

A separate Southern California Earthquake Center (SCEC) committee dealing with the issues of implementation of SP 117 (DMG, 1997) for landslide hazards has been formed and is working on a companion to the liquefaction hazards document discussed earlier. Factors controlling the stability of slopes include: 1) the slope height and inclination, 2) the engineering characteristics of the earth materials comprising the slope, and 3) the intensity of ground shaking. Engineered slopes should be designed to resist seismically induced failure. Slope design should be based on pseudo-static stability analyses using soil engineering parameters. These should be established on a site-specific basis from detailed geotechnical investigations that include subsurface soil sampling and laboratory testing. The stability analyses should factor in the intensity of ground shaking expected in the County.

1.6.6 Seiches

The County's water tanks, reservoirs, lakes and swimming pools are enclosed bodies of water that are subject to potentially damaging oscillations on the water surface, called **seiches**. A seiche can result from a number of factors including wind-driven currents, tides, variation in atmospheric pressure and ground shaking associated with near or distant earthquakes. In southern California, the greatest threat of seiches comes from earthquakes.

Whether an earthquake will create seiches depends upon a number of earthquake-specific parameters, including period or length of the seismic waves, earthquake location, and the style of fault rupture (e.g., dip-slip or strike-slip). Whether a seiche will cause damage can depend upon the size, shape and location of the body of water, storage tank strength, integrity of dam construction, underlying soil type, proximity of human-built structures, and local relief (variations in elevation).

Amplitudes of seiche waves associated with earthquake ground motion have typically been less than 0.5 meters high; however, some have exceeded 2 meters. A seiche in Hebgen reservoir, caused by an earthquake in 1959 near Yellowstone National Park, repeatedly overtopped the dam, causing considerable damage to the dam and its spillway (Stermitz, 1964). The 1964 Alaska earthquake produced seiche waves 0.3 m high in the Grand Coulee Dam reservoir, and seiches of similar magnitude in fourteen bodies of water in the state of Washington (McGarr and Vorhis, 1968). California earthquakes have generated (non-damaging) seiches in Florida swimming pools!

Lakes: Due to their relatively large size, proximity to major faults, and development near their shores, in Riverside County, Lake Elsinore and the Salton Sea create especial hazard from seiches.

Dams: An important method to decrease seiche hazard behind dams is to increase the freeboard distance (top of dam to top of water). This can be accomplished by either building up the dam, or by reducing the allowable reservoir storage capacity. Other mitigation measures include:

- replacing dams;
- adding buttresses and berms;
- flattening slopes;
- increasing drainages; and
- grouting foundations.

It seems likely that the threat to dam stability is increased if a dam simultaneously experiences forces associated with strong seismic ground shaking and seiches. Thus, to increase dam safety, these two hazards need to be considered together.

Swimming Pools: Damage from swimming pool seiches is a common problem. During seismic ground shaking, seiches created in private and public pools can expell considerable water. This often damages homes downslope, and sliding glass doors near the pool.

Water Tanks: Seiches damaged storage tanks during the 1992 Landers-Big Bear earthquakes and the 1994 Northridge earthquake. As a result, the American Water Works Association (AWWA) Standards for Design of Steel Water Tanks (D-100) now provide new criteria for seismic design (Lund, 1994).