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Stopping the Sinking

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The notion that some parts of Houston may be sinking is a harsh reality.

Some unique factors have combined to make the Texas Gulf Coast--and the area near Houston and Galveston in particular--vulnerable to the potentially devastating effects of land subsidence.

This area has already witnessed two brutal examples of subsidence-related flooding in the past decade. Brownwood, a subdivision of Baytown, was seriously flooded in 1979 and 1983 after suffering more than eight feet of subsidence. Subsidence at the San Jacinto Battlefield State Park had resulted in the permanent inundation of more than 100 acres of park land by 1974, with damages and losses estimated at $4.5 million.

Causes of Land Subsidence

Subsidence due to excessive pumping of groundwater is not just a Texas problem, but has been recorded in California, Arizona, Louisiana, Nevada, Idaho, and other states.

In Long Beach, California, excessive withdrawls of oil and gas resulted in 29 feet of subsidence. Near Fresno, California, for example, up to 29.5 feet of subsidence occurred between 1920 and 1970. During that same time, more than 4,500 square miles of irrigable farm land in the San Joaquin Valley subsided at least half a foot. Baton Rouge, Louisiana, has experienced a foot of subsidence over roughly 40 square miles. In the New Orleans area, more than two and a half feet of subsidence has occurred over 93 square miles.

Two major factors, the geology of coastal Texas and excessive groundwater pumping, make the Houston area a subsidence risk.

A large aquifer system composed of water-bearing sand and clay beds runs along the Texas coastline. The water held between the individual clay particles has kept them from fully compacting throughout geologic time. If excessive amounts of groundwater are withdrawn and aquifer levels decrease, the clay layers compact and the ground surface sinks closer to sea level.

Most of the effects of subsidence are irreversible. Loss of elevation due to subsidence is permanent. Even if water levels in an aquifer are restored to their original levels, the clay layers will not regain their previous thickness.

The aquifer system has provided the Houston area with good quality, inexpensive and easily attainable water. Surface water, on the other hand, has been much more expensive and must be transported from other areas. Until recently, Houston had developed an overdependence on groundwater for domestic, agricultural and industrial uses. Rapid growth in the area merely accelerated the problem. By 1976, groundwater pumpage in the Houston area was more than 455 million gallons a day (MGD). Today, that figure is roughly 390 MGD.

Subsidence in the greater Houston area has lowered surface land elevations by at least a foot in a 1,720 square mile area. This is one of the largest subsidence bowls in the nation.

Some of the most severe subsidence (up to 9.5 feet) has been centered near the Houston Ship Channel. The center of subsidence in the Houston area has shifted to Southwest Houston and the Galleria area where groundwater pumping continues to increase.

Significant groundwater pumping is also ongoing in extreme West and Northwest Harris County, due to steady urbanization of agricultural areas.

Loss of elevation due to subsidence has been a serious problem in Pasadena, Baytown, Texas City, Kemah and Galveston in the past. Subsidence rates in those areas have recently declined.

In a coastal area already near sea level, such as Houston and Galveston, subsidence dramatically increases the area's vulnerability for flooding.

When hurricane Carla struck in 1961, for example, 146 square miles of land were flooded. If a hurricane of similar strength attacked today, it would flood at least 171 square miles because of additional subsidence.

Another negative effect of subsidence is economic loss due to reduced property valuation and flooding. In 1977, for example, estimated annual costs of subsidence in the greater Houston area were $31.7 million.

Excessive groundwater pumping in the area has also been linked to increased movement in geologic faults, which contributes to breaks in street pavements, structural foundations, well casings, dams, highways, and airport runways. Research seems to indicate that there is significant fault movement in areas where great amounts of groundwater are being pumped. Conversely, in locations where groundwater pumping has been reduced, decreases in fault movement have been observed.

The Harris-Galveston Coastal Subsidence District

The Harris-Galveston Coastal Subsidence District was created by the Texas Legislature in 1975, under Article XVI, Section 59, of the Texas Constitution. That section, commonly known as the "Conservation Amendment," gives the state authority to conserve its natural resources.

The district is specifically charged with the responsibility " . . . to provide for the regulation of the withdrawal of groundwater within the boundaries of the district for the purpose of ending subsidence."

Perhaps the most striking difference between the subsidence district and other groundwater districts is that the subsidence district regulates use of groundwater in heavy urban and industrial areas, while other groundwater districts have a heavy agricultural orientation.

Duties of the district do not include many of the responsibilities of other groundwater districts: water quality and quantity, feasibility of recharge, efficient use of water, well spacing, regulations on production, or water conservation education.

The district does not have the power to require submittal of information on subsidence, or to control groundwater withdrawals outside its boundaries. This is a problem because groundwater withdrawals outside the district's boundaries significantly affect the amount of subsidence within the district.

The district cannot buy, sell, or transport surface water, nor can it issue bonds.

The district is governed by a 15-member board, which is appointed, not elected. Funding is generated through regulatory fees, not taxes.

The primary function of the district is to issue permits for the drilling and operation of water wells. The district currently serves almost 1,000 owners, operating more than 2,600 wells in Harris and Galveston counties.

The district regulates operators with wells of an inside casing diameter of greater than five inches, as well as operators with two or more wells, regardless of size.

Permits restrict the amount of groundwater withdrawn and may contain other limitations as well. Permit holders who pump large amounts of groundwater, for example, may be required to report to the district on their efforts to convert to surface water.

Permits are reviewed annually through public hearings. After public comment and testimony, a recommendation is made to the district's board which may then authorize the amount of groundwater withdrawal.

In reviewing permit applications, the district has to consider the quality and quantity of surface water at prices competitive with groundwater, the economic effect on the permit applicant, and the relative effect of a particular pumping on subsidence.

Each permit holder is required to pay a fee for the withdrawal of groundwater. In municipal systems this cost is passed on to individual homeowners. A typical fee for an average household pumping 10,000 gallons of groundwater monthly, would be 78 cents a year.

Regulating groundwater pumpage through permits, the district can control total withdrawals within a specific area to limit subsidence. In 1976, for example, more than 600 well operators were issued permits to withdraw in excess of 185 billion gallons annually. Roughly one-third of those permits required well owners to investigate the feasibility of converting to surface water.

Efforts at surface water conversion have been successful. In 1976, just a year after the creation of the district, surface water accounted for just 38 percent of the total water supplied to areas within the district's boundaries. By 1983, that figure had risen to 52 percent.

New facilities which supplied surface water included the completion of the Coastal Industrial Water Authority conveyance system between the Trinity River and the Houston Ship Channel, the Baytown Area Water Authority's new water treatment plant, and the expansion of the City of Houston's East Water Treatment Plant. Another new water treatment plant adjacent to the East Plant is now under construction.

Predicting and Monitoring Subsidence

Subsidence is monitored within the district in a variety of ways.

Borehole extensometers, for example, measure the amount of compaction occurring in the clay layers and provide a continuous record of subsidence at a particular location. Extensometers, which measure total subsidence, are installed by drilling a nonproducing well to a depth below which no measurable subsidence takes place. A pipe extending above the land surface is then set in concrete at the bottom of the well. As the land around the pipe subsides, it can be measured against the height of the pipe, which remains constant.

Thirteen borehole extensometers at 11 sites are currently in use within the district.

Releveling surveys are another way of measuring subsidence, but they are more useful for determining the extent of subsidence over a much greater area. The National Geodetic Survey uses surveying techniques to measure land elevations, which are compared to previous years. The difference in elevations between relevelings indicates the amount of subsidence which has taken place.

The last comprehensive releveling survey was performed in 1978, while the next survey is planned for 1986. Releveling projects of a limited scope were performed in 1976 and 1933.

In the future, remote sensing satellites may be employed to measure changes in land elevations due to subsidence. The primary advantage of using satellites is that information could be provided from areas which either do not have extensometers, or which have not been included in releveling surveys.

The district uses computer modeling to predict subsidence throughout the district based on different scenarios involving projections for population, water needs, and groundwater pumping.

Results of the modeling are an important tool of the district in structuring future plans and strategies for limiting the effects of subsidence.

District Efforts to Control Subsidence

One of the first decisions of the district was to identify the areas of extreme southeast Harris and Galveston counties as critical areas for subsidence control. Because these were low-lying lands along the coast, they would be most vulnerable to hurricane storm surge and flooding. This prompted immediate action by the district, which encouraged conservation measures by industry and surface water conversions. Now, groundwater withdrawals in this area have decreased and subsidence has been reduced.

The success of the district demonstrates that subsidence can be managed and controlled. Because subsidence is being controlled, the risk of flooding and faulting have been reduced.

Although some portions of Houston are still subsiding, the notion the city and the greater Houston area will sink into the Gulf of Mexico is now a less likely scenario.