Results of Global Positioning System Surveys in Antelope Valley, California

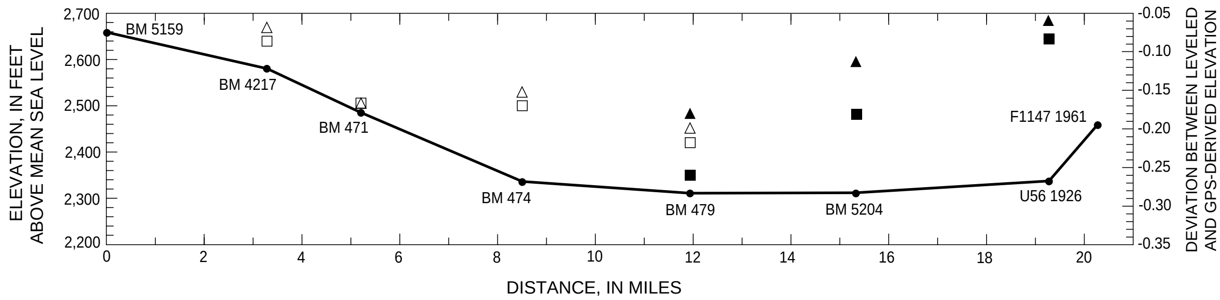
By Marti E. Ikehara

Land subsidence has been occurring in Antelope Valley, California, because of a long history of ground-water pumping that has exceeded natural recharge. Water demand is expected to increase rapidly with the projected increase in population from about 320,000 in 1994 to about 600,000 by the year 2010 (Templin and others, 1995). Much of this demand probably will be met through increased ground-water with- drawal. The flexibility of accurately measuring land-surface elevations of bench marks distributed at both regional and local-scale spacing can be achieved by Global Positioning System (GPS) surveying. A static survey of 85 geodetic stations throughout Antelope Valley and a kinematic survey of 85 stations concentrated along a 4-mile-long (6.4-kilometer) rocket-testing track at Edwards Air Force Base were done using GPS surveying. The objectives of the first survey were to measure current land-surface elevations for calculations of historical land subsidence and to establish ellipsoidal heights for future subsidence monitoring using repeated GPS measurements. The objective of the second survey was to establish horizontal and vertical positions for crustal-motion monitoring before the onset of pumping at new ground-water wells along the track.

Antelope Valley is in the western part of the arid Mojave Desert in southern California and is about 50 mi (80 km) northeast of Los Angeles. The triangular-shaped valley is bounded on the south by the southeastward-trending San Gabriel Mountains, on the northwest by the northeastward-trending Tehachapi Mountains, and by smaller ridges and buttes to the north and east. Antelope Valley is considered high desert, and elevations of the valley floor range from about 2,260 to 2,950 ft (690 to 900 m) above sea level. The valley is a topographically closed basin, and surface-water drainage terminates in several playas—the most notable of which are Rogers and Rosamond Lakes. Fine-grained sedimentary deposits predominate in the center of the basin and within the Lancaster ground-water subbasin, which is the source of much of the valley's water.

In the spring of 1992, the regional-scale GPS survey of 85 stations in Antelope Valley was carried out using from four to seven receivers simultaneously (Ikehara and Phillips, 1994). Dual-frequency signals were recorded at 15-second intervals for 5- to 7-hour durations at each station. The network included 7 horizontal-control stations and 10 stable vertical-control stations and resulted in 332 vectors, or relative-position coordinates, between two simultaneously observed bench marks. The least-squares adjustment in which coordinates for all control stations were held fixed produced a vertical-standard error (2σ) that ranged between 0.03 and 0.081 ft (0.9 and 2.4 cm) and averaged 0.05 ft (1.5 cm). The maximum error associated with the geoid model (GEOID90) used to compute orthometric heights (elevations) in this survey was about 0.2 ft (6 cm), as determined by a comparison with recent leveling for a 20.3-mile (32.7-kilometer) line along Sierra Highway between gravity and topographic highs and lows in the valley (fig. 1).

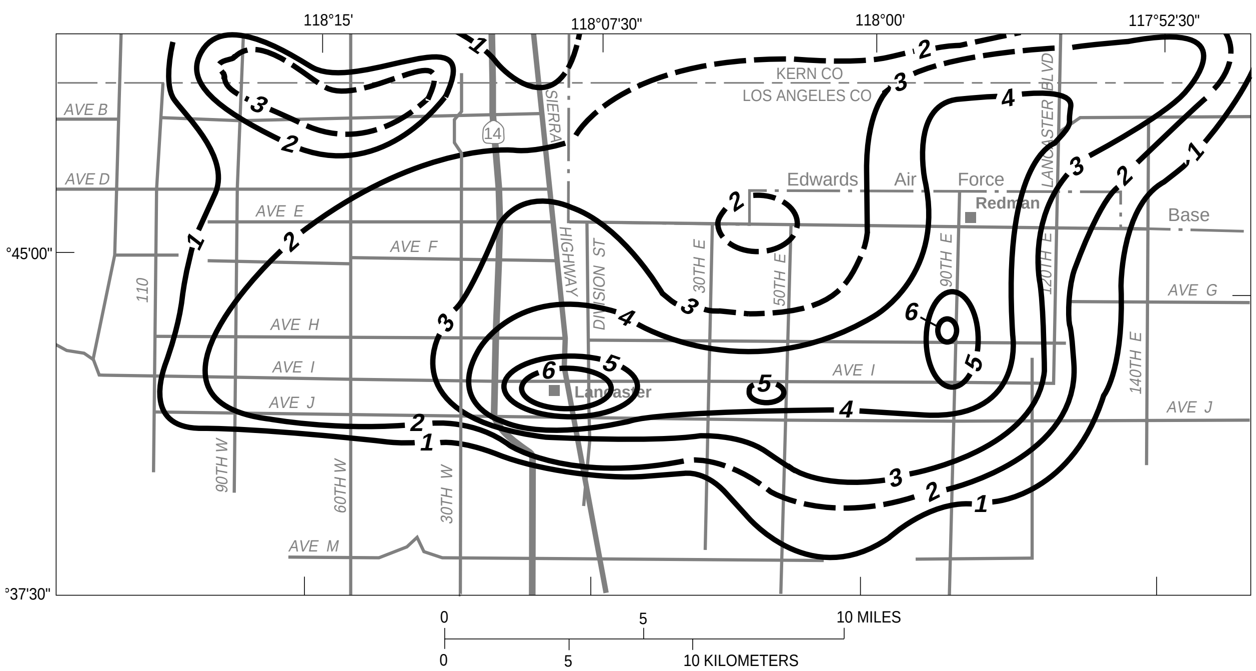
Between about 1930 and 1992, the maximum calculated magnitude of subsidence was more than 6.0 ft (1.83 m) in Lancaster, the largest city in Antelope Valley (fig. 2). Estimates of subsidence at other nearby bench marks, partially based on estimated values for the period before 1960, are as high as 6.6 ft (2.01 m). Between Lancaster and Redman, which is a predominantly agricultural area 12.5 mi (20 km) to the northeast, 4 ft (1.22 m) or more of subsidence has been measured at bench marks (fig. 2).



EXPLANATION

- Land-surface profile
- △ GEOID90 deviation, relative to BM 5159
- □ GEOID93 deviation, relative to BM 5159
- ▲ GEOID90 deviation, relative to F1147 1961
- ■ GEOID93 deviation, relative to F1147 1961

Figure 1. Land-surface profile on Sierra Highway between Palmdale and Rosamond and error for Global Positioning System-derived elevation differences relative to leveled differences of bench-mark pairs (modified from Ikehara and Phillips, 1994, fig. 1).



EXPLANATION

Line of equal magnitude of subsidence, in feet--Dashed where approximately located. Interval 1 foot

Figure 2. Magnitude of calculated or estimated subsidence in central Antelope Valley, 1930 to 1992 (modified from Ikehara and Phillips, 1994, fig. 8).

Land subsidence in Antelope Valley is caused by aquifer-system compaction that is related to water-level declines and the presence of fine-grained compressible sediments. The potentiometric surface and water-level declines of the Lancaster ground-water subbasin were mapped for several periods since the 1950's and compared to subsidence-rate maps. As expected, the correlation between water-level declines and the distribution and rates of subsidence were highest where compressible sediments were present generally toward the lowest parts of Antelope Valley. In contrast, areas, such as Palmdale, that are closer to the mountains and underlain by coarser sedimentary material showed little or no land subsidence even when water levels had declined tens of meters over decades.

The mechanics of land subsidence might be better understood if horizontal and vertical geodetic measurements of the land surface were made before as well as after the onset of stresses imposed on the aquifer. The establishment of a horizontal and vertical base line was accomplished by a recent local-scale geodetic survey of densely-spaced reference marks that was done before production in two new nearby ground-water wells. A kinematic GPS survey of 82 reference stations was done in August 1994 at a straight, 4-mile-long (6-kilometer-long) abandoned track that was built for testing rocket sleds at Edwards Air Force Base in the northeastern part of Antelope Valley. For the first part of the survey, the two nearest stable vertical-control stations that are part of the regional-scale network established in 1992 were observed in static mode simultaneously with the

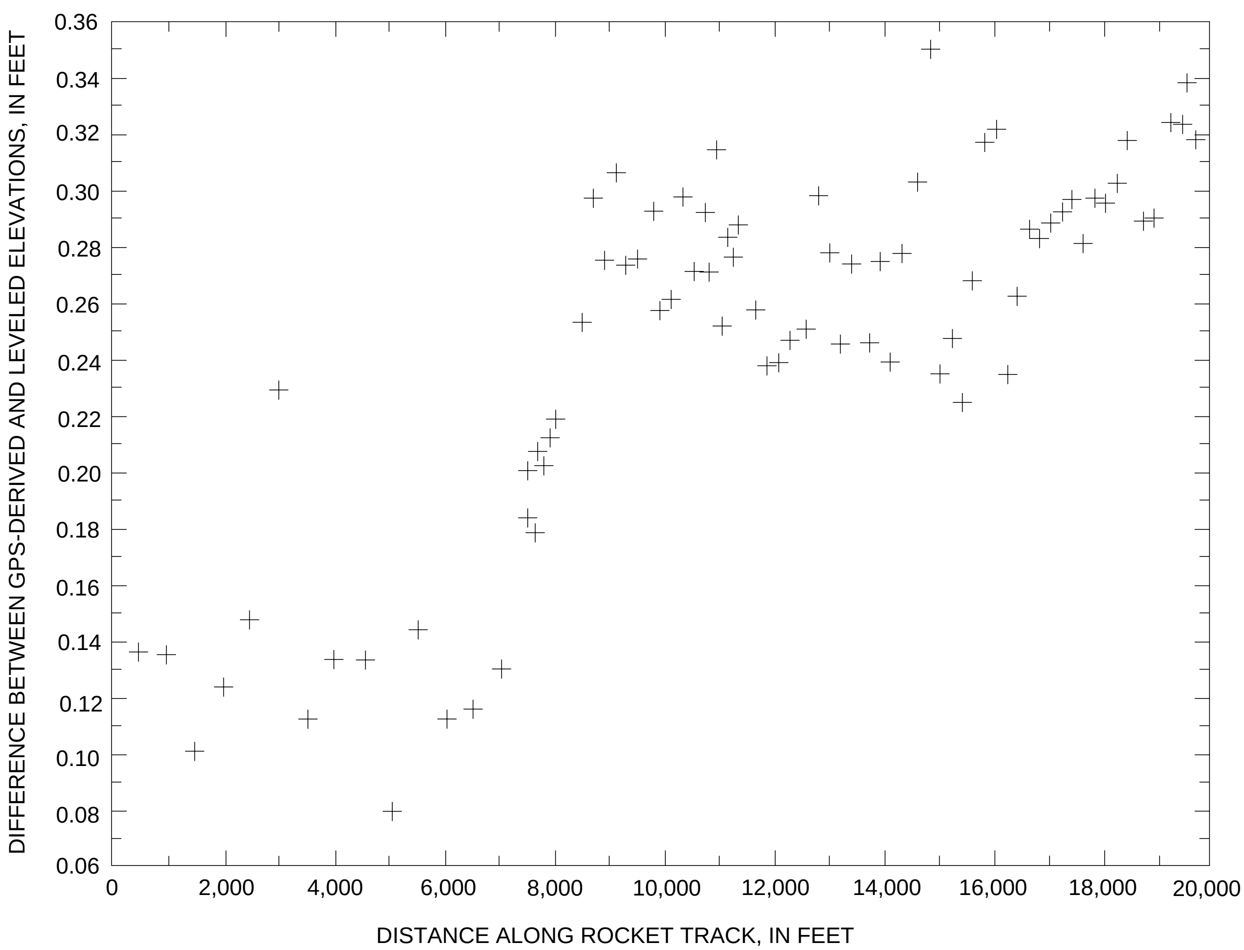


Figure 3. Comparison of Global Positioning System-derived elevations relative to leveled elevations of rocket-track stations measured at Edwards Air Force Base, Antelope Valley, August 1994.

two base stations established for the kinematic survey. The static observations were made at 15-second intervals for 2 hours at the track stations; the kinematic observations were made at 10-second intervals for 15 epochs (2.5 minutes). In kinematic surveys, an offset to the base station, called a swap station, is established for use by the rover, which is the antenna that visits all stations for which coordinates are to be determined. During postprocessing, horizontal and vertical coordinates were computed for 2 base stations, 1 swap station, and 80 track stations.

A leveling survey that included most of the 80 track stations was done during the same week. The survey was not double run because of time constraints; however, the data allowed a general comparison between elevations obtained by GPS and leveling methods (fig. 3). Relative to leveled elevations, GPS-derived values differed by 0.08 to 0.35 ft (2.4 to 10.7 cm). One possible explanation for the bimodal distribution of elevation differences is that the base station for the track stations between 8,000 and 20,000 ft (2,438 and 6,096 m) was not included in the leveling. Although the leveled elevations are considered known for this comparison, unadjusted leveling error at the breakpoint—the switch between base stations—may account for the abrupt change in the differences. The GPS-computed positions and ellipsoidal heights would be used as the base-line values with which future geodetic measurements of track stations could be compared.

REFERENCES CITED

Ikehara, M.E., and Phillips, S.P., 1994, Determination of land subsidence related to ground-water-level declines using global positioning system and leveling surveys in Antelope Valley, Los Angeles and Kern Counties, California, 1992: U.S. Geological Survey Water-Resources Investigations Report 94–4184, 101 p.

Templin, W.E., Phillips, S.P., Cherry, D.E., DeBortoli, M.L., and others, 1995, Land use and water use in the Antelope Valley, California: U.S. Geological Survey Water-Resources Investigations Report 94–4208, 97 p.