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U.S. GEOLOGICAL SURVEY

A Summary of Leveling Data
from Kilauea Iki Lava Lake
from 1960 to 1988

by

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Introduction

The purpose of this report is to compile and compare the leveling data of Kilauea Iki lava lake from 1960 to 1988.

Kilauea Iki crater is located to the east of the summit caldera of Kilauea volcano on the island of Hawaii (Fig. 1). The lava lake was formed by a 36-day summit eruption in November-December, 1959. The crater was filled with lava, producing a lake with a depth estimated between 120 meters (Peck et al., 1979) and 135 meters (Helz et al., 1993). Investigation of the lava lake began months after the crust solidified. The first leveling network was set up in 1960, with 2 perpendicular lines on the surface of the lake (Helz et al., 1980). Two surveys were completed in 1960, one in 1961 and one in 1962. In 1964, additional leveling stations were added parallel to the original lines to form a more complete grid (Fig. 2). Surveys of the full grid were conducted in 1964, 1965, 1966, 1967, 1968, 1971, 1973, 1975, 1979, 1981 and 1988, coordinated with drilling of the lava lake in 1967, 1975, 1976, 1979, 1981 and 1988. The leveling surveys were set up in conjunction with drill core work. A summary of the drilling results from 1960-1975 can be found in Wright et al. (1976). Core logs from the 1967-1979 drillings are summarized by Helz et al. (1984). Core logs from the 1981 and 1988 drilling are summarized by Helz and Wright (1983) and Helz (1993), respectively.

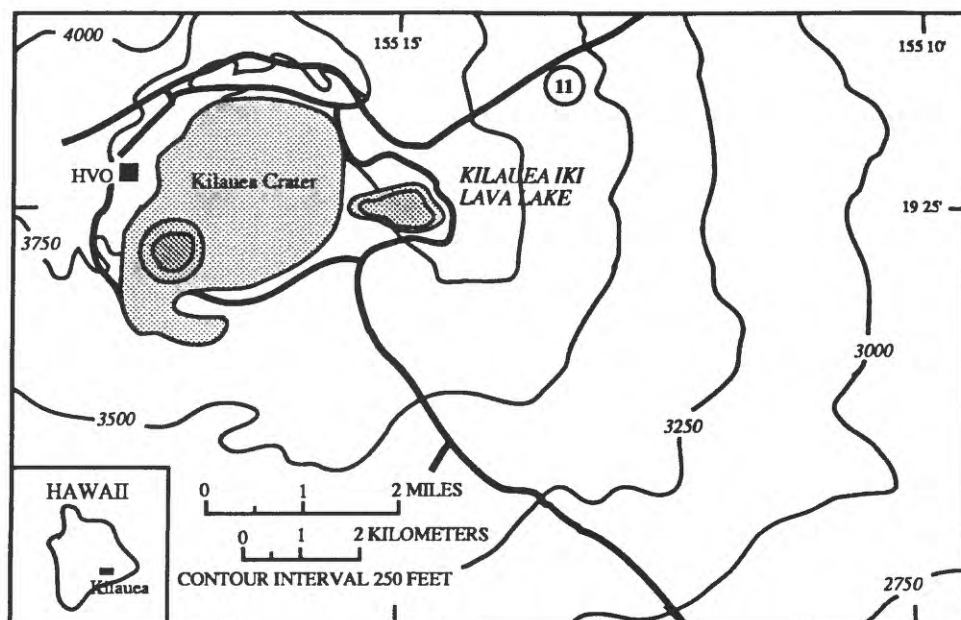


Figure 1. Index map to the summit area of Kilauea Volcano showing location of Kilauea Iki Lava Lake. (Reproduced from Wirght et al., 1976)

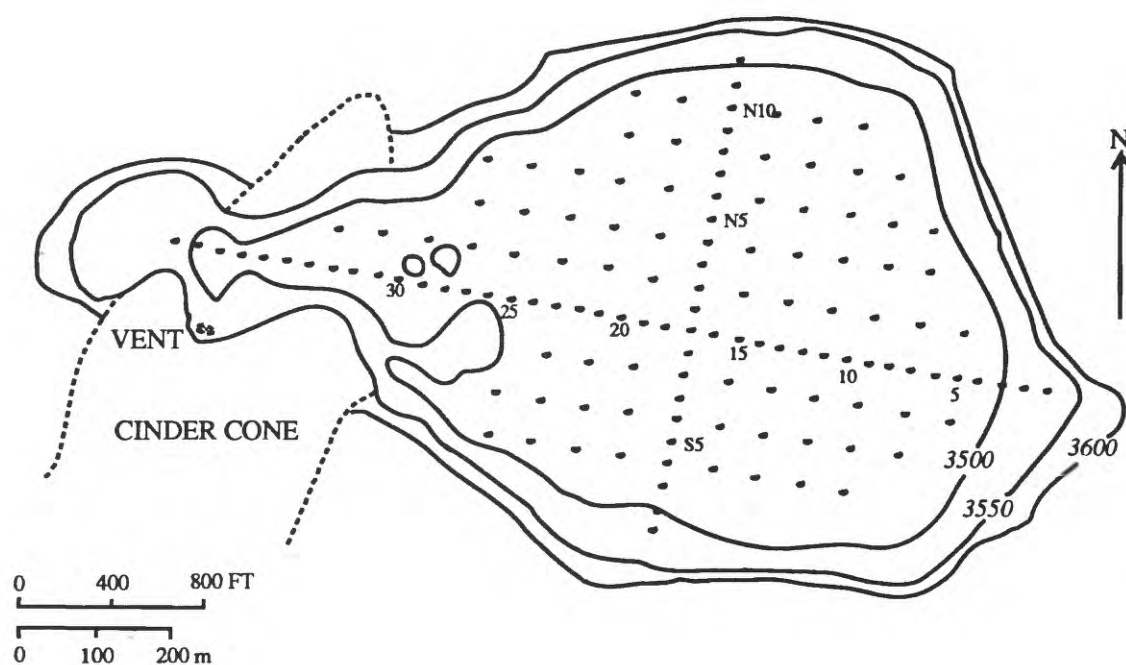


Figure 2. Station locations within Kilauea Iki Lava Lake. The points spaced 100 feet apart are the original perpendicular survey lines. The stations spaced at a 200 foot interval were added in the 1964 survey.

Description of the Figures

Four types of plots are used to describe the changes in elevation of the surface of Kilauea Iki lava lake. The survey years chosen are those which best represent the overall trend of elevation changes. Initial subsidence of the lake was rapid (Wright et al., 1976) and surveys were conducted almost yearly. As the rate of subsidence slowed and the changes between years became smaller, the surveys were conducted less often. Therefore, the time interval between leveling surveys in the early years, 1960-1971, is shorter than in the later years, 1971-1988.

Comparison of elevation contour maps (Figs. 3-8) for individual years show any changes in the surficial topography of Kilauea Iki lava lake.

The subsidence rate contour maps (Figs. 9-12) show where the rate of subsidence of the lake per year was the greatest. The subsidence rate contour maps were constructed by subtracting the leveling elevations determined in the older year from the leveling elevations determined in the more recent year. This elevation difference is then divided by the number of years between the older and more recent survey to give the rate of change in cm/year. Because the elevations of the more recent year are generally lower than the elevations of the older leveling survey, a negative value indicates subsidence while a positive value indicates inflation. The contour maps can only be generated for surveys after 1964, when the full station grid was established.

Profile plots (Figs. 13-20) are constructed parallel to the original two leveling lines. The number with the plotted line is the date of the survey, i.e. 3-60 represents the elevations for the March 1960 survey. The elevations are given in feet above sea level to represent the actual measurements made during the survey year. These figures were constructed starting with the 1960 leveling surveys and compare the change in elevation over time between pairs of survey years. They also demonstrate the vertical movement of individual stations between surveys.

The final plots (Figs. 21-26) show the change in elevation of a single station through time. Stations were chosen along the original survey lines.

Results

The elevation contour maps demonstrate that the overall shape of Kilauea Iki does not change. Station 35 is consistently has the lowest elevation, while the eastern edge, around stations 1 and 2, has the highest elevation in the crater. The local depressions increase in size and number from 1960 to 1988. The slope of the lake edges appears to decrease, especially in the 1979 and 1988 contour maps.

The subsidence rate contour maps show that for the first 7 years of the leveling surveys, that highest rate of subsidence was approximately 12 cm/year. This high rate of subsidence was located in the same place; the western side of the lava lake. This changes from 1971-1979 when the rate of subsidence went up to 20 cm/year and the highest rate of subsidence was located in the center of the lake. From 1979-1988 there is still subsidence toward the center of the lake and a new area of high subsidence on the western side.

The profile graphs demonstrate that although the topography changes, the shape of the surface is similar over time with occasional anomalies. The rate of overall decrease in elevation for each profile changes between both leveling surveys and along the survey line of a given survey. There is an large elevation change in the 1971-1979 profiles; this is consistent with the subsidence rate contour map for 1971/1979.

The individual station elevation time series emphasize the continual decrease in elevation, with the exception of the second 1960 survey, where there was an anomalous increase in elevation for two stations. The initial subsidence rate varies for all the stations; it is neither linear or logarithmic. There is a trend from approximately 1968-1981 for a linear decrease in elevation with the exception of an inflection for the 1971 survey. This rate of decrease slows from 1981 to 1988.

Elevation Contour Maps

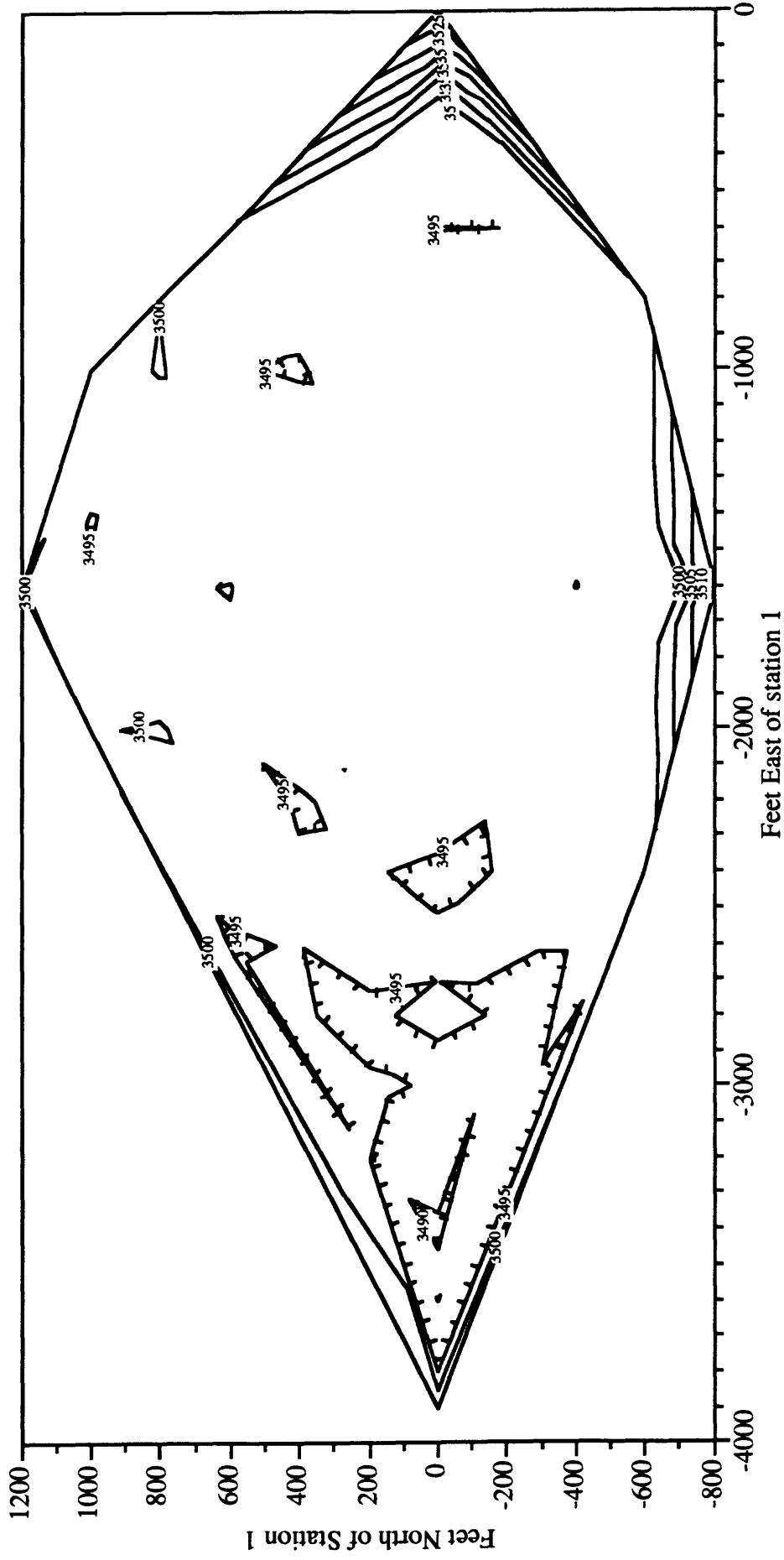
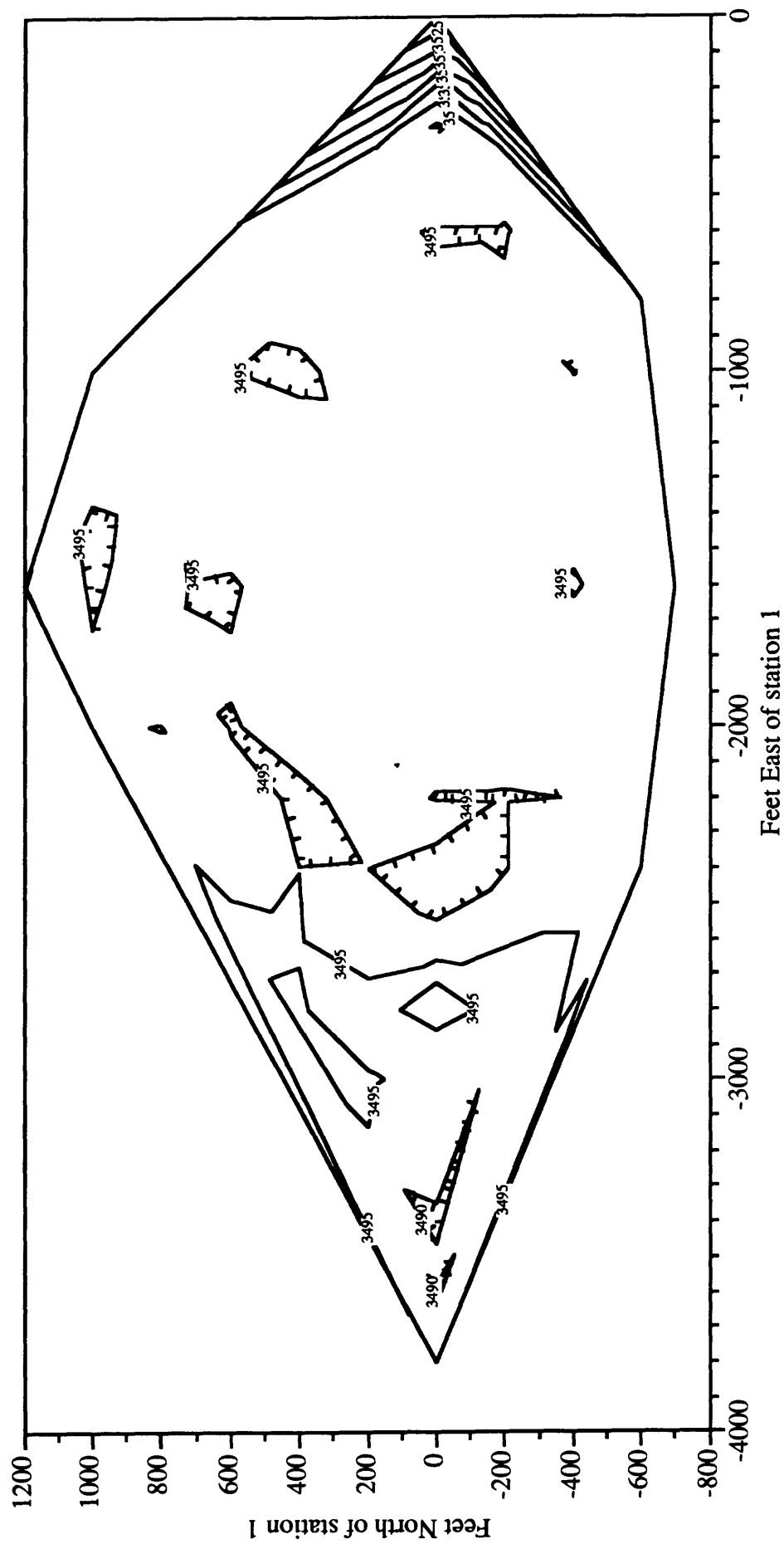


Figure 3. 1964 Elevation Contour Map. Contour interval 5 feet. The east wall of the crater is the steepest portion of the map. The floor is at a fairly constant elevation in the center with the exception of two depressed areas in the center of the crater. Each is about 200 meters long. The western area is the lowest in elevation with the largest depression centered at station 35.



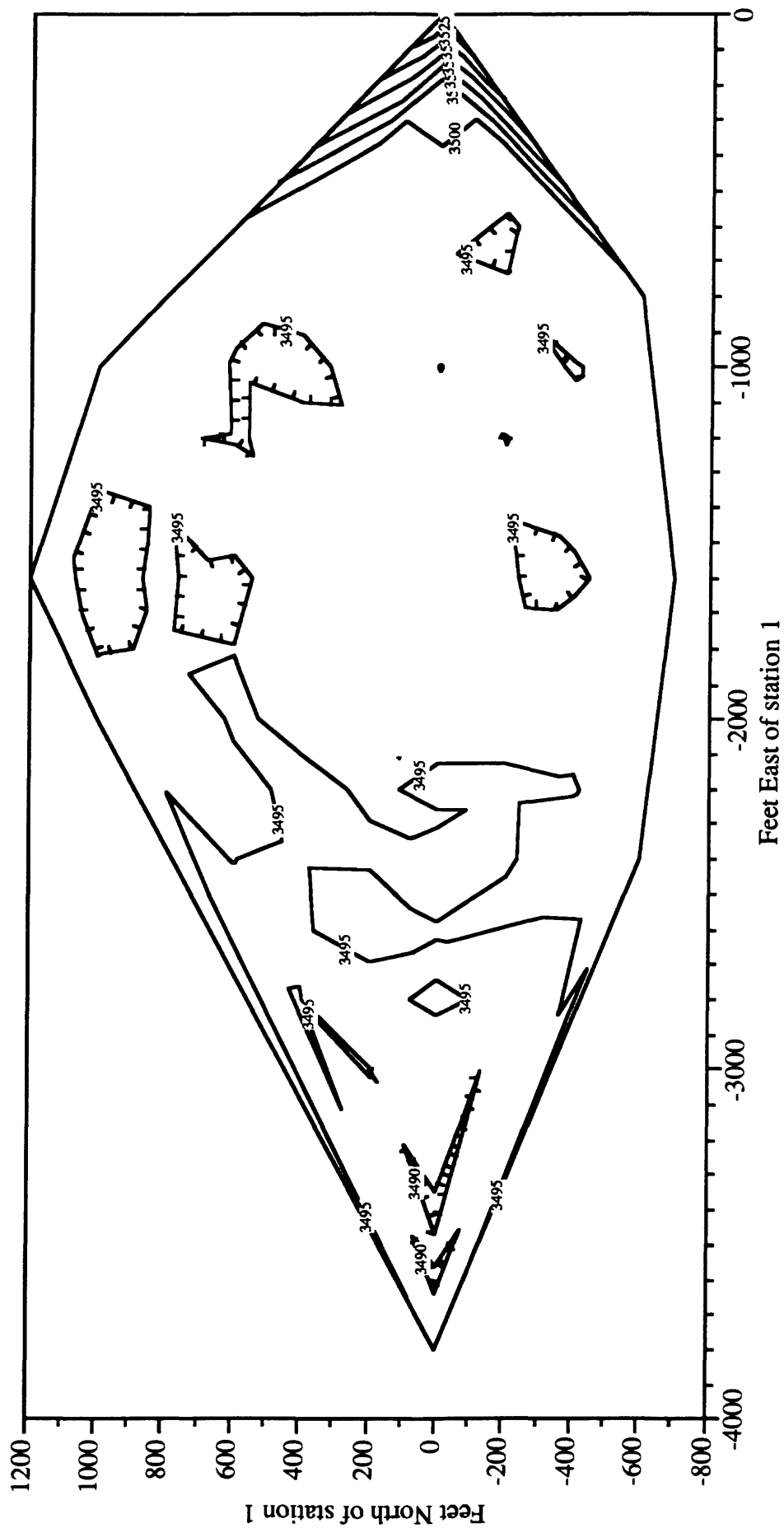


Figure 5. 1968 Elevation Contour Map. Contour interval 5 feet. The east wall remains the steepest and highest part of the crater. The floor is still at a constant elevation, however, the raised areas are no longer present. The northern depressions are larger (approximately 300 meters). There is a new small depression in the southern part of the crater as well. The western depression is larger than in 1966.

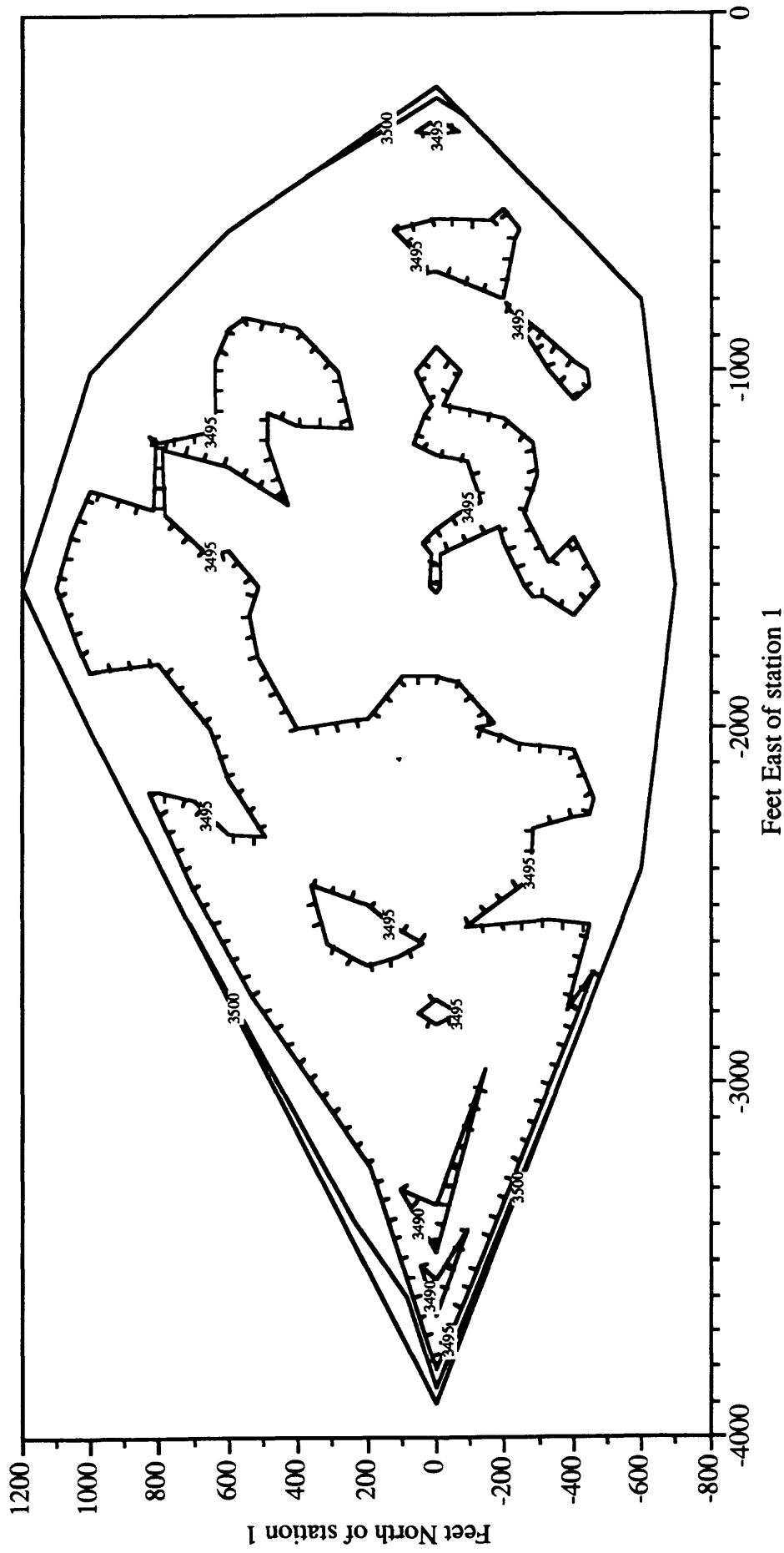


Figure 6. 1971 Elevation Contour Map. Contour interval 5 feet. The eastern edge is the steepest and highest in elevation, although this is not as apparent as before because there is no data for stations 2 and 3. The center of the floor is at a constant elevation, although the depression from the western side has migrated into the central area. The northern and southern central depressions also show an increase in size.

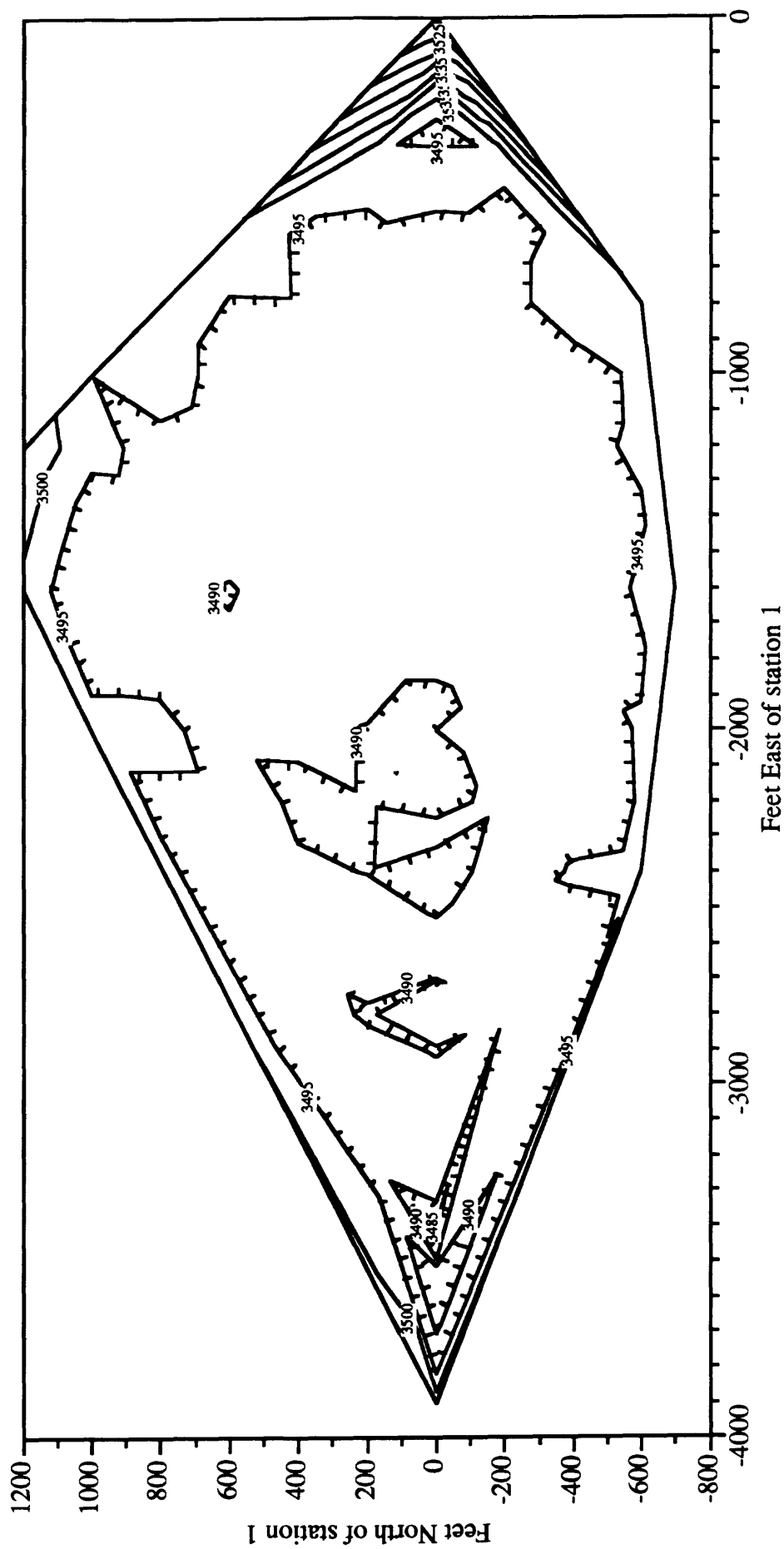


Figure 7. 1979 Elevation Contour Map. Contour interval 5 feet. This is the most significant change in the topography. The east wall is the highest point, and while the west still has a large depression at station 35, the lowest depression is in the center of the crater.

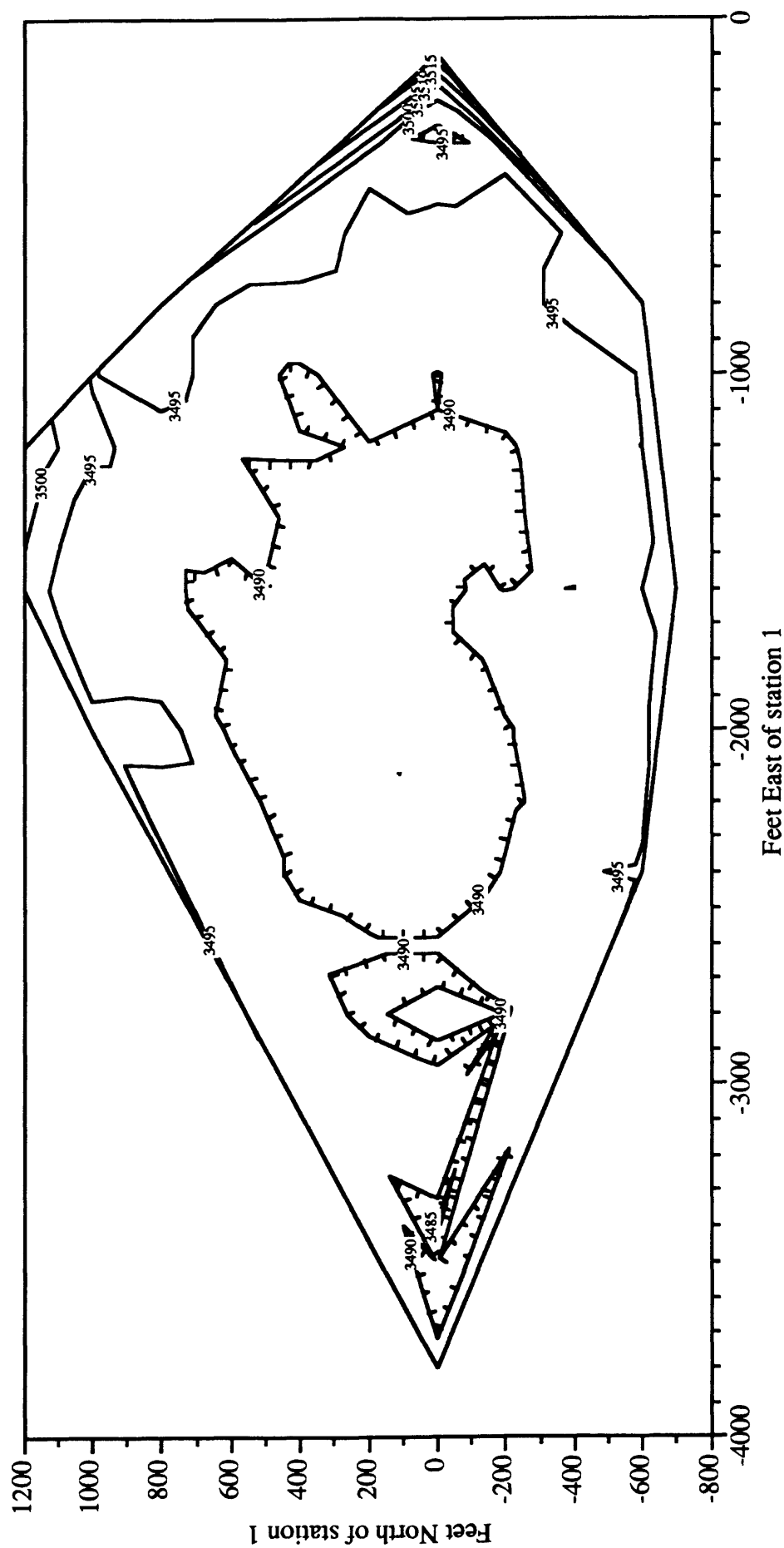


Figure 8. 1988 Elevation Contour Map. Contour interval 5 feet. The eastern wall is again the highest in elevation, although it should be noted that there is no data for station 2. The lowest points are at station 35 and in the center. The contour lines to the center are more evenly spaced than in the previous graphs.

Subsidence Rate Contour Maps

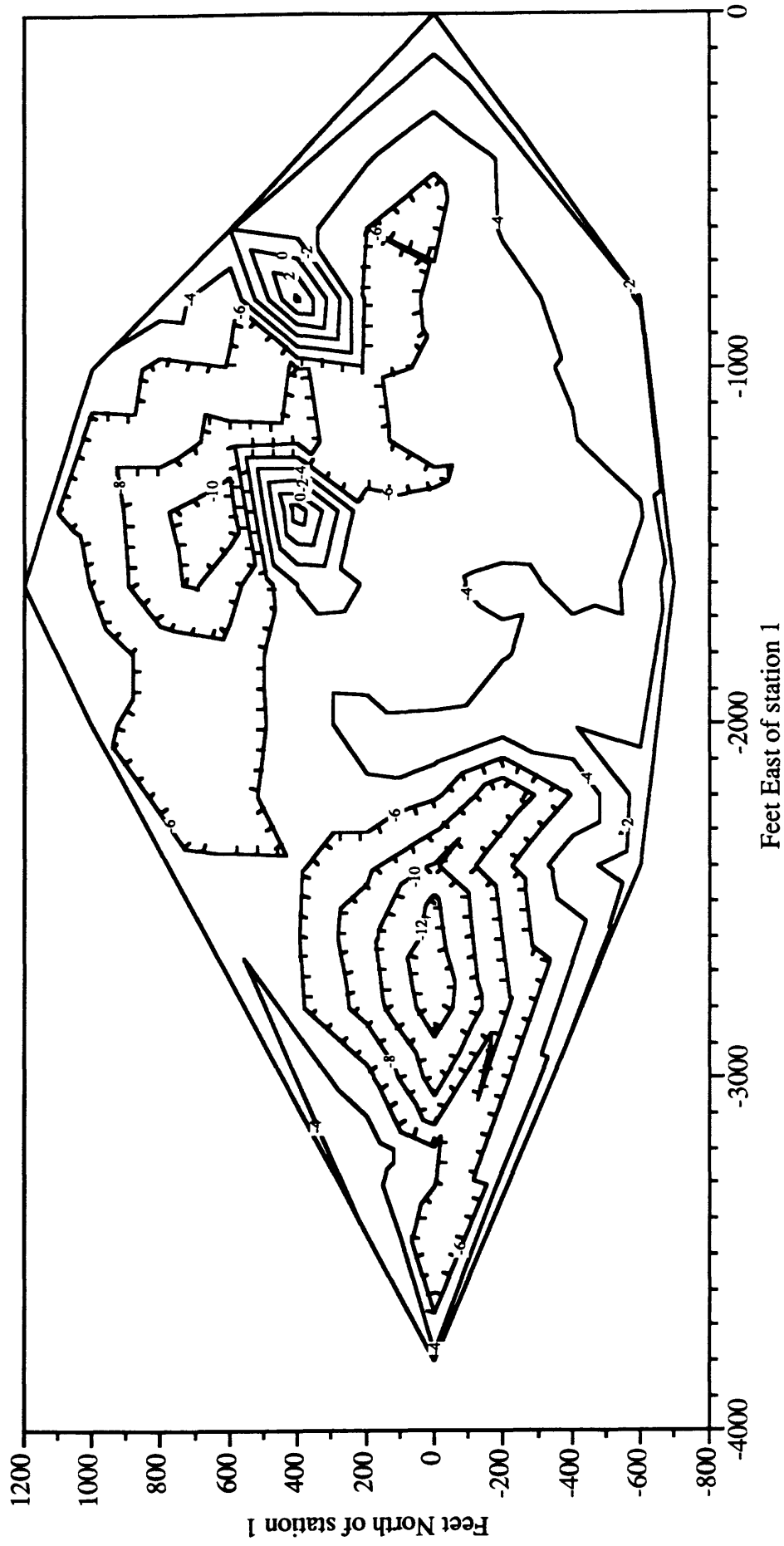


Figure 9. 1964-1967 Rate of Subsidence Contour Map. Contour interval is 2 cm/year. The western edge of the lake has the fastest rate of subsidence of 12 cm/year. There is an area in the eastern side of the lake that has a slight amount of inflation and an area in the center of the lake that had no change in elevation.

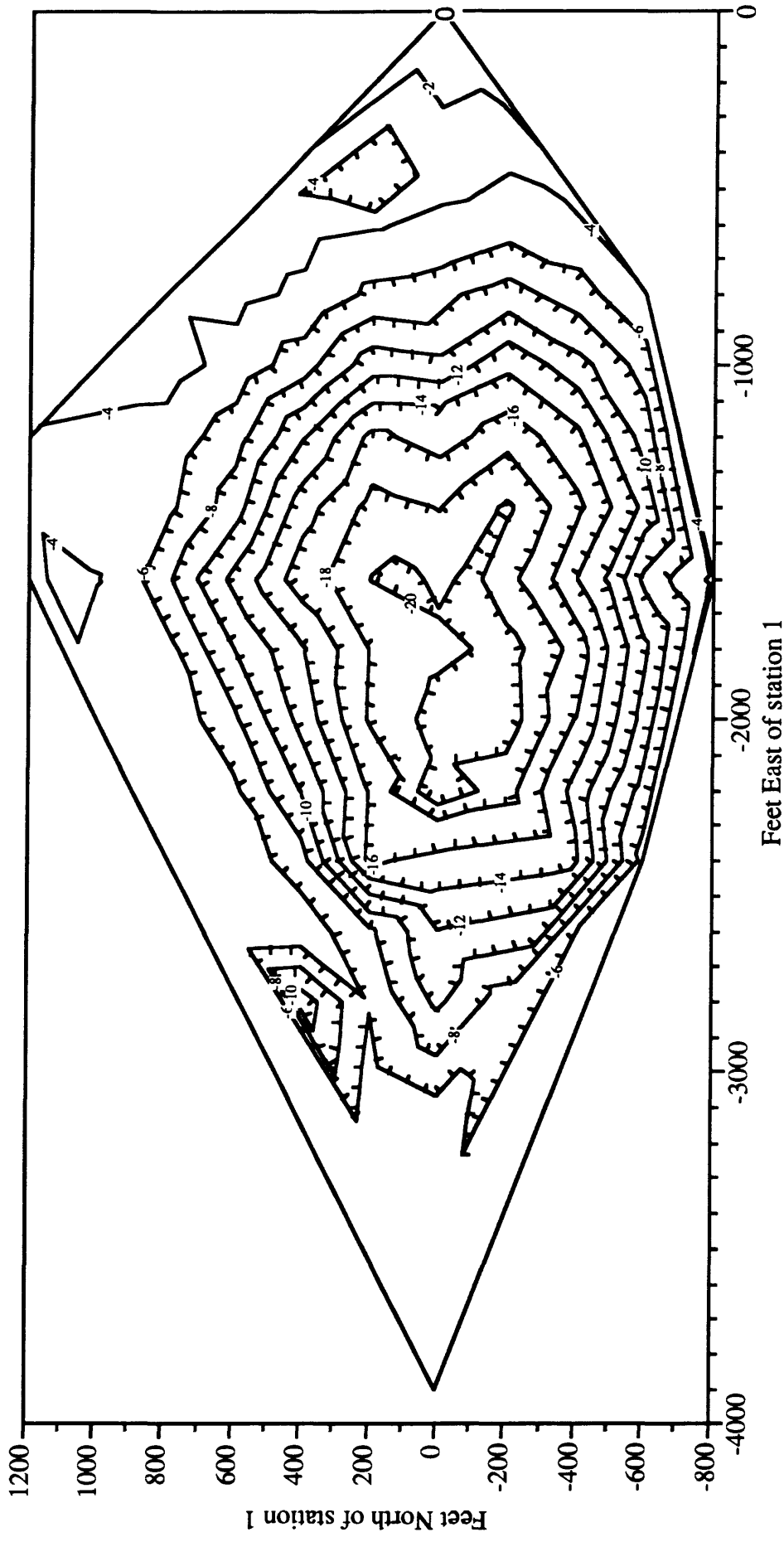


Figure 11. 1971-1979 Rate of Subsidence Contour Map. Contour interval is 2 cm/year. There is a concentric rate of subsidence towards the center of the crater. The highest rate of subsidence, at 20 cm/year, is in the middle of the crater.

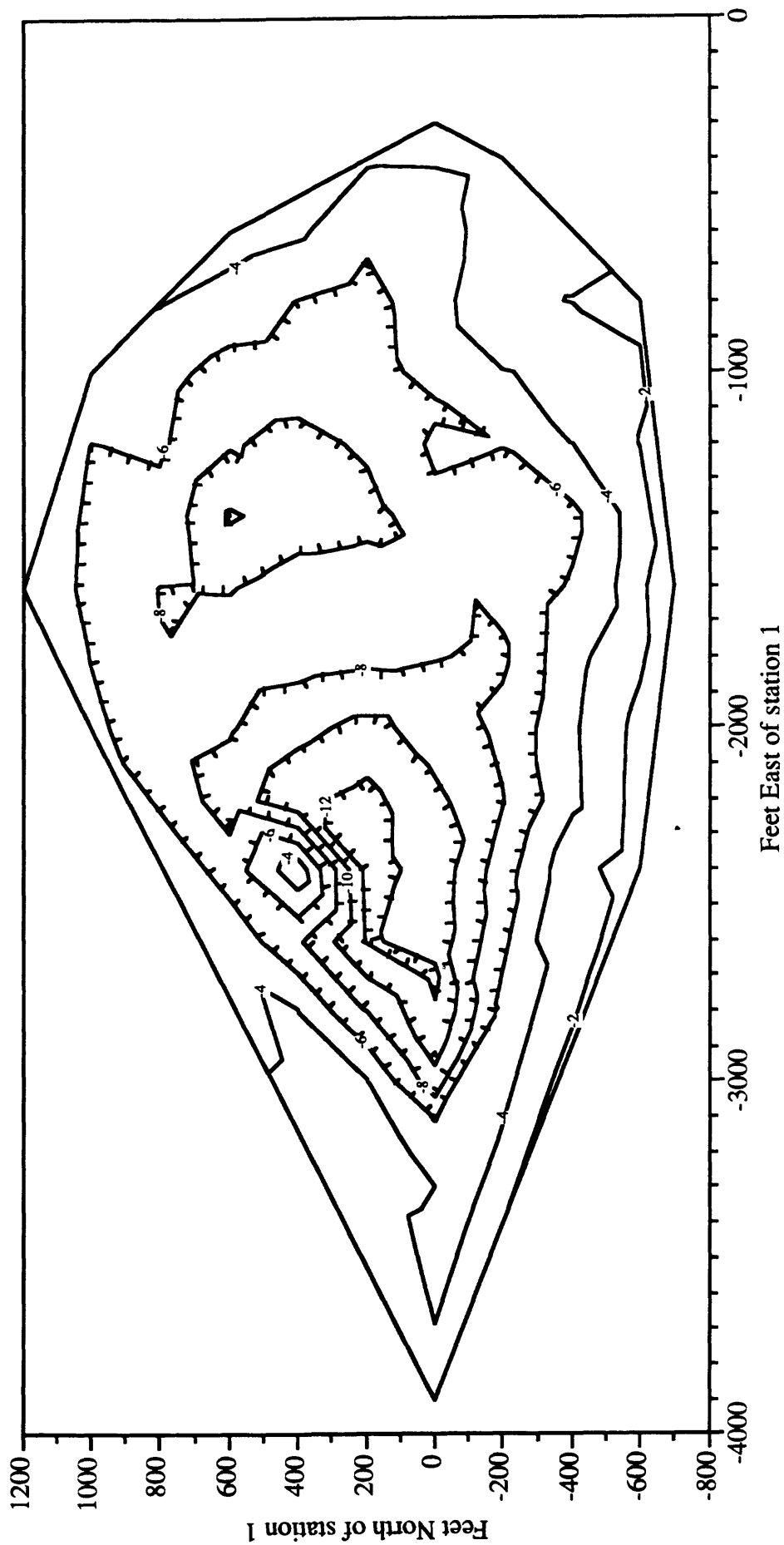


Figure 10. 1967-1971 Rate of Subsidence Contour Map. Contour interval is 2 cm/year. The highest rate of subsidence is 12 cm/year; this is located in the western side of the lake. The eastern area of inflation and constant elevation are gone; there is a depression that subsides at a rate of 8 cm/year.

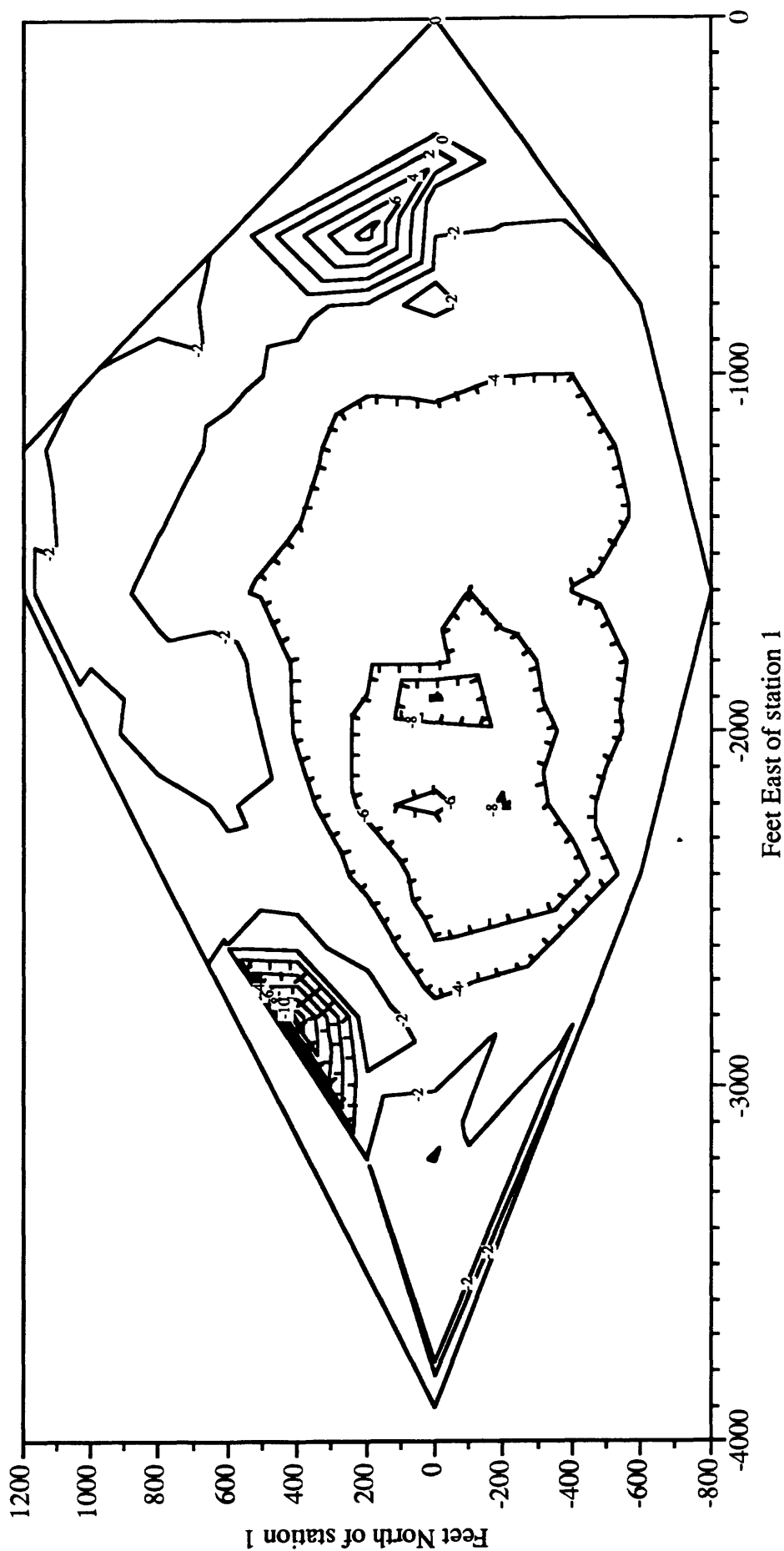


Figure 12. 1979-1988 Rate of Subsidence Contour Map. Contour interval is 2 cm/year. There is still a large area towards the center of the crater that has a high rate of subsidence, but it is much smaller than in the previous graph. The highest rate of subsidence is in the northwestern area. In the eastern area there is an area of inflation.

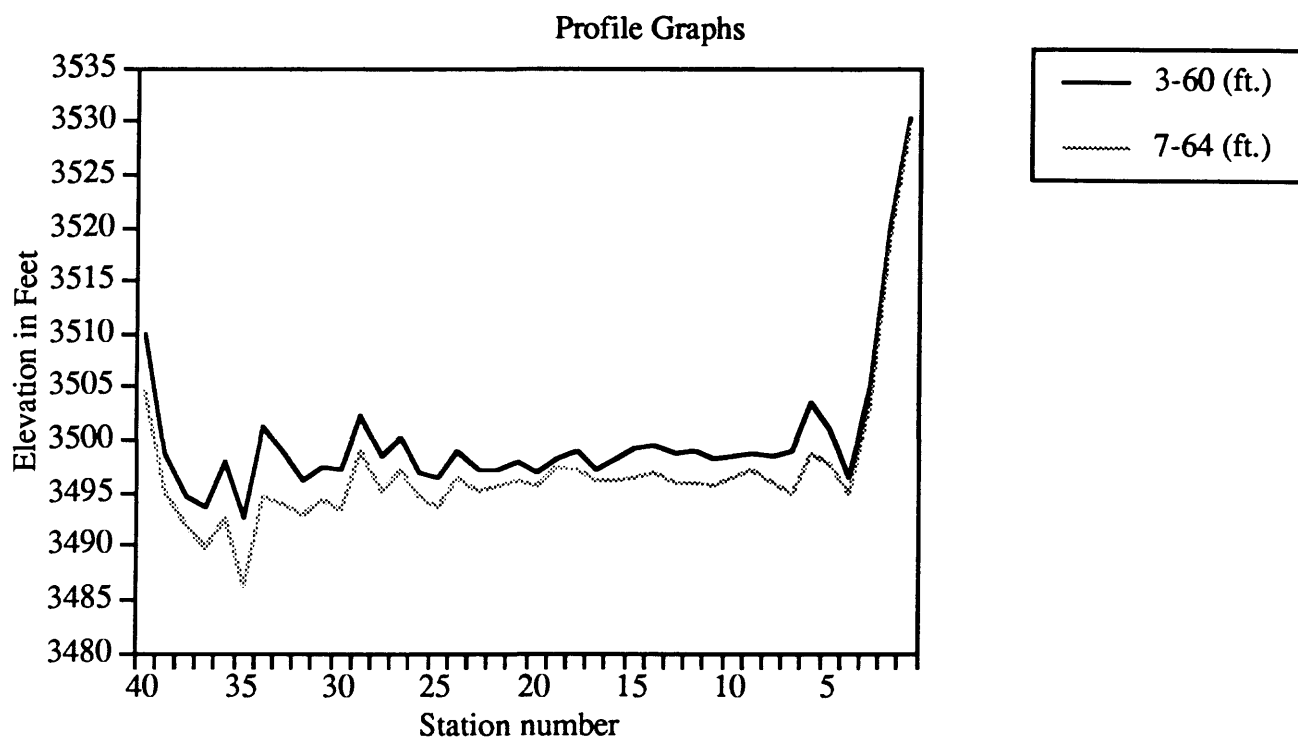


Figure 13. 1960-1964 east-west profile. Data point 0 is towards the east; data point 40 is towards the west. Stations 9 and 17 of the 1964 survey show a smaller decrease than the other stations relative to the 1960 line.

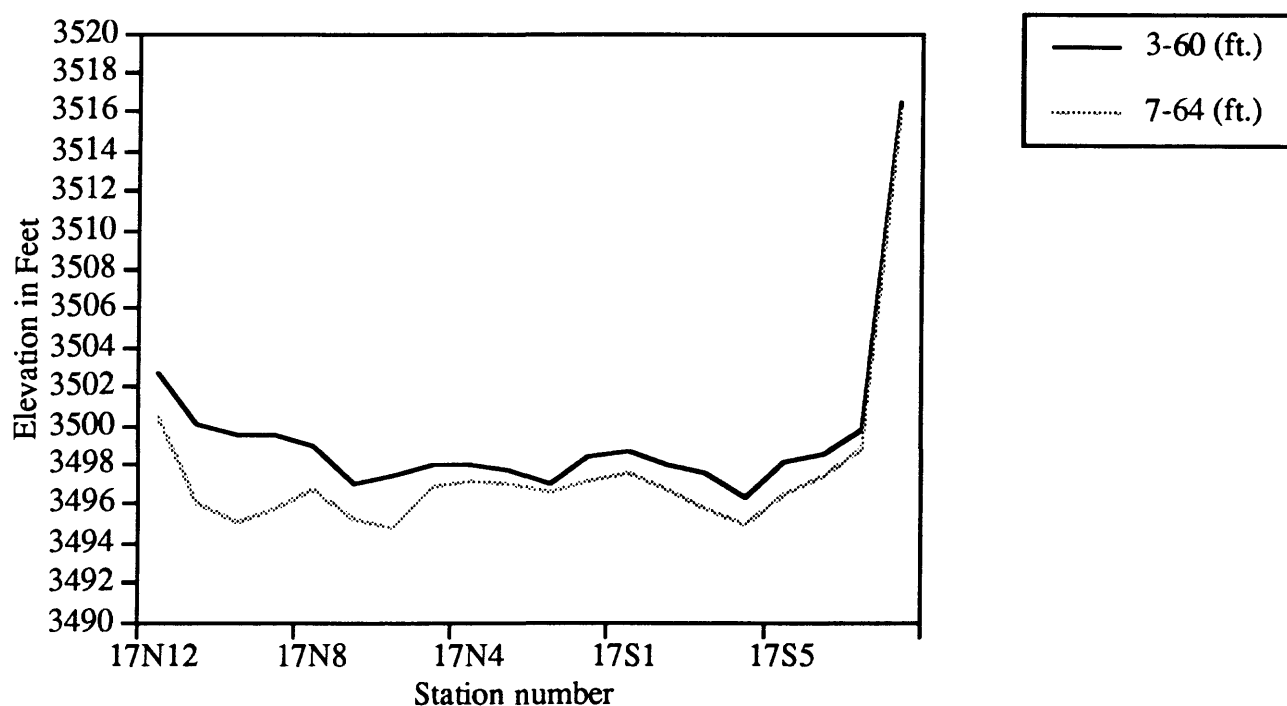


Figure 14. 1960-1964 north-south profile. The north-south profile shows stations 17N8 and 17S1 do not decrease in the 1964 survey as much as the surrounding stations. The lesser degree of decrease of station 17 is in agreement with the observations of the 1964 east-west profile.

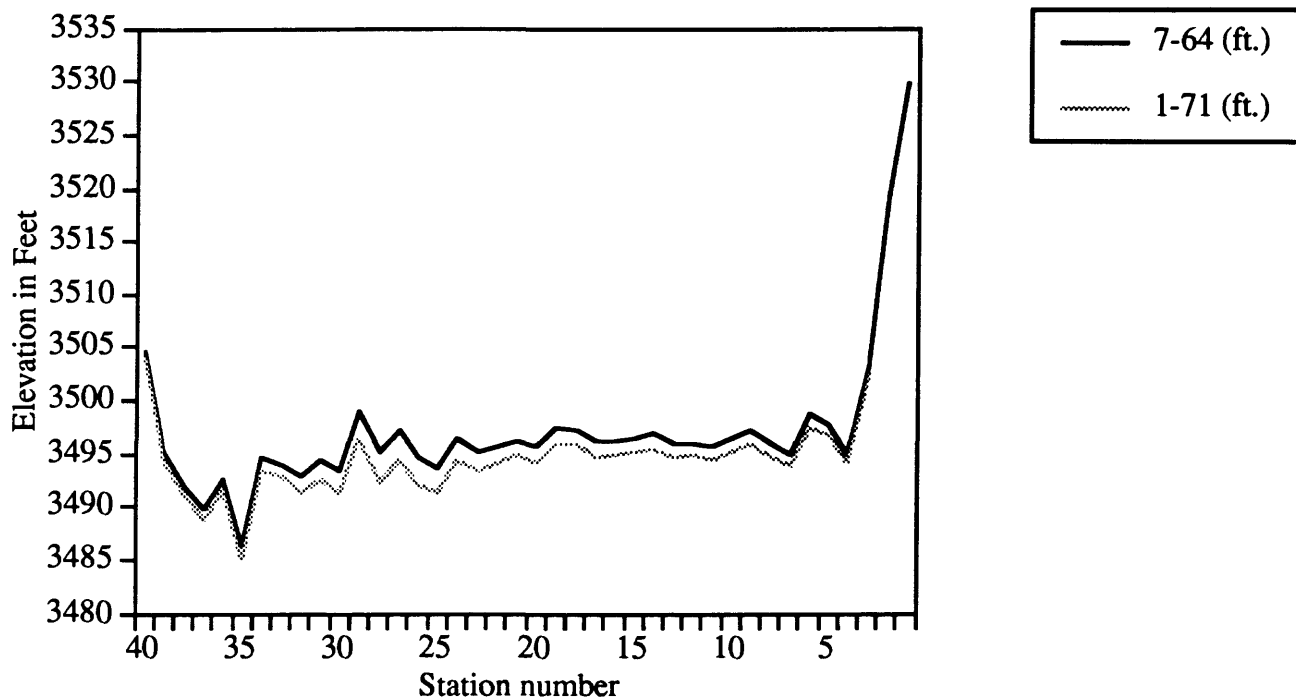


Figure 15. 1964-1971 east-west profile. Data point 0 is towards the east; data point 40 is towards the west. The east-west between these two years is remarkably similar. The center of the lake shows a slightly greater amount of elevation decrease.



Figure 16. 1964-1971 north-south profile. The north-south profiles are similar to each other; none of the stations appear to have a different degree of elevation change.

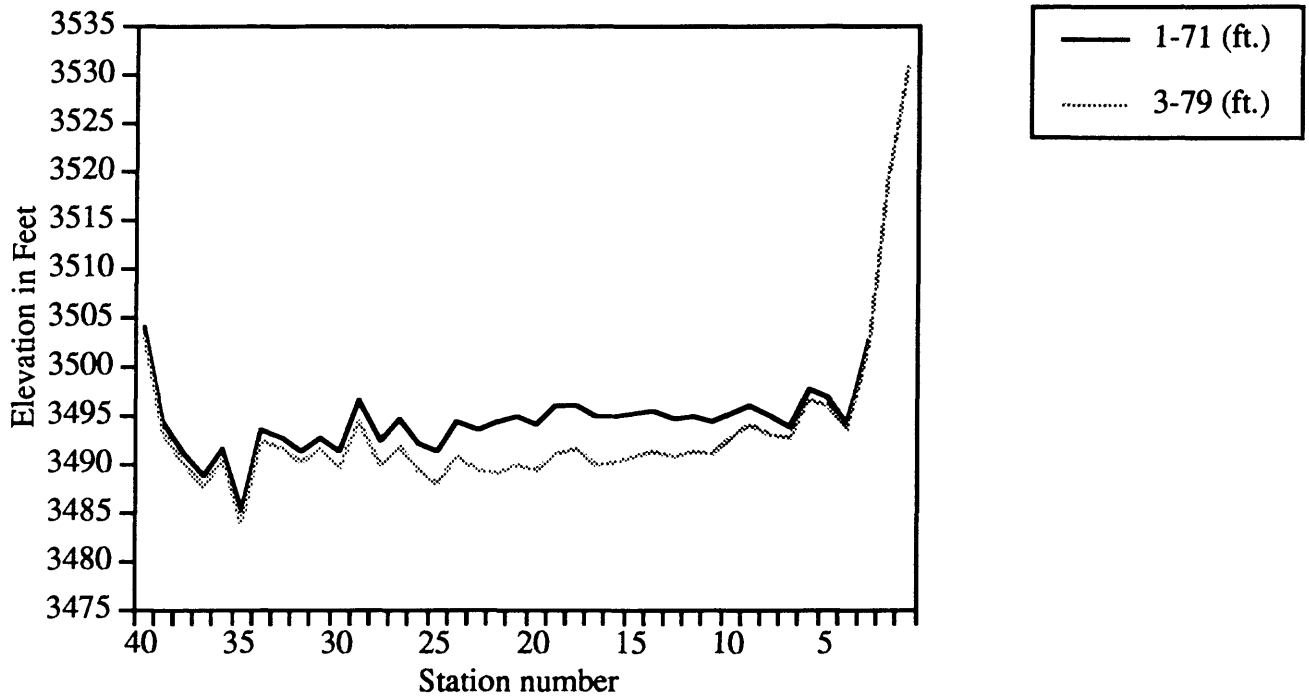


Figure 17. 1971-1979 east-west profile. Data point 0 is towards the east; data point 40 is towards the west. This profile shows the most marked decrease in elevation at the center of the line. Stations 30-40 and stations 7-1 show very little change in elevation while the middle stations show significant change. The middle of the crater showed the greatest amount of decrease. The profile line of each survey is similar; there is little variation in the relationships of the points to each other.

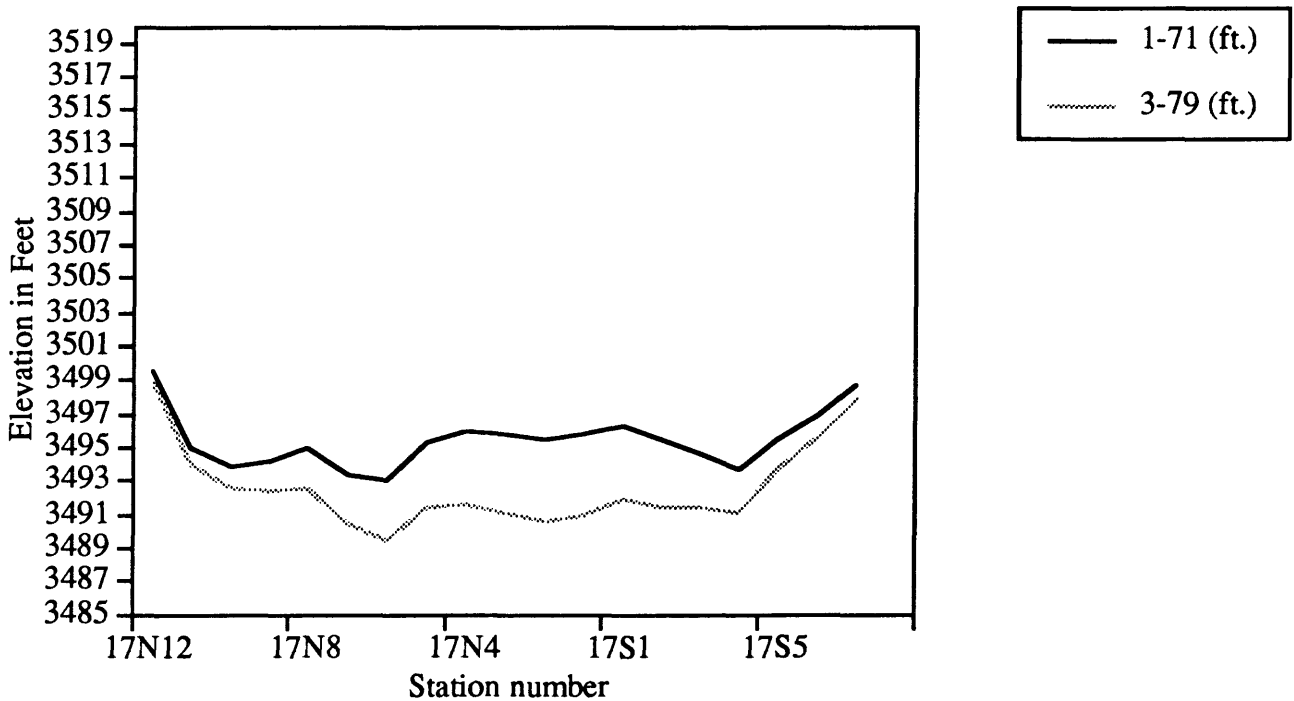


Figure 18. 1971-1979 north-south profile. The north-south profile also confirms the observation that the middle stations decrease in elevation relative to stations located on the edge of the crater.

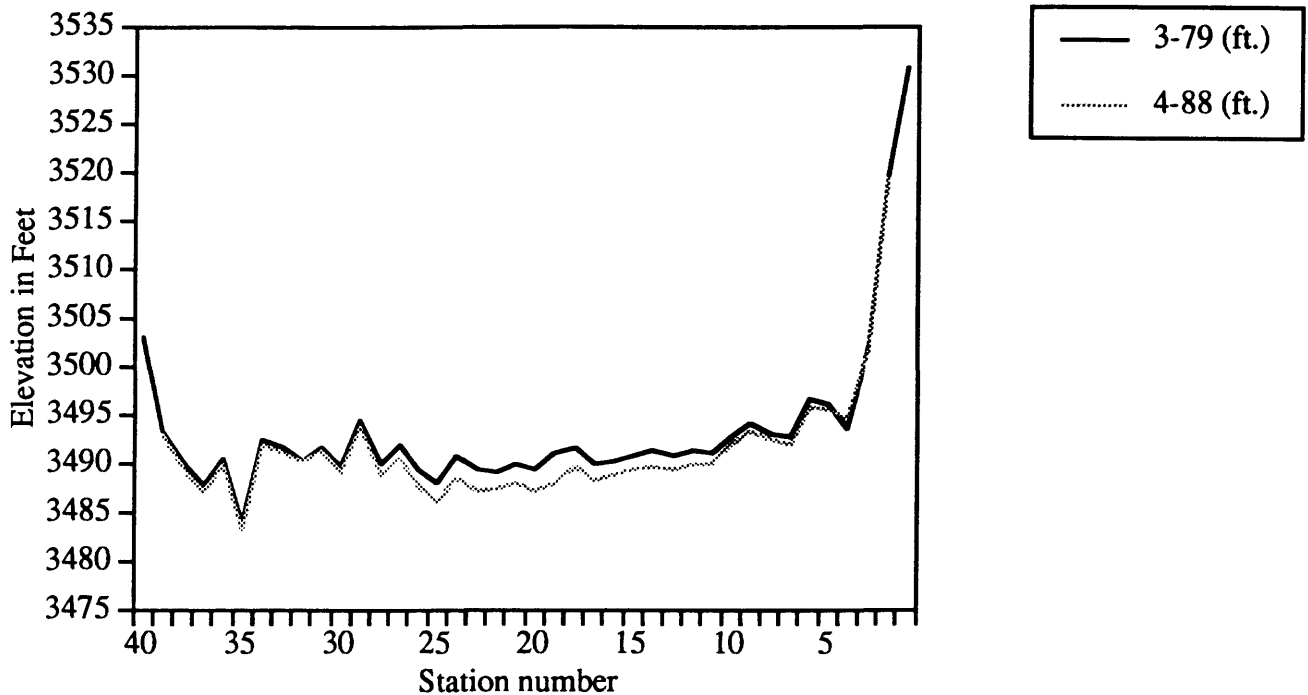


Figure 19. 1979-1988 east-west profile. Data point 0 is towards the east; data point 40 is towards the west. The profile indicates that the center had the largest elevation change, however, it is not nearly as great as the 1971-1979 change. The eastern edge underwent a slight drop in elevation. The relationship of the points to each other is consistent except for station 19; the 1988 profile indicates that station 19 dropped in elevation more than the surrounding stations.

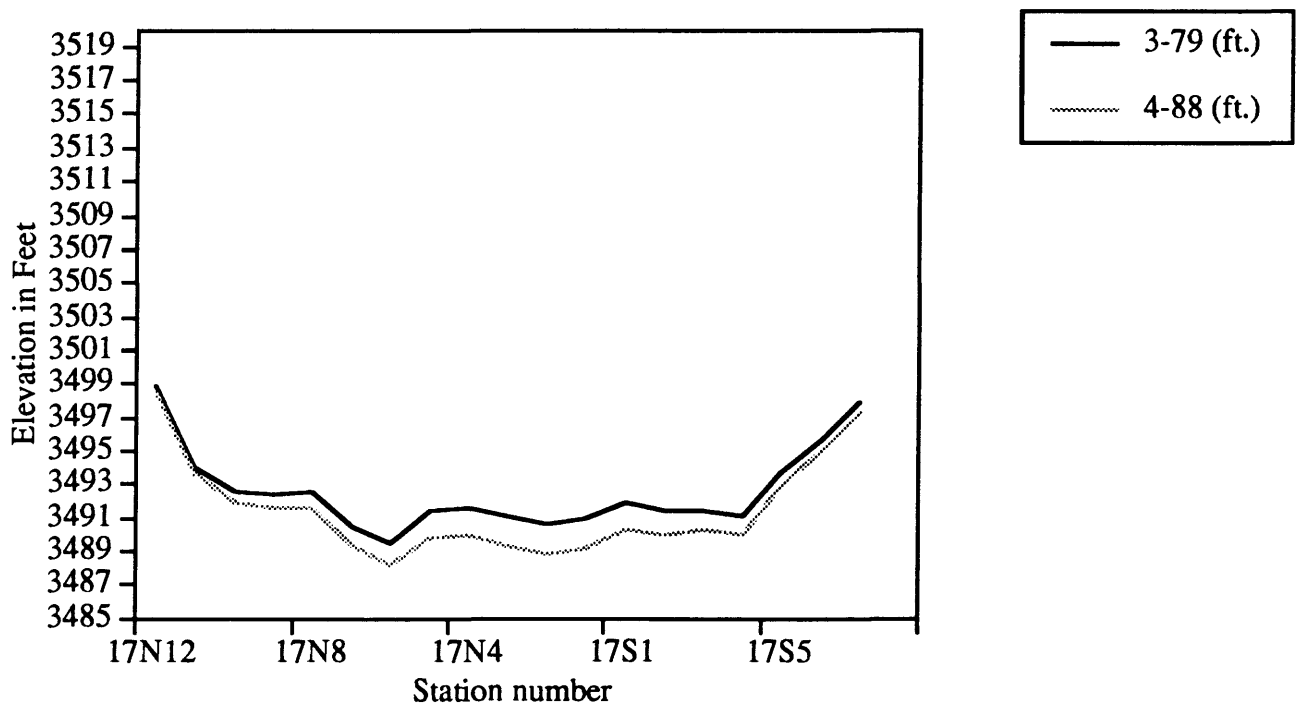


Figure 20. 1979-1988 north-south profile. The central stations have the largest elevation changes and the extreme northern and southern edges have lower rates of elevation change.

Individual Station Changes Over Time

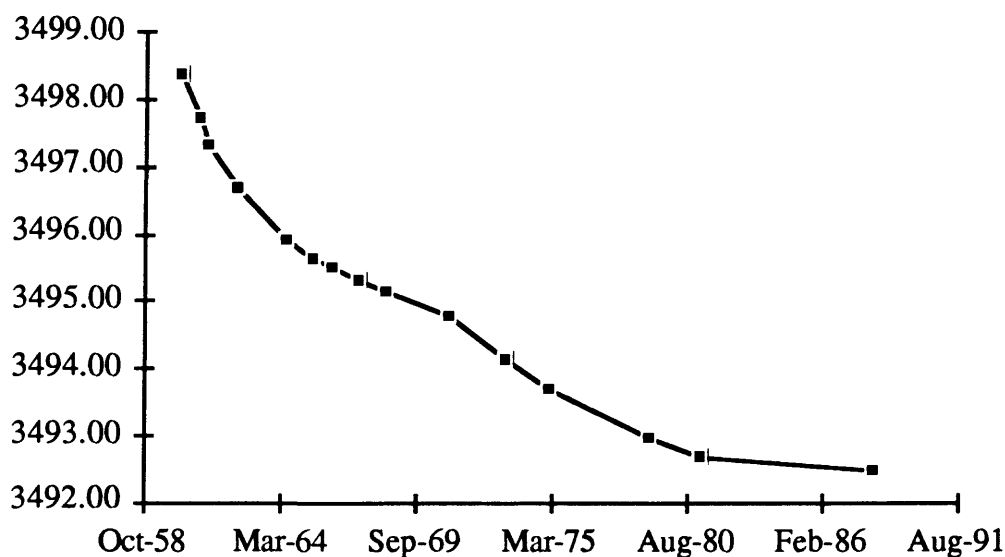


Figure 21. Station 8 Leveling Changes. Subsidence is at a constant rate, beginning around 1965 and continuing through 1971. From 1971-1979, the rate of subsidence remains linear for these years, but slows. The 1979-1988 surveys do not indicate a constant subsidence rate.

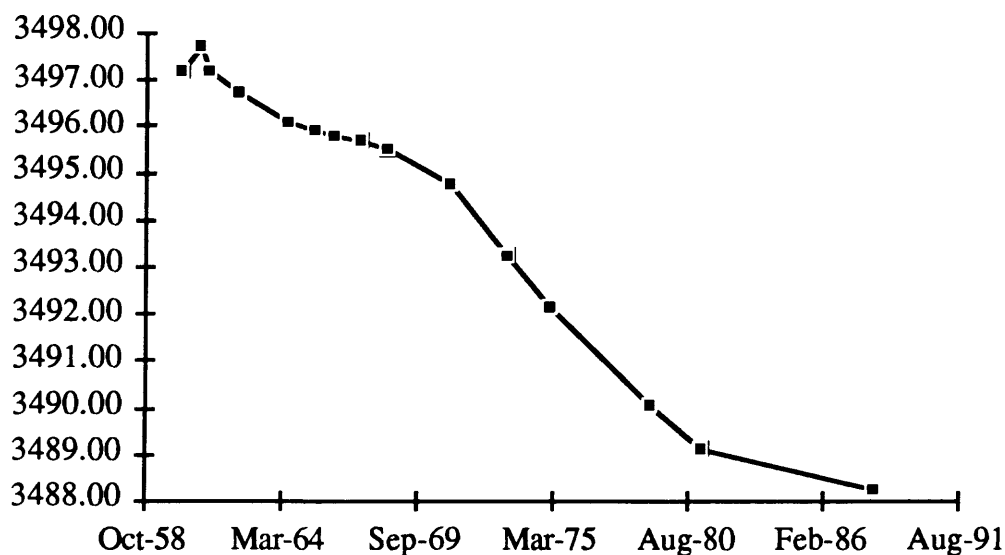


Figure 22. Station 17 Leveling Changes. There is an anomalous increase in elevation at station 17 for the second 1960 leveling survey. Following this peak, there is a non-linear decrease in subsidence from 1961-1968. A linear rate of subsidence begins in 1971 and continues through 1981. This rate decreases between 1981 and 1988.

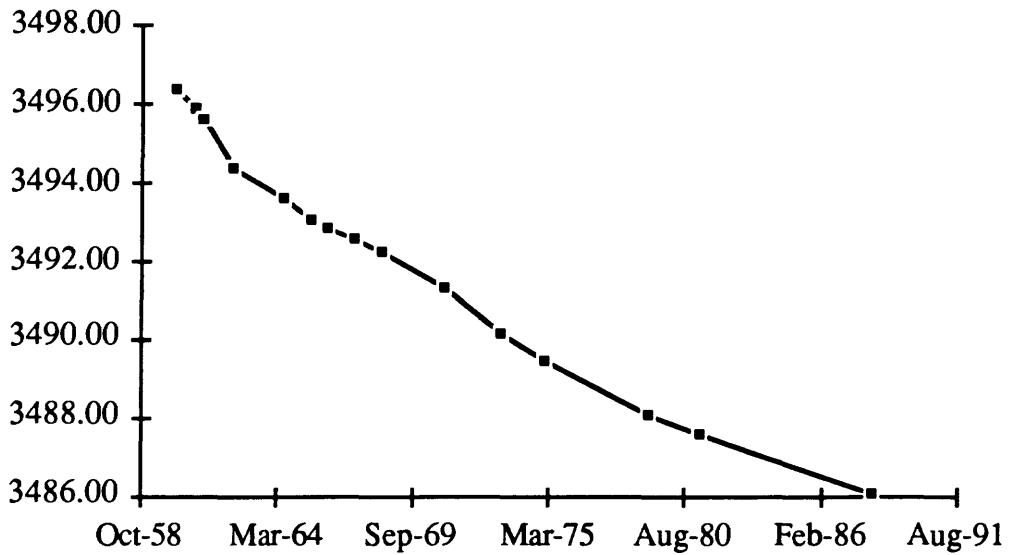


Figure 23. Station 25 Leveling Changes. Subsidence for this station can be divided up into 4 segments with different slopes. The first lasts from 1960-1962, the second from 1962-1971, the next from 1971-1979 and the final from 1979-1988.

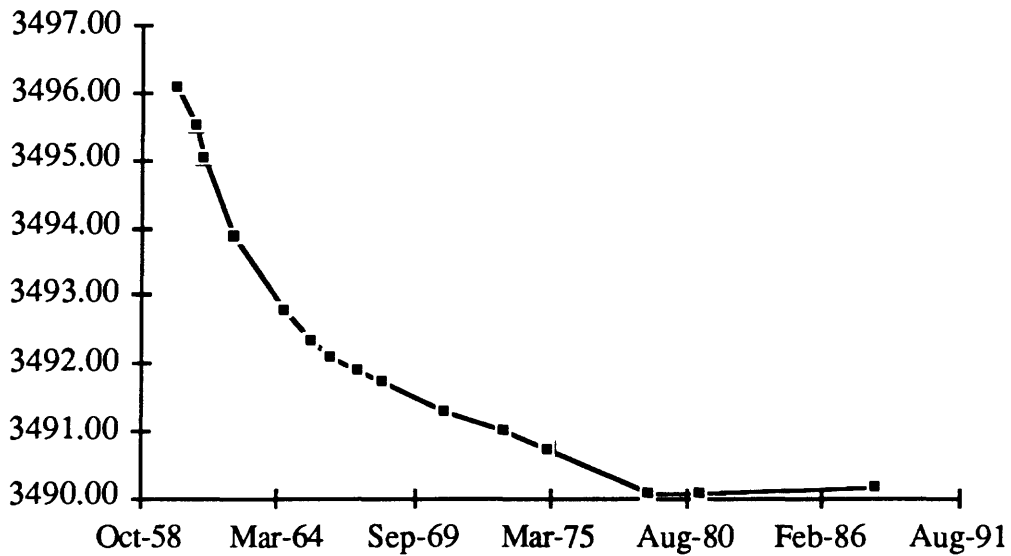


Figure 24. Station 32 Leveling Changes. The subsidence curve is non-linear from 1960-1968. A constant rate of subsidence is the trend from 1973-1979. A linear increase in elevation is the result of the 1979-1988 surveys.

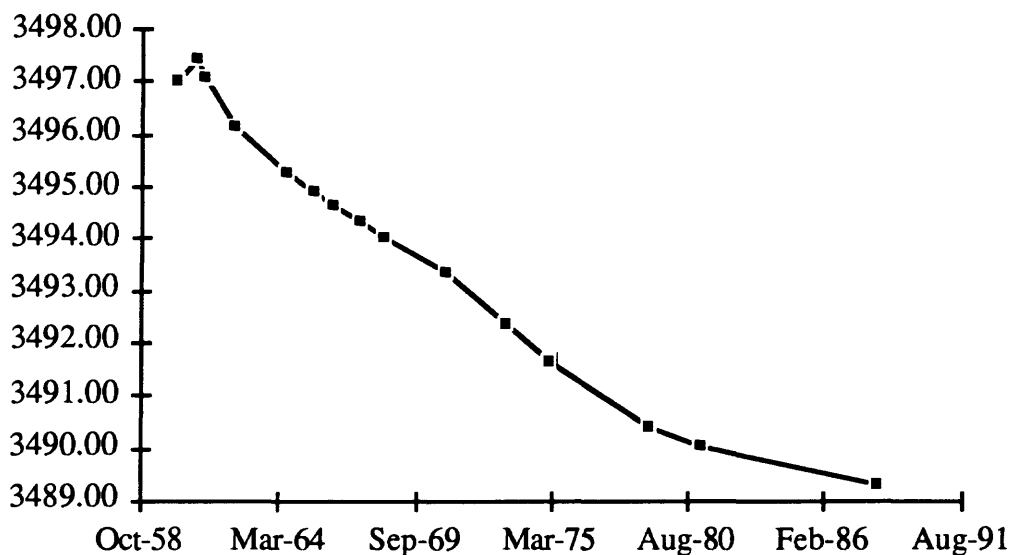


Figure 25. Station 17N7 Leveling Changes. There is a peak in the second 1960 survey. This is similar to, but not as great as, the anomalous increase in elevation for station 17 during this same year. A linear decrease in elevation is the trend from 1971-1981. The rate is lower between 1981 and 1988.

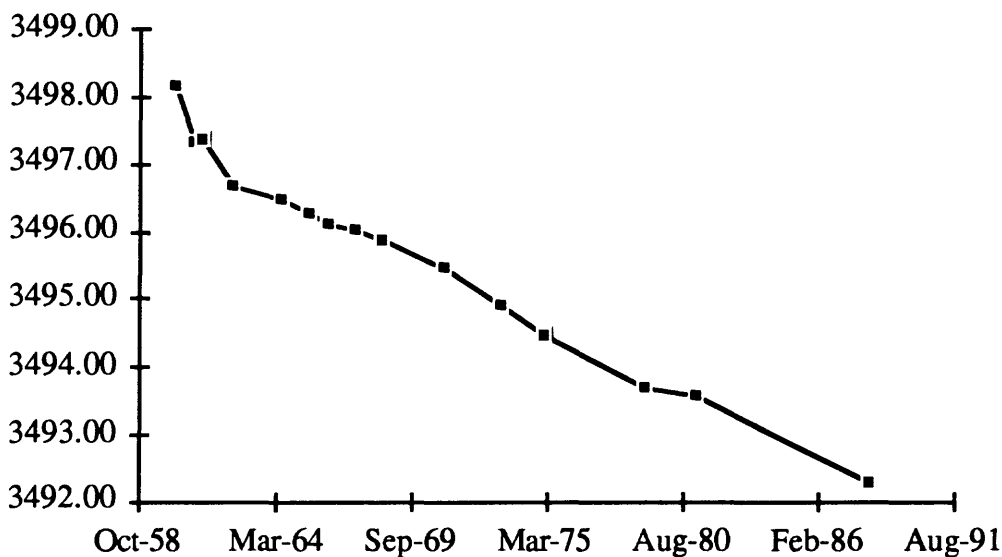


Figure 26. Station 17S5 Leveling Changes. This chart can be divided up into four lines of different slopes, similar to the results of the station 25 profile. Slope 1 is from 1960-1962, slope 2 covers 1962-1968, slope 3, 1968-1979 and the last slope is from 1981 to 1988.

References

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APPENDIX A

This is a compilation of the leveling data taken for Kilauea Iki Lava Lake. The **Date** row refers to the date the leveling survey was conducted. 3-60 indicates that the leveling was completed in March 1960. The elevations are given in feet above sea level. For the years March 1960 - July 1962, leveling was conducted along 2 perpendicular lines. The (-) symbol indicates that additional leveling stations were not present at the time of these survey. The additional stations were added in the July 1964 survey. The (nd) represents no data, indicating that the point was not included in the leveling survey for that year.

Date	3-60 (ft.)	12-60 (ft.)	4-61 (ft.)	7-62 (ft.)	7-64 (ft.)	8-65 (ft.)	5-66 (ft.)	6-67 (ft.)	7-68 (ft.)
Station									
Base elevation	3561.38	3561.38	3561.38	3561.38	3561.38	3561.38	3561.400	3561.400	3561.400
1	3530.41	3530.10	3530.05	3529.92	3529.888	3529.865	3529.875	3529.852	3529.832
2	3520.01	3519.73	3519.67	nd	3519.199	3519.126	3519.096	nd	nd
3	3505.16	3503.86	3503.73	3503.55	3503.289	3503.168	3503.101	3502.978	3502.850
4	3496.55	3495.65	3495.53	3495.28	3495.006	3494.846	3494.754	3494.604	nd
5	3501.16	3499.14	3498.82	3498.30	3497.838	3497.626	3497.498	3497.317	nd
6	3503.48	3500.72	3500.19	3499.41	3498.799	3498.555	3498.394	3498.177	3497.943
7	3498.93	3497.57	3496.80	3495.68	3494.920	3494.686	3494.555	nd	nd
8	3498.37	3497.71	3497.30	3496.67	3495.886	3495.625	3495.486	3495.313	3495.128
9	3498.68	3498.21	3498.22	3497.96	3497.103	3496.848	3496.700	3496.534	3496.366
10	3498.53	3497.76	3497.99	3497.53	3496.448	3496.187	3496.036	3495.878	3495.734
11	3498.34	3496.71	3497.14	3496.52	3495.651	3495.425	3495.261	3495.097	3494.941
12	3499.01	3496.55	3497.00	3496.39	3495.986	3495.818	3495.697	3495.547	3495.438
13	3498.64	3496.75	3496.96	3496.11	3495.857	3495.683	3495.579	3495.423	3495.293
14	3499.59	3498.59	3498.50	3497.28	3496.946	3496.660	3496.530	3496.336	3496.180
15	3499.21	3498.45	3498.04	3497.13	3496.523	3496.268	3496.151	3496.009	3495.832
16	3498.19	3498.21	3497.79	3497.09	3496.144	3495.572	3495.831	3495.730	3495.576
17	3497.21	3497.70	3497.16	3496.72	3496.109	3495.901	3495.779	3495.671	3495.511
18	3499.06	3499.20	3498.38	3497.77	3497.331	3497.156	3497.051	3496.920	3496.733
19	3498.3	3498.76	3498.54	3497.86	3497.362	3497.301	3497.127	3496.957	3496.705
20	3497.06	3496.66	3496.71	3496.39	3495.738	3495.561	3495.400	3495.250	3495.027
21	3498.08	3497.37	3497.39	3497.03	3496.258	3496.170	3496.062	3495.950	3495.727
22	3497.15	3496.94	3496.87	3496.46	3495.789	3495.695	3495.554	3495.430	3495.173
23	3497.12	3496.85	3496.66	3495.90	3495.258	3495.056	3494.894	3494.718	3494.414
24	3498.93	3498.97	3498.70	3497.16	3496.470	3496.128	3495.927	3495.713	3495.368
25	3496.34	3495.86	3495.63	3494.36	3493.566	3493.064	3492.831	3492.587	3492.231
26	3497.04	3497.12	3496.81	3495.79	3494.620	3494.003	3493.737	3493.438	3493.068
27	3500.25	3499.69	3499.33	3498.38	3497.217	3496.625	3496.344	3496.006	3495.566
28	3498.50	3498.00	3497.46	3496.30	3495.072	3494.469	3494.159	3493.772	3493.311
29	3502.26	3501.71	3501.21	3500.28	3499.079	3498.516	3498.201	3497.819	3497.406

Date	3-60 (ft.)	12-60 (ft.)	4-61 (ft.)	7-62 (ft.)	7-64 (ft.)	8-65 (ft.)	5-66 (ft.)	6-67 (ft.)	7-68 (ft.)
Station									
30	3497.11	3496.07	3495.58	3494.66	3493.523	3493.016	3492.720	3492.393	3492.036
31	3497.47	3497.30	3496.89	3495.77	3494.498	3493.983	3493.708	3493.457	3493.206
32	3496.08	3495.53	3495.05	3493.87	3492.766	3492.333	3492.096	3491.907	3491.715
33	3498.81	3496.35	3495.77	3494.60	3493.806	3493.504	3493.353	3493.254	3493.124
34	3501.17	3497.08	3496.36	3495.30	3494.588	3494.276	3494.134	3494.021	3493.874
35	3492.56	3488.74	3488.17	3487.20	3486.338	3486.008	3485.837	3485.688	3485.510
36	3498.06	3495.35	3494.85	3493.77	3492.745	3492.367	3492.197	3492.059	3491.909
37	3493.64	3492.35	3492.03	3491.00	3489.910	3489.497	3489.308	3489.179	3489.035
38	3494.67	3493.88	3493.66	3492.80	3491.951	3491.652	3491.417	3491.447	3491.348
39	3498.70	3496.69	3496.37	3495.65	3495.065	3494.846	3494.650	3494.724	3494.664
40	3510	nd	nd	3505.02	3504.505	3504.303	nd	nd	nd
5N1	-	-	-	-	3497.790	3497.654	3497.573	3497.431	3497.287
5S1	-	-	-	-	3497.529	3497.362	3497.280	3497.174	3497.051
7N3	-	-	-	-	3498.967	3498.905	3498.874	3498.785	3498.662
7N2	-	-	-	-	3496.246	3496.126	3496.062	3495.947	3495.806
7N1	-	-	-	-	3496.859	3496.617	3496.481	3496.285	3496.078
7S1	-	-	-	-	3495.011	3494.827	3494.742	3494.648	3494.550
7S2	-	-	-	-	3497.781	3497.639	3497.574	3497.510	3497.410
9N4	-	-	-	-	3499.885	3499.806	3499.743	3499.604	3499.433
9N3	-	-	-	-	3496.743	3496.532	3496.382	3496.196	3495.984
9N2	-	-	-	-	3496.538	3497.251	3497.122	3496.953	3496.750
9N1	-	-	-	-	3497.163	3496.894	3496.761	3496.570	3496.349
9S1	-	-	-	-	3495.739	3495.504	3495.385	3495.285	3495.214
9S2	-	-	-	-	3499.303	3499.091	3499.022	3498.978	3498.928
9S3	-	-	-	-	3497.581	3497.474	3497.436	3497.407	3497.350
11N5	-	-	-	-	3496.808	3496.667	3496.570	3496.381	3496.176
11N4	-	-	-	-	3500.392	3500.172	3499.990	3499.757	3499.532
11N3	-	-	-	-	3495.442	3495.227	3495.068	3494.854	3494.622
11N2	-	-	-	-	3494.522	3494.160	3493.956	3493.730	3493.517
11N1	-	-	-	-	3497.984	3497.793	3497.564	3497.368	3497.198

Date	3-60 (ft.)	12-60 (ft.)	4-61 (ft.)	7-62 (ft.)	7-64 (ft.)	8-65 (ft.)	5-66 (ft.)	6-67 (ft.)	7-68 (ft.)
Station									
11S1	-	-	-	-	3496.986	3496.796	3496.680	3496.564	3496.361
11S2	-	-	-	-	3495.211	3495.016	3494.934	3494.841	3494.740
11S3	-	-	-	-	3497.564	3497.408	3497.319	3497.268	3497.185
13N6	-	-	-	-	-	-	-	-	-
13N5	-	-	-	-	3499.037	3498.784	3498.602	3498.365	3498.116
13N4	-	-	-	-	3496.213	3495.978	3495.788	3495.547	3495.342
13N3	-	-	-	-	3495.765	3495.460	3495.236	3494.926	3494.655
13N2	-	-	-	-	3497.576	3497.252	3497.045	3496.754	3496.497
13N1	-	-	-	-	3497.130	3496.883	3496.722	3496.485	3496.271
13S1	-	-	-	-	3495.576	3495.372	3495.256	3495.105	3494.960
13S2	-	-	-	-	3496.687	3496.505	3496.414	3496.295	3496.176
13S3	-	-	-	-	3497.395	3497.270	3497.204	3497.152	3497.093
15N6	-	-	-	-	-	-	-	-	-
15N5	-	-	-	-	3494.858	3494.660	3494.492	3494.250	3493.988
15N4	-	-	-	-	3496.535	3496.196	3495.917	3495.595	3495.347
15N3	-	-	-	-	3499.419	3498.971	3498.698	3498.346	3497.990
15N2	-	-	-	-	3459.922	3496.654	3496.494	3496.224	3495.960
15N1	-	-	-	-	3497.180	3496.919	3496.810	3496.639	3496.428
15S1	-	-	-	-	3495.969	3495.747	3495.648	3495.553	3495.395
15S2	-	-	-	-	3497.007	3496.729	3496.579	3496.437	3496.233
15S3	-	-	-	-	3496.606	3496.397	3496.526	3496.199	3496.113
17N12	3502.67	3501.36	3501.09	3500.86	3500.487	3500.298	3500.180	3500.011	3499.817
17N11	3500.04	3497.74	3497.15	3496.51	3496.112	3495.930	3495.813	3495.612	3495.380
17N10	3499.50	3497.92	3496.95	3495.69	3495.148	3494.965	3494.813	3494.566	3494.295
17N9	3499.49	3498.81	3497.89	3496.50	3495.771	3495.527	3495.320	3495.019	3494.726
17N8	3499.03	3499.30	3498.80	3497.65	3496.785	3496.453	3496.192	3495.859	3495.553
17N7	3497.04	3497.42	3497.09	3496.16	3495.288	3494.876	3494.620	3494.315	3494.031
17N6	3497.47	3496.24	3496.19	3495.55	3494.796	3494.374	3494.180	3493.963	3493.721
17N5	3498.02	3498.14	3498.29	3497.67	3496.937	3496.555	3496.429	3496.287	3496.101
17N4	3498.05	3498.59	3498.71	3497.95	3497.137	3496.901	3496.847	3496.758	3496.602

Date	3-60 (ft.)	12-60 (ft.)	4-61 (ft.)	7-62 (ft.)	7-64 (ft.)	8-65 (ft.)	5-66 (ft.)	6-67 (ft.)	7-68 (ft.)
Station									
17N3	3497.67	3497.98	3498.01	3497.60	3496.999	3496.790	3496.738	3496.658	3496.508
17N2	3497.10	3497.61	3497.45	3497.17	3496.629	3496.391	3496.321	3496.238	3496.102
17N1	3498.44	3498.03	3498.47	3497.81	3497.158	3496.904	3496.811	3496.722	3496.599
17S1	3498.70	3498.78	3498.39	3498.13	3497.602	3497.451	3497.339	3497.225	3497.031
17S2	3498.04	3497.83	3497.64	3497.22	3496.688	3496.554	3496.431	3496.318	3496.127
17S3	3497.57	3497.00	3497.00	3496.06	3495.823	3495.682	3495.556	3495.450	3493.289
17S4	3496.37	3495.87	3495.94	3495.10	3494.923	3494.732	3494.570	3494.449	3494.286
17S5	3498.16	3497.33	3497.35	3496.66	3496.446	3496.266	3496.112	3496.010	3495.866
17S6	3498.60	3498.37	3498.43	3497.79	3497.490	3497.333	3497.236	3497.191	3497.126
17S7	3499.87	3499.27	3499.33	3499.10	3498.886	3498.791	3498.754	3498.771	3498.765
17S8	3516.47	3516.41	3516.51	3516.29	3516.114	nd	nd	nd	nd
19N5	-	-	-	-	3495.352	3495.244	3495.116	3494.887	3494.634
19N4	-	-	-	-	3496.261	3496.092	3495.896	3495.613	3495.335
19N3	-	-	-	-	3495.932	3495.636	3495.414	3495.221	3495.068
19N2	-	-	-	-	3497.099	3496.875	3496.757	3496.661	3496.536
19N1	-	-	-	-	3497.225	3497.023	3496.887	3496.777	3496.626
19S1	-	-	-	-	3498.077	3498.009	3497.841	3497.682	3497.443
19S2	-	-	-	-	3497.407	3497.346	3497.212	3497.131	3497.001
19S3	-	-	-	-	3496.355	3496.210	3496.092	3496.039	3495.964
21N5	-	-	-	-	3499.562	3499.398	3499.266	3499.029	3498.804
21N4	-	-	-	-	3500.564	3500.349	3500.175	3499.918	3499.660
21N3	-	-	-	-	3495.294	3495.014	3494.774	3494.570	3494.409
21N2	-	-	-	-	3496.544	3496.362	3496.223	3496.110	3495.950
21N1	-	-	-	-	3496.446	3496.327	3496.227	3496.112	3495.891
21S1	-	-	-	-	3496.282	3496.229	3496.122	3496.026	3495.853
21S2	-	-	-	-	3495.950	3495.498	3495.811	3495.753	3495.654
21S3	-	-	-	-	3496.916	3496.746	3496.690	3496.686	3496.674
23N4	-	-	-	-	3495.925	3495.664	3495.476	3495.249	3495.020
23N3	-	-	-	-	3497.237	3496.963	3496.765	3496.555	3496.333
23N2	-	-	-	-	3494.658	3494.503	3494.380	3494.245	3493.996

Date	3-60 (ft.)	12-60 (ft.)	4-61 (ft.)	7-62 (ft.)	7-64 (ft.)	8-65 (ft.)	5-66 (ft.)	6-67 (ft.)	7-68 (ft.)
Station									
23N1	-	-	-	-	3496.182	3496.062	3495.938	3495.777	3495.470
23S1	-	-	-	-	3495.637	3495.034	3494.856	3494.717	3494.492
23S2	-	-	-	-	3495.512	3495.172	3495.031	3494.944	3494.814
23S3	-	-	-	-	3496.595	3496.486	3496.448	3496.482	3496.461
25N3	-	-	-	-	3495.793	3495.539	3495.403	3495.245	3495.040
25N2	-	-	-	-	3495.388	3495.184	3495.022	3494.837	3494.528
25N1	-	-	-	-	3495.544	3495.269	3495.061	3494.821	3494.442
25S2	-	-	-	-	3497.221	3497.051	3496.999	3496.971	3496.907
25S3	-	-	-	-	3497.189	3497.089	3497.064	3497.092	3497.075
27N3	-	-	-	-	3494.761	3494.575	3494.465	3494.365	3494.208
27N2	-	-	-	-	3495.115	3494.869	3494.724	3494.544	3494.281
27N1	-	-	-	-	3499.316	3498.932	3498.701	3498.413	3497.990
29N2	-	-	-	-	3495.845	3495.570	3495.431	3495.301	3495.153
29N1	-	-	-	-	3492.662	3492.279	3492.063	3491.817	3491.511
29S1	-	-	-	-	3493.265	3492.856	3492.630	3492.453	3492.263
31N1	-	-	-	-	3495.812	3495.567	3495.427	3495.303	3495.167
33N1	-	-	-	-	3495.037	3494.854	3494.787	3494.773	nd

Date	1-71 (ft.)	5-73 (ft.)	2-75 (ft.)	3-79 (ft.)	4-81 (ft.)	4-88 (ft.)
Station						
Base elevation	3561.400	3561.400	3561.400	3561.400	3561.400	3561.400
1	nd	nd	nd	3530.765	3524.962	nd
2	nd	nd	nd	3519.653	3519.584	3519.451
3	3502.636	3502.461	3502.340	3502.114	3502.002	3501.789
4	3494.166	3493.958	3493.803	3493.510	3494.789	3494.558
5	3496.734	3496.453	3496.275	3495.918	34.95.788	3495.501
6	3497.561	3497.160	3496.910	3496.449	3496.275	3495.861
7	3493.883	3493.385	3493.049	3492.569	3492.368	3491.912
8	3494.758	3494.124	3493.695	3492.953	3492.701	3492.466
9	3495.966	3495.220	3494.733	3493.987	3493.705	3493.169
10	3495.259	3494.381	3493.810	3492.767	3492.454	3491.791
11	3494.358	3493.266	3492.473	3491.119	3490.721	3489.840
12	3494.883	3493.715	3492.848	3491.360	3490.937	3489.992
13	3494.710	3493.433	3492.477	3490.763	3490.313	3489.287
14	3495.516	3494.144	3493.109	3491.281	3490.808	3489.709
15	3495.135	3493.725	3492.648	3490.773	3490.294	3489.248
16	3494.836	3493.359	3492.250	3490.239	3489.710	3488.655
17	3494.770	3493.248	3492.107	3490.019	3489.104	3488.253
18	3495.991	3494.514	3493.446	3491.455	3490.421	3489.713
19	3495.922	3494.343	3493.221	3491.123	3490.519	3488.063
20	3494.170	3492.512	3491.347	3489.236	3488.579	3487.122
21	3494.803	3493.144	3492.019	3489.995	3489.625	3487.838
22	3494.202	3492.654	3491.580	3489.070	3489.091	3487.475
23	3493.432	3492.013	3491.049	3489.322	3488.751	3487.014
24	3494.383	3493.129	3492.279	3490.738	3490.247	3488.643
25	3491.283	3490.165	3489.457	3488.040	3487.608	3486.041
26	3492.121	3491.104	3490.416	3489.312	3488.972	3487.569
27	3494.544	3493.129	3492.942	3491.803	3491.504	3490.407
28	3492.385	3491.538	3490.944	3489.922	3489.729	3488.922
29	3496.548	3495.844	3495.331	3494.440	3494.351	3493.680

Date	1-71 (ft.)	5-73 (ft.)	2-75 (ft.)	3-79 (ft.)	4-81 (ft.)	4-88 (ft.)
Station						
30	3491.302	3490.740	3490.304	3489.611	3489.439	3488.976
31	3492.736	3492.393	3492.070	3491.446	3491.460	3491.206
32	3491.301	3491.005	3490.706	3490.092	3490.064	3490.149
33	3492.783	3492.552	3492.238	3491.654	3491.648	3491.123
34	3493.497	3493.234	3492.890	3492.265	3492.259	3491.742
35	3485.072	3484.804	3484.450	3483.795	3483.786	3483.288
36	3491.527	3491.338	3491.015	3490.412	3490.423	3489.942
37	3488.717	3488.557	3488.233	3487.569	3487.602	3487.152
38	3491.075	3490.902	3490.578	3489.902	3489.935	3489.255
39	3494.430	3494.240	3493.878	3493.231	3493.286	3492.917
40	3504.059	3503.885	3503.518	3502.884	3502.970	nd
5N1	3496.986	3496.715	3496.534	3496.139	3496.021	3495.730
5S1	3496.827	3496.653	3496.484	3496.064	3495.921	3495.540
7N3	3498.439	3498.173	3497.956	3497.636	3497.508	nd
7N2	3495.513	3495.233	3495.035	3494.621	3494.457	3497.270
7N1	3495.642	3495.188	3494.918	3494.460	3494.279	3493.837
7S1	3494.352	3494.040	3493.829	3493.294	3493.126	3492.658
7S2	3497.201	3496.968	3496.771	3496.330	3496.213	3495.533
9N4	3499.144	3498.526	3498.618	3498.310	3498.178	3497.863
9N3	3495.612	3495.267	3495.027	3494.596	3494.448	3494.107
9N2	3496.239	3495.656	3495.292	3494.708	3494.487	3493.980
9N1	3495.772	3494.997	3494.492	3493.692	3493.442	3492.862
9S1	3495.016	3494.523	3494.163	3493.403	3493.168	3492.571
9S2	3498.748	3498.459	3498.274	3497.755	3497.619	3497.058
9S3	3497.225	3497.076	3496.930	3496.494	3496.389	3495.929
11N5	3495.822	3495.480	3495.264	3495.062	nd	3494.716
11N4	3499.120	3498.727	3498.442	3498.019	3493.938	3497.532
11N3	3494.065	3493.450	3493.031	3492.370	3492.149	3491.660
11N2	3492.921	3491.969	3491.335	3490.280	3489.953	3489.237
11N1	3496.556	3495.426	3494.672	3493.362	3492.996	3492.172

Date	1-71 (ft.)	5-73 (ft.)	2-75 (ft.)	3-79 (ft.)	4-81 (ft.)	4-88 (ft.)
Station						
11S1	3496.082	3495.292	3494.678	3493.549	3493.203	3492.355
11S2	3494.441	3493.934	3493.569	3492.780	3492.590	3491.875
11S3	3497.003	3496.779	3496.588	3496.023	3495.925	3495.336
13N6	-	-	-	3504.263	3504.138	3503.855
13N5	3497.654	3497.204	3496.919	3496.542	3496.391	3496.171
13N4	3494.871	3494.243	3493.824	3493.171	3492.936	3492.456
13N3	3494.006	3492.998	3492.312	3491.192	3490.861	3490.218
13N2	3495.736	3494.378	3493.456	3491.827	3491.354	3490.229
13N1	3495.581	3494.166	3493.172	3491.483	3491.016	3489.881
13S1	3494.408	3493.326	3492.487	3491.006	3490.595	3489.480
13S2	3495.830	3495.148	3494.649	3493.693	3493.473	3492.708
13S3	3496.924	3496.675	3496.450	3495.816	3495.711	3495.063
15N6	-	-	-	-	3502.965	-
15N5	3493.493	3493.002	3492.690	3492.221	3492.029	3491.669
15N4	3494.819	3494.049	3493.517	3492.670	3492.389	3491.771
15N3	3497.138	3495.868	3494.991	3493.541	3493.131	3492.378
15N2	3495.172	3493.732	3492.654	3490.764	3490.234	3489.006
15N1	3495.622	3494.063	3492.918	3490.821	3490.280	3489.130
15S1	3494.714	3493.478	3492.534	3490.820	3490.372	3489.311
15S2	3495.682	3494.820	3494.202	3492.994	3492.729	3491.865
15S3	3495.846	3495.514	3495.265	3494.574	3494.488	3493.824
17N12	3499.526	3499.225	3499.025	3498.839	3498.736	3498.506
17N11	3494.996	3494.615	3494.371	3494.069	3493.926	3493.635
17N10	3493.781	3493.293	3492.483	3492.500	3492.324	3491.934
17N9	3494.115	3493.450	3493.022	3492.352	3492.117	3491.605
17N8	3494.915	3494.072	3493.483	3492.497	3492.191	3491.574
17N7	3493.365	3492.346	3491.625	3490.376	3490.024	3489.301
17N6	3493.009	3491.528	3490.961	3489.480	3489.336	3488.218
17N5	3495.390	3494.086	3493.096	3491.345	3491.117	3489.869
17N4	3495.914	3494.518	3493.463	3491.545	3491.279	3489.979

Date	1-71 (ft.)	5-73 (ft.)	2-75 (ft.)	3-79 (ft.)	4-81 (ft.)	4-88 (ft.)
Station						
17N3	3495.818	3494.329	3493.186	3491.074	3490.750	3489.345
17N2	3495.418	3493.908	3492.722	3490.555	3490.209	3488.770
17N1	3495.876	3494.356	3493.195	3491.012	3489.710	3489.220
17S1	3496.294	3494.898	3493.869	3491.928	3491.432	3490.367
17S2	3495.442	3494.175	3493.231	3491.451	3491.000	3489.936
17S3	3494.681	3493.596	3492.807	3491.381	3491.009	3490.208
17S4	3493.762	3492.891	3492.265	3491.036	3490.784	3489.940
17S5	3495.460	3494.895	3494.469	3493.682	3493.546	3492.816
17S6	3496.917	3496.632	3496.368	3495.671	3495.627	3494.989
17S7	3498.691	3498.567	3498.393	3497.847	3497.840	3497.241
17S8	nd	nd	nd	nd	nd	nd
19N5	3494.175	3493.708	3493.430	3492.955	3492.861	3492.502
19N4	3494.677	3493.820	3493.255	3492.310	3492.010	3491.986
19N3	3494.411	3493.321	3492.509	3491.147	3491.011	3489.867
19N2	3495.816	3494.431	3493.390	3491.547	3491.258	3489.873
19N1	3495.898	3494.317	3493.120	3490.973	3490.302	3489.006
19S1	3496.706	3495.378	3494.429	3492.629	3492.151	3491.039
19S2	3496.587	3495.855	3495.282	3494.110	3493.889	3493.028
19S3	3495.759	3495.507	3495.246	3494.508	3494.437	3493.767
21N5	3498.373	3497.965	3497.697	3497.340	3497.251	3496.946
21N4	3499.062	3498.362	3497.952	3497.274	3497.354	3497.263
21N3	3493.647	3492.572	3491.843	3490.655	3490.549	3489.391
21N2	3495.001	3493.497	3492.471	3490.691	3490.309	3488.753
21N1	3494.869	3493.127	3491.955	3489.883	3489.457	3487.632
21S1	3495.142	3493.908	3493.019	3491.377	3490.916	3489.720
21S2	3495.252	3494.619	3494.133	3493.077	3492.872	3492.051
21S3	3496.521	3496.326	3496.066	3495.332	3495.256	3494.572
23N4	3494.487	3494.118	3493.676	3493.189	3493.069	3492.651
23N3	3495.508	3494.668	3494.001	3493.122	3492.925	3492.186
23N2	3492.884	3491.543	3490.539	3489.054	3488.546	3487.131

Date	1-71 (ft.)	5-73 (ft.)	2-75 (ft.)	3-79 (ft.)	4-81 (ft.)	4-88 (ft.)
Station						
23N1	3494.292	3492.691	3491.677	3489.861	3489.235	3487.455
23S1	3493.763	3492.764	3492.033	3490.622	3490.319	3489.191
23S2	3494.424	3493.992	3493.574	3492.713	3492.590	3491.966
23S3	3496.330	3496.185	3495.925	3495.232	3495.186	3494.527
25N3	3494.425	3493.917	3493.405	3492.759	3492.619	3492.015
25N2	3494.529	3492.533	3491.774	3490.690	3490.375	3489.348
25N1	3493.332	3492.058	3491.288	3489.912	3489.461	3487.769
25S2	3496.667	3496.452	3496.148	3495.446	3495.402	3494.762
25S3	3496.959	3496.874	3496.608	3495.911	3495.903	3495.320
27N3	3493.834	3493.605	3493.168	3492.724	3492.676	3492.255
27N2	3493.639	3493.128	3492.591	3491.859	3491.731	3491.081
27N1	3496.974	3495.991	3495.358	3494.319	3494.057	3490.419
29N2	3494.832	3494.635	3494.219	3493.394	3493.652	3493.187
29N1	3490.875	3490.446	3489.937	3489.231	3489.158	3488.539
29S1	3491.823	3491.524	3491.185	3490.511	3490.490	3489.797
31N1	3494.847	3494.696	3494.269	3493.657	3493.657	3493.063
33N1	3494.526	3494.430	3494.010	3493.416	3493.410	3492.903