Evaluating the Repeatability of Lateral Spreading

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Investigations Undertaken

This research explores the repeatability and, therefore, predictability of lateral spreading associated with liquefaction during strong ground shaking. Current geotechnical research is investigating the geotechnical parameters that control the location, size, and orientation of lateral spreading during liquefaction. These studies are focused on identifying specific locations of lateral spreads within areas of high susceptibility to liquefaction. The underlying premise or assumption to these studies is that the location and magnitude of lateral spreading is a predictable phenomenon subject to epistemic uncertainty and does not occur randomly within an area of liquefaction. Our research is a first step towards testing this premise by evaluating geologic evidence for repeated lateral spreading. The consequence of this study will be whether or not we can treat lateral spreads similar to fault ruptures such that specific locations, magnitudes, and orientations can be predicted for evaluation of impact to the built environment (i.e., lifelines, buildings).

Through trench exposures and standard paleoseismic techniques we have evaluated the recurrence of lateral spreads at two sites in northern California. From late August through early October, 2003, we excavated trenches across the floodplains of the Pajaro River, near Watsonville, CA, and Coyote Creek, near Milpitas, CA, on sites that have experienced historic lateral spread failures. The Watsonville site exposed a record of 3 to 5 lateral spreads and paleoliquefaction events that recurred in a narrow (~1-m-wide) zone. This site motivated our formulation of a hypothesis that the depositional environment and local geologic and geomorphic site history create conditions that can localize lateral spreading over a range of earthquake magnitudes.

Results

Exploratory trenches across the late Holocene floodplains of the Pajaro River and Coyote Creek, northern California, revealed evidence for liquefaction-induced lateral spreading. This first-year feasibility study, designed to evaluate whether lateral spreads occur

repeatedly in the same location, established an example of recurring sand injection and lateral spreading along a stratigraphic unconformity within the Pajaro River floodplain near Watsonville. We excavated two trenches across a lateral spread formed after the 1989 Loma Prieta earthquake on the Pajaro River floodplain near Watsonville, in an area identified and studied by US Geological Survey geologists and geotechnical engineers after that event (Holtzer et al., 1994; Bennett and Tinsley, 1995). In addition to liquefaction-related features produced in 1989, the trench walls revealed evidence for 2 to 4 prior lateral spread failures and associated liquefied sand bodies. The site likely included failure from the 1906 M7.8 San Francisco and penultimate San Francisco-type events. The repeated spreading occurred along a ~1-m-wide zone that coincides with a buttress unconformity between mid Holocene floodplain deposits and late Holocene to historic fluvial deposits of an aggraded inset river terrace of the Pajaro River (Dupré and Tinsley, 1980). Small (<1 cm) vertical offsets several meters inboard of the main lateral spread zone are associated with minor ground cracking observed after the 1989 event. Although it is permissible that an earlier lateral spread event produced some of the minor normal fault displacements, the small magnitude of these failures relative to the massive failure along the main lateral spread zone indicates that this secondary deformation is minor and that the main zone of failure occurs in a repeatable fashion. Charcoal collected from the terrace deposits is presently being analyzed for ^{14}C to limit ages on the paleo-lateral spread events. Efforts to place limiting ages on younger floodplain sediments using the presence or absence of non-native pollen species (Mensing and Byrne, 1998) were not successful, based on poor preservation of pollen within the oxidized silt and sand stratigraphy.

A single trench excavated across the floodplain of Coyote Creek near Milpitas, California, did not encounter evidence of lateral spread failures, despite reports of widespread lateral spreading in the vicinity during the 1906 San Francisco earthquake and the 1868 M 7 Hayward earthquake (Lawson et al., 1908; Youd and Hoose, 1978). Evidence from this trench precludes lateral spread failures during the 1868 and 1906 earthquakes at this site that is underlain by susceptible deposits as identified in previous detailed investigations (Egan et al., 1992), and suggests that lateral spreading during both events was confined to a narrow zone proximal to the Coyote Creek stream bank. Two narrow sand dikes that terminate upwards in different units may provide evidence for liquefaction associated with the 1906 or 1989 earthquakes. By analyzing charcoal collected from the surrounding units, the presence or absence of post-1950 bomb carbon has the potential to evaluate whether liquefaction did occur during the 1989 earthquakes in the Coyote Creek floodplain. This question is important because post-earthquake investigations following the 1989 event failed to find surface evidence for liquefaction in this area mapped as high liquefaction susceptibility (Knudsen et al., 2000).

Non-Technical Summary

This research evaluates the repeatability and, therefore, predictability of lateral spreading associated with liquefaction during strong ground shaking. Several recent earthquakes have produced lateral spreads that damaged port facilities, airports, lifelines, bridges and buildings. Similar to surface fault rupture, the precise and accurate location of where

lateral spreads may occur is essential for properly mitigating this hazard. Our study provides direct geologic observations to assess historic and prehistoric lateral spreading at two sites in northern California. At one site, along the Pajaro River near Watsonville, we found evidence for repeated lateral spreading in a narrow zone that coincides with a boundary between older and younger floodplain deposits. This site shows that lateral spreading recurred in the same place during the 1989 Loma Prieta, 1906 San Francisco, and other large earthquakes near the Monterey Bay area.

Reports Published

None

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