Ground subsidence near Espanola, New Mexico

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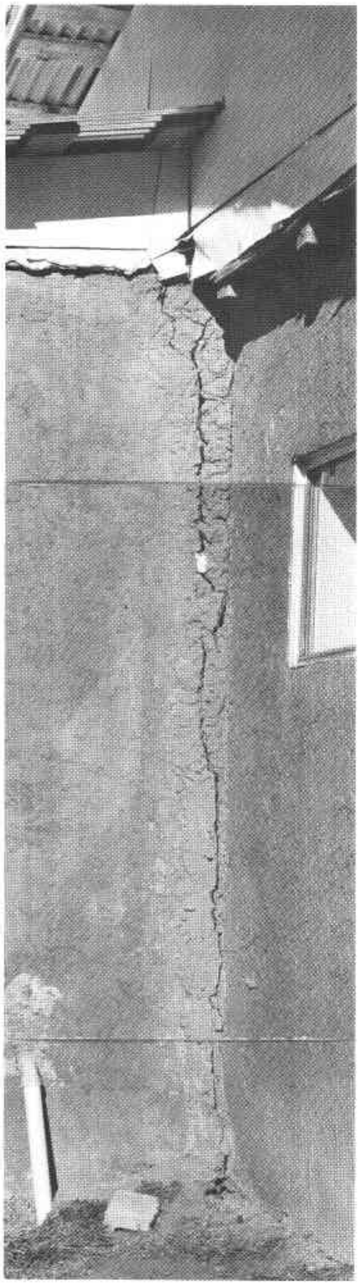

FIGURE 2—Crack in exterior wall of adobe house that the owner has repaired without lasting success.

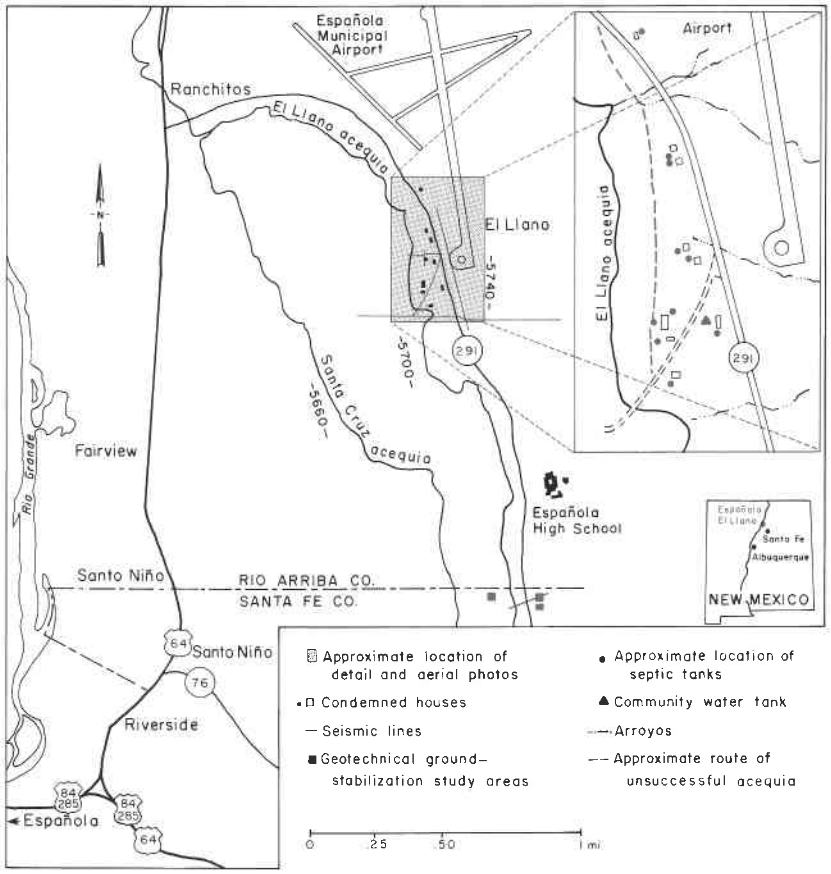

FIGURE 1—Location map of study area in and around El Llano, near Española, Rio Arriba and Santa Fe Counties, New Mexico.

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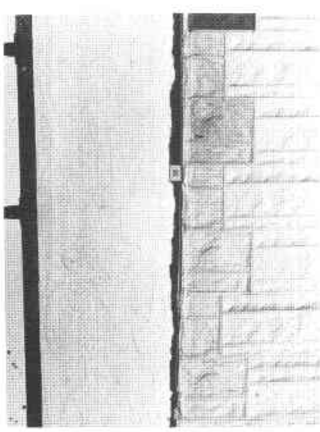

FIGURE 3—Wall crack in two-story stone and wood house.

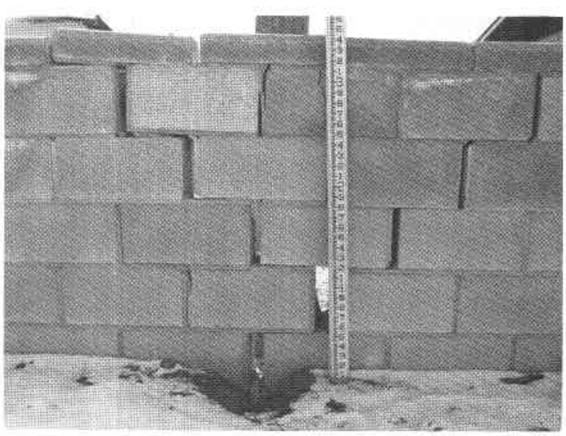

FIGURE 4—Concrete-block wall that was cemented flush originally. The hole in the ground is called a sótano, which literally means basement or cellar but, in this case, signifies an unexplained hole that, if found in a field, could drain much of the surface water directly to the subsurface.

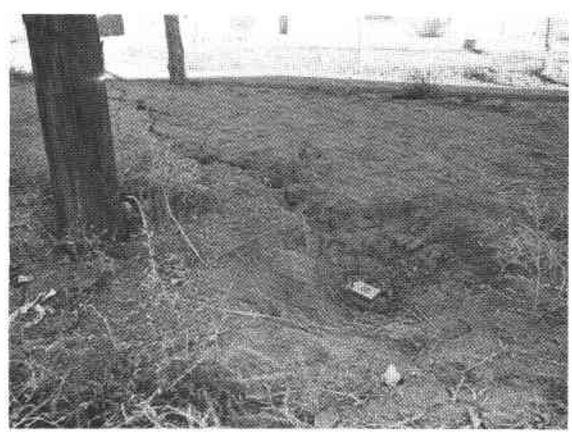

FIGURE 5.—Cracks and circular depression in an El Llano backyard.

Engineering and environmental geologists from New Mexico Bureau of Mines and Mineral Resources (NMBMMR) were called late last fall to investigate ground subsidence in and around the small community of El Llano, northeast of Española (Fig. 1). Residents had become extremely concerned about the rapidly developing cracks in their houses and the ground subsidence around them. Although they had noticed minor structural damage for some time, it was apparently only in the last few months of 1984 that rapid soil collapse and differential settlement caused walls to separate in some structures (Figs. 2, 3, 4) and backyards to develop circular depressions (Fig. 5). The possibility of gas lines breaking became frighteningly real. In addition to these problems, investigating geologists found a broken water line, leaking septic tanks, and ground cracks in the area.

In early December, NMBMMR geologists and El Llano homeowners met in Santa Fe with representatives from the offices of the Governor, Civil Emergency Preparedness, Red Cross, and Construction Industries Division (CID). The CID concluded that it would be potentially hazardous for some of the people to remain in their homes, and they condemned nine houses. The families were housed initially at a local motel. On December 13 Governor Anaya signed an executive order declaring El Llano a state disaster area. This order freed state monies to study the subsidence, which also affects state highways, a high school, and utilities. Unfortunately for the nine families, the state constitution forbids direct aid to individuals for such losses.

NMBMMR was designated the lead state agency to conduct a detailed geotechnical study of the site in cooperation with other state agencies and consultants knowledgable in soil and structural stability. It is hoped that this study will provide the information necessary to enable repair of damaged houses and to prevent further damage in El Llano and in other areas where similar problems exist (Fig. 6).

The multi-faceted study includes drilling and soil testing, trenching, installation of water- and ground-monitoring wells, topographic, cultural, and seismic surveying, ground-vibration monitoring, geologic mapping, aerial and ground photography, collection of local history, and conducting a geotechnical ground-stabilization study.

Geology

Surficial deposits in the El Llano area are as much as 100 ft thick and, in places, consist of low-density, unconsolidated alluvium. In most places this alluvium overlies a layer of river sand and gravel deposited by the ancestral Rio Grande thousands of years ago, probably during the last glacial stage of the Pleistocene. In some places the alluvium overlies the Santa Fe Group, which crops out east of the condemned houses. During Holocene time (last 10,000 yrs) the river channel has shifted westward about 2 mi to its present position (Fig. 1). The alluvium overlying the ancient river deposits is a wedge-shaped body of sand to clay, with some gravel; it was deposited by tributary arroyos heading in the badland area that forms the eastern bluffs of the Rio Grande valley. Most of the alluvium was derived from erosion of sandy to clayey basin fill of the Santa Fe Group. The Santa Fe Group also underlies the arroyo alluvium and river deposits in the El Llano area at depths of about 125–150 ft, is slightly tilted to the west, and is faulted locally (Hawley, 1978). Kelley (1978) made a general (1:125,000 scale) map of the geology of the Española Basin. He mapped several faults in the El Llano area, none of which appear to be active or to offset surficial alluvial deposits.

Possible causes

A number of causes for the subsidence are being evaluated: deep-seated tectonic faulting or down warping, water-table-related features such as solution subsidence of caves, excessive precipitation, soil-related problems of shrinking and swelling clays or undercompacted soils, and heavy highway traffic on NM–291. In addition, residents were concerned about the possible impact of geophysical tests conducted in the Española Basin in November 1984. Information about these tests has been compiled and the tests seem unrelated to the cracking because the charges were minor and other houses closer to the testing did not develop cracks. Earthquakes registering

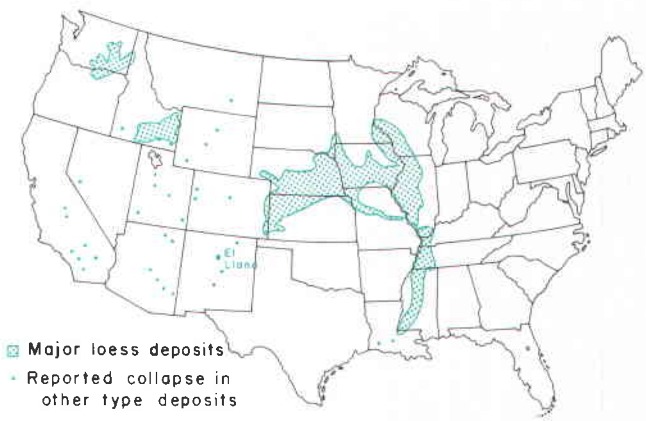

FIGURE 6—Map of the U.S. showing extent of loess deposits, soils known to be collapsible, and other areas where soil collapse has been reported; modified from Arman and Thornton, 1972.

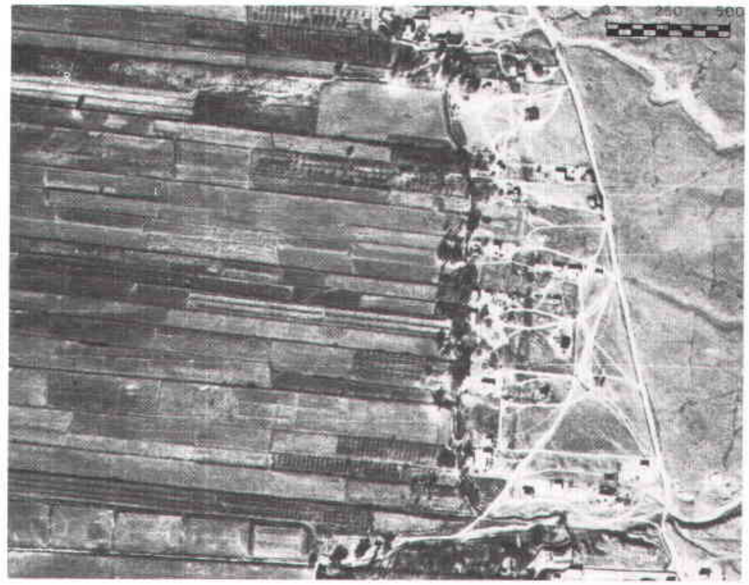

FIGURE 7—Aerial photograph of part of El Llano taken in 1949. Area shown includes, but extends farther west than, detail shown in Fig. 1. The scale is in feet.

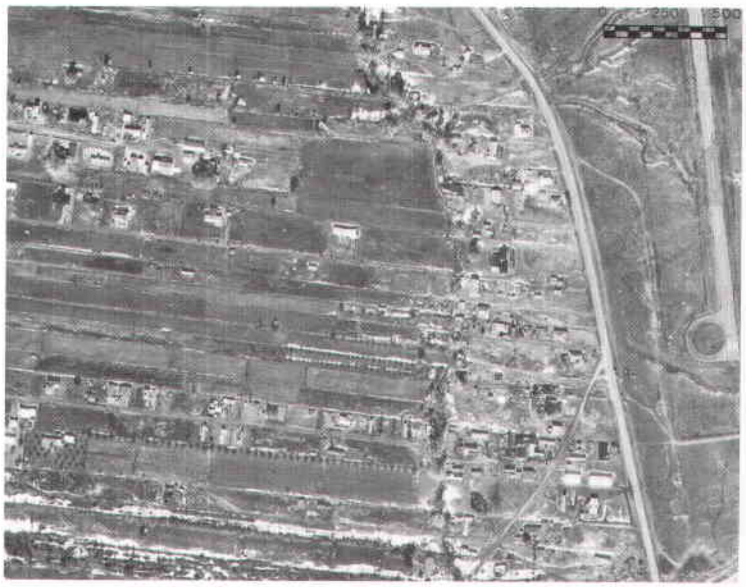

FIGURE 8—Aerial photograph of part of El Llano taken January 15, 1985. Note the concentration of structures east of the acequia near the highway. Area shown includes, but extends farther west than, the detail shown in Fig. 1. The scale is in feet.

magnitudes up to VII on the modified Mercalli scale have been recorded this century in northern New Mexico (Stover et al., 1983). However, available data indicate that these larger events were not felt in El Llano. Earthquakes of lower intensity (V or less, modified Mercalli scale) have been recorded in the Española area, but earthquakes of this magnitude usually do not cause substantial structural damage.

Gary Johnpeer, NMBMMR Engineering Geologist, has not ruled out the possibility of multiple causes for the ground subsidence, but he suspects the main cause is collapsing soils. He postulates that the addition of water to near-surface soils is causing the young, unconsolidated, porous sediments to collapse. Land west of the subsiding area lies between two irrigation ditches (acequias; Fig. 1) and has been saturated with water for a long time. Land in that area probably compacted before any structures were built on it.

Although El Llano is not a newly settled area, only within the last 25 yrs has the area been subdivided and built up significantly. Aerial photographs (Fig. 7, 8) reveal very long, narrow land subdivisions, which represent typical Spanish land grants. Originally, properties were divided so that each owner had a portion of land that bordered on a dependable water source such as an acequia or a river. An unsuccessful attempt was made in the early 1900's to build an acequia that would have flowed close to some of the now-settling houses (Fig. 1, detail). According to available information, El Llano lands east of the existing acequia have never been irrigated or wetted significantly. Newer houses generally have been built at the eastern edge of the original land grants, uphill from the irrigated lands (Figs. 1, 8). Indoor plumbing and septic tanks have been used increasingly since the mid 1940's, and, because most El Llano houses are not connected to the Española sewage system, septic tanks are utilized. Other sources of increased moisture include leaky water lines, surface runoff (unusually high rainfall was recorded in October 1984), disruption of natural runoff, and outdoor watering.

Geotechnical tests

Numerous tests have been set up for continuous monitoring. Ground-vibration monitors were installed in two condemned houses. These instruments should reveal whether or not vehicular traffic or other sources of vibration have contributed significantly to cracking in the houses. Rebar, driven into the ground where cracking is apparent, is being resurveyed periodically to measure subsidence.

Forty-five drill holes were completed within an approximately 4 mi^2 area that includes and surrounds the most intense damage. The holes ranged in depth from 29 to 123 ft. Ten of the holes were converted to ground-water monitoring wells so that fluctuations in the water table can be documented. Other drill holes are being used to monitor changes in surface elevation; settlement monuments were placed vertically in six drill holes to detect surface subsidence, and more precise settlement probes (Sondex casing) were placed in eight drill holes to detect collapse at specific subsurface depths. Completed drill holes were backfilled with soil and bentonitic clay. Generally, the drilling sites were located near condemned structures adjacent to major cracks (Fig. 9), but a number of holes were drilled in control areas away from suspected subsidence. One control area was located west of El Llano between the two acequias, and others were located away from any possible moisture sources such as surface drainage, acequias, or septic tanks.

Laboratory testing of undisturbed (Shelby tube and continuous core) and disturbed (split-spoon) samples will give more precise information about subsurface soils and geology. Detailed cross sections will be drawn based on field and laboratory data.

The seismic surveys have helped geologists make subsurface interpretations. The tests were run across a possible buried fault mapped by Kelley (1978) as well as in strategic locations around the condemned houses. These data indicate that the mapped fault is not active. They also show an upper low-velocity zone that is consistent with known collapsing-soil areas elsewhere.

In addition, 12 exploration trenches were excavated where surface cracks occurred to determine depth of the cracks and if faulting was evident. After the trenches were excavated the details of the trench walls were logged. Offset indicative of faulting was not apparent, although several cracks extended deeper than the 12-ft-deep trenches; other cracks died out a few feet below the surface. In several trenches animal burrows (krotovina) appear in close association with the cracks.

The geotechnical ground-stabilization study is intended to demonstrate the relationship between ground wetting and subsidence and may provide data that can be used to prepare sites before construction. Data from the study also are being analyzed to determine the feasibility of saturating an area so that the ground (and any structures on it) will subside uniformly. For the first phase of this study three areas were chosen that had not been wetted previously (Fig. 1). The ground is being saturated at each site by injecting water continuously into holes lined with perforated PVC casing. The areas are being monitored carefully to measure the amount of wetting and the uniformity of subsidence. A larger-scale experiment is anticipated to begin soon. The ground beneath an existing or specially built structure will be wetted and the subsidence monitored. Although never attempted before in a developed area, this procedure could be applied to ground beneath already cracked structures in order to stabilize them.

Summary

Collapsing soils are a natural geologic process that cause problems when structures are built on them before subsidence is complete. However, adequate preparation of these soils before construction can minimize subsequent damage. Unfortunately, remedial measures made on existing utilities or other structures have not been very successful. In New Mexico, ground subsidence from collapsing soils as well as from other causes is a common occurrence. Increases in population and building necessitate practical and expedient solutions because the damage caused by soil collapse is not only costly in dollars but also in emotional stress for those directly affected. Data generated during this study will help mitigate the problem of ground subsidence in El Llano and in other parts of New Mexico.

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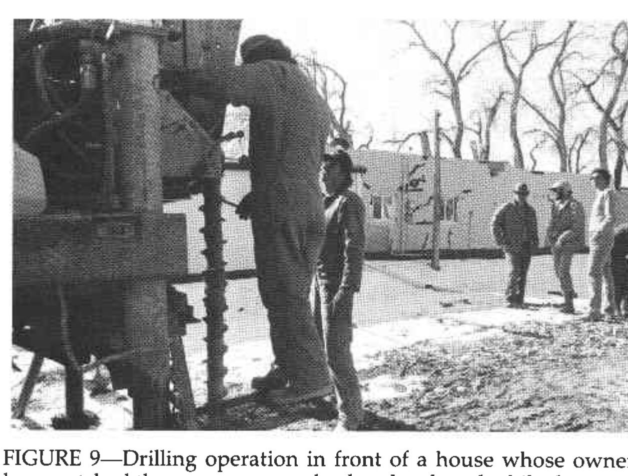

FIGURE 9—Drilling operation in front of a house whose owners have patched the numerous cracks that developed while they were on vacation in the summer of 1984.