Subsidence and Fissures

Subsidence near Eloy amounted to 15.4 feet from 1952 to 1985 and continues as more groundwater is pumped. The subsidence at this site has not been measured since 1985. *(Photo courtesy of Herbert Schumann)*

Land Subsidence

Withdrawal of groundwater at rates faster than natural recharge leads to lowering of water tables, eventually causing the land surface to lower or subside. More than 3000 square miles of central and southern Arizona, including parts of the Phoenix and Tucson metropolitan areas, have subsided because of groundwater pumping. Water levels in parts of Tucson's central well field declined by more than 150 feet by 1981. By 1986, more than 300 feet of groundwater lowering had been measured near San Simon, Apache Junction, Queen Creek, Harquahala Valley, and Luke Air Force Base. West of Casa Grande, the water table has dropped nearly 500 feet.

Groundwater produces a buoyancy force that supports part of the weight of the sediments that have been deposited in Arizona's numerous deep basins. Removal of groundwater and the associated buoyancy force results in compaction of the sediment, reduction of pore space, and subsidence at the Earth's surface. In every Arizona basin where substantial groundwater overdraft has occurred, subsidence has followed. The land has subsided more than 15 feet in the Picacho basin near Eloy and 18 feet in the Luke basin, west of Phoenix. In Tucson, subsidence was detected in re-leveling surveys in 1952, but maximum total subsidence was only about 6 inches by 1980. Recent surveys using a satellite-based method (radar interferometry) showed that subsidence is continuing as water levels decline under central Tucson. During the mid- to late-1990s, the Tucson area subsided about 0.6-0.8 inch per year. Based on the amount and rate of past subsidence, parts of the Tucson basin could experience an additional 2 feet of subsidence by the year 2030 if groundwater pumping continues at the current rate.

Subsidence can cause serious problems to infrastructure. Because irrigation canals, storm drainage systems, and sewage systems depend on gravity flow, subsidence can change carefully engineered slopes so the that flow can speed up, stop, or even reverse in extreme cases.

Gradients of streams flowing into a subsiding basin become steeper and cause increased erosion. Storm runoff may flood areas that have sunk and are now lower than their surroundings. Farm fields that are flood-irrigated may need constant re-leveling to ensure that water flows in the right direction. Water well casings can be so badly damaged by compaction from subsidence that new wells must be drilled. Land elevation surveys and contour lines on topographic maps are rendered obsolete when surface elevations change due to subsidence.

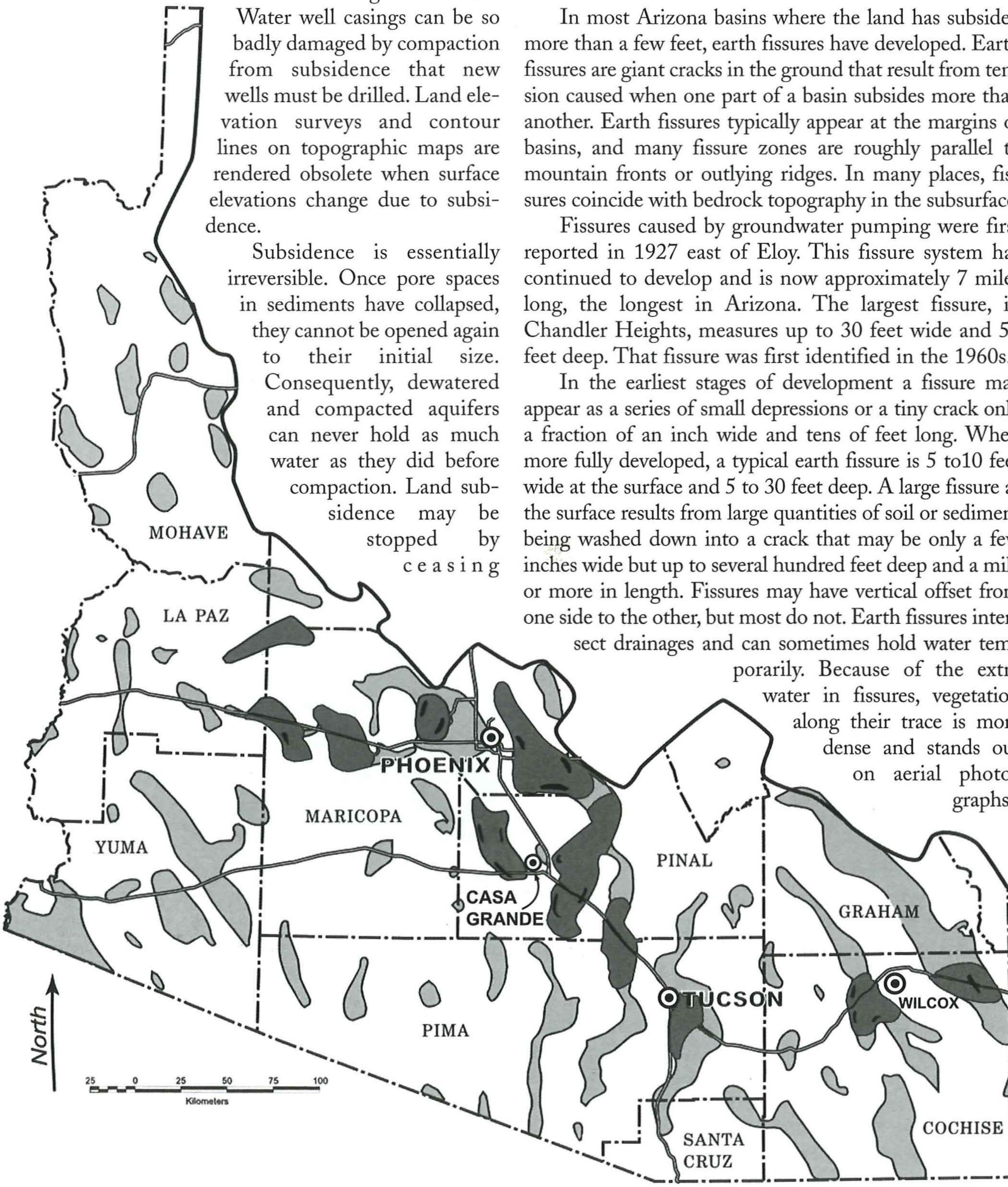
Subsidence is essentially irreversible. Once pore spaces in sediments have collapsed, they cannot be opened again to their initial size. Consequently, dewatered and compacted aquifers can never hold as much water as they did before compaction. Land subsidence may be stopped by ceasing groundwater overpumping, but recovery of groundwater levels does not bring the ground surface back to its original elevation.

Earth Fissures

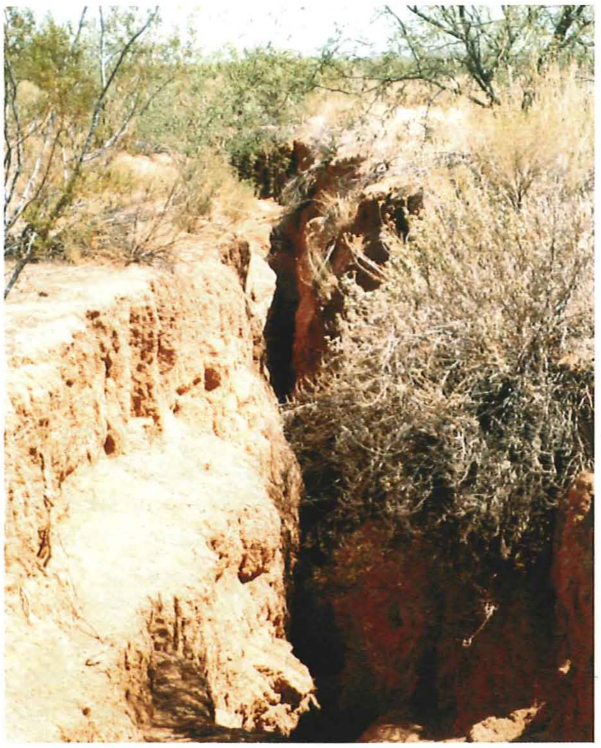
In most Arizona basins where the land has subsided more than a few feet, earth fissures have developed. Earth fissures are giant cracks in the ground that result from tension caused when one part of a basin subsides more than another. Earth fissures typically appear at the margins of basins, and many fissure zones are roughly parallel to mountain fronts or outlying ridges. In many places, fissures coincide with bedrock topography in the subsurface.

Fissures caused by groundwater pumping were first reported in 1927 east of Eloy. This fissure system has continued to develop and is now approximately 7 miles long, the longest in Arizona. The largest fissure, in Chandler Heights, measures up to 30 feet wide and 50 feet deep. That fissure was first identified in the 1960s.

In the earliest stages of development a fissure may appear as a series of small depressions or a tiny crack only a fraction of an inch wide and tens of feet long. When more fully developed, a typical earth fissure is 5 to10 feet wide at the surface and 5 to 30 feet deep. A large fissure at the surface results from large quantities of soil or sediment being washed down into a crack that may be only a few inches wide but up to several hundred feet deep and a mile or more in length. Fissures may have vertical offset from one side to the other, but most do not. Earth fissures intersect drainages and can sometimes hold water temporarily. Because of the extra water in fissures, vegetation along their trace is more dense and stands out on aerial photographs.



Subsidence and related problems occur in many Arizona basins. Those basins that have more than 1600 feet of sediment are indicated by light gray tone. Areas where subsidence has occurred are shown with medium gray. Areas known to have earth fissures are shown in black.



(Above) At first glance, a typical earth fissure may look like a wash but has steep sides and does not have a flat, sandy bottom. *(Photo by Raymond C. Harris)*

(Above) One of Arizona's newest earth fissures, this one opened in the Harquahala Valley following heavy rain from Hurricane Nora in September 1997. *(Photo by Raymond C. Harris)*

(Right) A young earth fissure near Queen Creek made this road impassable. This fissure is in an area of rapid residential development. *(Photo by Raymond C. Harris)*

(Left) Earth fissures are sometimes used as dumps. Because earth fissures may be hundreds of feet deep and extend down to the water table, they could provide conduits for contaminants to reach aquifers. *(Photo by Larry D. Fellows)*

Earth fissures can cause significant damage to infrastructure such as roads, canals, railroads, and pipelines. Earth fissures may extend through the ground and beneath buildings for hundreds to thousands of feet. Buildings can suffer extensive cracking. Houses have been completely destroyed by fissures that opened up beneath them. The presence of cracks in foundations and walls, however, does not necessarily indicate that subsidence or earth fissures are to blame. Expansive soil, hydrocompaction, and normal settling of fill material can produce cracks similar to fissures that are caused by overdraft of groundwater.

Fissures pose a serious threat to water quality because they may serve as open conduits to the water table (aquifers). Contaminants that enter a fissure may travel almost unimpeded into regional aquifers that supply drinking water. Fissures have commonly been used as illegal dumping sites for household garbage, industrial waste, tires, construction debris, and animal waste. Using fissures for this purpose increases the potential for groundwater contamination.

Fissures also pose a potential safety hazard to humans and animals. A fall into a deep fissure may be life threatening. Some fissures cross roads and are large enough to swallow a motorcycle or car.

What To Do About Earth Fissures

One cannot predict with certainty where new fissures may develop. Fissure development requires that several conditions be met simultaneously: significant lowering of groundwater levels, substantial differential compaction of sediment, sediment of appropriate thickness and grain size, or buried bedrock topography (which aids differential compaction). New fissures commonly form in those areas that have already experienced fissuring. Newer fissures generally tend to form basinward of the older ones as indicated by studies of areas where both new and old fissures are found. Areas of known earth fissures have been well documented by geologists from the U.S. Geological Survey and Arizona Geological Survey, and in master's theses done by students at Arizona universities.

Earth fissures may be mitigated to some degree, but they are better avoided completely. Because fissures commonly open or become larger after heavy rains, runoff should not be allowed to flow into them. Water may be directed away from fissures with ditches, berms, or walls, or over fissures with culverts. Filling an active earth fissure with rock or soil is not an effective solution. Any active fissure that is filled may eventually begin to open again, especially after a large rainfall or application of irrigation water. Remember, a fissure is only a surface indication of a crack that may extend down hundreds of feet and have a length of thousands of feet.

The presence of earth fissures in an area does not mean that development cannot take place. It simply means that knowledge of the existing fissures and the potential for more fissures to develop must be taken into account when planning development to avoid future problems. Knowing where to locate certain types of structures (or more importantly, where *not* to locate them) can help prevent unnecessary repairs and legal costs later.

Where To Go For Information

Groundwater levels in wells are measured periodically by the Arizona Department of Water Resources, which has subsidence data for limited areas in the Phoenix region. The Arizona Geological Survey maintains the Center for Land Subsidence and Earth Fissure Information (CLASEFI), a clearinghouse for information on subsidence and earth fissures in Arizona. For more information, contact CLASEFI or visit the AZGS website.

Selected References

Land Subsidence, Earth Fissures, and Water-Level Change in Southern Arizona, by H.H. Schumann and R.B. Genualdi, 1986: Arizona Bureau of Geology and Mineral Technology [now Arizona Geological Survey] Map 23, scale 1:1:000,000.

Potential for Aquifer Compaction, Land Subsidence, and Earth Fissures in the Tucson Basin, Pima County, Arizona, by S.R. Anderson, 1988: U.S. Geological Survey Hydrologic Investigations Atlas HA-713, 3 sheets, scale 1:250,000.

Land Subsidence and Earth Fissures in Arizona, by Steven Slaff, 1993: Arizona Geological Survey Down-to Earth 3, 24 p.

A Reconnaissance of Earth Fissures near Apache Junction, Chandler Heights, and Southwestern Picacho Basin, by R.C. Harris, 1994: Arizona Geological Survey Open-File Report 94-11, 5 p., 2 sheets, scales 1:24,000 and 1:26,700.

A Reconnaissance of Earth Fissures near Stanfield, Maricopa, and Casa Grande, Western Pinal County, Arizona, by R.C. Harris, 1995: Arizona Geological Survey Open-File Report 95-6, 6 p., 1 sheet, scale 1:24,000.

Earth Fissures in the Bowie-San Simon Area, Cochise County, Arizona, by R.C. Harris, 1997: Arizona Geological Survey Open-File Report 97-19, 10 p., 1 sheet, scale 1:24,000.

Ground-Water Pumping Causes Arizona to Sink, by L.D. Fellows, 1999: *Arizona Geology* [Arizona Geological Survey newsletter], Fall 1999, v. 29, no. 3, pp. 1-4.