1.6 Secondary Earthquake Hazards

Secondary earthquake hazards are those separate from, but induced by, the primary effects of strong ground shaking and fault rupture. Secondary geologic hazards include ground and slope failures and seiches, discussed below. (More broadly, secondary hazards also include non-geologic effects such as fires and toxic chemical spills).

1.6.1 Liquefaction

Liquefaction is a process by which water-saturated materials (including soil, sediment, and certain types of volcanic deposits) lose strength and may fail during strong ground shaking. Liquefaction is defined as "the transformation of a granular material from a solid state into a liquefied state as a consequence of increased pore-water pressure" (Youd, 1973). Liquefaction occurs worldwide, commonly during moderate to great earthquakes. In California, liquefaction-related ground failures occurred in 1857 (Fort Tejon earthquake), 1906 (San Francisco earthquake), 1933 (Long Beach earthquake), 1971 (San Fernando earthquake), 1973 (Point Mugu earthquake), 1979 and 1981 (Imperial Valley earthquakes), 1989 (Loma Prieta earthquake), and 1994 (Northridge earthquake), and others. Four kinds of ground failure commonly result from liquefaction: lateral spread, flow failure, ground oscillation, and loss of bearing strength.

Lateral Spread: Lateral displacement of surficial blocks of sediment as the result of liquefaction in a subsurface layer is called a lateral spread. Once liquefaction transforms the subsurface layer into a fluidized mass, gravity plus inertial forces caused by the earthquake may move the mass downslope towards a cut slope or free face (such as a river channel or a canal). Lateral spreads most commonly occur on gentle slopes that range between 0.3˚ and 3˚, and commonly displace the surface by several meters to tens of meters. Such movement typically damages pipelines, utilities, bridges, and other structures having shallow foundations. During the 1906 San Francisco earthquake, lateral spreads causing displacement of only a few feet damaged every major pipeline. Thus, liquefaction compromised the ability to fight fires - and fires caused about 85 percent of the damage to San Francisco.

Flow Failure: The most catastrophic mode of ground failure caused by liquefaction, flow failure usually occurs on slopes greater than 3˚. The flows are principally liquefied soil or blocks of intact material riding on a liquefied subsurface zone. Displacements are commonly tens of meters, but in favorable circumstances, material gets displaced for tens of miles, at velocities of tens of miles per hour. The extensive damage to Seward and Valdez, Alaska, during the 1964 Great Alaskan earthquake was caused by submarine flow failures.