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A SIMPLE METHOD TO HELP DEFINE THE FISSURE HAZARD FOR SITES IN THE LAS VEGAS VALLEY, NEVADA

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ABSTRACT

Subsidence-induced earth fissuring has affected the rapid growth and development in Las Vegas Valley. Concerns over fissure-induced damage have led in part to new building codes (Clark County) requiring detailed geotechnical evaluations near pre-existing faults in the valley. These faults are located throughout the valley and have been historically reactivated by groundwater-withdrawal induced land subsidence. The faults are also associated with fissuring. The spatial relationship of fissures with respect to faults in the Las Vegas Valley have been analyzed by others. Cumulative distribution plots show that about 90% of the mapped fissures occur within 2000 feet (610 m) of mapped faults. This has been used to determine the hazard zone in the new codes. Using only this criteria in the geotechnical evaluation, the assessment of the risk for fissuring for a given site within this zone would be considered conservative since only about 10 percent of the faults (by length) in the valley have associated fissures.

A simple method has been developed to help further define the risk for fissuring within these fault-based buffer zones. This method evaluates and weighs several site aspects and conditions related to the formation of fissures. These include: 1) shallow groundwater conditions (depth to), 2) soil conditions at the site, 3) distance to the nearest fault and high capacity pumping well(s), 4) location within land subsidence bowl(s) in the valley, 5) presence of intervening faults and the center of each subsidence bowl, and 6) orientation of nearest fault(s) with center of subsidence bowl. We suggest the use of GIS applications to evaluate and adjust the relative "weight" of each of these site parameters by comparison to existing fissure maps.

INTRODUCTION

The formation of earth fissures around preexisting faults in Las Vegas Valley has been attributed to the effects of historical land subsidence due to the regional extraction of groundwater. The Windsor Park subdivision is a residential development that has seen significant damage (Fig. 1) due in part to fissures since the early 1980's (Bell, 1981, Bell & Price, 1991 and Linnert, et al., 1994). In response to the damage to Windsor Park, the U.S. Department of Housing and Urban Development (HUD) required detailed studies be conducted for all new residential developments located within potential fissure hazard zones or 500 feet (150 m) on either side of the numerous faults mapped in Las Vegas Valley. For planning and siting purposes, Bell, et al. (1992), offered as an alternative to the HUD 500-foot (150 m) zone: a 2000-foot (610 m) zone around faults that was found to enclose 90% of all presently known and mapped fissures. In 1996, Clark County introduced revisions to their building codes requiring detailed geotechnical evaluations for sites within 2000 feet (610 m) of the preexisting faults in the valley. Concerns over the potential for damage to residential subdivisions from the effects of land subsidence including fissures led to these new codes.

Cumulatively, approximately 100 linear miles (160 km) of preexisting faults are mapped across the floor of Las Vegas Valley. Based on the fault and fissure map in Bell & Price (1991), it appears that only 10% of the faults have associated fissuring. Geotechnical investigations performed within fissure hazard zones usually include surface reconnaissance and possibly trenching to assess the fissure hazard at the site. Commonly, evidence of fissures will not be found with this approach even for sites that are thought to have a high risk for fissuring. If in fact, fissures are found at a site or maybe, as in some cases, surface features only suggestive of fissuring are observed, then how can one use this information alone to provide a basis for their judgment as to the ultimate risk to development of the site? Although from a regulatory and investigative standpoint it may be prudent to examine sites within 2000-feet (610 m) of faults in the valley to provide a "first look" extent, a method is needed to assist in the decision process for mitigation purposes or even for continued development of the site. With this in mind, a simple method to help define the risk for fissuring within these fault-based buffer zones has been developed. This method has been resolved by looking at the occurrence of fissures in the valley and identifying factors that may control the development of fissures at particular sites.

GEOLOGIC SETTING

Geologic and Hydrologic Setting

The Las Vegas valley, located in the Basin and Range physiographic province is approximately 50 miles (80 km) long and varies from 5 to 25 miles (8 to 16 km) wide. The valley is bounded on the west by the Spring Mountains; on the north by the Desert, Sheep and Las Vegas Ranges; on the east by Frenchman and Sunrise Mountains; and on the south by the River and McCullough Mountains. The basin drains into the Colorado River at Lake Mead principally by Las Vegas Wash.

The Las Vegas Valley is a deep structural basin. Deposits within the basin are primarily Plio-Pleistocene fill characterized by coarse-grained alluvium and fine-grained fluvial and lacustrine basin fill (Bell, 1981). The coarse-grained alluvial deposits are believed to be coalescing alluvial fans derived from the mountain ranges surrounding the valley. The fine-grained basin fill is believed to have been deposited primarily in a paludal or playa environment during the late Cenozoic prior to the formation of the Colorado River System (Mifflin and Wheat, 1979).

Two separate aquifers exist in the Las Vegas Valley: a shallow relatively unconfined aquifer and a series of deep confining water-bearing zones (Plume, 1984). Each zone typically contains granular sediments that are contained by low permeability silts and clays. The fine-grained sediments occur as lenses or layers which act as semi-confining barriers or aquitards that impede vertical flow. The majority of the groundwater withdrawn in the valley is from the deeper aquifer zone at depths greater than 200 feet (61 m).

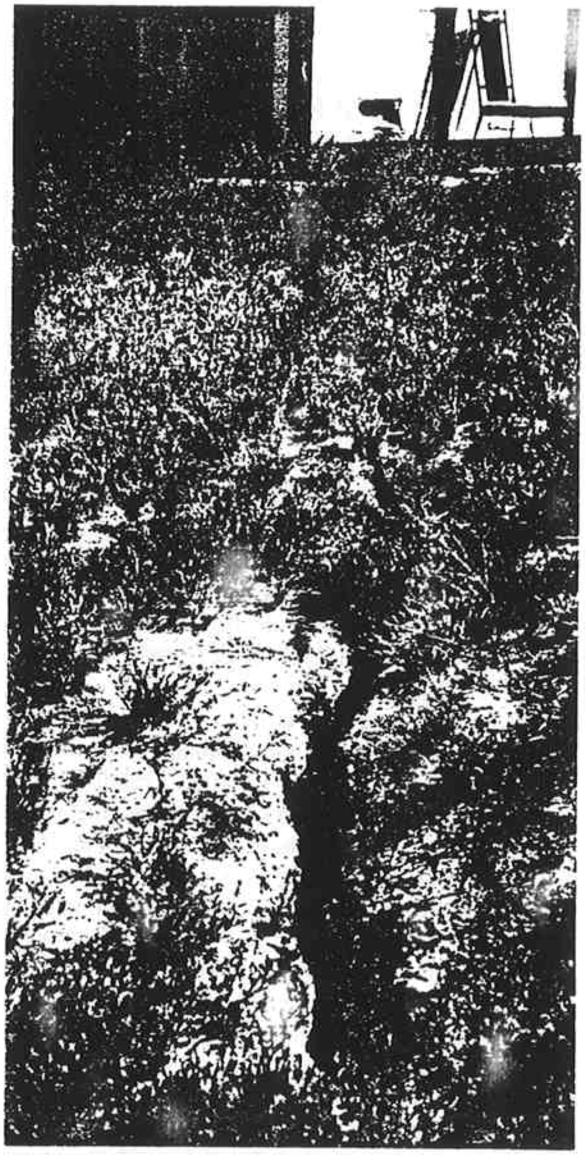

Figure 1. Earth fissure located in a backyard at the Windsor Park subdivision in North Las Vegas, Nevada. The house had incurred serious damage due in part to fissuring.

Geologic Constraints

There are several geologic constraints in the Las Vegas Valley including geologic faults, land subsidence and earth fissures.

Geologic Faults

Several north-trending fault scarps extend through the center of the valley (Figure 2) and are

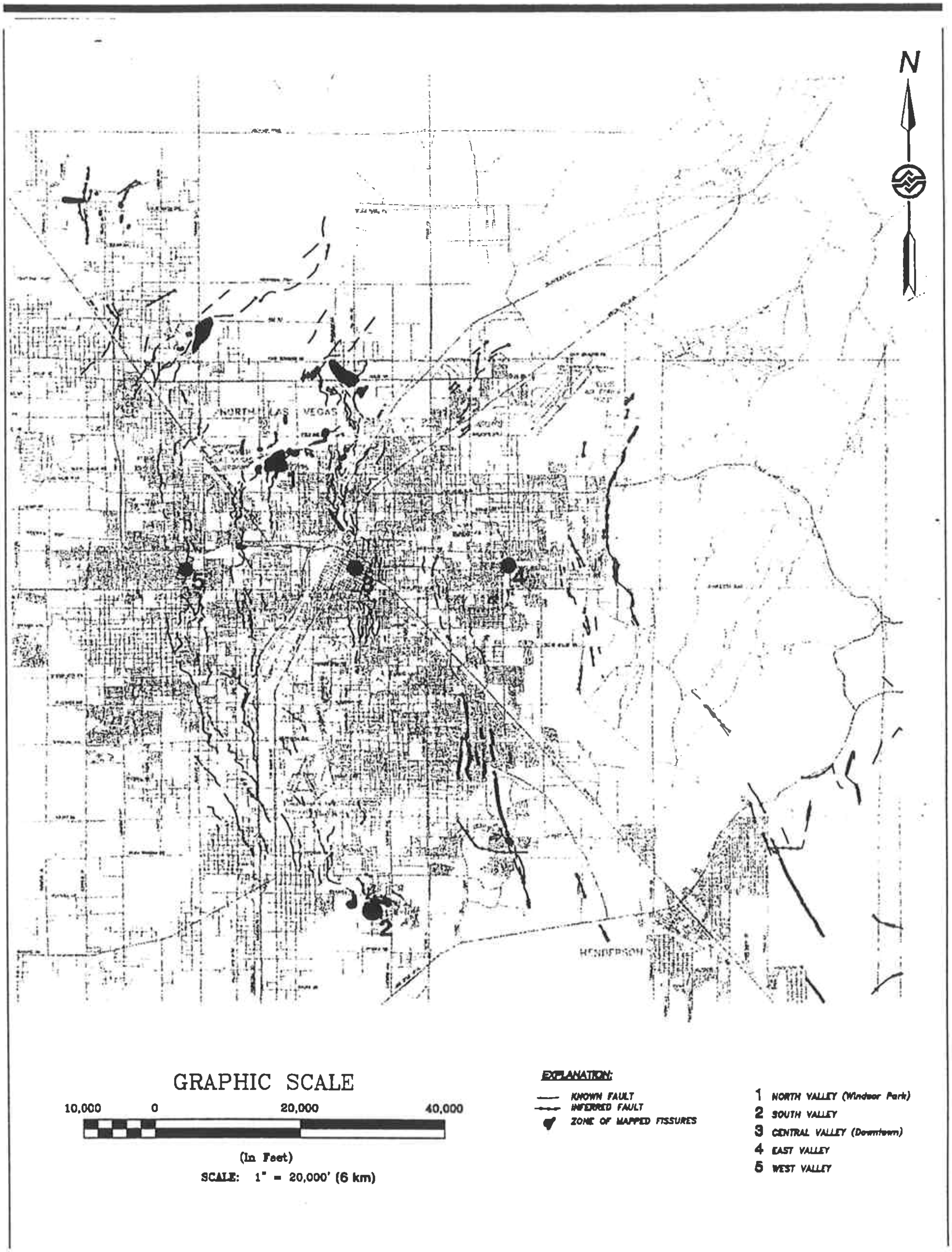

Figure 2. Map of faults and fissure zones in the Las Vegas Valley (Bell and Price, 1991). Scale: 1 : 240,000.

believed to be of late Quaternary age. The scarps are in excess of 100 feet (30 m) high and nearly all show displacement down to the east (Bell, 1981). These faults significantly affect the movement of groundwater, both laterally and vertically between aquifers. Prior to artesian head decline as a result of heavy pumping, flowing springs were often observed along these fault scarps (Bell, 1981).

The origin of these faults scarps is still debated. One theory suggests the scarps are the surface expressions of prehistoric differential consolidation or compaction of alluvial and playa-like sediments having dissimilar grain-size and compressibility characteristics (Maxey & Jameson, 1948 and Cibor, 1983). The second theory states the fault escarpments are tectonic in origin from faults extending up from the bedrock basement underlying the valley. The latter would be capable of generating seismic events (Bell and Price, 1991).

Regardless of origin, the faults have been historically reactivated due to differential land subsidence as a result of groundwater withdrawal. They are also associated with earth fissures, former spring deposits and adverse geotechnical conditions (Linnert, et. al., 1994).

Land Subsidence

The principal cause of historical land subsidence in the Las Vegas Valley is the regional extraction of groundwater. The valley soils contain silt and clay sediments which are very conducive to consolidation upon fluid extraction.

Evidence for land subsidence is based upon regional land level surveys conducted over years and was first documented in 1940 (Bell, 1981). Elevation surveys conducted between 1963 and 1986/87 shown the pattern for valley-wide subsidence as one large subsidence bowl punctuated by three secondary localized zones (see Figure 3). As of the last survey in 1986/87, the localized bowl in the northwest portion of the valley was the most actively subsiding of the three. Over 5 feet of surface subsidence was measured in this area between 1963-1986/87 (Bell and Price, 1991).

Earth Fissures

Earth fissures in the Las Vegas Valley are usually formed in the subsurface by tensional associated with groundwater withdrawal (Helm, 1992). They are expressed either as groups of short, discontinuous, dendritic cracks or as a single, continuous, linear crack. A fissure is believed to originate as a tensional crack approximately 0.1 to 0.2 inch (0.2 to 0.5 cm) wide in relatively loose sediment (Werle and Stilley, 1991). Infiltration of surface runoff widens the crack, and collapse of overlying sediments exposes the fissure to the ground surface. Surface water runoff further erodes and enlarges the feature.

In addition, fissures are common around high capacity groundwater pumping wells. Soils, such as hydrocollapsible sediments and expansive clays, have also been associated with fissures in localized areas of the valley (Bell, 1981, and Linnert, et. al., 1994)

FACTORS AFFECTING THE FORMATION OF FISSURES IN LAS VEGAS VALLEY

Six factors have been recognized that influence the formation of fissures at sites within the valley. These conditions and/or site aspects are presented below.

Shallow Groundwater

Fissures are more likely to occur in the southwestern United States where there is characteristically a thick unsaturated and a partly saturated zone above the local water table. Sediments in this reasonably permanent passive zone would be prone to brittle deformation, as compared to the sediments beneath the water table (Helm, 1992). Sediments below the water table would be prone more to ductile deformation. Thus, fissures are unlikely beneath the water table and in the capillary fringe.

Areas of the Las Vegas Valley having depths to water less than 30 feet (9 m) are shown on Figure 4. In general, the depth to shallow ground water decreases following the flow gradient from northwest to southeast (Zikmund, 1996).

Soil Conditions

Soil conditions are a major factor influencing the likelihood of fissure formation at a site. Erodability and brittleness are governed by the consistency and type of soil. These characteristics affect the likelihood of fissure formation as well as the rate of expansion and propagation.

The nature of some soils may undergo processes which produce fissure features but which may be directly unrelated to groundwater withdrawal or land