

Consultants Corner

Engineering for the future



Subsidence: That Sinking Feeling

It happened in the San Joaquin Valley in the middle of the last century. It occurred in the Santa Clara Valley during approximately the same time frame, and later in the Antelope Valley. San Luis Obispo was affected in the 1980s. The Coachella Valley is experiencing it now. The potential repercussions can be daunting; the flow of water in streams can be disrupted or even reversed; bridges, roads, underground utilities and wells can be damaged. In coastal areas, tidal waters can move inland and groundwater supplies can be impacted by salt water intrusion.

It is subsidence, the sinking of the land surface in response to changes underground. Typically, it's not a natural geologic phenomenon, but the result of the activities of man. Most commonly, it occurs when the rate at which groundwater is pumped exceeds the ground's natural ability to recharge. Other situations that can lead to subsidence are extraction of oil and gas deposits, seismic activity or hydrocompaction due to the wetting of certain types of soils.

Up until the early 1900s, farmers' irrigation needs could be satisfied by use of surface waters and wells drilled in areas where shallow groundwater was plentiful. As the agricultural industry in California expanded, so did the need for a reliable water supply.

With the advent of improved deep well turbine pump technology and the spread of electricity into rural areas, more and deeper wells were drilled as yields from shallow wells and surface waters diminished due to the increased demand.

In the 1920s in the Santa Clara Valley, new wells were being drilled at the rate of 1,700 per year. By 1955, about one-fourth of the total groundwater extracted for irrigation in the entire United States was being pumped from the San Joaquin Valley. The pumping was associated with significant declines in groundwater levels.

It was in the early 1930s that engineers began to notice the lowering of the ground surface in areas of extensive pumping activity. Comparisons between previously established benchmarks and new survey maps revealed startling results. In the Santa Clara Valley, surveys showed that between 1912 and 1933, the Santa Clara Valley had settled an average of four feet. Subsidence in the San Joaquin Valley was first noted in 1935, but was not extensively studied until the 1950s, when engineers realized that changes in ground surface elevations could threaten the newly-completed Delta-Mendota Canal.

The United States Geologic Survey (USGS), in conjunction with the California Department of Water Resources, began investigating and documenting the relationship between groundwater extraction and land subsidence. Comprehensive surveys of land subsidence in the San Joaquin Valley, completed in 1970, showed that subsidence in excess of one foot had affected more than 5,200 square miles of agricultural land, or one-half of the entire San Joaquin Valley. The greatest subsidence had occurred just southwest of Mendota, California, where the land surface in 1970 was over 28 feet lower than it had been in 1928.



Photo courtesy Richard Ireland, USGS

Pictured above is a pole near benchmark S661 in the San Joaquin Valley southwest of Mendota, California, showing the decline in land surface elevation between 1925 and 1975.

Groundwater is stored in permeable, water-bearing geologic units known as aquifers. When water is pumped out of an aquifer, the water pressure is reduced. In some cases, the reduction in water pressure results in a loss of support for the overlying soil, and compression occurs. This compression is what causes land

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subsidence. Depending upon the soil conditions, sometimes the compression can be reversed when the groundwater is recharged, but often the compression, and resulting subsidence, becomes permanent.

As the correlation between excessive groundwater extraction and land subsidence became known, most governmental jurisdictions established policies and implemented measures to control subsidence. These efforts were aided by federal reclamation projects, the completion of the California Water Project and the construction of numerous canals and aqueducts. Safe yields, or the amount of water that can be withdrawn without inducing subsidence, were established for many areas. In the San Joaquin and Santa Clara Valleys, groundwater levels began to recover, accompanied by decreases in the rates of subsidence.

Despite the modern understanding of how excessive pumping of groundwater can lead to subsidence, overdraft of groundwater resources still continues in some areas. When drought struck the San Joaquin Valley in 1976-77 and again in 1987-91, some water agencies and farmers refurbished old pumping plants and drilled new wells in an attempt to augment the imported water supply. Groundwater levels rapidly declined and subsidence resumed. More disturbingly, the decline in the groundwater levels and the accompanying subsidence occurred at a vastly accelerated rate.

Recently, the Coachella Valley Water District and the USGS released a study indicating that between 1996 and 2005, significant subsidence occurred in several areas within the Coachella Valley. Subsidence ranging from just over 7 inches to nearly 13 inches occurred in Bermuda Dunes, Coachella, Rancho Mirage, La Quinta and Indian Wells. Current estimates indicate that about 100,000 to 150,000 more acre-feet are pumped from the aquifer underlying the valley than are being replaced. The study concluded that unless measures are implemented to halt the overdraft, taxpayers could end up paying millions of dollars in repairs to sewers, roads and other infrastructure that could be adversely impacted by subsidence.

The specter of future droughts raises concern about the potential for further subsidence throughout California. Drought is a recurring condition in this state; since 1900, there have been eight multi-year periods classified by the Department

of Water Resources as droughts. With California's ever-burgeoning population and more than 10 million acres of cropland that require irrigation, there is intense pressure on water districts and

other government agencies to ensure an adequate water supply at all times, irrespective of climatic conditions.

When the demand for readily available imported water exceeds the supply, it will be tempting to further exploit groundwater resources to make up for the shortfall, despite the risk of potentially permanent subsidence. Prior to planning a development in subsidence prone areas, the subsidence history and potential should be evaluated.

Earth Systems companies are familiar with the causes and characteristics of subsidence and can assist clients with appropriate planning and mitigation.

—Margaret McQuade
Earth Systems Pacific



This sign, warning motorists of subsidence hazard, was erected after an earth fissure damaged Snyder Hill Road in Pima County, Arizona, in 1981.

Photo courtesy S. R. Anderson, USGS

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