WATER FACT SHEET

U.S. GEOLOGICAL SURVEY, DEPARTMENT OF THE INTERIOR

LAND SUBSIDENCE IN THE SACRAMENTO-SAN JOAQUIN DELTA, CALIFORNIA

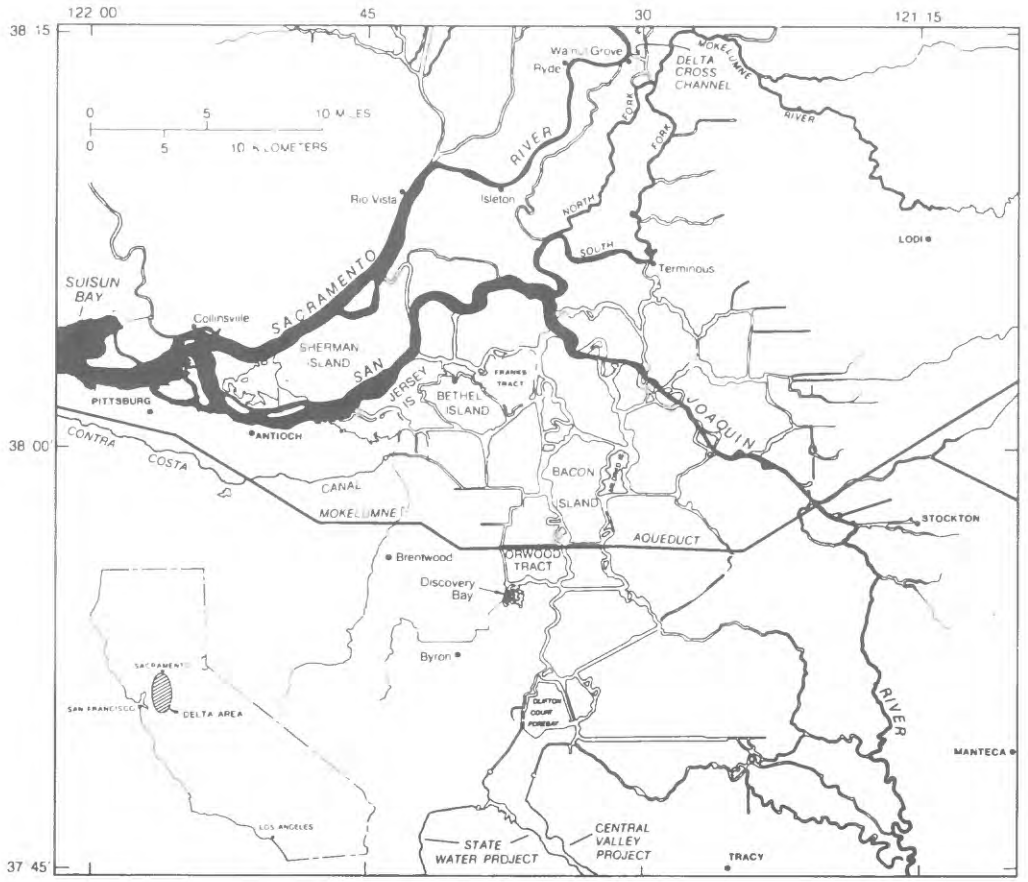
THE NATURE OF LAND SUBSIDENCE

Land subsidence is defined as a decrease in land-surface elevation and is caused by a variety of mechanisms. Subsidence refers to the vertical lowering of the land surface over an area of many square miles, although small-scale horizontal movements may occur at the same time. The primary cause of subsidence on the many reclaimed islands in the Sacramento-San Joaquin Delta is decomposition of organic soils such as peat, a type of organic soil that contains more than 50 percent organic matter. Exposing this partially decayed organic matter to oxygen causes (aerobic) decomposition, the process whereby the metabolic activity of microbial organisms converts organic carbon solids to carbon dioxide and other gases. As peat decomposes, new surfaces are exposed, resulting in further decomposition and land subsidence.

Land subsidence affects many people--growers and consumers of food products, residents and visitors, distributors and recipients of freshwater--so it is important that subsidence be minimized. Personnel of the U.S. Geological Survey (USGS), in cooperation with the California Department of Water Resources (DWR), are studying the locations, rates, amounts, and causes of subsidence in the delta. One objective of this research is to identify land- and water-use practices that would be most effective in reducing subsidence.

EFFECTS OF SUBSIDENCE

The Sacramento-San Joaquin Delta, covering more than 1,000 square miles, was once tidal marshland formed by the flood plains of the Sacramento and San Joaquin Rivers upstream from their confluence near Suisun Bay. The delta



includes nearly 60 leveed tracts or islands, most of which were reclaimed from marshland for agricultural use in the early 1920's. In the central delta, the land surface has subsided as much as 21 feet over time and is now more than 15 feet below sea level.

Subsidence adversely affects water conveyance structures (aqueducts), which are either pipelines or concrete-lined canals. Joints and foundations of the Mokelumne Aqueduct, a pipeline that transports water from the upper reaches of the Mokelumne River through the delta to communities west of the delta, need frequent maintenance because of the effects of subsidence. The natural channels or sloughs of the delta, which are part of the California State Water Project and the U.S. Bureau of Reclamation Central Valley Project, transport water from and through the delta enroute to central and southern California. Continued regional subsidence could sufficiently alter the gradients of channels and aqueducts so that additional pumping would be required to maintain the flow. Subsidence also increases agricultural drainage requirements because water must be pumped from farmland to maintain a sufficient unsaturated zone below land surface for crop production.

Land subsidence increases the potential for levee failures and flooding. Flooding damages real and personal property, disrupts agricultural production, and endangers lives. When surrounding waterways are in flood stage or an island subsides, the pressure against a levee increases. This rise in pressure, coupled with the fact that many levees were poorly constructed, increases the probability of levee failure. Subsidence also lowers the height of levees, which reduces the freeboard (distance between the water surface and the top of the levee) and flood protection capability.

RECENT RESEARCH IN THE DELTA

Several possible causes of subsidence in the Sacramento-San Joaquin Delta, in decreasing order of importance, include: (1) near-surface loss of organic soils, such as peat, caused by aerobic decomposition (oxidation) and wind erosion; (2) intermediate-depth compaction of saturated soils caused by ground-water withdrawal; and (3) compression of sediments at great depth as a result of natural gas withdrawal.

To quantify the magnitude and rate of subsidence of organic soils in the delta, shallow extensometers penetrating the peat have been constructed on Jersey and Sherman Islands and on Orwood Tract. An extensometer is an instrument that measures the amount of vertical movement of subsurface soil layers with respect to a relatively stable reference mark. Loss of carbon, both in the drainage water and in the form of carbon dioxide gas leaving the soil, is also measured at each extensometer site. The rate of shallow subsidence also has been measured in the vicinity of structures with deep foundations by measuring the increase in above-ground exposure of pilings for electrical-transmission lines. Since 1910, between 2 and 8 feet of pilings have been exposed on Sherman Island.

Data collected at extensometers measuring intermediate-depth compaction on Bacon and Bethel Islands from 1987 through 1991 indicate that compaction caused by fluid withdrawal is an insignificant component of land subsidence in the delta. Compaction of only several thousandths of a foot was recorded during seasonal water-level declines of a few feet. When water levels recovered during the winter, the subsurface materials expanded and no net compaction was measured.

Subsidence can also be caused by withdrawal of gas from depths between 1,000 and 10,000 feet below land surface. Data on gas production show that several natural-gas fields in the delta have undergone pressure declines exceeding 1,500 pounds per square inch since gas withdrawal began in the 1930's. This pressure decline is analogous to water-level decline in that a reduction in pore pressure due to either gas or water withdrawals can cause subsidence. Preliminary analysis indicates that subsidence in the delta does not seem to be related to a decline of natural-gas pressure. Thus, the focus of subsidence research in the delta has shifted from processes occurring at moderate and great depths to near-surface causes of land subsidence.

The accurate measurement of elevations in the delta is important to determine the magnitude of subsidence. A new surveying method, Global Positioning System (GPS), is being used to obtain elevations of some bench marks in the delta. This system has several advantages over conventional surveying. All levee heights will be accurately related to each other because all elevations are referenced to the same datum. Data from each site are obtained much faster than with conventional spirit leveling, and subsidence occurring between the start and finish of fieldwork is minimal. The GPS method is much more accurate over long distances than conventional methods. However, some inaccuracy exists because a correction factor, called the geoid height, is not a known quantity.

CONTINUING RESEARCH

Land subsidence research in the Sacramento-San Joaquin Delta is continuing under a cooperative agreement between the USGS and the DWR. Results from both spirit leveling and GPS surveying are being processed. Continued repetitive measurements at the same bench marks are necessary to determine rates and amounts of land subsidence on a regional scale. Additional research focuses on carbon fluctuations in organic soils under a variety of land- and water-management practices, the measurement of rates of carbon loss under reducing (usually aqueous) and oxidizing (aerobic) conditions, and an assessment of the factors that affect carbon loss.

For more information on studies of land subsidence in California please write:

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