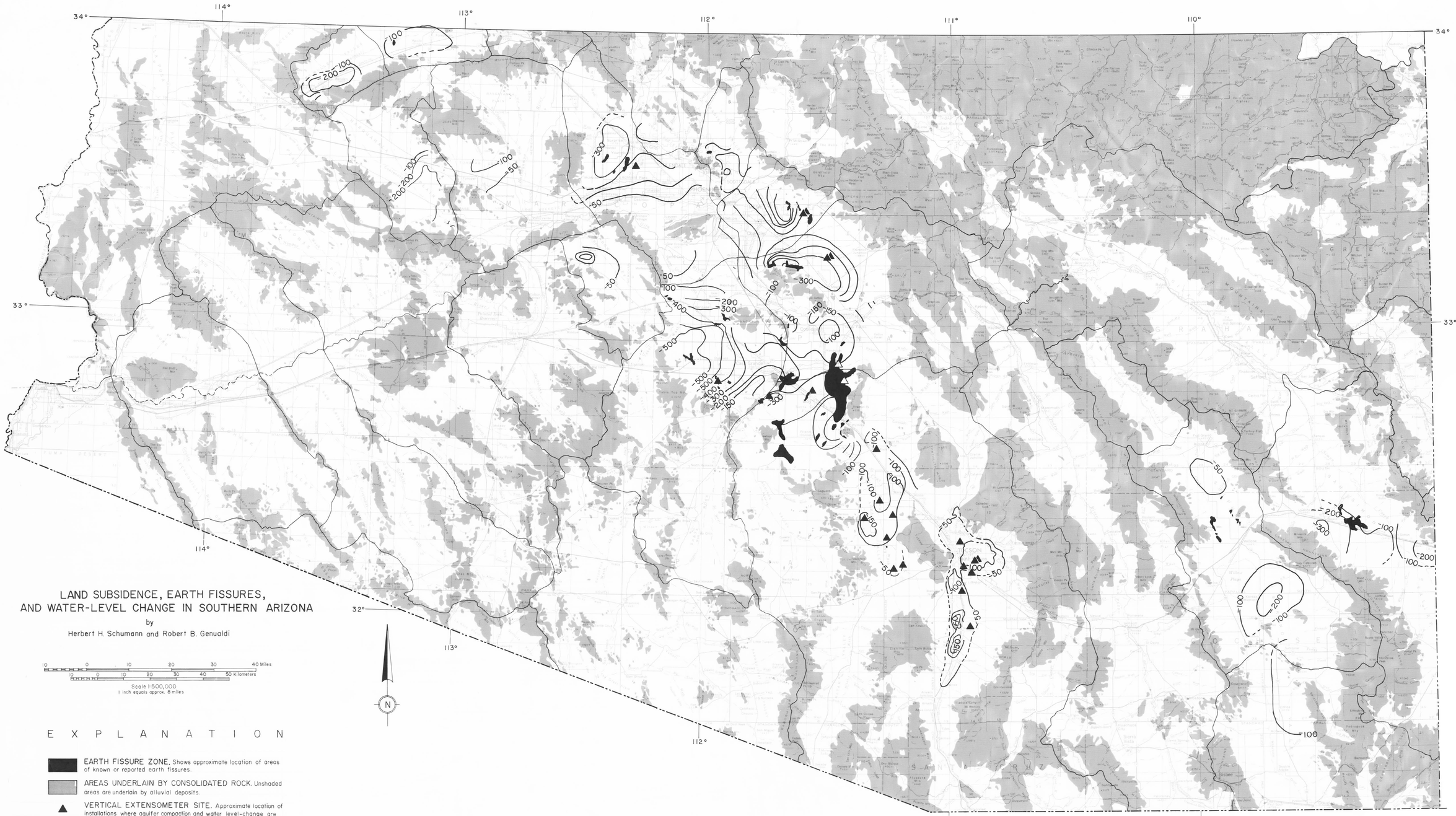

LAND SUBSIDENCE, EARTH FISSURES, AND WATER-LEVEL CHANGE IN SOUTHERN ARIZONA

by

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E X P L A N A T I O N

EARTH FISSURE ZONE. Shows approximate location of areas of known or reported earth fissures.

AREAS UNDERLAIN BY CONSOLIDATED ROCK. Unshaded areas are underlain by alluvial deposits.

▲ **VERTICAL EXTENSOMETER SITE.** Approximate location of installations where aquifer compaction and water level-change are being monitored.

-300- **LONG TERM WATER-LEVEL CHANGE** Measured in feet

Introduction

Land subsidence and earth fissures, which are caused by ground-water depletion, pose geologic hazards in many parts of southern Arizona. Subsidence has affected more than 3,000 mi² in the State, including parts of Arizona's largest metropolitan areas, Tucson and Phoenix (Strange, 1983). Differential land subsidence and earth fissures have damaged a variety of engineering structures including buildings, streets, highways, railroads, earthen dams, water wells, water-distribution systems, and wastewater-treatment facilities. Earth fissures have also adversely affected urban and agricultural land use.

This map provides a general overview of ground-water depletion and resultant land-subsidence and earth-fissure problems in the Basin and Range Province of southern Arizona. Although this physiographic province extends north of lat 34° N., the cutoff line used on this map, such phenomena have not been observed north of this latitude, nor do they pose problems in the Transition Zone or Colorado Plateau (see index map). This map updates the water-level and earth-fissure map prepared in 1983 by the Arizona Department of Water Resources, U.S. Geological Survey, U.S. Bureau of Reclamation, and National Geodetic Survey (Strange, 1983). The current map was prepared by the U.S. Geological Survey, Arizona Department of Water Resources, Arizona Department of Transportation, and Arizona Bureau of Geology and Mineral Technology as part of an ongoing effort by the Arizona Land Subsidence Committee. This map is the first in a series of maps on land subsidence and earth fissures to be published by the Arizona Bureau of Geology and Mineral Technology.

Southern Arizona is characterized by broad alluvial valleys bounded by rugged mountains that consist mainly of igneous, metamorphic, and consolidated sedimentary rocks. The valley floors have gentle relief and are underlain by permeable unconsolidated to moderately consolidated alluvium that stores large volumes of ground water.

Large-scale pumping of ground water began about 1900 and increased dramatically in the late 1940's. By 1984 nearly 196 million acre-feet had been withdrawn from the alluvial aquifer system (U.S. Geological Survey, 1985). Ground water is used mainly to irrigate crops, although municipal and industrial use of ground water is increasing. Ground-water withdrawals from the alluvial aquifer system have greatly exceeded recharge, and most of the pumped water was removed from storage (Arizona Water Commission, 1975).

Water-Level Change and Aquifer Compaction

Throughout most of the study area, ground-water depletion has caused water levels in wells to decline, some by more than 550 ft (Thomsen and Baldys, 1985). Ground-water depletion has caused the aquifer system to compact. This compaction, in turn, has resulted in large areas of land subsidence.

The relation between water-level change, aquifer compaction, and land subsidence in Arizona was first documented at the vertical extensometer installation near Eloy in the lower Santa Cruz basin (Schumann and Poland, 1970). Such installations are being used to measure and monitor aquifer compaction and water-level changes at 24 sites in southern Arizona. Data collected at these sites indicate that aquifer compaction is continuing in the Salt River Valley and in the Santa Cruz basin.

Land Subsidence

An extensive review of leveling information by Strange (1983) indicated that measurable land subsidence had been detected in nine ground-water areas. Subsidence was first detected in southern Arizona in 1948 through releveling of bench marks near Eloy in the lower Santa Cruz basin (Robinson and Peterson, 1962). Subsequent investigations indicated that land subsidence was continuing near Eloy and that the areas of greatest subsidence corresponded to the areas of greatest water-level decline (Schumann and Poland, 1970). By 1977 about 425 mi² in the Stanfield area and 675 mi² in the Eloy area were affected by subsidence in southern Pinal County (Schumann and others, 1986). By 1977 11.8 ft and 12.5 ft of subsidence had occurred near Stanfield and Eloy, respectively (Laney and others, 1978). In 1985 more than 15 ft of subsidence was measured south of Eloy (Carl C. Winikka, Arizona Department of Transportation, written commun., 1985).

In the western part of Salt River Valley, an area of 140 mi² near Luke Air Force Base west of Phoenix and an area of 230 mi² near Queen Creek were reported to have subsided more than 3 ft by 1977 (Poland, 1981). Water-level declines prior to 1977 in both areas exceeded 300 ft. Between 1948 and 1981, about 5.2 ft of subsidence was measured east of Mesa, where water-level declines had exceeded 300 ft by 1977 (Strange, 1983).

In the eastern part of Salt River Valley, subsidence rates as great as 0.35 ft/yr have been reported in the Paradise Valley area (Harmon, 1982). As much as 5 ft of subsidence was reported in that same area between 1965 and 1982 (Péwé and Larson, 1982).

Land subsidence is of great concern in the upper Santa Cruz basin, where ground water is the principal water source for municipal, industrial, and agricultural use. About 0.4 ft of subsidence was measured between 1952 and 1980, and water levels in wells have declined more than 100 ft near Tucson (Strange, 1983).

Level data along the northwestern part of Avra Valley indicate that 1 ft of subsidence occurred near Red Rock between 1948 and 1980. Water-level declines in wells in Avra Valley have exceeded 100 ft (Strange, 1983). A comparison of level data collected in 1927 and 1981 indicates that 0.6 ft of subsidence has occurred in the Harquahala Plains. The maximum water-level decline in wells in this area was more than 300 ft (Strange, 1983). Water levels have declined 50 ft north of Willcox, and 5.3 ft of subsidence had occurred northwest of Willcox by 1974 (Holzer, 1980). Southeast of Willcox, water levels have declined 200 ft, and subsidence and earth fissures have been reported.

A comparison of 1952 and 1974 level data indicates that 4.7 ft of subsidence occurred near Bowie in the San Simon basin (Holzer, 1980). Level data collected in 1952 and 1980 indicate that 5.8 ft and 1.3 ft of subsidence occurred near Bowie and San Simon, respectively (Strange, 1983). Water-level declines in wells exceed 300 ft near Bowie and 200 ft near San Simon.

Less than 0.2 ft of subsidence was reported near Tonopah in the lower Hassayampa area and in the Gila Bend basin (Strange, 1983). Although 200 ft of water-level decline was measured in McMullen Valley, releveling data are not available to document land subsidence (Strange, 1983). Significant water-level declines and the presence of earth fissures, however, indicate that subsidence has probably occurred.

Earth Fissures

Earth fissures mainly occur in the alluvium near seven areas that are experiencing ground-water depletion (Schumann and others, 1986). The fissures tend to connect and form long linear systems. In the lower Santa Cruz basin, one of these systems is about 10 mi long.

Earth fissures first appear as narrow cracks that are generally less than 1 in. wide or as alignments of shallow holes or sinklike depressions that are typically less than 3 in. in diameter. The newly opened fissures have vertical sides, generally exhibit no evidence of lateral or vertical movement, and range from a few feet to more than one-half mile in length. The simple horizontal separation of the land blocks indicates that the fissures are probably tensional breaks (Schumann and Poland, 1970). Vertical offset has been observed along a few fissures after the initial break occurred.

Earth fissures generally occur on the periphery of subsidence areas, transect natural drainage patterns, and capture large volumes of surface runoff. Water flowing into these fissures has produced gullies as deep as 16 ft and wider than 50 ft. The fissures, however, extend below the gullies as narrow openings that often fill with clay, silt, and sand washed from above. The fissures enlarge by slumping, by erosion along the upstream sides, and by rapid piping along the strike of the fissures.

Surface geophysical investigations and deep drilling indicate that some fissures were formed by differential subsidence over buried ridges or other irregularities in the consolidated bedrock surface beneath the unconsolidated alluvium (Schumann and Poland, 1970; Jachens and Holzer, 1979; Holzer and Pampeyan, 1981; Schumann and Tosline, 1983).

The greatest concentration of earth fissures is found in the lower Santa Cruz basin, where the greatest amounts of water-level decline and land subsidence were measured. Earth fissures were also mapped or reported in six other areas including the Harquahala Plains; McMullen, Salt River, and Avra Valleys; and Willcox and San Simon basins. Significant amounts of ground-water depletion have occurred in all of these areas.

Environmental Effects of Land Subsidence and Earth Fissures

Environmental effects of land subsidence and earth fissures include actual and potential damage to engineering structures, accelerated erosion along earth fissures and drainages, increased flood hazards, and the potential for ground-water pollution. Damaged engineering structures include streets, highways, and railroads. Vertical offsets at the fissure site east of Picacho required regrading of the highway roadbed and the addition of ballast along the railroad (Winikka and Wold, 1977; Jachens and Holzer, 1979). Land subsidence and earth-fissure damage are important factors to be evaluated during the design of major engineering structures in areas of measured subsidence.

Land subsidence and earth fissures have damaged water and sewer systems. Water-well casings have collapsed as a result of compression, making expensive repairs or replacement of irrigation and municipal wells necessary. Irrigation canals, buried pipelines, and earth-filled dams have been damaged in or near subsiding areas. Releveling of irrigated fields was necessary in the western Salt River Valley, the lower Santa Cruz basin, and the Willcox basin. Land subsidence decreased the gradient of sewer lines in northeast Phoenix (Harmon, 1982). Reduced sewer capacity and subsequent generation of excessive sewer gases may require the installation of expensive pumping systems and chemical treatments.

Erosion along earth fissures results in the loss of valuable irrigated land, and open fissures pose serious hazards to people, wildlife, and livestock. Accelerated erosion also occurs in natural drainages along the periphery of subsiding basins where the gradient between the basin floor and the surrounding mountains has increased. Such erosion removes topsoil and deepens ephemeral-stream channels.

An important environmental consideration is the increased potential for ground-water pollution. Earth fissures may extend to great depths, even to the water table. If the fissures do extend to the water table, they could provide a direct path to ground water, which would eliminate the natural filtration process during percolation through sediments in the unsaturated zone. Pesticides, herbicides, chemical fertilizers, animal wastes, and other toxic materials that may be contained in surface runoff are potential sources of ground-water pollution at or near earth fissures.

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