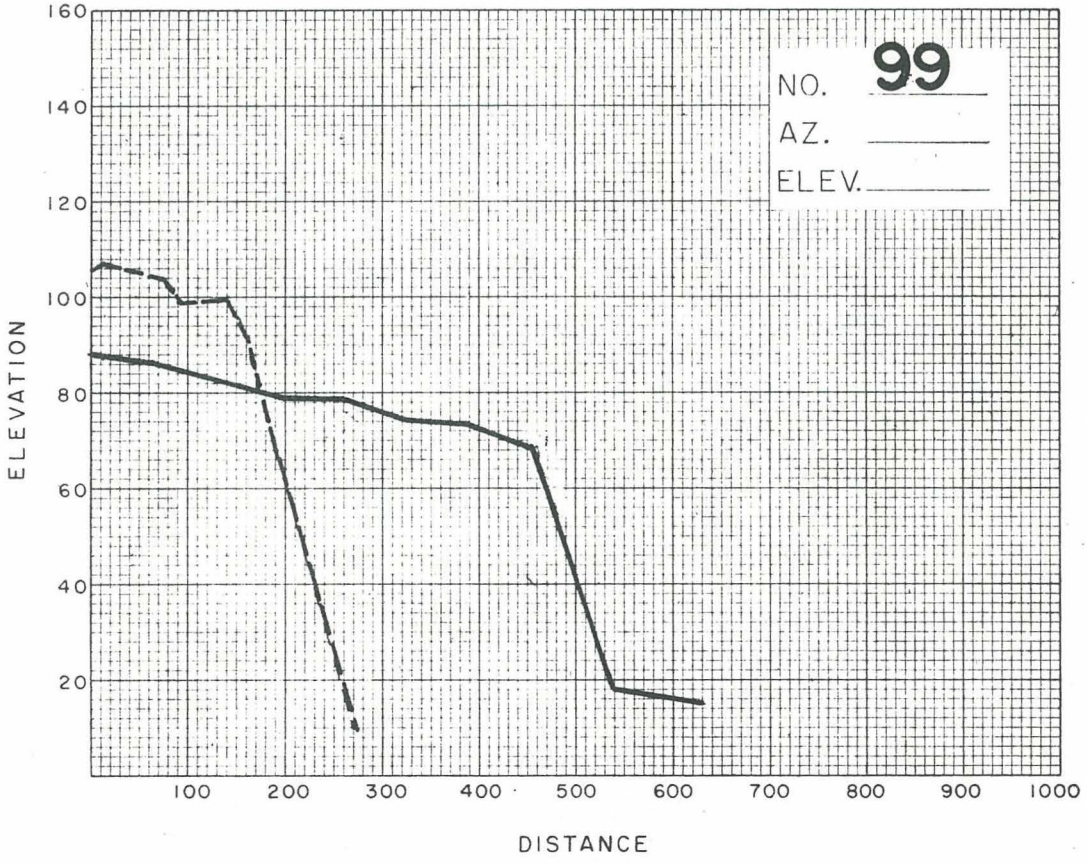
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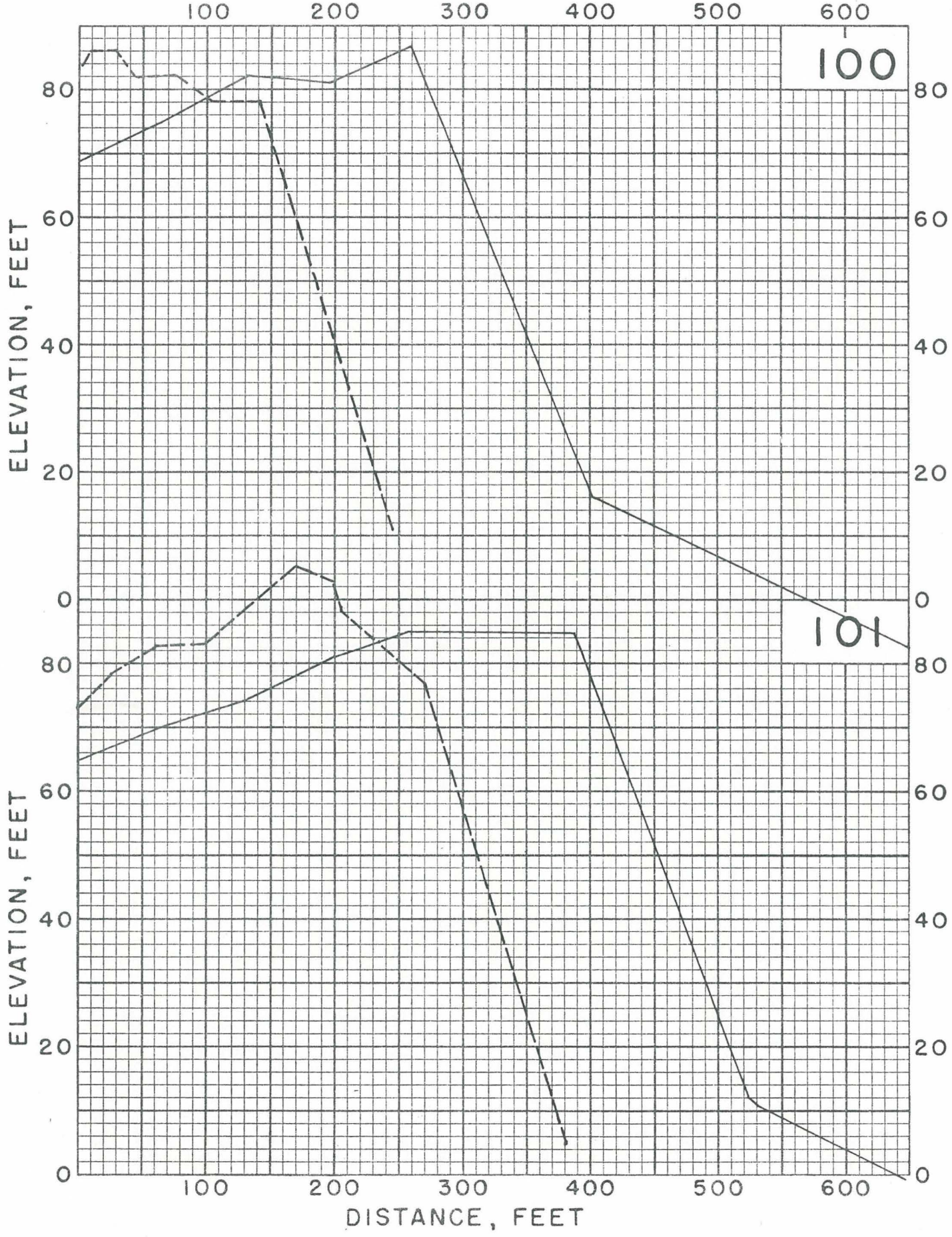
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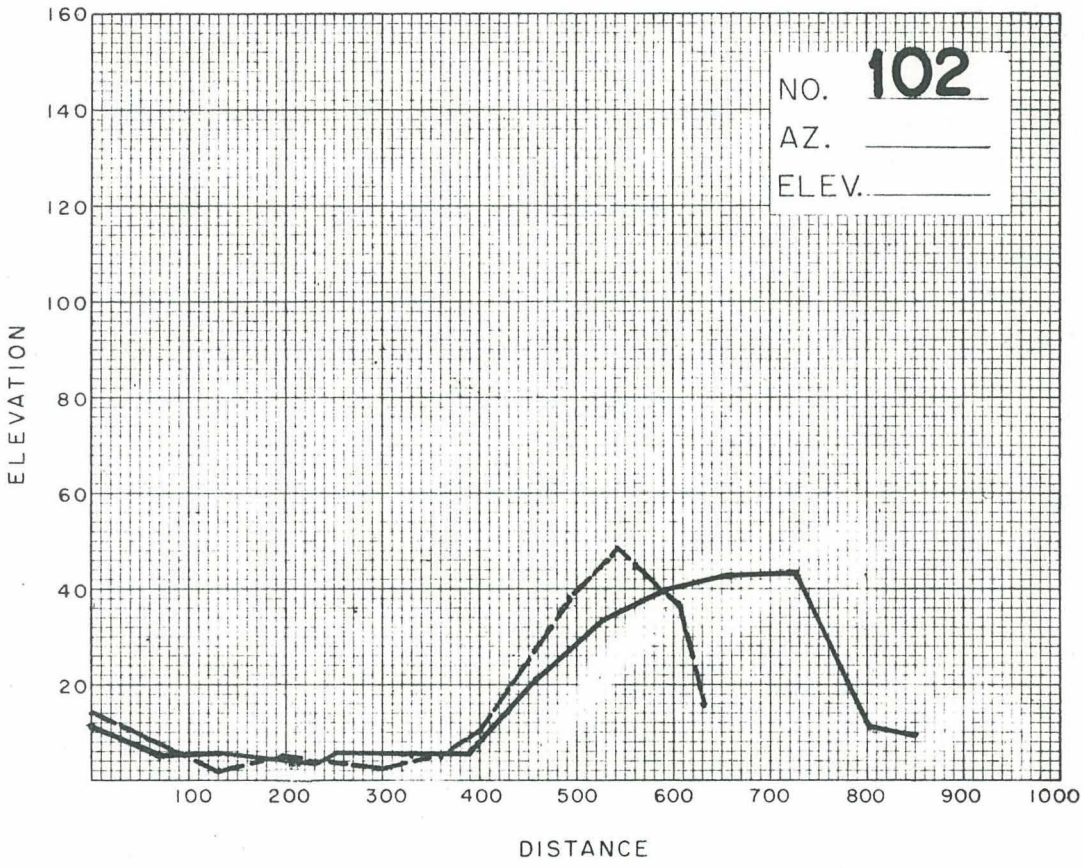
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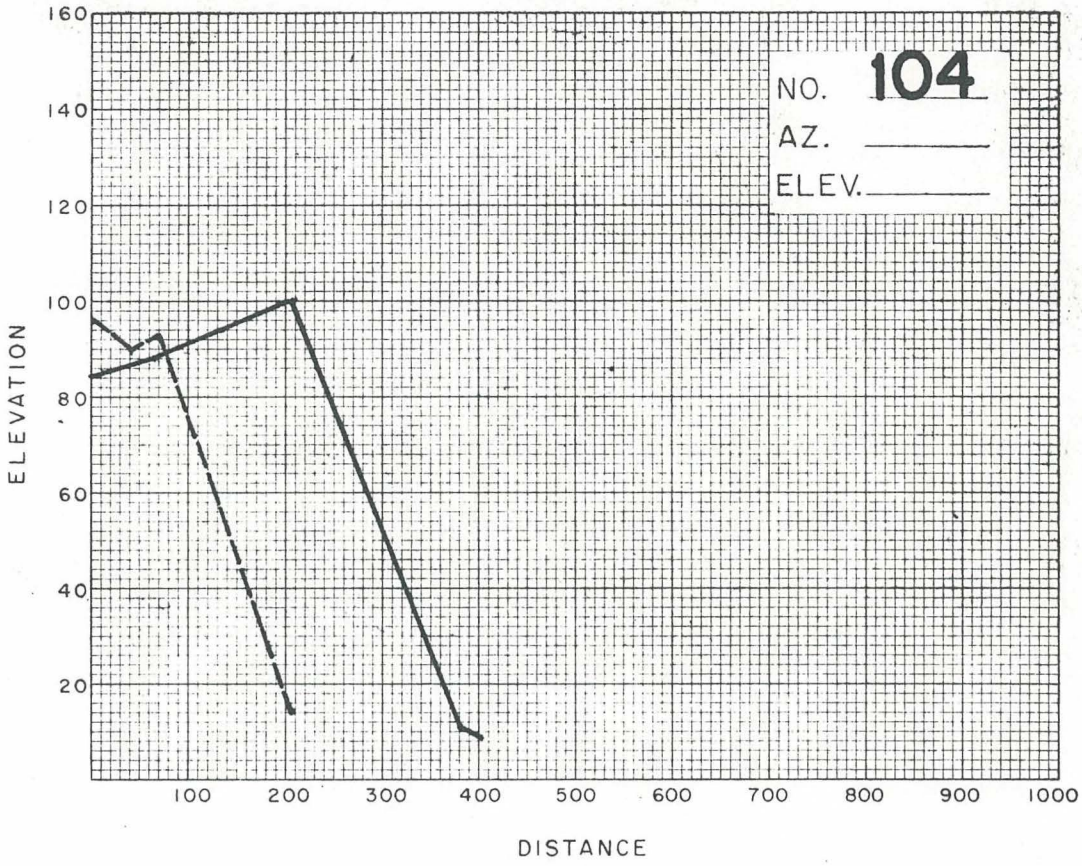
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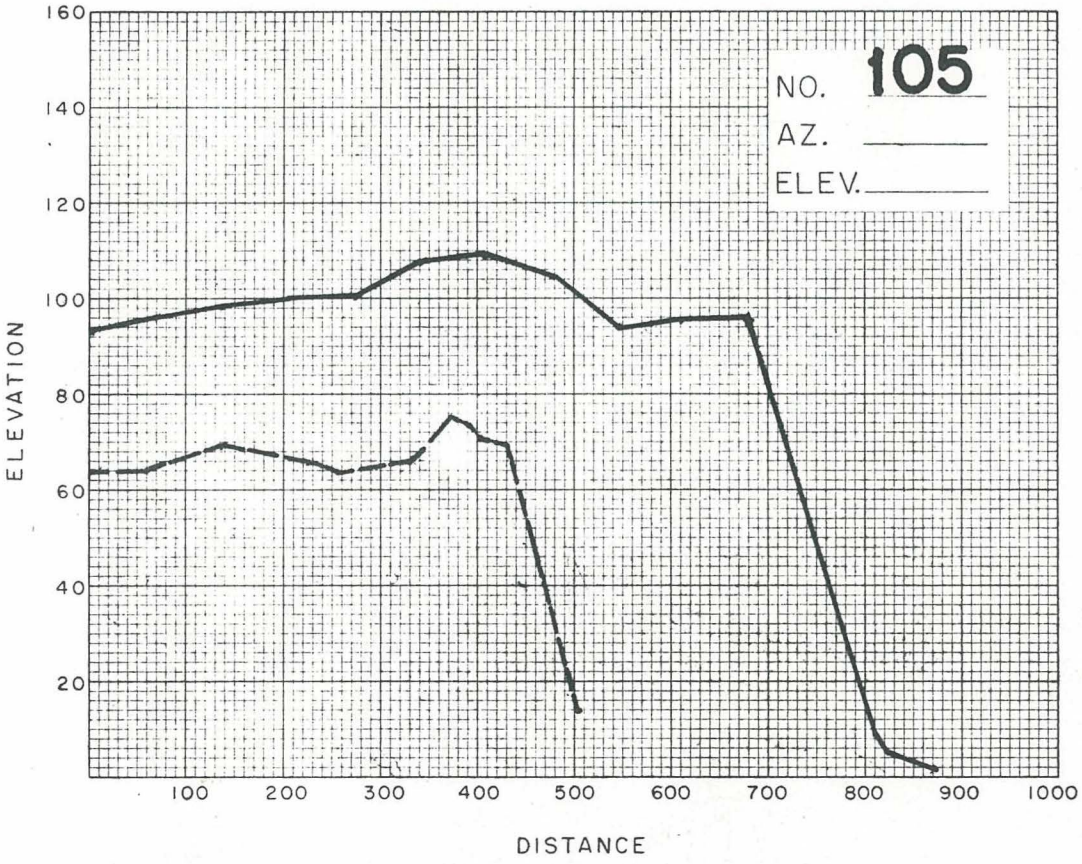
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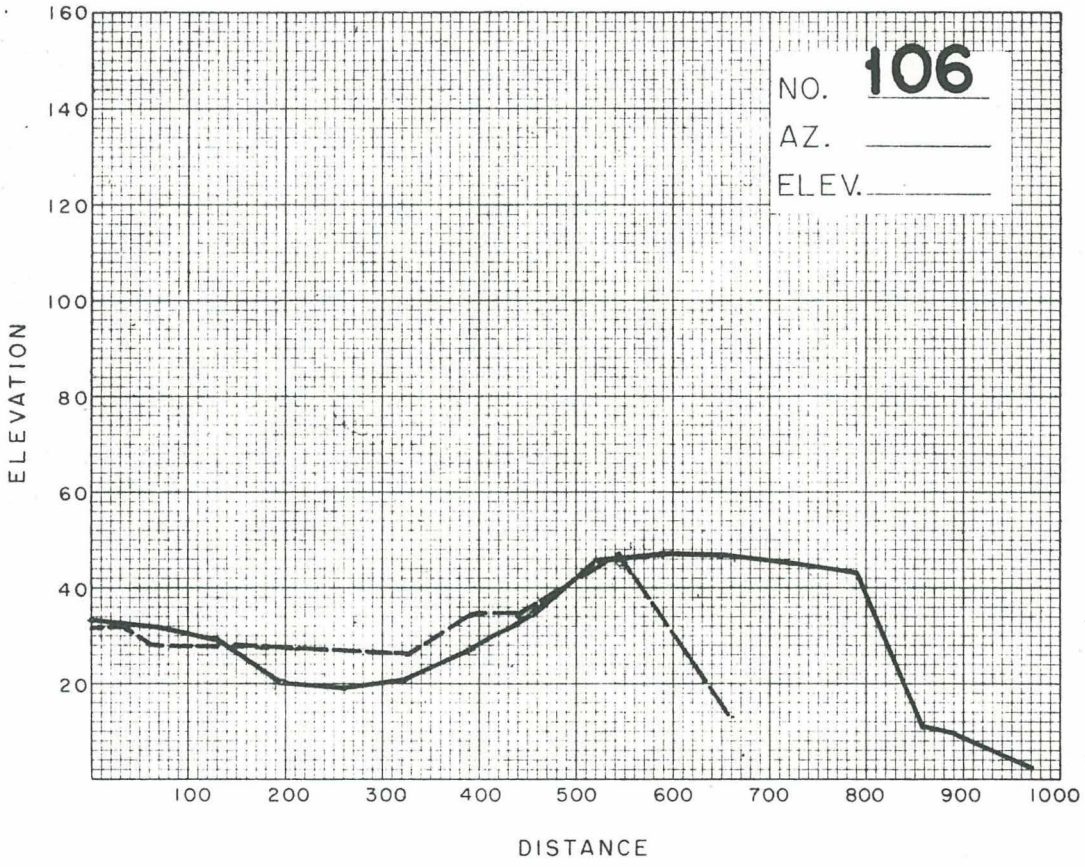
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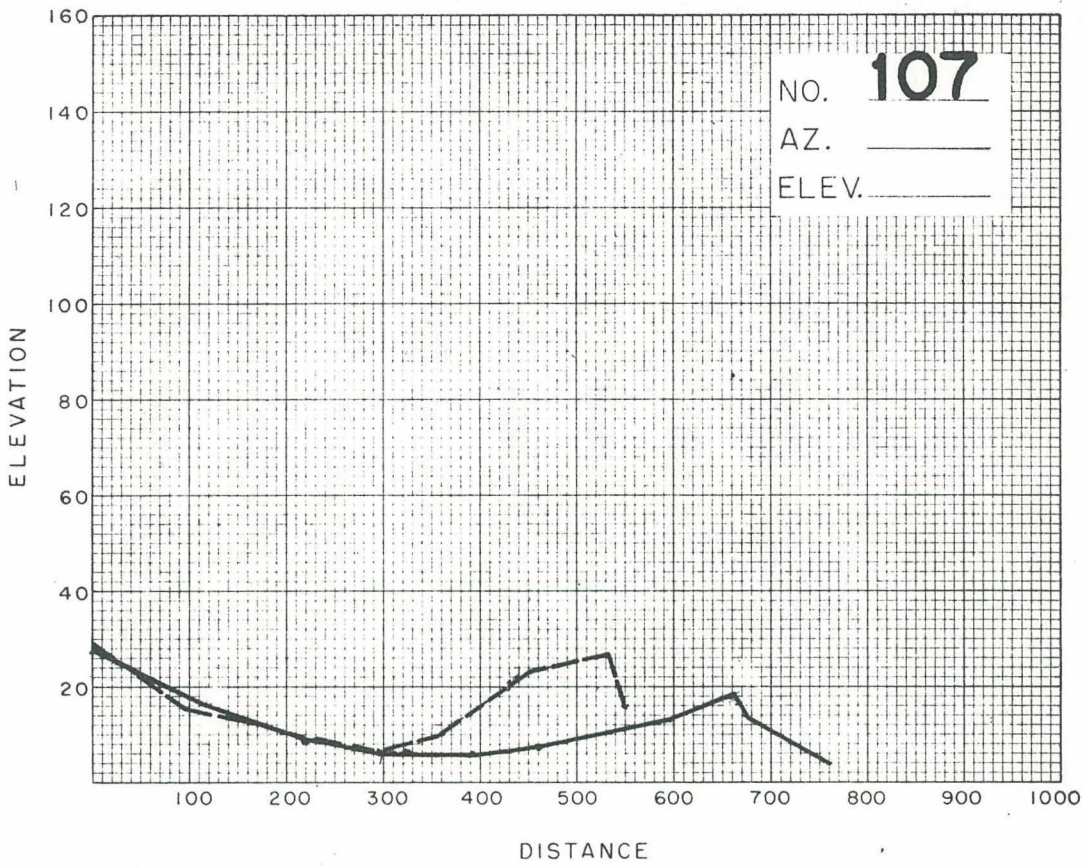
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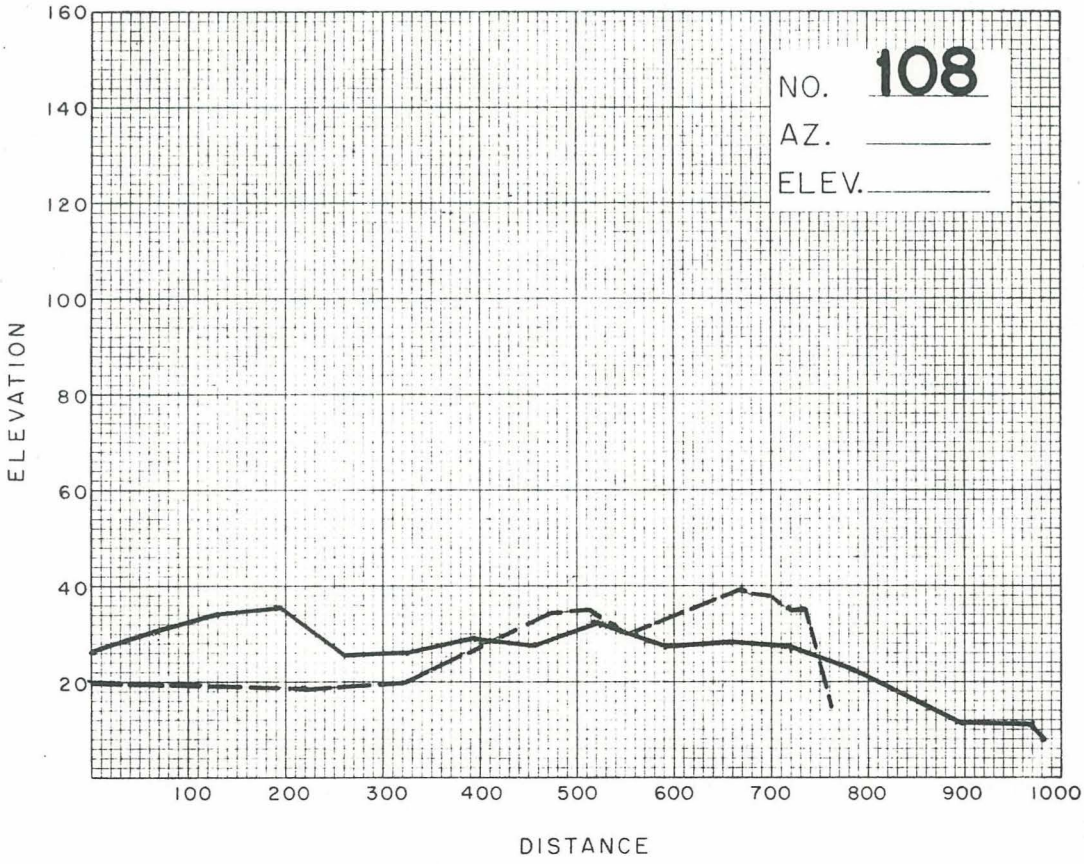
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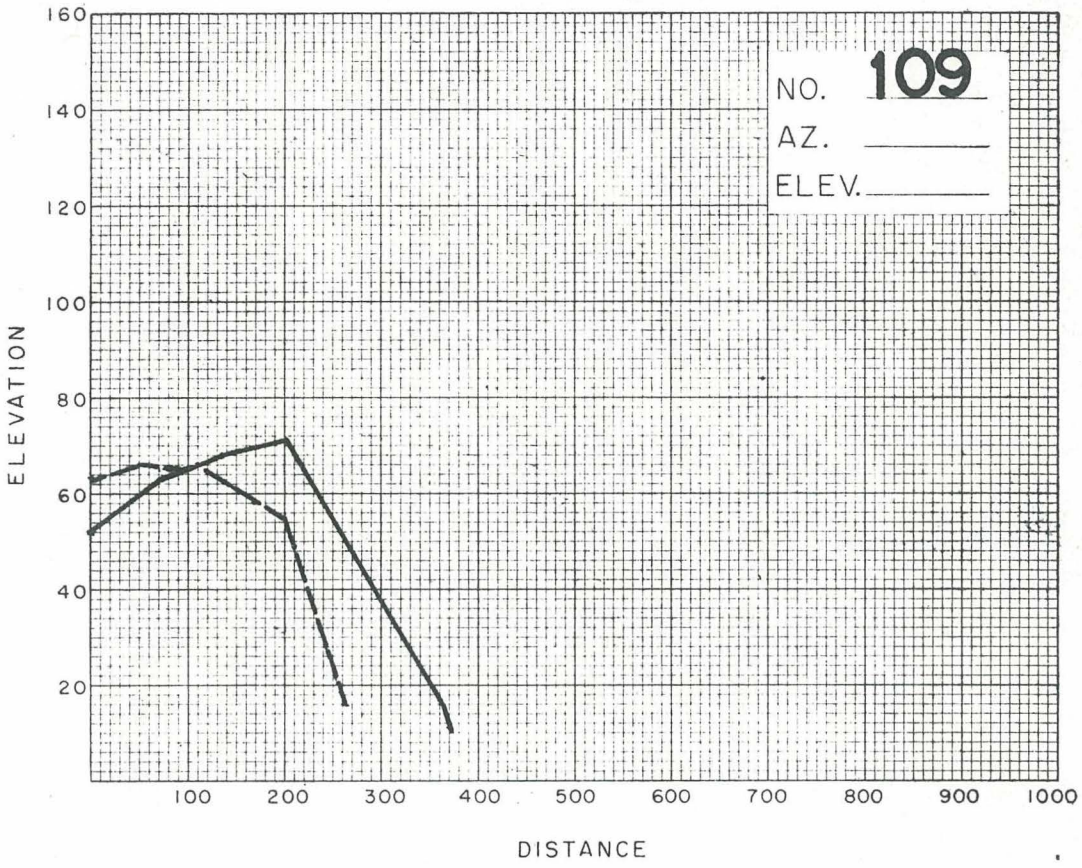
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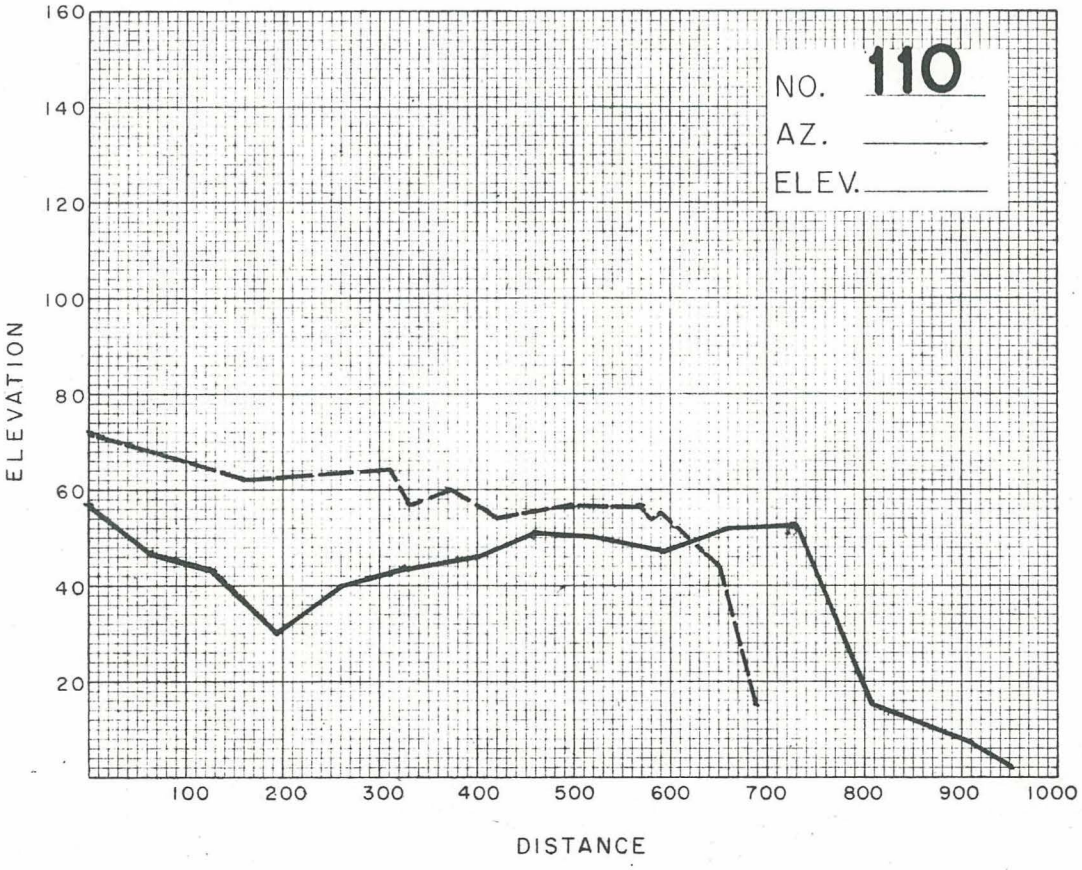
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DISTANCE


NO. 112
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ELEV. _____
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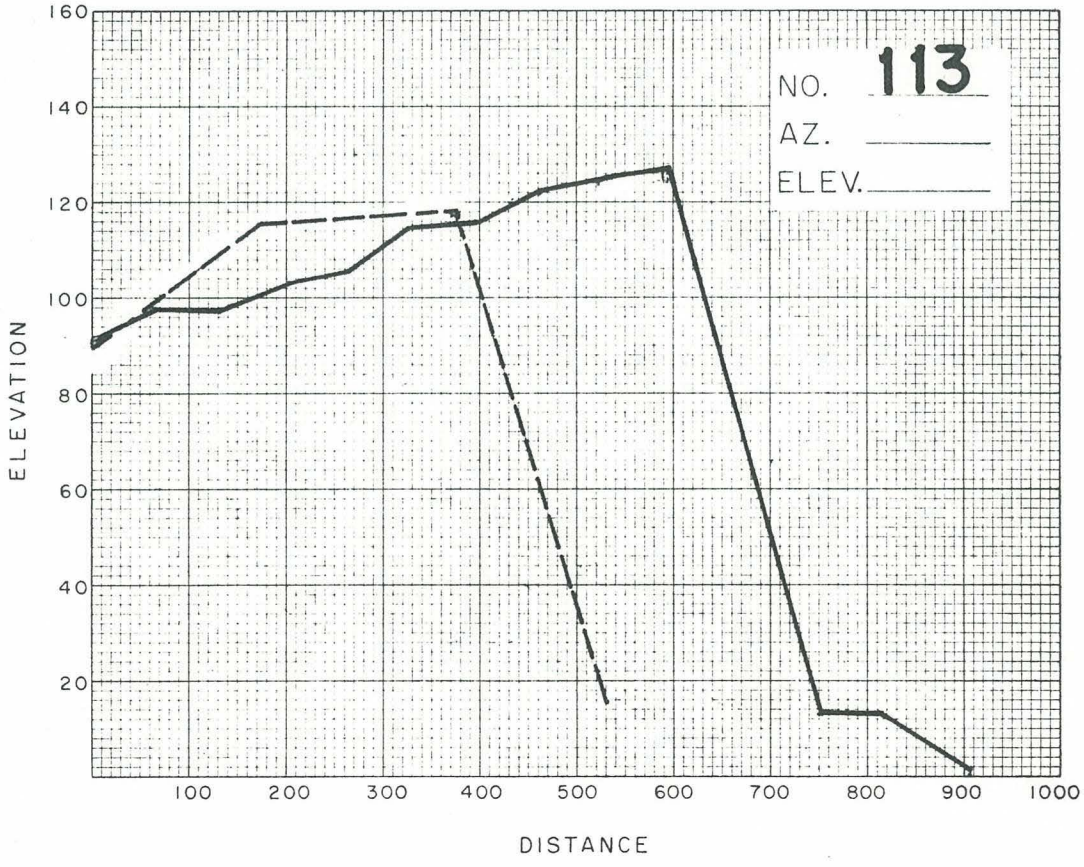
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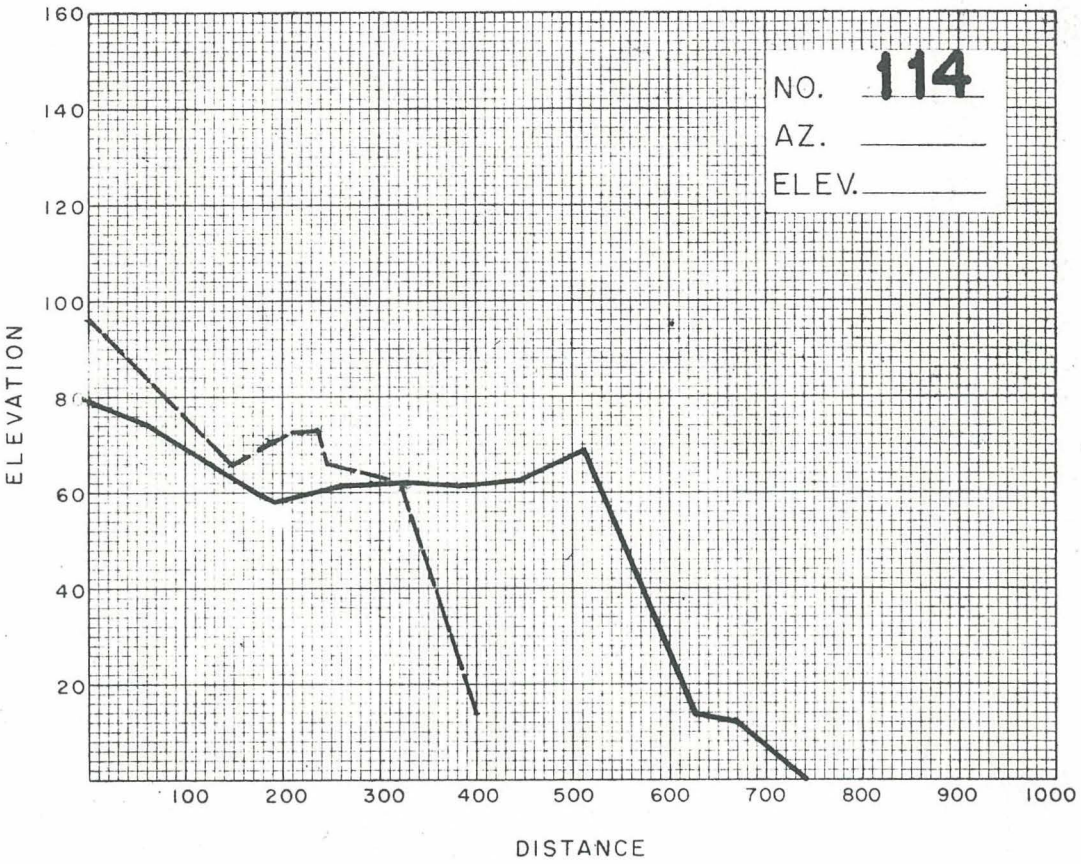
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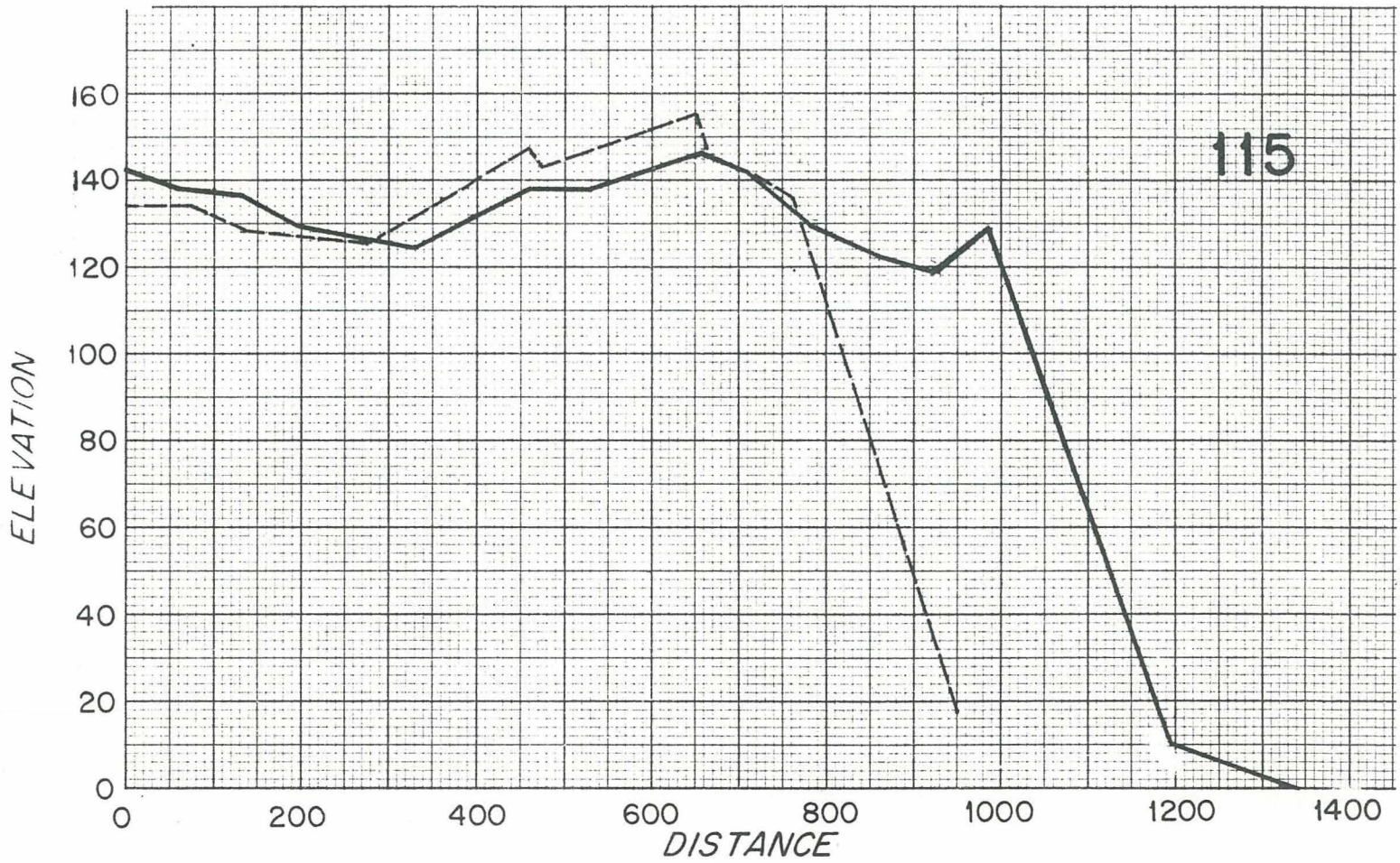
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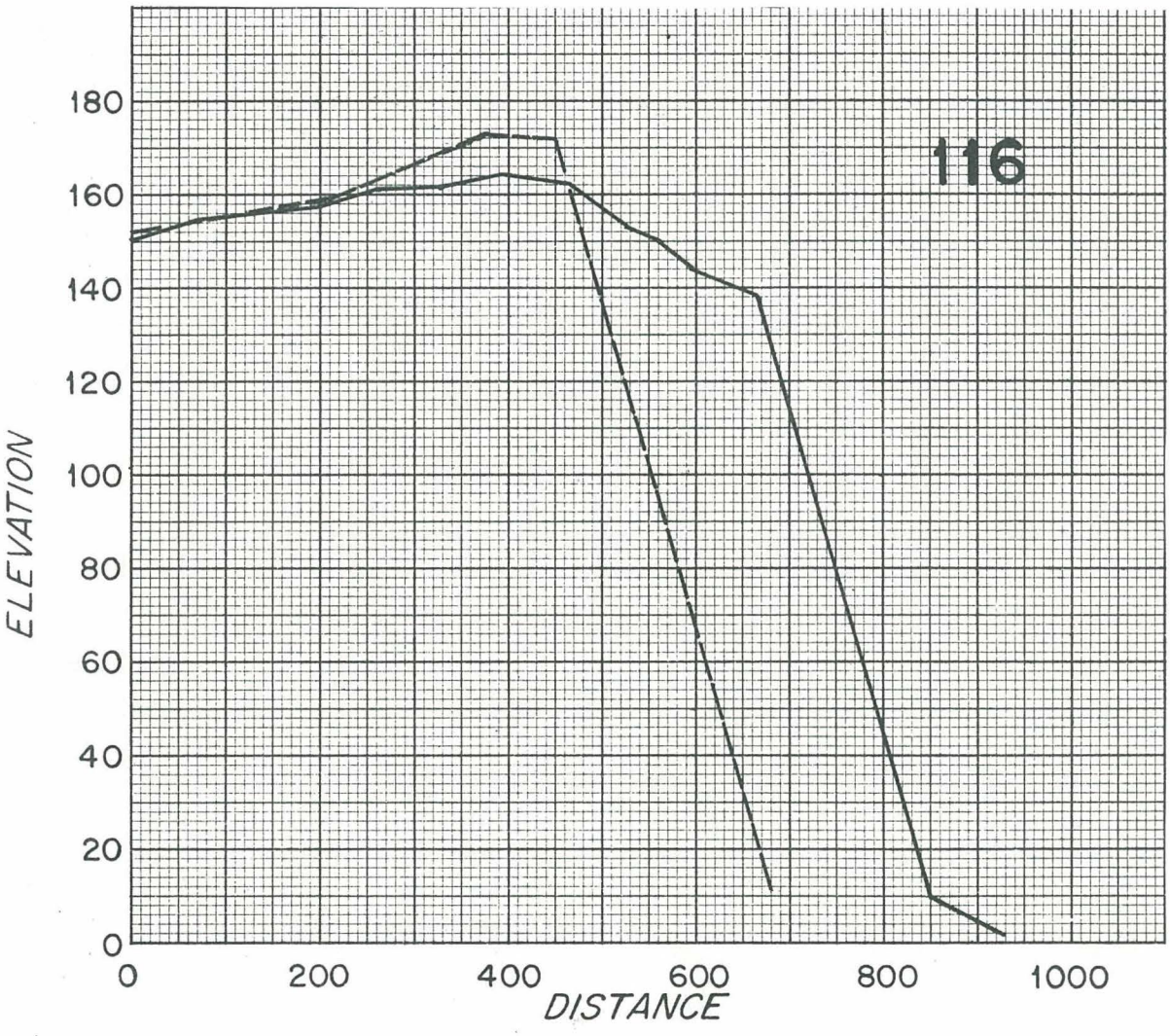
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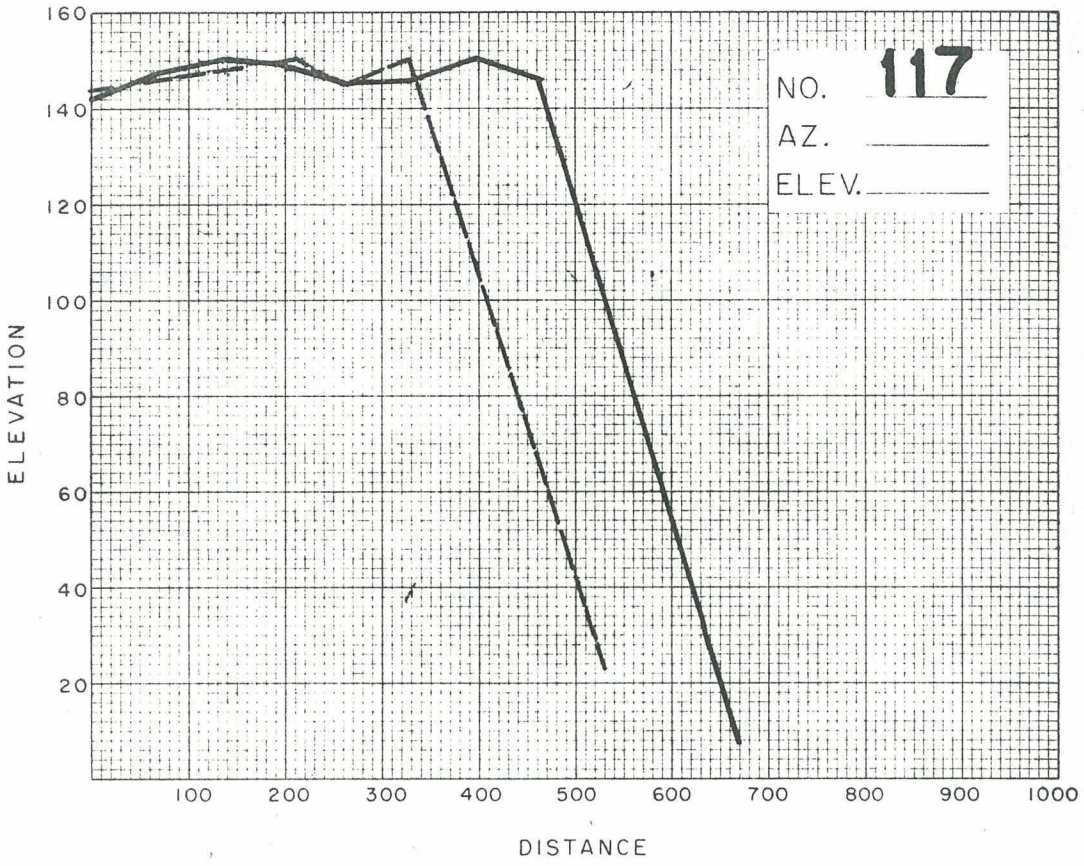
NO. 117
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DISTANCE


NO. 118
AZ. _____
ELEV. _____
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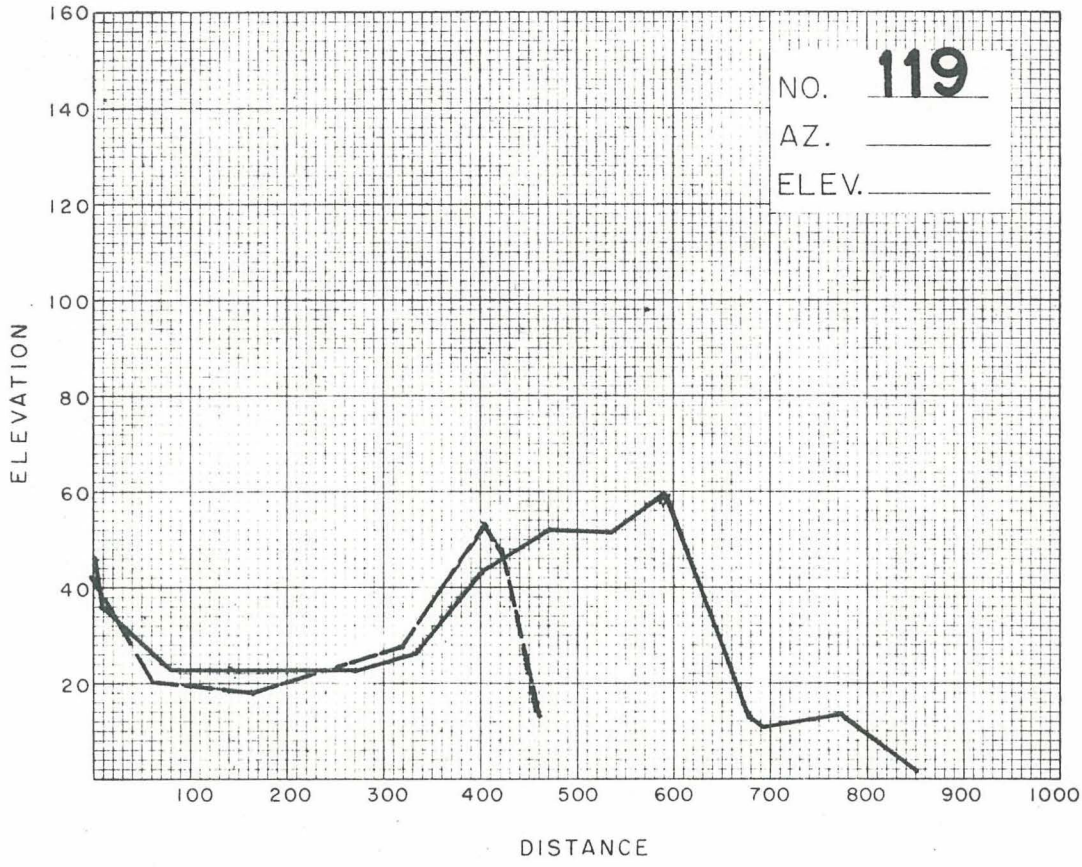
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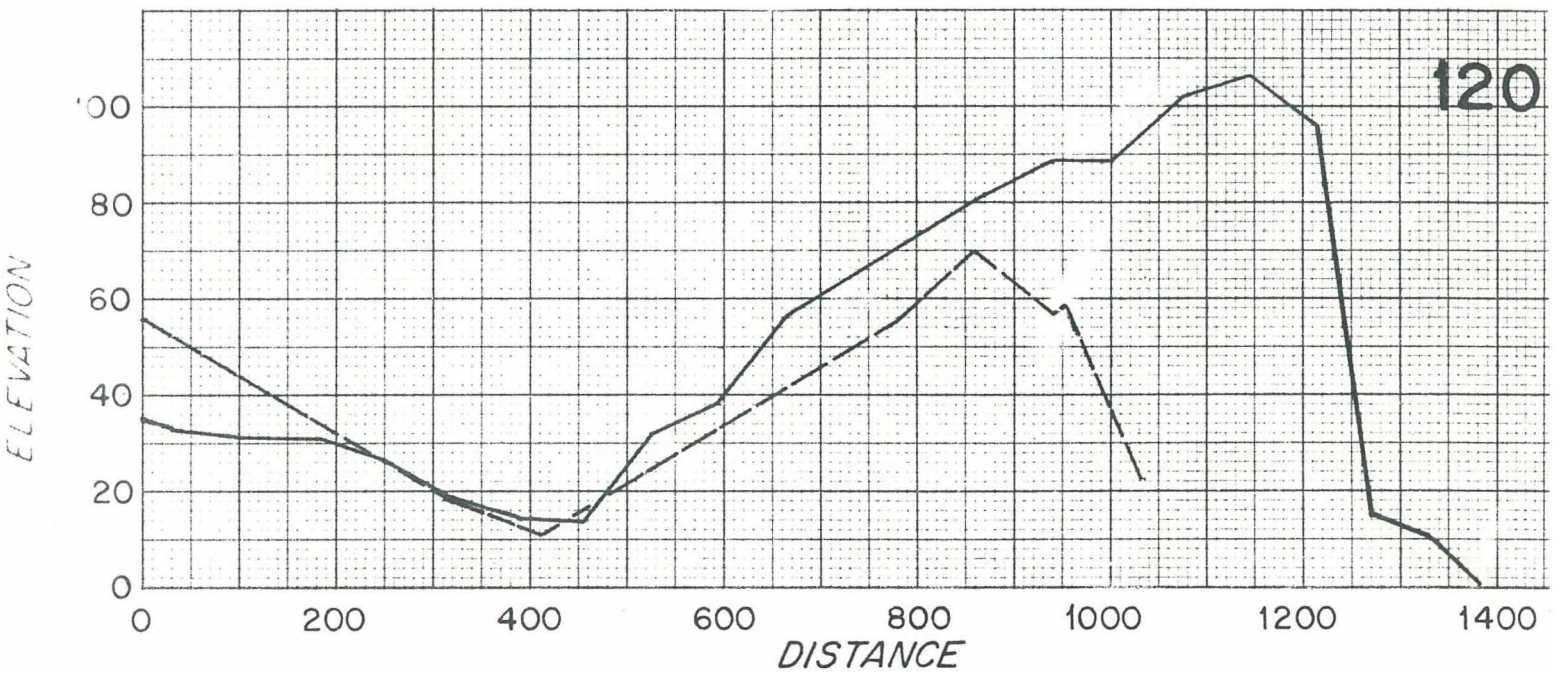
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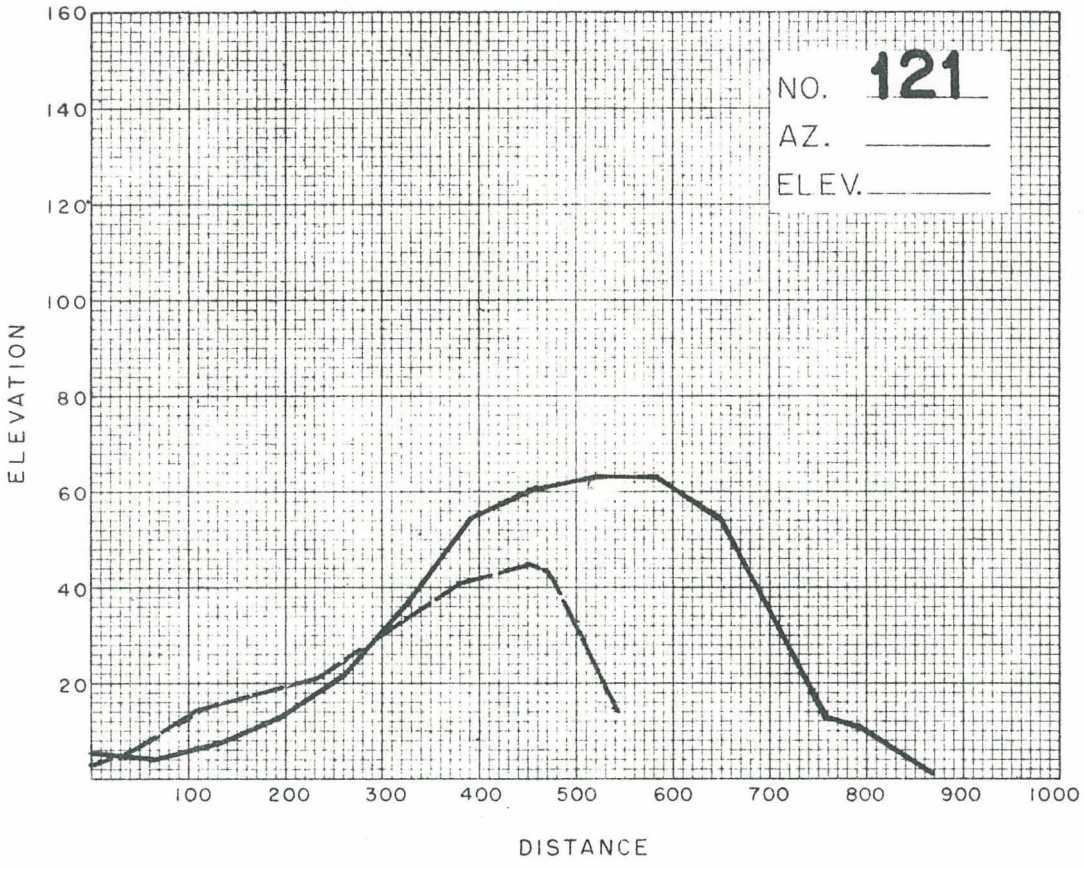
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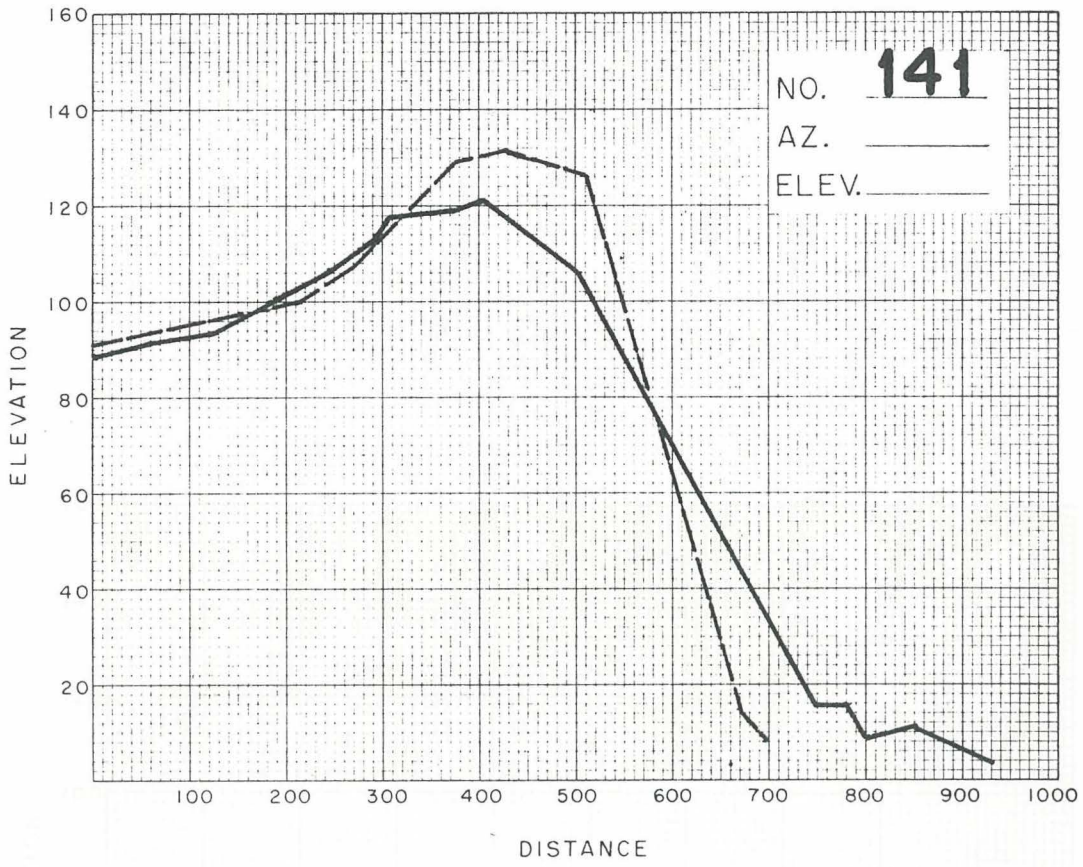
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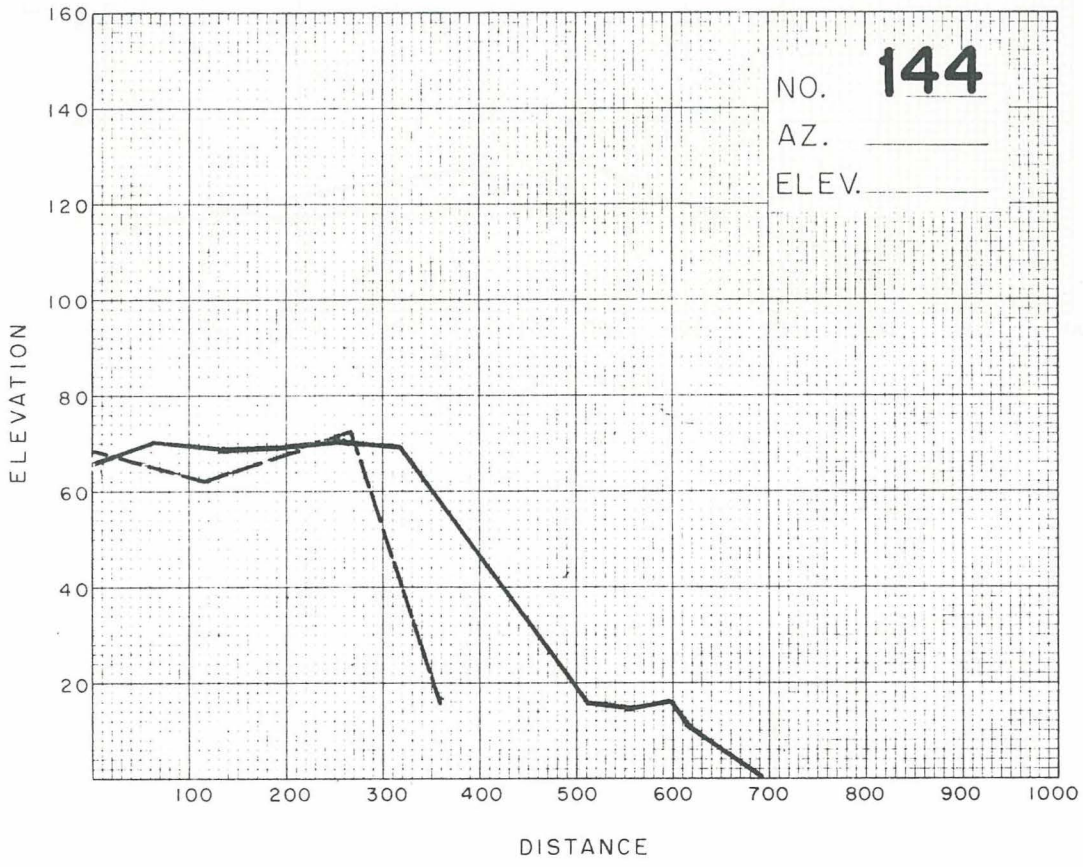
DISTANCE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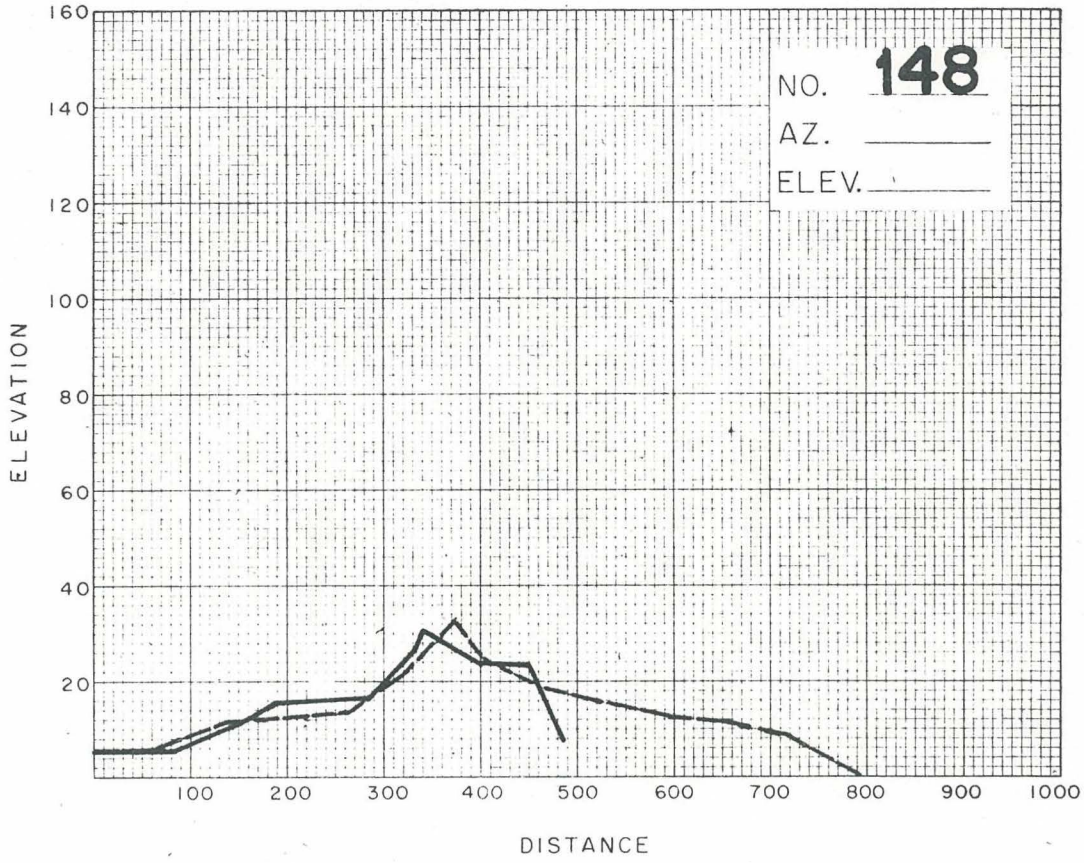
DISTANCE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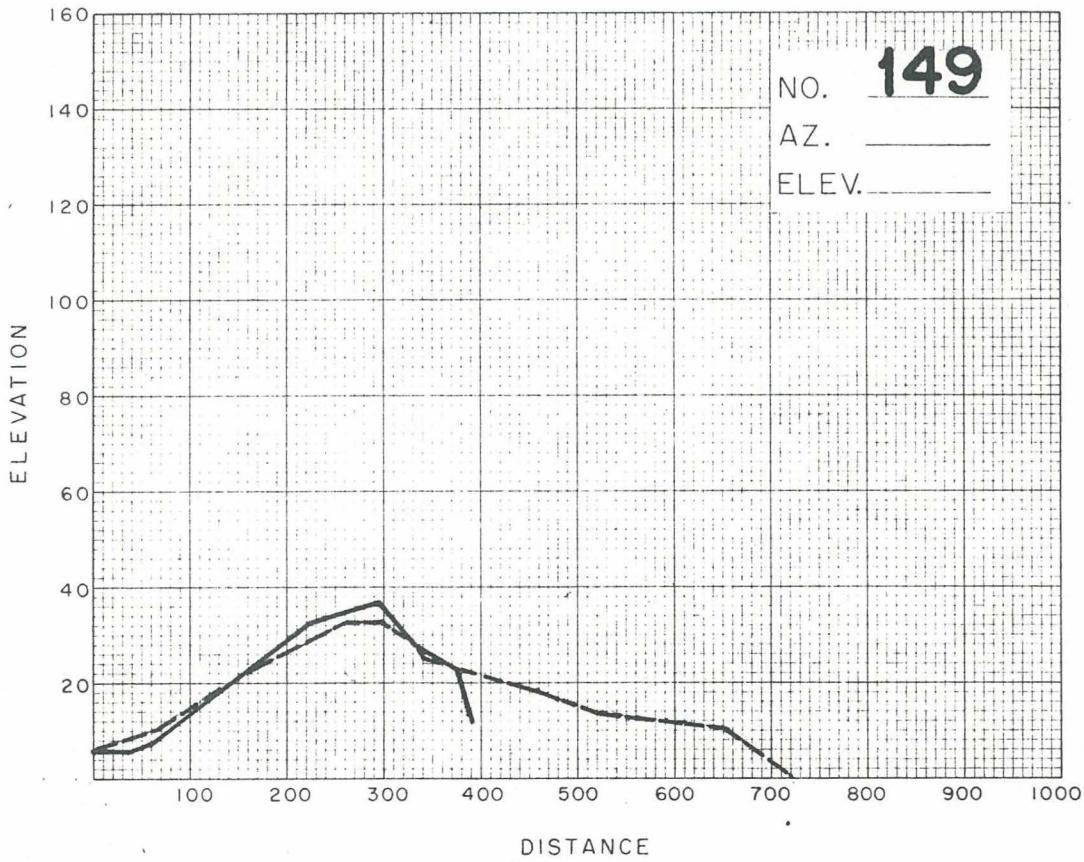
1000
DISTANCE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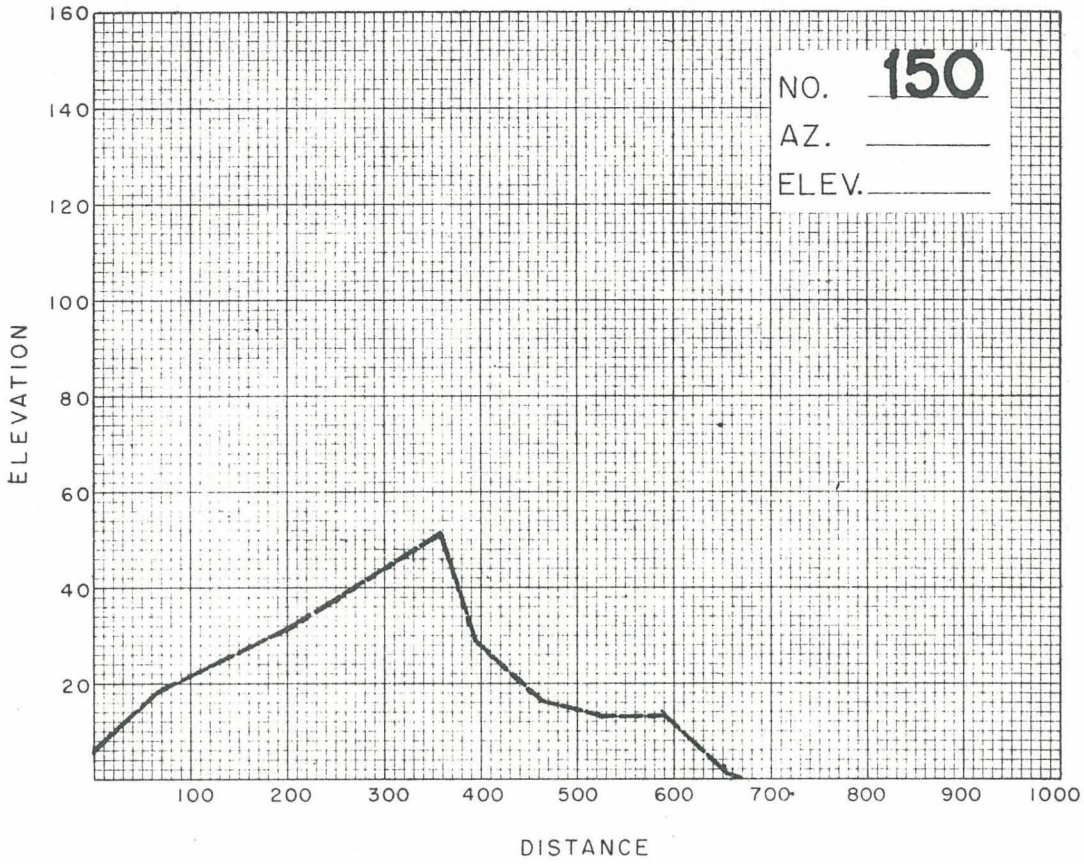
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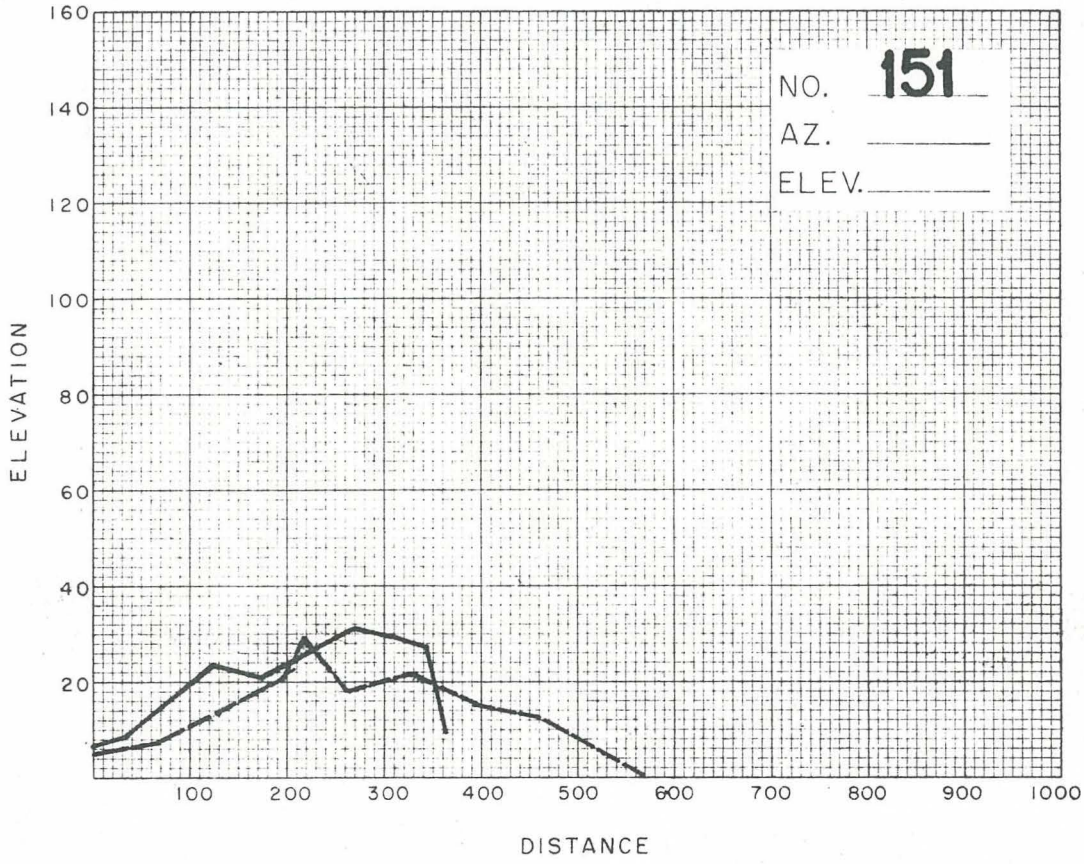
DISTANCE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ELEVATION
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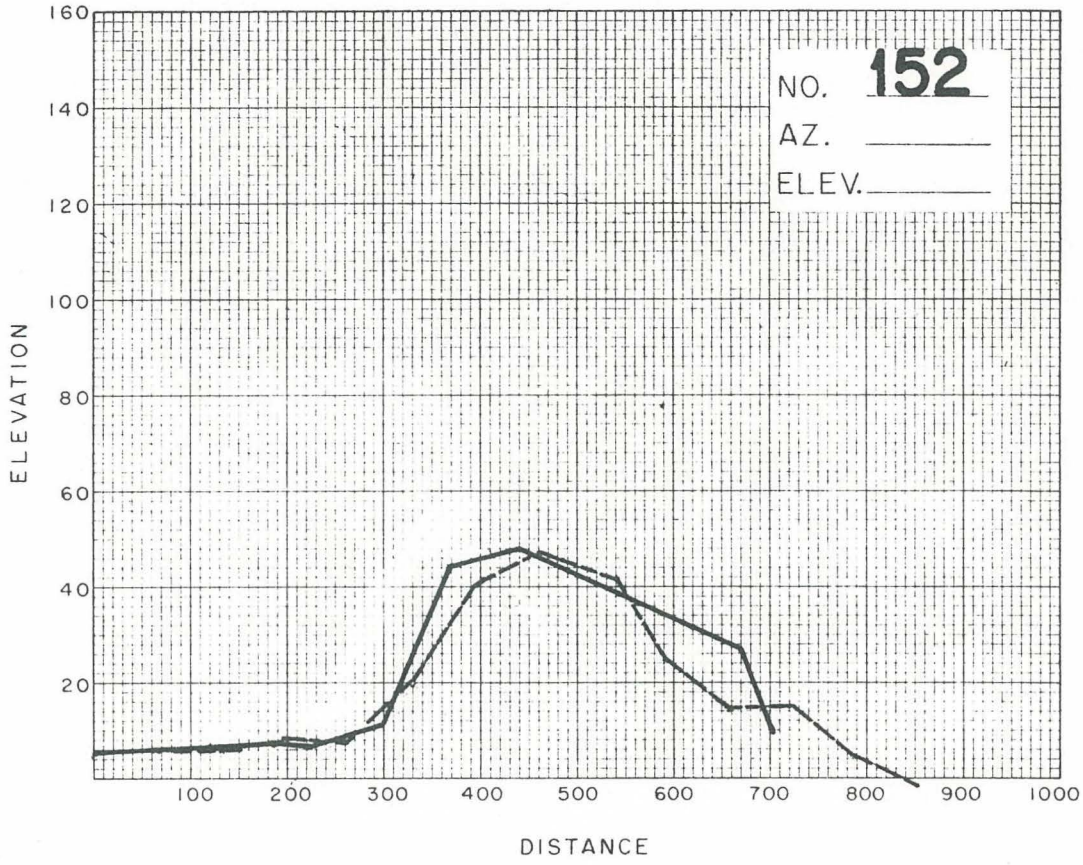
1000
DISTANCE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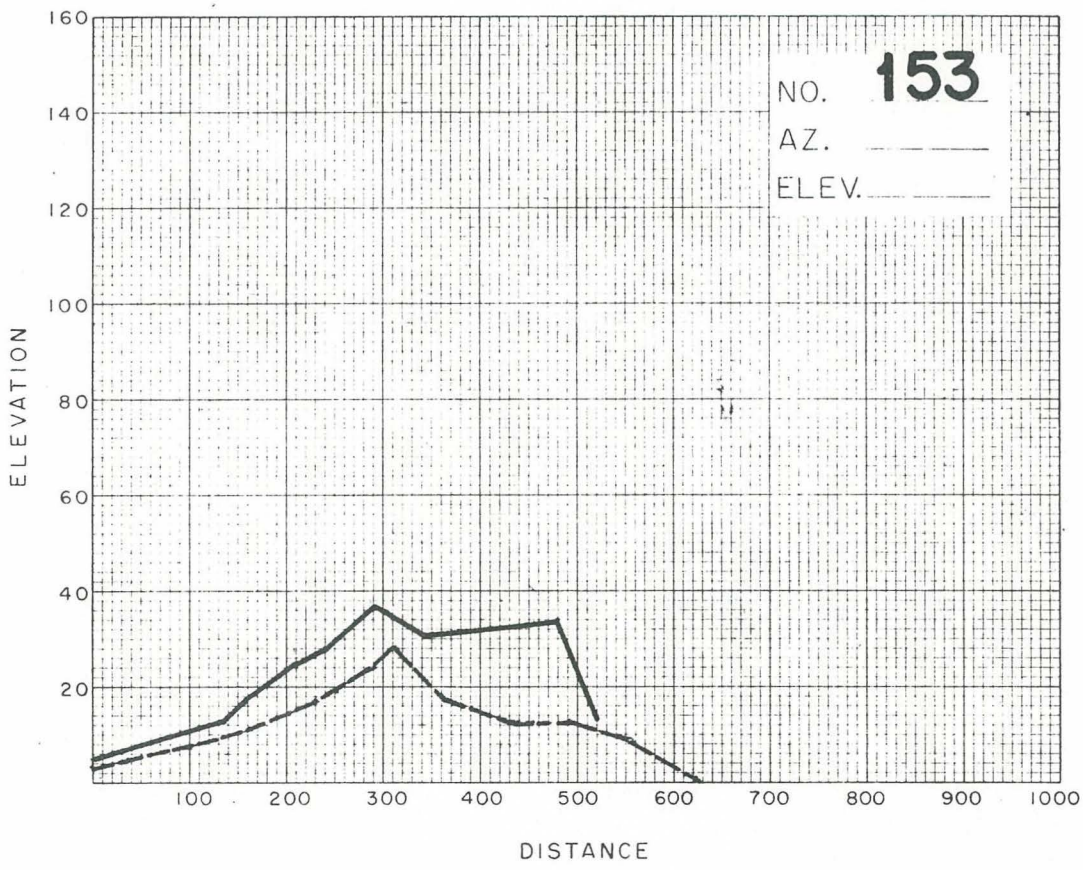
DISTANCE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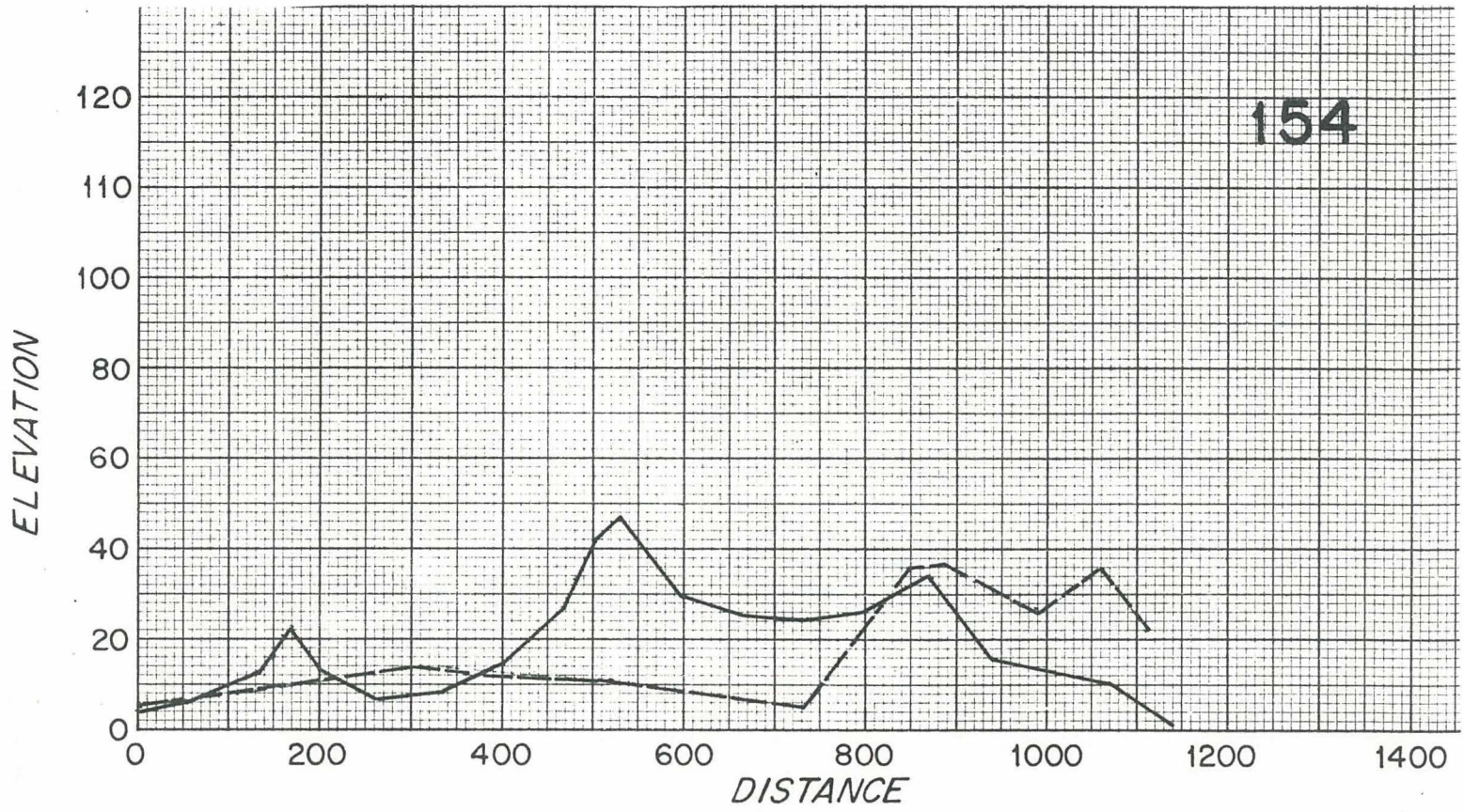
DISTANCE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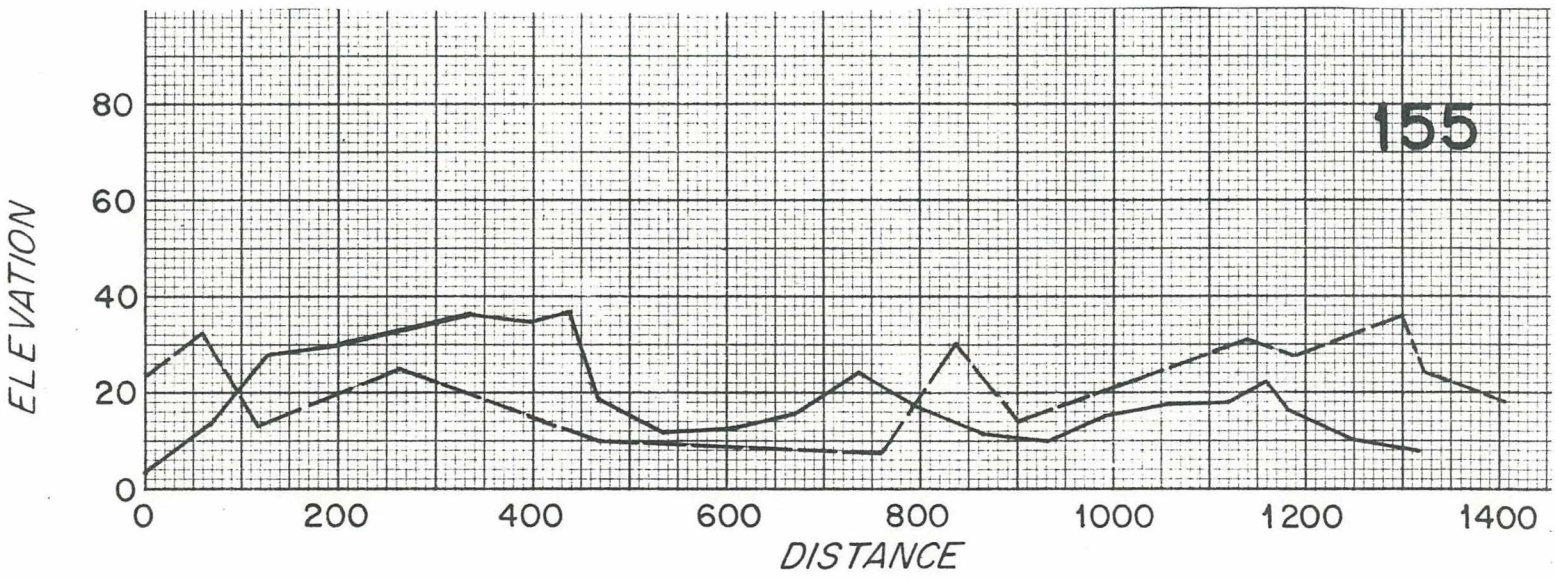
DISTANCE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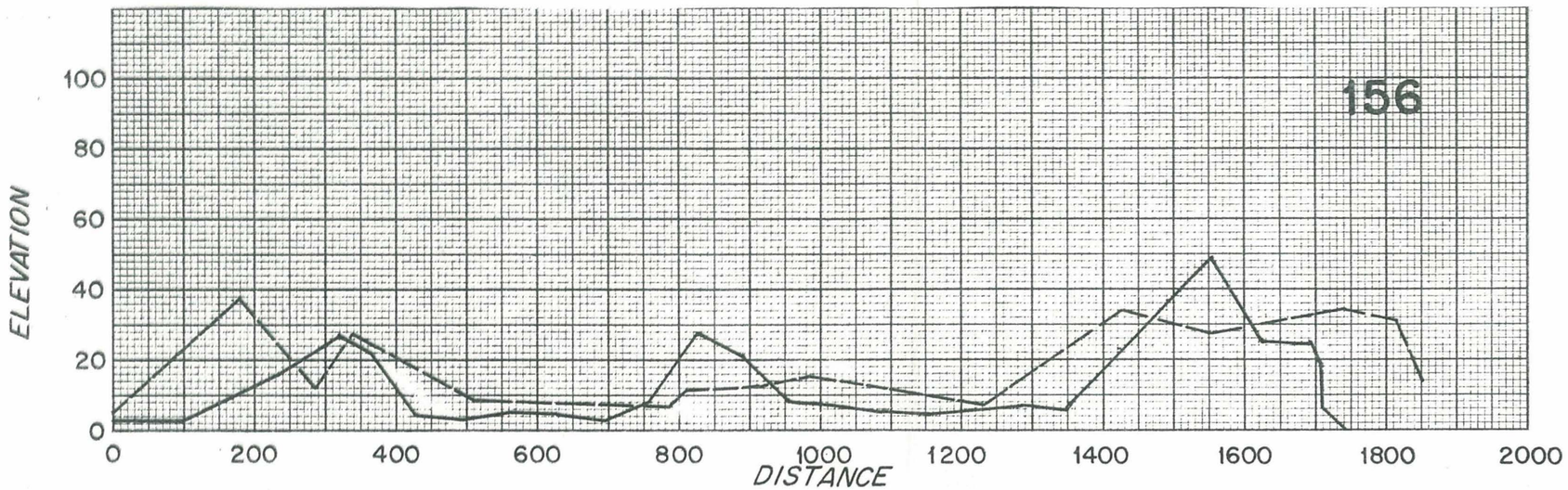
1400
DISTANCE


156
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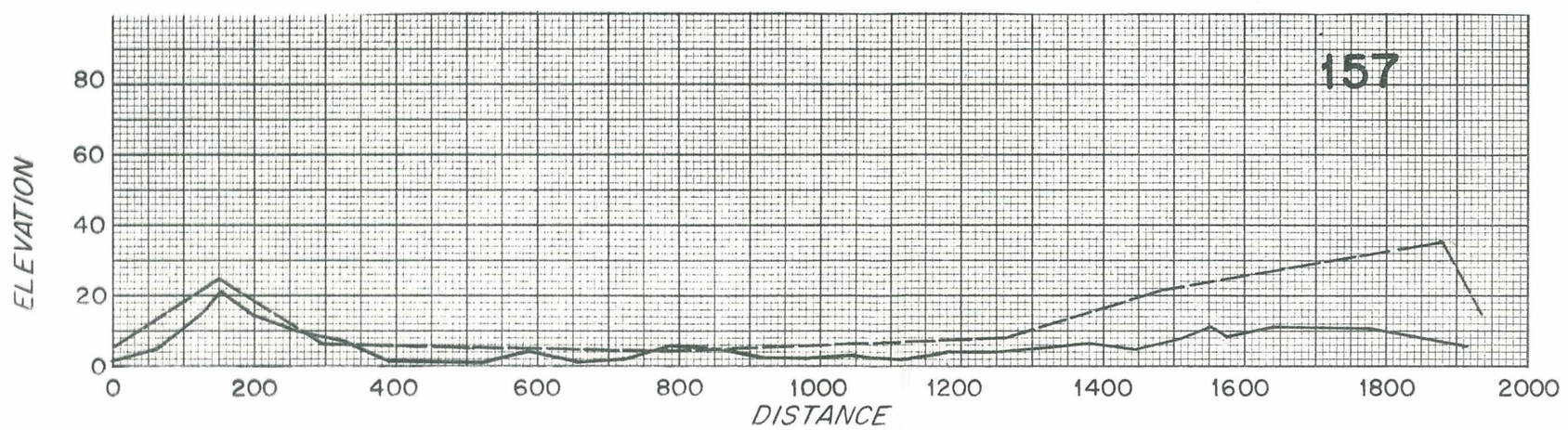
DISTANCE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ELEVATION
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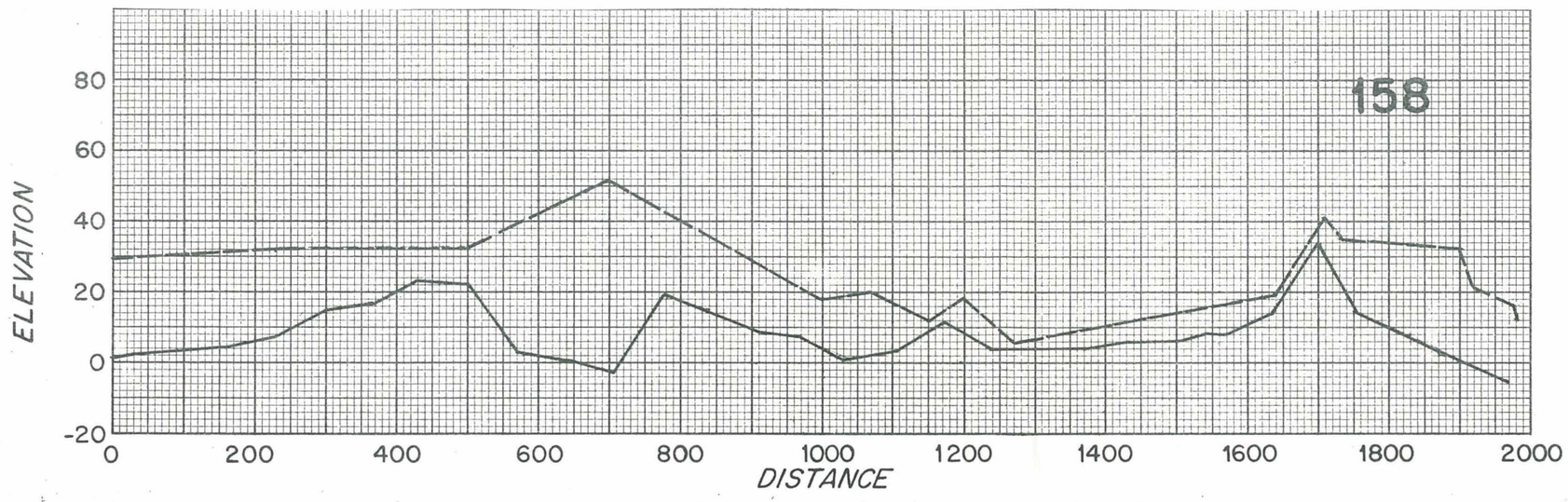
DISTANCE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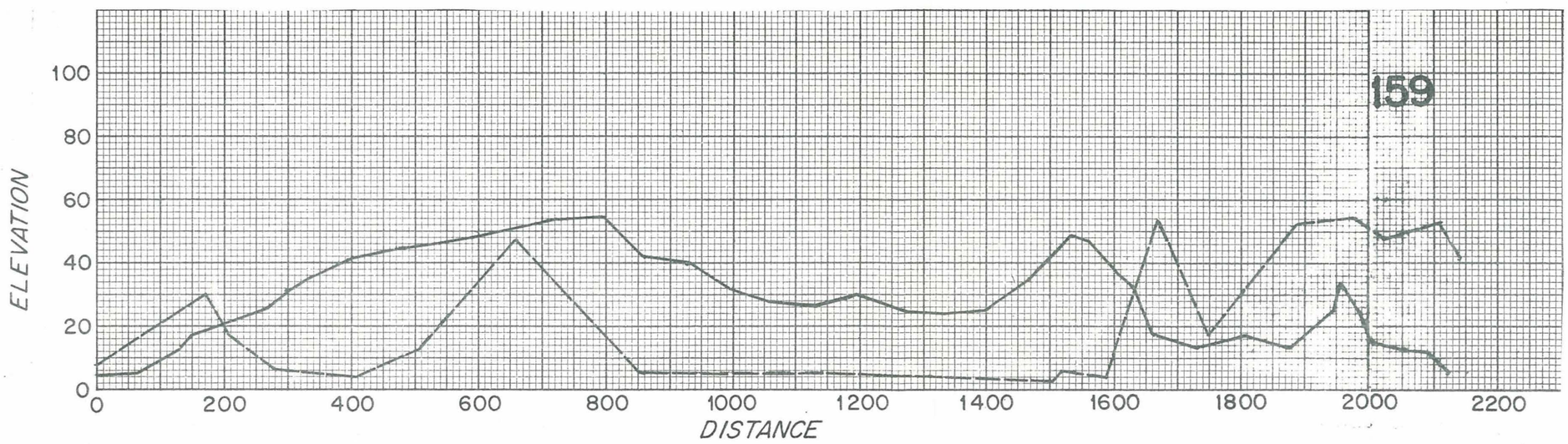
DISTANCE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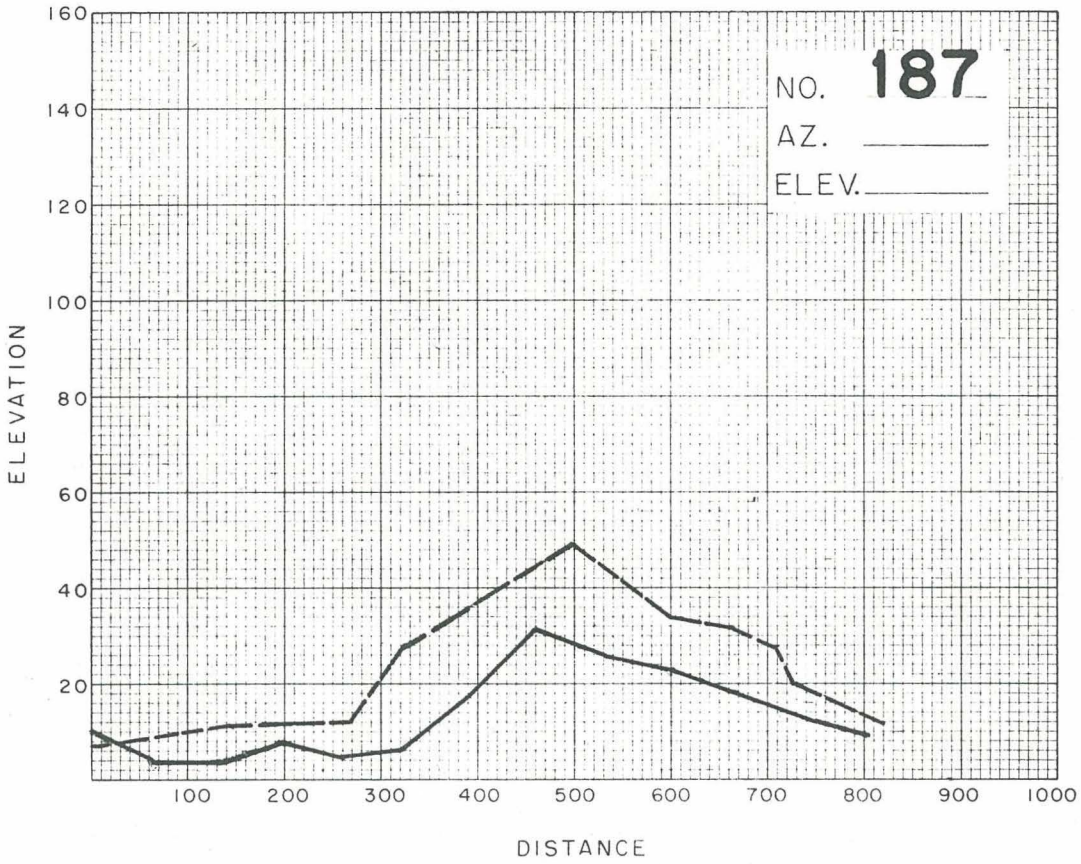
2200
DISTANCE


NO. 187
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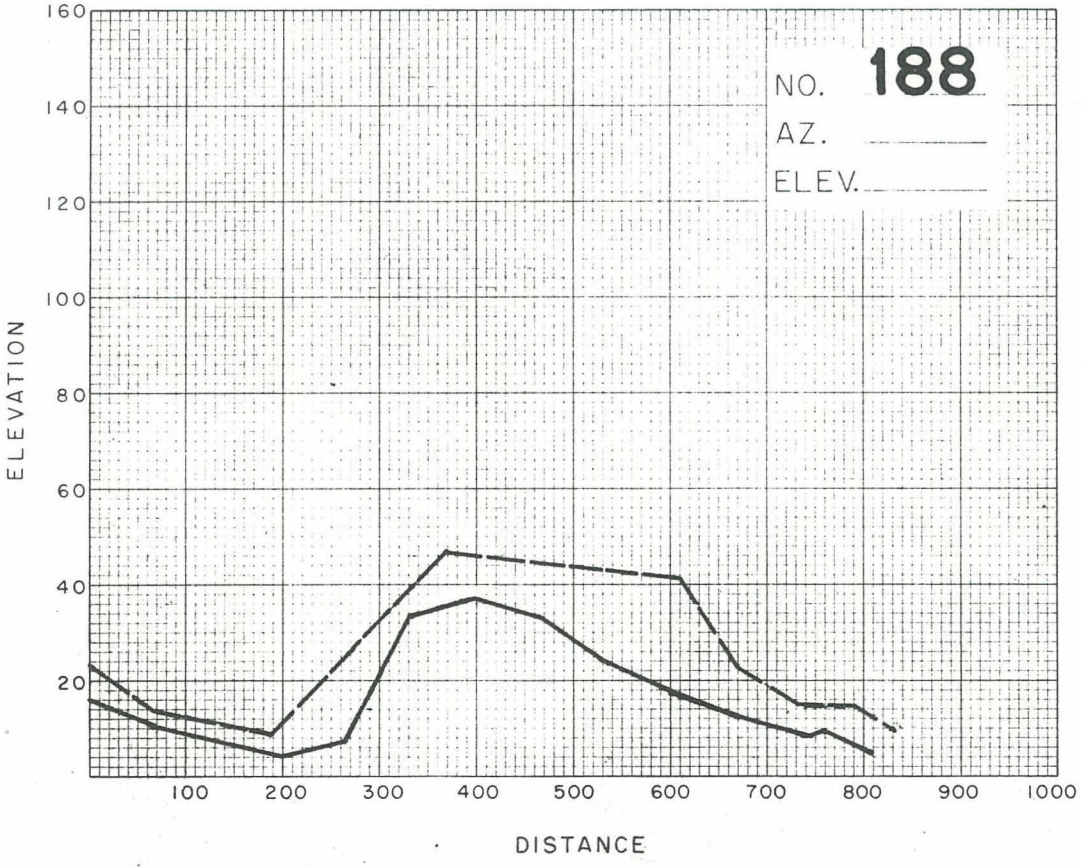
DISTANCE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1000
DISTANCE